(2)

US Army Corps
of Engineers
Construction Engineering
Research Laboratory

USACERL TECHNICAL REPORT P-89/12
March 1989
An Integrated AI-Based Project Management System

AD-A207 077

Using Project Management Systems at the Construction Field Office

by
E. William East
Jeffrey G. Kirby

Automated construction scheduling is required for U.S. Army Corps of Engineers construction contracts over $500,000. Because of the more than 200 widely varied automated systems available, engineers at the construction field office (or resident office) are faced with the overwhelming task of choosing which software to purchase to help them analyze contractor schedules. To gain information to help with this decision, the U.S. Army Construction Engineering Research Laboratory (USACERL) talked with schedulers at field offices, served as scheduling consultants, and conducted comparisons of several systems to identify outstanding features and potential problems.

The Project Management System (PMS) features that allow easy implementation include sophisticated user interfaces, simple report production and analysis, and ease in posting cost progress and defining constraints. Several systems allow data to be input from a floppy disk and provide a method of allocating resources. Potential problems that may occur while using the schedule include conflicts when operating on different work schedules (5- or 7-day workweeks), accepting system default dates, and out-of-sequence progress as the result of routine changes.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USACERL TR P-89/12	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Construction Engr Research Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 4005 Champaign, IL 61824-4005	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION HQUSACE 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) 20 Massachusetts Ave., NW. Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 4A161101 / PROJECT NO. AT23 / TASK NO. SA / WORK UNIT ACCESSION NO. E59

11. TITLE (Include Security Classification)
Using Project Management Systems at the Construction Field Office (U)

12. PERSONAL AUTHOR(S)
East, E. William, and Kirby, Jeffrey G.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ______ TO ______	1989, March	91

16. SUPPLEMENTARY NOTATION
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	project management; software; microcomputers; scheduling; critical path methods
05	01		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Automated construction scheduling is required for U.S. Army Corps of Engineers construction contracts over $500,000. Because of the more than 200 widely varied automated systems available, engineers at the construction field office (or resident office) are faced with the overwhelming task of choosing which software to purchase to help them analyze contractor schedules. To gain information to help with this decision, the U.S. Army Construction Engineering Research Laboratory (USACERL) talked with schedulers at field offices, served as scheduling consultants, and conducted comparisons of several systems to identify outstanding features and potential problems.

The Project Management System (PMS) features that allow easy implementation include sophisticated user interfaces, simple report production and analysis, and ease in

(Cont'd)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL GLORIA J. WIENKE	22b. TELEPHONE (Include Area Code) (217)352-6511 (ext. 353) 22c. OFFICE SYMBOL IMT-E

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

BLOCK 19 (Cont'd)

posting cost progress and defining constraints. Several systems allow data to be input from a floppy disk and provide a method of allocating resources. Potential problems that may occur while using the schedule include conflicts when operating on different work schedules (5- or 7-day workweeks), accepting system default dates, and out-of-sequence progress as the result of routine changes.

FOREWORD

This investigation was performed under Project 4A161101AT23, "Basic Research in Military Construction;" Technical Area SA; Work Unit E59, "An Integrated, AI-Based Project Management System."

Appreciation is expressed to Mr. Diego Botero, whose graduate studies at the University of Illinois provided much of the background investigation for this report. Appreciation is also expressed to the many software vendors who supported this effort.

This work was performed by the Facilities Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (USACERL). Dr. Michael J. O'Connor is Chief of FS. The Technical Editor was Gloria J. Wienke, USACERL Information Management Office.

COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

FIGURES

TABLES

TABLES (Cont'd)

USING PROJECT MANAGEMENT SYSTEMS AT THE CONSTRUCTION FIELD OFFICE

1 INTRODUCTION

Background

Engineer Regulation (ER) 1-1-11[1] requires that automated Critical Path Management (CPM) scheduling be specified for use by the contractor in all U.S. Army Corps of Engineers construction contracts over $500,000. The main reason for specifying automated scheduling is to provide quality assurance personnel at the construction field office (or resident office) with a tool to analyze the contractor's schedule and anticipate potential problems. According to a recent survey, there are over 200 microcomputer-based project management systems from which the construction management engineers at the field office must choose when purchasing CPM software.[2] Because of the great number and wide variety of these systems, scheduling expertise is limited. In response to this problem, the U.S. Army Construction Engineering Research Laboratory (USACERL) evaluated many of these systems to determine the ease of implementing them and to identify any potential problems.

Objectives

The objectives of this study were to (1) identify those Project Management System (PMS) features that allow easier implementation within the construction field office and (2) describe potential scheduling problems that may occur while using the PMS schedule during the construction project.

Approach

To gain information to help engineers choose scheduling software, USACERL talked with schedulers at field offices throughout the Corps of Engineers, served as scheduling consultants, and conducted comparisons of several widely used project management systems to identify outstanding features and potential problems.

Scope

This study is intended for readers with a basic knowledge of CPM scheduling who currently are, or will be using PMSs. This report assumes that the reader has some familiarity with CPM, also referred to as the Network Analysis System (NAS). The Reference list provides a bibliography of additional information on construction scheduling. Hands-on experience with microcomputers is not necessary, although it may be helpful.

---

[1]Engineer Regulation (ER) 1-1-11, *Network Analysis System* (U.S. Army Corps of Engineers, 15 October 1985).

[2]*Buyer's Guide to Project Management Software*, Kenneth M. Stepman, Ed. (New Issues Inc., 1987).

Mode of Technology Transfer

This report will be distributed to the Chief Construction Division at each Division and District Office and each Construction Field Office for use to (1) enhance existing scheduling expertise and (2) develop consistent scheduling practices. Information in this report will also be included in a guide for scheduling on microcomputers to be published by Van Nostrand Reinhold in 1990.

2 INSIDE PROJECT MANAGEMENT SYSTEMS

PMS Benefits

PMSs facilitate communication and improve project control through the exchange and understanding of project information between the contractor and the field office. This improved communication increases efficiency in construction progress monitoring and analysis, and is based on a common CPM language. This common language is embodied in the list of activities, the relationships between activities, and the activity durations. Automated tools to perform schedule calculation and analysis have, in the past 5 years, become so affordable that many field offices have been able to purchase them. Affordable software has been part of a more general trend in the decreasing cost of computer technology. Reduced hardware costs also have increased the proliferation of computer systems throughout the Army.

The affordability of hardware and software has not been lost on contractors, who will either purchase PMSs or contract to consultants who use them. This combination of decreased cost and contractor use of microcomputer-based PMSs has prompted many field offices to purchase their own computers and programs. The total investment can be recovered from the savings in extended overhead charges from the time saved in just one modification to one project.

PMS Use

Several examples of the ways the field office and the contractor may use PMSs are: the government and contractor may directly exchange project data to eliminate most of the time required for data entry, quality assurance representatives may monitor job progress by generating a list of activities that must start and finish during the upcoming week, office engineering staff may identify all activities pertaining to a particular specification section to verify the completeness of the contractor's schedule, and the contract administration staff may determine the impact of changes to work expected in a contractor's proposal.

Although there is great promise for effective use of PMSs at the field office, these systems are often not fully utilized. The most important causes of underutilization appear to be: (1) inconsistent terminology between systems and (2) incomplete understanding of the impact of PMS features.

This chapter describes specific technical aspects of microcomputer-based PMSs to provide an "inside" view of how these programs operate. The impact of these technical aspects on daily quality assurance practices will also be discussed. A consistent terminology for system features is also introduced.

To present the technical aspects of PMSs realistically, this chapter discusses the processes a field office scheduling engineer must follow to create a schedule and use PMS effectively.

The construction project shown in Figure 1 will be used for many of the examples in this chapter. The scope of work for the example project requires the contractor to: install a section of pipe between two manholes, temporarily relocate an electrical line, and grade and sod the ground that was disturbed.

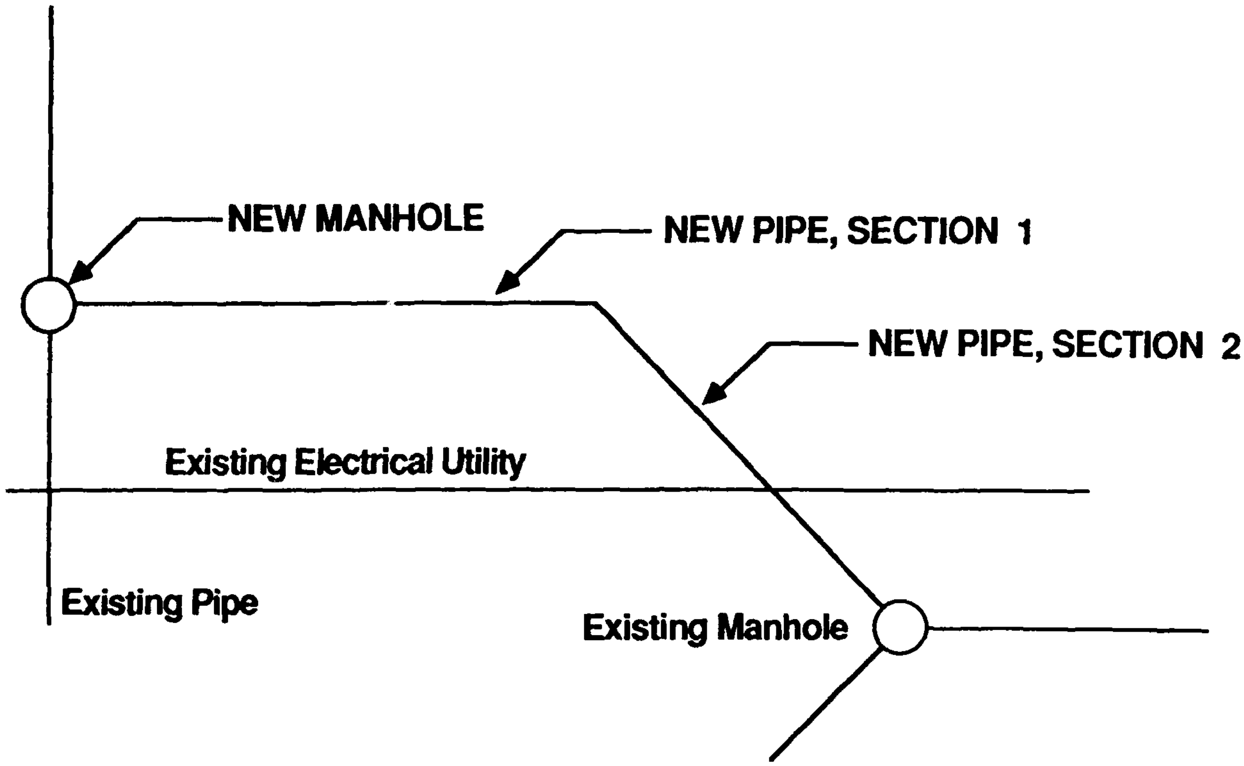


Figure 1. Plan view of the example project.

Installation Factors

The program documentation includes the instructions for installing and activating the program. However, hardware factors and office factors are often overlooked during installation. All systems specify the minimum computer hardware required for satisfactory results. The hardware specification typically includes an IBM PC/AT or compatible, 640 kilobytes of random access memory, and 5 megabytes of free hard disk space. Although some systems may operate with less restrictive requirements, schedule processing speed often suffers.

A field office that wants to use a PMS effectively must not only purchase the correct equipment, but also make it readily available. The system is often installed on a computer shared by several people, which will frustrate PMS users who must "bargain" with the full-time system users for schedule analysis time. If project personnel cannot obtain necessary information on several successive occasions, they may quit trying to use the system. Each field office should seriously consider the issue of computer access when selecting PMS hardware.

Creating the Overall Project

Almost all PMSs provide features helpful to the project manager. To begin using these features, the user selects an item from a list of choices, or menu. Three types of menus are used in project management systems: standard menus, top or bottom line menus, and pulldown menus.

Standard menus are recognized as a list, usually in the middle of the computer screen. The user is prompted at the bottom of the screen to make a selection. To select one of the available options, the user presses a number or letter corresponding to the selection. As with every style of menu, this selection may either prepare the system to accept information from the user or access other menus.

Top or bottom line menus list the options on either the top two or bottom two lines of the computer screen. The user selects an option either by pressing a designated letter of the option (often capitalized and highlighted) or by using the arrow keys to move a highlighted bar to the option and pressing the "Enter" (or the "Return") key. If the selection offers a choice of other menus, these will often be shown as the highlighted bar passes over each option.

The pulldown menu is perhaps the most impressive type. The pulldown menu is a form of the top or bottom line menu, but it is more graphically interesting and may be used with a "mouse." The user selects the action to be performed in two steps. The first step is to move the highlighted bar or mouse over the top line where the general menu is typically located. Once in place, another menu "pulls down" and appears. As the highlighted bar or mouse is moved, the menu disappears.

Some project management systems allow the user to create menus and define "macro" commands to automate many functions that help the user maneuver through a complex menu system. A macro command may help access data entry screens directly, speeding up the menu selection process. A well documented system provides the user with descriptions of each menu and the outcome of each selection.

The first menu option that must be selected to create a new project will generally be called "Add a new project." Once the user has executed this selection, the system asks for a project number, the title of the project, the contractor's name, and the project start date. Initial project information is typically entered by using a data entry screen. Although entering the initial project information may not seem very important, it is the first of many essential elements in creating a useful schedule.

Initial project data must clearly communicate what construction project is being scheduled. This is not a trivial point if the system requires the user to create and select projects based on a four-character project number, which is typical of several systems. Even though the Corps construction contract format (DACA-FY-C-####) provides four numbers (####), this type of contract identification number may not be sufficient for projects that span several years. Other projects may have the same last four numbers but a different fiscal year (FY) designation. Another item that the user should consider before assigning an activity number is the method of updating the project. Some PMSs require the user to enter a new project number for each version of the project.

Other information needed to properly process schedule calculations includes network model specification, duration and start of the workweek, calendars and holidays, and project (activity code) libraries. This data is often entered with the initial project data. Many systems use predetermined default values for these items if the user does not specify them. Each item will be discussed in this chapter.

Network Scheduling Models

Once the initial information is completed, the project must be divided into activities. To most effectively create a large construction schedule, the contractor and major subcontractor(s) should first create a network diagram.

The schedule defines each activity by a description, a logical relationship with other activities, and a duration. The Corps of Engineers recognizes two types of network models to represent projects. These are the Arrow Diagram Method (ADM) and the Precedence Diagram Method (PDM). These models are referred to in some texts as Activity-on-the-Arrow and Activity-on-the-Node diagrams.

One potential list of activity descriptions, logical relationships, duration, and cost for the example project is presented in Table 1. The ADM representation of the network is provided in Figure 2, and the PDM model is given in Figure 3.

Although there has been significant debate within the Corps of Engineers regarding the use of PDM, the method is very useful when representing repetitive construction projects such as multistory units or highways. PDM is able to model the overlapping relationships between activities that often occur in repetitive construction projects.

Table 1

Example Project Activity List

Activity Number	Successor Activities	Description	Duration (days)	Cost
1	2,3	Notice to Proceed	1	0
2	10	Relocate Electrical	6	4,200
3	4	Excavation	3	3,000
4	5,6	Install Pipe Section One	10	12,000
5	7	Backfill Section One	5	3,500
6	7,8	Install Pipe Section Two	12	14,400
7	9	Backfill Section Two	8	5,600
8	9,10	Test Pipe Sections	3	1,500
9	12	Grade and Sod	7	2,100
10	11	Install Man Hole	3	3,000
11	12	Test Relocated Electrical	2	6,000
12		Final Inspection	1	0

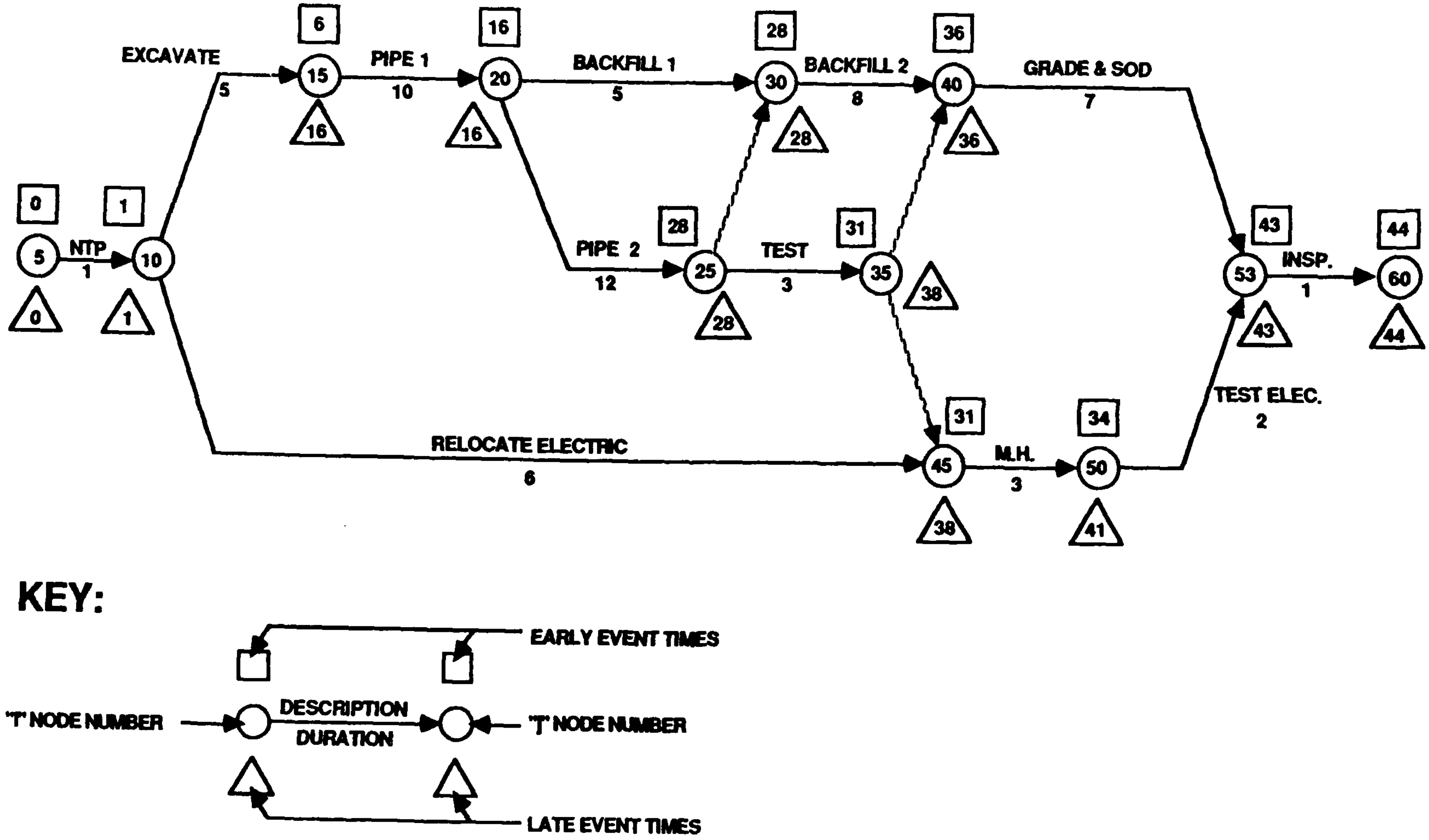


Figure 2. Arrow diagram method for the example project.

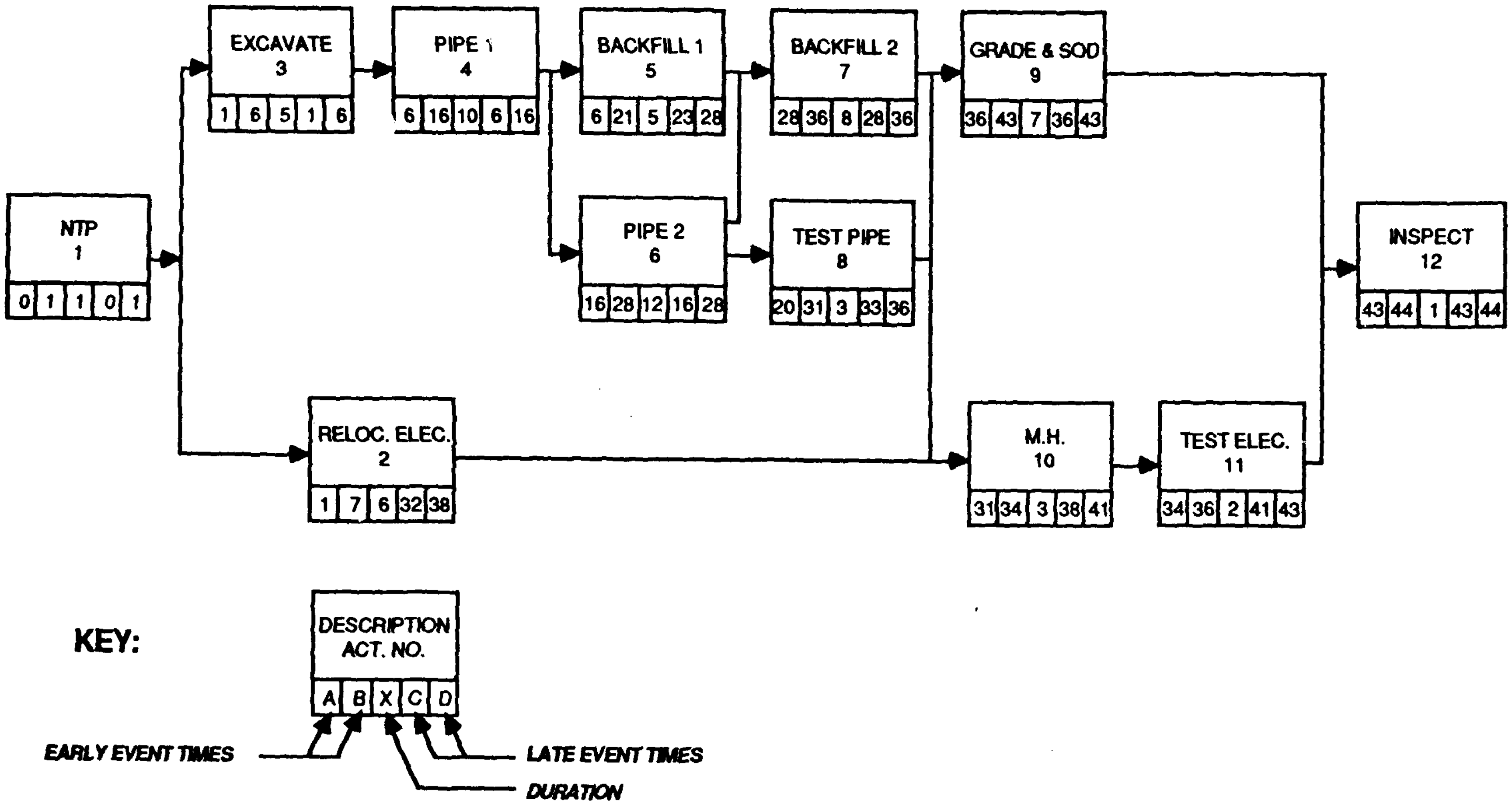


Figure 3. Precedence diagram method for the example project.

The example project in the ADM includes the following sequence of activities (Figure 2): Pipe 1 (15-20), Backfill 1 (20-30), Pipe 2 (20-25), Backfill 2 (28-36), and Test (35-40). These construction activities require seven different network activities, including the two "dummy" activities, 25-30 and 35-40. These dummy activities are necessary to reflect the logical relationship between completion of the second section of pipe (20-25) and the start of the second backfill operation (30-40), and completion of testing (25-35) and completely covering the pipe (30-40). No dummy activities are necessary in the PDM network (Figure 3). On a large project, following the construction pattern through several hundred activities without having to keep track of dummy activities may prove to be much easier for those analyzing the schedule.

The main objective of any scheduling contract clause is to provide quality assurance personnel at the construction field office with a tool to anticipate potential problems in a construction contractor's plan of action. The most important factor affecting this objective is the contractor's commitment to use the schedule as a planning tool. Therefore, it is critical that the resident office does not require the contractor to use either ADM or PDU since it may inhibit the contractor from using the model they are most familiar with.

The other essential factor in meeting the objective of the scheduling contract clause is the resident office's ability to analyze a construction schedule. Since a resident office is typically not able to specify the network model, each office should have some expertise in both the ADM and PDM models.

The potential risk of a contractor or PMS vendor protesting a specification that allows only one type of network model is very high. The risk is increased if the contractor has existing PMS policies that are in conflict with the specification. The construction field office and District Office should be very cautious when specifying only one network model in the construction contract. Specifying a particular system in the contract documents has also caused protests and is to be avoided in accordance with ER 1-1-11, paragraph 9.G.

Activity Identification and Relations

Two critical types of data elements are required for network analysis systems to uniquely define every activity in a network: the activity identification numbers and the logical relationship designations. In programs with the ADM model, the "i" and "j" node numbers express both the activity identification and the logical relationships of the network. In the PDM model, the activity number uniquely identifies the activity, and a list of the preceding or succeeding activities is required to specify the logical relationships.

For people to easily interact with the electronic model of the construction project, activity descriptions for every activity in the network should be entered. The user should be sure to enter the activity descriptions when the activity identification numbers and logical relationships are defined. From these basic elements (activity identification numbers, logical relationships, and activity descriptions) a project management system may provide powerful tools for CPM users. The following paragraphs explore some of these tools.

Many "rules of thumb" about scheduling have been circulated. For example, "All activity identification numbers should be separated by no less than five numbers, in case activities need to be inserted into the schedule later." Another rule explains that

"Activity descriptions should contain mnemonic aides to the actual work being accomplished by that task." While rules of thumb are valid under certain circumstances, institutional or wholesale application of the rules has obscured their real meaning. As a result, many powerful elements of the basic network models, such as activity numbering and descriptions, have been overlooked.

As noted before, the purpose of the schedule is to provide an effective communication device between the construction contractor and project engineer. The depth of this communication is based, to a great degree, on the way the computer model project is constructed. In most construction projects, there is a natural flow of activities that occur as the project is completed.

A general pattern for many mechanical and electrical construction activities may be summarized as: (1) submit, (2) government approval, (3) fabricate and deliver, (4) rough-in, (5) test, and (6) finish. One way to represent these activities to enhance human communication may be to enforce certain conventions on their identification numbers. For example, if all fabricate and deliver actions were represented by activities with PDM activity numbers between 300 and 399, the project engineer would have a built-in schedule analysis tool. A similar effect could be obtained if the "i" node number of an activity in an ADM network was constructed in this fashion.

More sophisticated levels of conventions may also be built into the activity numbers, depending on the type of construction being modeled. Construction projects that have inherently repetitive activities, such as multistory building or highway projects, may incorporate at least two levels of sophistication in the activity numbers. Each section of the construction, either a floor of a multistory building or a reach of highway, may have a specific overall coding such as the digit in the hundreds column. For example, all second floor activities might be between 200 and 299. A second level of description may be included also if similar activities on each floor are coded with the same digit in the tens place. For example, all mechanical rough-ins could have the number 40 buried in the overall activity number.

Combining both of these types of coding, one for location and the other for type of activity, promotes clear and concise communication about job progress without interference from the numeric model or the computer that processes the model. If, for example, the project engineer wanted information about the fourth floor mechanical rough-in, he/she could automatically go to activity number 440.

Requiring activity identification numbers, as one institutionalized rule of thumb advises, is not bad advice for scheduling engineers; it is just incomplete. Activity identification numbers should allow for a crisp and concise model of the physical construction project.

The activity description DEL REF STL is a good example of the inappropriate use of mnemonic abbreviations in developing activity descriptions. This type of activity description will mask the real world that the network model should explicitly communicate as much as using random activity identification numbers. Activity descriptions must clearly indicate the nature of the work to be accomplished. In the example description (DEL REF STL), DELIVER REBAR would be a much clearer description.

Persons unfamiliar with the project, or the project engineer reviewing the schedule at a later date, will find English descriptions a critical factor in the ability to reconstruct the actual sequence of construction.

One way the scheduling engineer might approach activity descriptions is to think of any activity as a combination of an action verb (approve, deliver, or test) and an object (plumbing, ductwork, or carpet). Occasionally these object words might be used to modify other types of objects. For example, a particular activity might be to approve electrical shop drawings. In addition to using clear language, activity descriptions must be used consistently. Although a complete description would be most effective, abbreviations are occasionally necessary due to the limited capability of computer software. In this case, a legend to translate these abbreviations should also be included with any schedule.

Another critical consideration when creating a network model of a construction project is the adequate representation of the relationships between the activities. The general standard of practice in developing the relationships is to have activities interact to meet the construction company's preconceived notion of how the work will be accomplished. While this has worked well on many projects, the way in which these plans are developed may hide some important features.

When creating a model of a construction project, the construction company's scheduler will first divide the work into spacial areas such as first and second floors or east and west wings. Once this is completed, the scheduler then visualizes crews moving through those spaces, completing the work in one area, and moving on to the next area. When the first crew moves into the second area, the next crew follows them into the first area.

While this type of model is very efficient for repetitive construction and allows the contractor's forces to take advantage of the learning curve productivity gains, the scheduler using this model makes assumptions that may not be valid. One assumption is that all crews operate at the same rate of production in a given area. Unless all crews complete a given space in the same amount of time, the project may lose money. In nonrepetitive projects, such as rehabilitation of existing facilities, the scheduler needs to develop activities and their relationships by the natural constraints imposed by the facility itself, not by "crew chases." Once this type of schedule is constructed, the scheduler may determine efficient crew levels through resource analysis techniques.

When defining the relationships between construction activities, the application of actual construction constraints, and not the generally accepted practice of roughing out a crew chase, is the most effective way to create an efficient schedule. Resource analysis techniques are then used to determine an efficient level of workers on the site each day. While some schedulers may feel this amount of effort is unnecessary, it is essential if real productivity gains are to occur on the construction site. The Resident Engineer who convinces contractors of the potential productivity gains to be realized through effective modeling of the construction project has fewer cost and time overruns.

Data Entry and Access

All activity data, as well as other information, is entered into the PMS data base through data entry screens. These screens contain the basic information discussed throughout this chapter in a wide variety of formats. In many of the more powerful programs, menus and data entry screens may contain information that is not required for Corps use. However, these more complex programs generally allow the user to customize the screen fields and formats to local requirements. The more powerful programs may not be suitable for the infrequent user, since customization will be required for easy access to activity data.

In every project management system, an individual activity is selected for on-screen viewing and modification is accomplished by entering the activity's identification number and pressing a key or series of keys that instruct the program to find and display the information. If the user wants to view many related activities, however, this process is tedious and requires him/her to constantly refer to a printed report to find the desired activity identification numbers. To help the user rapidly enter activity information, software vendors have included a number of time-saving features in data retrieval screens.

Several programs allow the user to select a group of activities to access. The selection might be based on the need to update the network. In this case, the user selects the activities that the contractor has scheduled to begin by the current date. The ability to search for a subset of activities selected is an extremely useful feature of several PMSs.

Another variation of the multiple activity access feature is the use of table editors. Table editors allow the user to scroll through and access all activities within a table. This feature, while useful, is not as powerful as the search for particular activities since the user still must look through the list of all activities to locate those required for modification or updating.

Activity Durations

It is usually in the best interest of all parties in the construction process to complete a project as quickly as possible. Rapid completion allows the user to benefit from the facility and the contractor to move to another project and realize more profits. Although many contractors believe the government uses schedules to unfairly expedite construction, the contractors themselves are missing large increases in profits by not expediting projects on their own.

The total contract completion time is made up of the time required to complete all activities. Activity durations are based on the amount of work to be accomplished and the production rate of the workers and equipment. An estimator typically determines the production rate and provides a duration for each activity. This data may be entered into the construction schedule. Figures 2 and 3, respectively, show the results of the ADM and PDM calculations used to determine the earliest a project may be completed and the earliest and latest each activity may be started and/or finished to meet the project completion date.

The difference between the date when an activity <u>may</u> start and when an activity <u>must</u> start is called "float." For example, activity five of the example network may begin as early as 16 days or as late as 23 days after the project starts and the project will still complete on day 44. This 7-day difference is the float.

One or more paths through the schedule have activities with zero float. These activities must be started on schedule or the project's completion date will change. For example, activity six must begin on day 16 and end on day 28 for the project to be completed by day 44. The activities in a network that have zero float are on a path from the beginning of the project until the end of the project. This "critical path" is so named because these activities are the most important to the project plan at a particular time.

The example project's schedule will take 44 days to complete. Although this schedule is only a model, any assumptions made may affect the "real world" completion of the project in 44 days. Certain assumptions included in this 44 day schedule bear investigating. The first item that should be obvious is that construction crews, unless paid overtime, do not work 7 days a week, 24 hours a day. The example schedule eliminates weekend work and limits the crews' work to 8 hours a day.

Project management systems provide several tools that allow the user to define hours of the workday, days in the workweek, and specialized calendars. For the example project, the workday begins at 0700 hours and ends at 1530 hours. While this assumption is reasonable, it will yield some unanticipated results for an unaware user. Activities will seem to have durations of 1 day less than the intended durations. For example, an activity with a 1-day duration will be shown in a computer model as starting and completing on the same day. Subsequent activities begin on the following day at 0700. When reviewing a network, the Resident Office staff should remember this problem and attempt to determine how workdays are calculated in the project management system.

Some project management systems allow scheduling of shiftwork over the entire 24-hour clock. This type of customization may not be needed for most Corps' construction on military facilities. However, Civil Works and Operations and Maintenance (O&M) projects may need this additional flexibility.

Project management software often allows the user to define a calendar that specifies the days of the week on which activities may post progress. Holidays may also be included in the calendars to denote days that are not counted when progress is posted to an activity. Several project management programs allow different calendars to be specified within one schedule.

Variable work week duration is another feature of many project management systems. These systems allow the user to provide different calendars for different types of crews. Although this option is a very powerful tool for a complex job, many projects do not need this level of complexity. Figure 4 shows how placement of the weekends affects the example network "Excavation," which has a 3-day duration.

The problems between 5- and 7-day workweek schedules have been discussed at length among Corps policymakers. The 5-day workweek schedule provides a realistic version of the way most contractors work; Monday through Friday, with Saturday and Sunday off. The 5-day workweek does, however, pose a problem if the contractor actually works on a weekend. The Corps and the contractor must specifically discuss each activity that has weekend work to determine the amount of work completed and the new activity completion times. The activity completion times provided in a 5-day workweek schedule will be later than the actual completion that may occur due to working a weekend.

Another approach to modeling the working week is to allow the contractor to use a 7-day workweek and add extra days for the weekend days of no work. Adding days to the duration results in an "equivalent" duration. These additional days will cause the activity to finish on the same date as the 5-day workweek schedule.

The Corps has often required construction contractors to provide a schedule based on a 7-day workweek. There are two reasons why a construction field office may want to carefully consider specifying either a 5- or 7-day workweek are: (1) the modernization of processing techniques, and (2) the perceived ability of a construction field office to require weekend work. These are discussed in the following section.

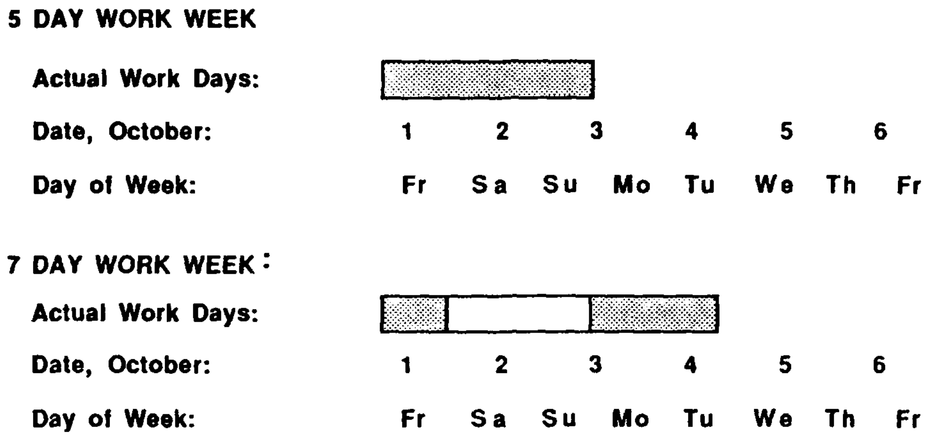


Figure 4. The effect of calendars.

When many scheduling requirements were developed, the primary computer "platform" for project management systems was the mainframe computer. These systems were typically not designed to provide calendars. If mainframe systems were not available, the scheduler had to rely on calculating a network directly on the diagram as in Figures 2 and 3. As projects became larger, this task became very complicated. Because it was difficult enough for the scheduler to calculate the number of days past the Notice to Proceed date, the Corps of Engineers implicitly adopted a 7-day workweek standard.

The 7-day workweek may also be thought to allow a contractor to more easily make up for lost time by showing weekends and holidays as potential workdays. Weekend days, in most cases, are not used by the contractor. Improving productivity during regular hours is the option chosen most often. If the contractor has caused the delay, the project must still be completed on time, regardless of the methods used to accomplish this. Using a 7-day workweek to force a contractor to make up work is a weak construction management tactic and generally only serves to cloud progress discussions.

The original schedule of the example network introduced in Table 1 has been recalculated to illustrate the results of both 7- and 5-day calendars. Table 2 uses a 7-day workweek, a work day from 0700 to 1500 hours, and no holidays. Table 3 presents a 5-day workweek, a work day from 0700 to 1500, and typical federal holidays.

The schedule produced on a 7-day workweek shows a completion date of 11 Nov 87. The completion date of the schedule on the 5-day workweek is 1 Dec 87. The obvious differences in these calculations will lead to major difficulties for the construction field office if workweeks and holidays are not coordinated with the contractor before initial submission of the contractor's schedule.

Table 2

Schedule Report for a 7-day Workweek

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Early Start/Finish	Late Start/Finish	Float
1/2,3	NTP	1	1	1 Oct 87 1 Oct 87	1 Oct 87 1 Oct 87	0
2/10	Reloc Elec	6	6	2 Oct 87 7 Oct 87	31 Oct 87 5 Nov 87	29
3/4	Excavate	3	3	2 Oct 87 4 Oct 87	2 Oct 87 4 Oct 87	0
4/5,6	Pipe 1	10	10	5 Oct 87 14 Oct 87	5 Oct 87 14 Oct 87	0
5/7	Backfill 1	5	5	15 Oct 87 19 Oct 87	22 Oct 87 26 Oct 87	7
6/7,8	Pipe 2	12	12	15 Oct 87 26 Oct 87	15 Oct 87 26 Oct 87	0
7/9	Backfill 2	8	8	27 Oct 87 3 Nov 87	27 Oct 87 3 Nov 87	0
8/9,10	Test Pipe	3	3	27 Oct 87 29 Oct 87	1 Nov 87 3 Nov 87	5
9/12	Grade & Sod	7	7	4 Nov 87 10 Nov 87	4 Nov 87 10 Nov 87	0
10/11	Man Hole	3	3	30 Oct 87 1 Nov 87	6 Nov 87 8 Nov 87	7
11/12	Test Elect	2	2	2 Nov 87 10 Nov 87	9 Nov 87 10 Nov 87	7
12	Inspect	1	1	11 Nov 87 11 Nov 87	11 Nov 87 11 Nov 87	0

Table 3

Schedule Report for a 5-day Workweek With Holidays

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Early Start/Finish	Late Start/Finish	Float
1/2,3	NTP	1	1	1 Oct 87 1 Oct 87	1 Oct 87 1 Oct 87	0
2/10	Reloc Elec	6	6	2 Oct 87 9 Oct 87	12 Nov 87 19 Nov 87	29
3/4	Excavate	3	3	2 Oct 87 6 Oct 87	2 Oct 87 6 Oct 87	0
4/5,6	Pipe 1	10	10	7 Oct 87 20 Oct 87	7 Oct 87 20 Oct 87	0
5/7	Backfill 1	5	5	21 Oct 87 27 Oct 87	30 Oct 87 5 Nov 87	7
6/7,8	Pipe 2	12	12	21 Oct 87 5 Nov 87	21 Oct 87 5 Nov 87	0
7/9	Backfill 2	8	8	6 Nov 87 17 Nov 87	6 Nov 87 17 Nov 87	0
8/9,10	Test Pipe	3	3	6 Nov 87 10 Nov 87	13 Nov 87 17 Nov 87	5
9/12	Grade & Sod	7	7	18 Nov 87 30 Nov 87	18 Nov 87 30 Nov 87	0
10/11	Man Hole	3	3	11 Nov 87 13 Nov 87	20 Nov 87 24 Nov 87	7
11/12	Test Elect	2	2	16 Nov 87 17 Nov 87	25 Nov 87 26 Nov 87	7
12/	Inspect	1	1	1 Dec 87 1 Dec 87	1 Dec 87 1 Dec 87	0

Activity Access

The most important task for a resident office is the timely and specific analysis of a construction schedule. While there may be many steps to this process, the initial step is to find information on only those activities necessary for the particular analysis. In the early releases of mainframe PMSs, the user had to search through stacks of paper reports to select the appropriate activities. Microcomputer systems began to provide a limited ability for interaction by allowing the user to see one activity on the computer terminal after typing in the node or activity numbers. Unfortunately, this was not necessarily a step forward because the user still had to search through the paper reports to determine the activity numbers.

The advent of relational data base technology has revolutionized many types of computer applications, including PMSs for the construction industry. The essential element of this type of computing power is the ability to select and sort information depending on conditions supplied by the user.

Selection is the process of creating a temporary file that contains only a subset of the total activities in the network; for example: all electrical activities, all government approval activities, and all activities that relate to a particular specification section. The selection may include more than one condition, for example, all electrical activities on the first floor, all government approvals that must be completed this week, or all mechanical submittals that have not been received at the resident office.

The computer cannot directly answer these questions since it does not understand the activity description. However, one way to add that information to the schedule is to develop a coding scheme. It is this coding scheme that provides activity access flexibility for the resident office.

Many types of activity codes can be used if the system provides enough data fields. PMSs provide as many as three levels for activity coding: fixed length, variable length, and flexible.

Fixed length codes are provided by specific data entry fields. The most common are the responsibility codes and work area codes. The responsibility code generally refers to a field that contains a designation for the subcontractor providing the service for a given activity. The work area code is typically included for the user to group activities scheduled in the same physical area.

A few systems provide features that allow the user to create any codes necessary, provided the total number of characters in all the codes does not exceed a fixed ceiling. In this way, codes of variable lengths can be developed for each project in the network. Since people will have to work with these codes, they should be able to understand the meanings without a dictionary. For example, if a user wanted to distinguish between submittal, approval, and installation activities, then a code "TYPE" could be created. The values of the TYPE code could be "SUBMIT," "APPROV," and "INSTAL." Although two of these codes are abbreviations, all resident office personnel will be able to relate the codes to a real construction project.

The most flexible coding scheme allows the user to create codes for various projects and also to access any given character within that code. This level of sophistication may be required to analyze codes that have multiple levels of meaning. For example, the generic Specification Sections from the Construction Specification Institute (CSI) have three levels of meaning: the overall category of tasks (e.g., mechanical, electrical), the general area within a category (e.g., steam distribution, electrical panels) and the specific construction item (e.g., valves, circuit breakers). To use the power of this type of code, the user must specify both the name of the code and the position of the characters within the code.

Assigning activity codes is very important since these values determine the degree of analysis possible for large construction projects. To decide what coding is appropriate for a particular project, the scheduler should make some educated guesses about what kind of scheduling information he/she would like to see. The following activity codes are suggested possibilities for use in large networks: responsibility, work area, activity type, specification section, building system, weather sensitivity, and modification number. One potential use of these codes is provided in Table 4.

A wide variation in the actual implementation of coding in PMSs is possible. The minimum typically provided are the responsibility code and the work area code. These two codes generally appear on the activity information data entry form. While the data fields for these codes may be labeled with "Responsibility" or "Subcontractor," and "Work Area" or "Location," these fields may actually be used for any code the scheduler desires. This factor is often overlooked by many novice PMS users. It should be emphasized that the codes included in a PMS are not actually defined by the system. If, for example, a particular construction project's biggest problems would arise from material delivery, the user may want to define the contents of the responsibility and work area fields as a specification section and an activity type. Although one of these fields has a particular

Table 4

Possible Library of Activity Codes

Code Name	Code	Definition/Recommendations for Use
Responsibility	RESP	Designation for the trade or subcontractor who is responsible for the work. This is very useful in large complicated projects but may be used on all projects.
Work Area	AREA	Designation for a particular area of the work such as floors or buildings; this may also be expanded to refer to phases of work. This may be used to complement the activity number designation for data extraction.
Type of Activity	TYPE	Designation for the type of activity which is being modeled, such as: submittal, approval, deliver, install, test. This is important for all projects.
Specification Reference	SPEC	Reference for the activity to the construction specification. is very useful for all projects but should always be used on large projects.
Building System Reference	SYST	Reference for the activity to the building system index (BSI). This allows all activities which contribute to a particular building element to be isolated. This code should be used for all complex projects.
Weather Sensitive	WETH	Designation of the weather sensitive activities. This code should be used for all complex projects.
Modification Number	MOD	Reference to construction modification. This should be used for all projects.

name, use of the field and the data stored in the field do not necessarily have to match the name. Thus, a PMS with limited or fixed coding features may be used as the office wishes.

Most PMSs allow the user to define the names of some of the codes. The most simple system provides generic fields labeled CODE1, CODE2, etc., that the user may define. This is little different from providing named fields since the user may define the contents of the field. When using these codes, the scheduler and everyone else who will have access to project data needs a code dictionary. Keeping track of many dictionaries will become quite cumbersome for the resident office that has many projects.

Other PMSs provide a fixed number of fields and characters that may be used as desired. This type of system allows the user to define a set of codes for a particular project and to name fields that correspond to those codes. This type of coding is extremely useful because it promotes communication by allowing English words to be used for the codes as well as their values. Rather than use CODE1 to represent a phase of work required by the contract, the resident office may use PHASE and restrict the values to PHAS1, PHAS2, etc.

The temptation to use only numerical descriptions for activity codes, as many veteran programmers experience, must be avoided since the goal of scheduling is to enhance communication among the construction team and not to demonstrate elegant programming.

The most sophisticated level of coding, which is seldom needed, is the ability to add directly to a PMS data base structure. Unless the system provides an interface to allow for this feature, additional codes may be difficult to create. This type of modification will not be necessary for most resident office applications.

Each project has different coding variations, however, variation in overall coding schemes for a given resident office may be fairly limited. To assist the user in assigning codes to a network, some systems provide a library facility. Libraries are a user-defined set of codes that may be used for all the projects at a resident office. There are two levels of activity code libraries: transferring code schemes, and directly transferring codes to activities.

When creating a new schedule, many PMSs allow the scheduler to import code schemes and code values from an existing project. The user must then assign codes to all the activities in the network. A similar technique, frequently available when creating a new version of the same project and before posting progress information, is to essentially copy the entire project and then modify only those activities necessary for an update.

Another technique for entering activity codes into a network is to create a program that directly manipulates the PMS data base. This type of programming is very complicated because the user has to know the details of the data base. Unless resident office personnel have substantial programming experience, this technique is not recommended.

One problem that may be encountered when using a complex coding scheme is the need to add codes several months after a project has begun. To accomplish this, the user will have to add the new codes to each version of the schedule and manually add all the data into each activity. The need for more detailed analysis often occurs when the resident office has a project that appears straightforward but turns out to be quite complicated. If the contractor is not required to use a robust coding scheme at the beginning of the project, the resident office may spend up to 2 or 3 days recording and debugging all the versions of a network.

Resource Information

Many contractors are beginning to realize the positive impact that monitoring resources through a schedule has on their profits. For this reason, many PMSs provide not only a method of allocating resources to an activity, but also provide algorithms designed to help a project manager efficiently plan a project.

In reality, resource information is only a specialized type of activity coding. Each activity may be assigned certain codes that designate the type of crew that must be used to accomplish the task. A PMS may also provide other code fields related to resources. Some examples of these fields are: the number of crews planned to work on the activity, the rate of production of a given crew, the quantity of work to be completed during the duration of the activity, and the equipment and/or material quantities necessary to complete the work.

The most versatile use of resource codes, as with activity codes, allows the contractor to create a library. This library may contain materials and equipment required, and production rates for each crew used on any project. Once crews are assigned to specific activities, the crew schedule, material lists, equipment lists, and many cost-related reports may be generated.

Another feature that benefits a construction contractor is the ability to study the use of resources on the project. On most projects, the most efficient use of contractor personnel is to move crews on the site and have them work at a steady rate until the work is completed. Once the work is completed, the workers move on to another project. As the first crew completes their task, the second crew takes over and completes their tasks, followed by the third, fourth, and any other crews. This type of crew allocation is often referred to as a crew chase.

In contrast, one of a contractor's worst nightmares is that workers complete some tasks, leave the project, and return days later to work on other tasks. This type of staggered crew scheduling will significantly reduce worker productivity and should be avoided by the contractor if possible.

The Resident Engineer may wish to use resource allocation to schedule preliminary, initial, and followup inspections. The PMS may allow, through resource coding, a schedule indicating which technical inspectors need to be at a project site. Codes could be created for each specialty inspector in an office and assigned to those activities that require their particular talents. Reports could then be generated for one project or all projects to provide a work schedule for the inspectors. If a PMS has very limited resource coding, activity codes may be used for this function.

To help contractors analyze their crew allocation, many PMSs include features that provide a list of daily worker requirements for any of the resource codes that are part of the project. For example, a program may be able to show, over the entire course of the project, the number of carpenters required every day. If this number is not consistent, the contractor may want to consider modifying the schedule.

There are several methods that the contractor may use to modify the schedule. This process, called resource leveling, is explained in detail in many of the books listed in the Reference section. The essential element of resource leveling is that the contractor is able to allocate workers, without affecting the critical path of the schedule, by "sliding" from a schedule based on an early start of all activities to a schedule that shows some activities starting at a later date. Shifting to a late start schedule may concern many resident office personnel; however, it is the contractor's responsibility to perform the work within the number of days specified in the construction contract.

Another resource algorithm used to modify the schedule is called constraining. Constraining limits the use of a resource. This type of analysis may help a resident office anticipate the contractor's ability to complete the project using a limited number of workers. While the Resident Engineer may not direct the contractor to perform work in any particular way, resource analysis may be another tool with which to monitor the contractor's performance.

Project Progress

After construction begins, a contractor will request payment for the progress made to date. For payment, the schedule becomes a spreadsheet program that will calculate a dollar amount to pay the contractor, based on some measure of completion of each activity. While this is an important function of a construction schedule, it is not the most important. Anticipating and avoiding construction bottlenecks is the most important use of the schedule.

Before exploring how a PMS may be used to analyze progress on the construction site, several important technical aspects of project management systems must be defined. These include time-based progress, use of the data date, default calculations, out-of-sequence progress, and fiscal compensation.

The terminology used to post progress in a PMS is one issue that the resident office and contractor must agree on early in the process. In addition to the definitions of the terms, the methods that the programs will use to manipulate this information to schedule the project must also be discussed. As in the examples that describe the workweek definitions, failure to agree on these issues may cause the contractor and the resident office to obtain completely different results from the same "raw" project data.

The percent of the payments made to the contractor is an essential element in determining the status of a project. This percentage should be a sum of the progress the contractor has made on each activity. For the following example, it is assumed that a contractor is trying to determine if he/she is ahead of or behind schedule based only on time.

To update the progress schedule, the contractor must first agree with the Resident Engineer's representative on the actual start date of an activity, the remaining duration of that activity, and/or the date the activity was completed. Table 5 provides this information for the example project.

The user should be aware of two dates before beginning any progress analysis. The first and more important is the point in time that progress is measured to. This is referred to as the "data date." The way this schedule calculation date will be used is explained in the following paragraphs. The second date is the actual day that the schedule is being updated. Since information entered into a PMS is often several days to a week old, the user must keep in mind that the data date is the date the PMS uses to reschedule updates.

Table 5

Progress Data as of November 2, 1987

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Actual Start	Actual Finish
1/2,3	NTP	1	0	1 Oct 87	1 Oct 87
2/10	Reloc Elec	6	3	8 Oct 87	
3/4	Excavate	3	0	5 Oct 87	9 Oct 87
4/5,6	Pipe 1	10	0	12 Oct 87	23 Oct 87
5/7	Backfill 1	5	0	26 Oct 87	30 Oct 87
6/7,8	Pipe 2	12	7	26 Oct 87	
7/9	Backfill 2	8	8		
8/9,10	Test Pipe	3	3		
9/12	Grade & Sod	7	7		
10/11	Man Hole	3	3		
11/12	Test Elect	2	2		
12	Inspect	1	1		

The resident office and contractor PMS user must understand how a system uses the data date, remaining duration, and actual start and finish dates to calculate a schedule. One possible schedule report based on the update progress information from Table 5 is shown in Table 6. This report is somewhat different from the report in Table 3 because the actual dates and remaining duration estimates from the progress data have been substituted for scheduled dates. To assist the user in identifying those activities that have progress, the letter "A" or a special symbol, such as an asterisk, is placed beside the actual date.

Before analyzing the contractor's poor performance (the schedule slipped 3 working days, from 1 December to 4 December, 1987), the importance of understanding the methods that may be used to calculate these dates will be explained by several examples. These examples explore the types of problems that might be expected to occur during a progress updating session at any resident office. It is important to note that each "progress" measuring approach is valid, but since they evaluate different items, they will provide different answers.

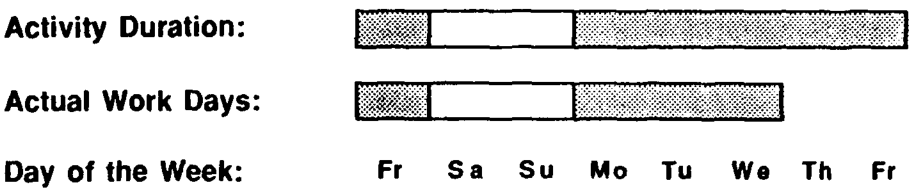
In the most basic sense, an activity is "in progress" if the remaining duration is between the original duration and zero. Although the remaining duration is used frequently as the indication of progress, another method to describe an activity in progress is the expended duration. The expended duration represents the number of days of work already accomplished.

Time-based percent complete is an important concept and is often used interchangeably with remaining or expended duration. The time-based percent complete is calculated by dividing the remaining duration by the original duration. The relative values of the two durations and the time-based percent complete for the possible progress conditions are given in Figure 5.

Table 6

Updated Schedule Report

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Early Start/Finish	Late Start/Finish	Float
1/2,3	NTP	1	0	1 Oct 87 A	1 Oct 87 A	
2/10	Reloc Elec	6	3	8 Oct 87 A 3 Nov 87	19 Nov 87 23 Nov 87	14
3/4	Excavate	3	0	5 Oct 87 A	9 Oct 87 A	
4/5,6	Pipe 1	10	0	12 Oct 87 A	23 Oct 87 A	
5/7	Backfill 1	5	0	26 Oct 87 A	30 Oct 87 A	
6/7,8	Pipe 2	12	7	26 Oct 87 A 10 Nov 87	2 Nov 87 10 Nov 87	0
7/9	Backfill 2	8	8	11 Nov 87 20 Nov 87	11 Nov 87 20 Nov 87	0
8/9,10	Test Pipe	3	3	11 Nov 87 13 Nov 87	18 Nov 87 20 Nov 87	5
9/12	Grade & Sod	7	7	23 Nov 87 3 Dec 87	23 Nov 87 3 Dec 87	0
10/11	Man Hole	3	3	16 Nov 87 18 Nov 87	25 Nov 87 1 Dec 87	7
11/12	Test Elect	2	2	19 Nov 87 20 Nov 87	2 Dec 87 3 Dec 87	7
12	Inspect	1	1	4 Dec 87 4 Dec 87	4 Dec 87 4 Dec 87	0



Original Duration: 6 Days
Remaining Duration: 2 Days
Expended Duration: 4 Days

Time-Based Percent Complete = (4/6)(100) = 66%

Figure 5. Duration and time-based progress.

Figure 6 shows how a computer may calculate an activity that has an actual start date and a remaining duration. As may be expected with the CPM, the remaining duration is added to the data date to calculate the early finish of the activity.

Another way of showing that an activity is in progress is to note if the start date for the activity has the symbol denoting that the date is an actual date. If the symbol is present, the activity is in progress.

Use of Default Activity Start Dates

Although the date an activity begins (and ends) should be entered into the program, the exact date is not always known by the person updating the network. To provide for this situation, many programs allow progress to be defined by entering only the remaining or expended activity duration. However, taking this shortcut is not recommended since systems differ widely in the method of calculating the schedule if the actual dates are not provided.

Two situations could arise if a remaining or expended duration is reported without entering the actual start date of an activity. While the first case is very straightforward the second situation reflects a large difference in scheduling philosophy. The first case occurs when the data date is the same date as an activity's early start date. The program assigns the data date as the actual start date and then calculates the early finish date as the actual start date plus the remaining duration. The previously calculated early start date and the original duration are disregarded by the scheduling program. Figure 7 provides an example of this situation (Case 1).

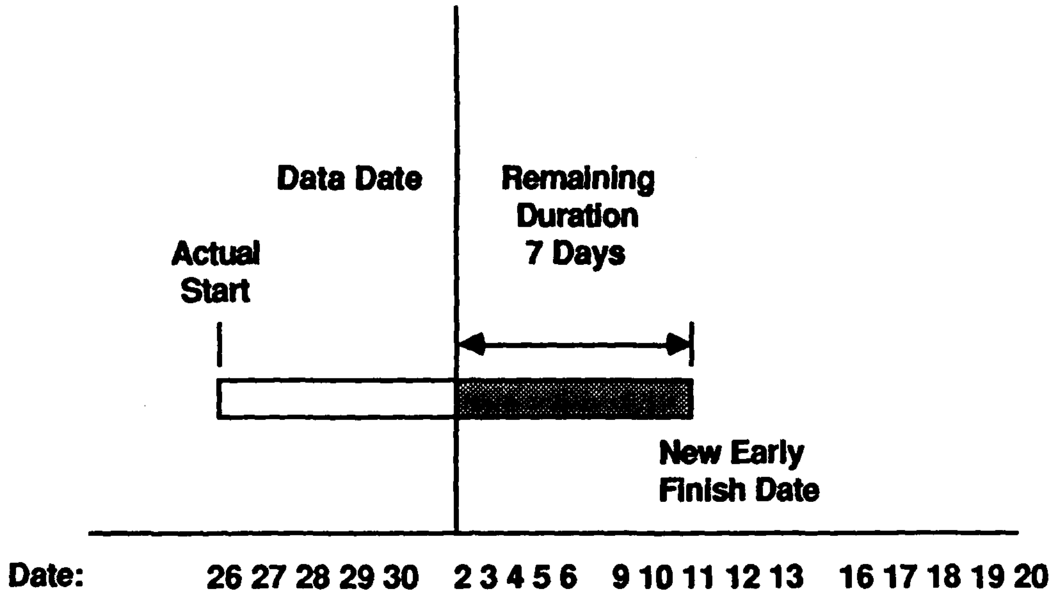


Figure 6. Schedule calculation with actual start and remaining duration.

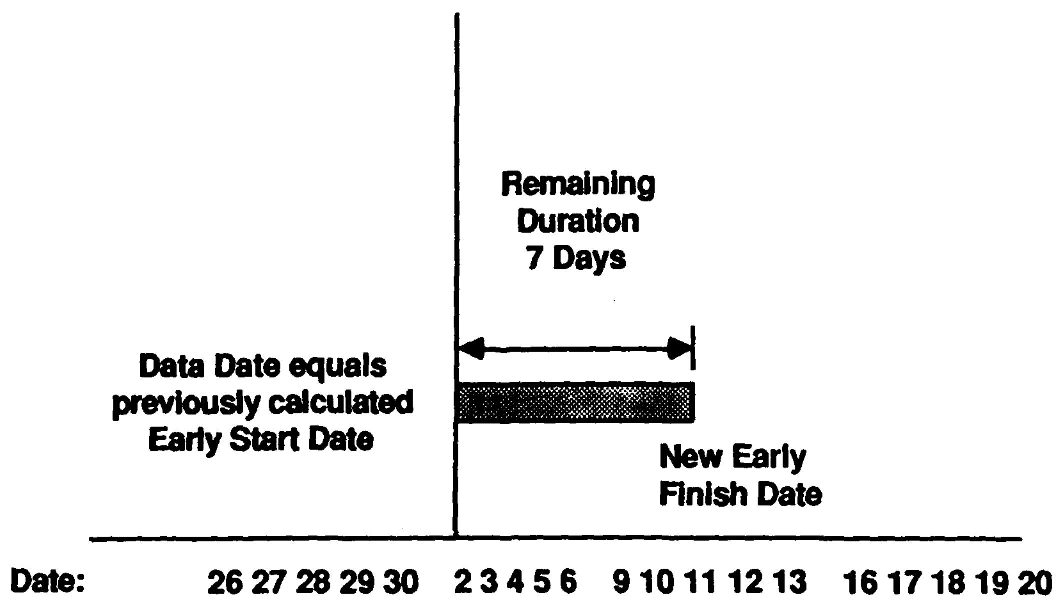


Figure 7. Schedule calculation using default for actual start (case 1).

While the first case seems to be what one might expect a program to do, there are other factors to consider before using the default feature of some PMSs. One of the most important reasons for using a construction network is to communicate. The default calculation used in Case 1 will mask the actual progress of the construction project. Another reason to avoid this case is that in some programs the default date (in this case the data date) is printed without being flagged as such. Systems that do not provide some type of identification for activities that use default information should be thoroughly investigated before use.

In the second case (using default values for early start dates), the actual start date of an activity precedes the data date. Two different scheduling algorithms may be applied, depending on the PMS being used. In the first algorithm, the actual start date is set to equal the data date and, as in the previous example, the early finish is set to be the sum of the default date and the remaining duration. Figure 8 shows the result of this type of calculation (Case 2a).

The second scheduling algorithm will calculate a different early finish date for the activity. This algorithm sets the actual start to the activity's previously calculated early start date. The early finish will be the sum of the actual (early) start date and the remaining duration. As shown by Figure 9, the early finish date for this activity will be earlier than for the first algorithm. The activity will finish early by the number of days difference between the previously calculated early start and the data date. If this difference is larger than the remaining duration entered by the user, some programs will indicate that the activity has been completed. Figure 9 graphically illustrates this scheduling algorithm (Case 2b).

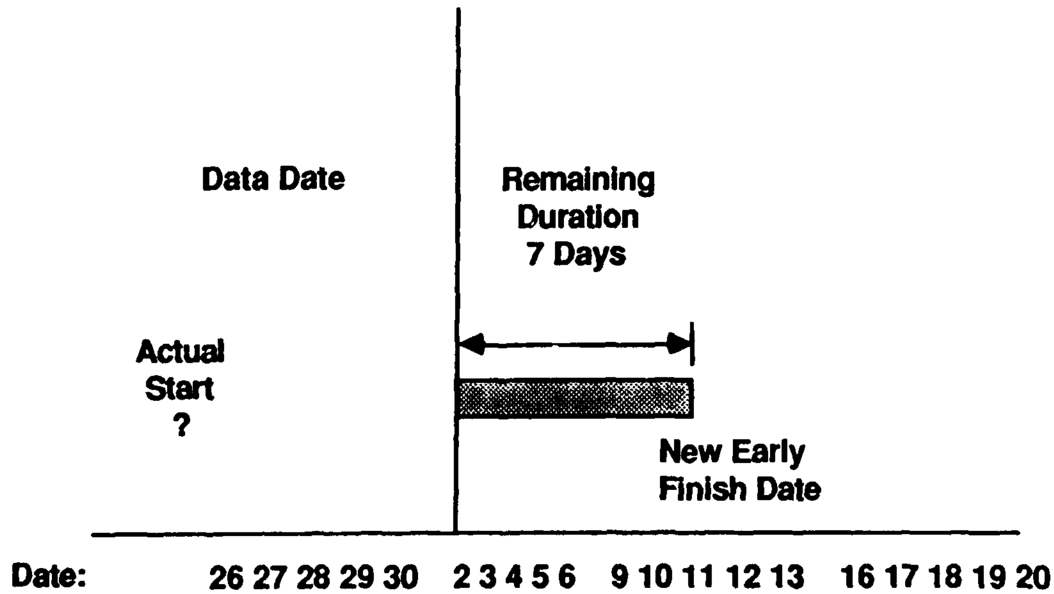


Figure 8. Schedule calculation using default for actual start (case 2a).

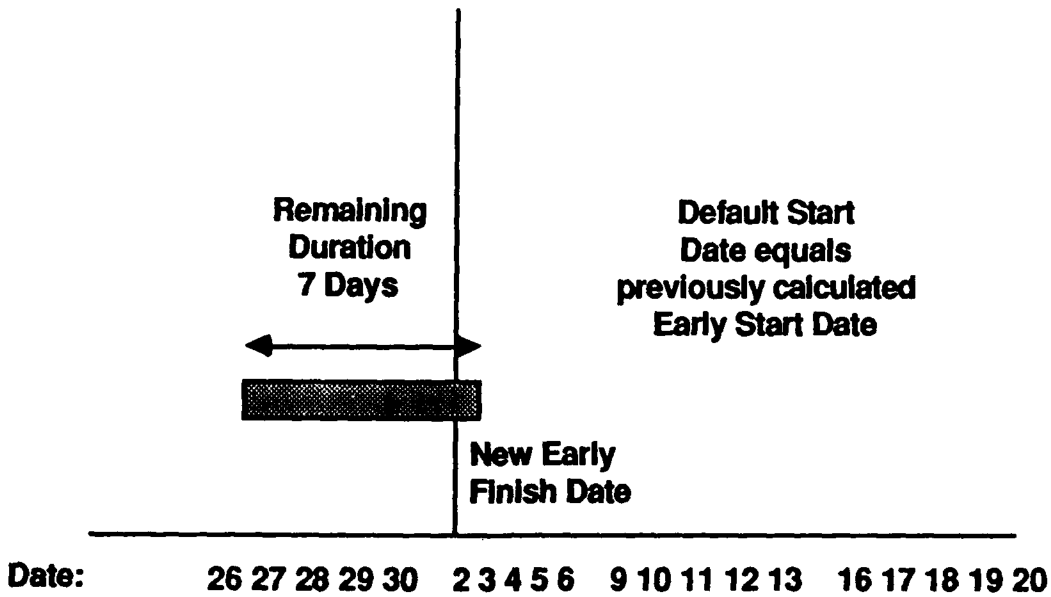


Figure 9. Schedule calculation using default for actual start (case 2b).

Although the use of default dates may be misleading from the resident office perspective, programs that allow this default capability are appropriate for Corps use if sufficient time is available to analyze potential conflicts. If a resident office discovers that the program being used inserts default dates into the schedule, the office needs to be especially careful that any activities that are going to show progress have an Actual Start Date and Remaining Duration. This policy may also be extremely valuable if someone has to reconstruct the project later from the construction schedule.

Out-of-Sequence Progress

It is common for the critical path models developed at the beginning of a project to change as the contractor evaluates the most efficient means to perform an activity. As activities are added, deleted, or changed to reflect revisions in the plans, the resident office must review the new schedule and provide comments as appropriate. One example of this type of change occurs when a contractor's schedule calls for one activity to precede another activity, while on the construction site both activities are underway. This type of problem is called "out-of-sequence progress."

Out-of-sequence progress is very controversial since it indicates that the logic of the schedule is incorrect. The contractor should be required, in significant cases, to revise the network to show the actual logic of the project.

Most PMSs generally allow two ways to schedule a network with out-of-sequence progress. These will be referred to as the Logical Calculation Method (LCM) and the Progress Calculation Method (PCM). These calculations are often difficult to trace and should be avoided unless the resident office staff and the contractor thoroughly understand the way these algorithms operate.

To calculate the schedule for out-of-sequence progress, the LCM performs the following actions: (1) calculates the early finish of the first activity by adding the remaining duration to the data date, (2) sets a temporary start date for the second activity to be the previous activity's early finish, and (3) calculates the section activity's early finish as the sum of the temporary start date and the second activity's remaining duration. This method is called the Logical Calculation Method because in step 2 the logic of the schedule is used to determine the second activity's temporary start date. Figure 10 illustrates this method.

The PCM calculates the early finish of the second activity by adding the remaining duration of the out-of-sequence activity to the data date. This method essentially ignores the logical constraints imposed by the first activity. Since this algorithm relies only on the progress of the activities and disregards logical constraints, it is called the Progress Calculation Method. Figure 11 illustrates this method.

If the resident engineer staff produced a report based on the LCM and the contractor submitted a schedule based on the PCM, a great deal of confusion could result. The resident engineer staff needs to be very careful in the method of updating the progress of out-of-sequence work.

Figures 12 through 14 provide a specific example of the type of problem that may be encountered in the example project. Figure 12, the baseline for these examples, has progress posted according to the information in Table 6. If Activity 7 (Backfill Section Two) had actually started 2 days after the start of the second section of pipe (Activity 6) instead of upon completion of Activity 6, there would be an out-of-sequence problem. Figures 13 and 14 illustrate the results of this out-of-sequence progress and show the information that would be provided by a PMS. Table 7 shows a report produced by the LCM for the out-of-sequence progress. Table 8 shows a report produced by the PCM for the out-of-sequence progress.

If neither the contractor nor the government knew different algorithms were used, the resident engineer might direct the contractor, who used the PCM, to provide a schedule with the "real" early finish dates, provided by the resident engineer's LCM. The contractor might comply with this request by "doctoring" the durations of the activities that would change the early start and finish dates to be the same as on the LCM schedule. However, the backward pass would be significantly different from what the resident office may have expected when the request to modify the schedule was made.

When the resident office and the contractor discuss the requirements for the schedule, out-of-sequence progress calculation must be on the list of topics. The point of this discussion should be to determine what actions may be taken to modify a schedule that has a significant amount of activities with out-of-sequence progress. If only a few activities are out of sequence during the project, the resident office may only want to exchange information regarding the scheduling algorithms being used.

A resident office generally takes a conservative approach in determining the completion of a particular activity on the schedule. This approach justifies the use of the LCM for out-of-sequence activities, since LCM is more conservative for two important

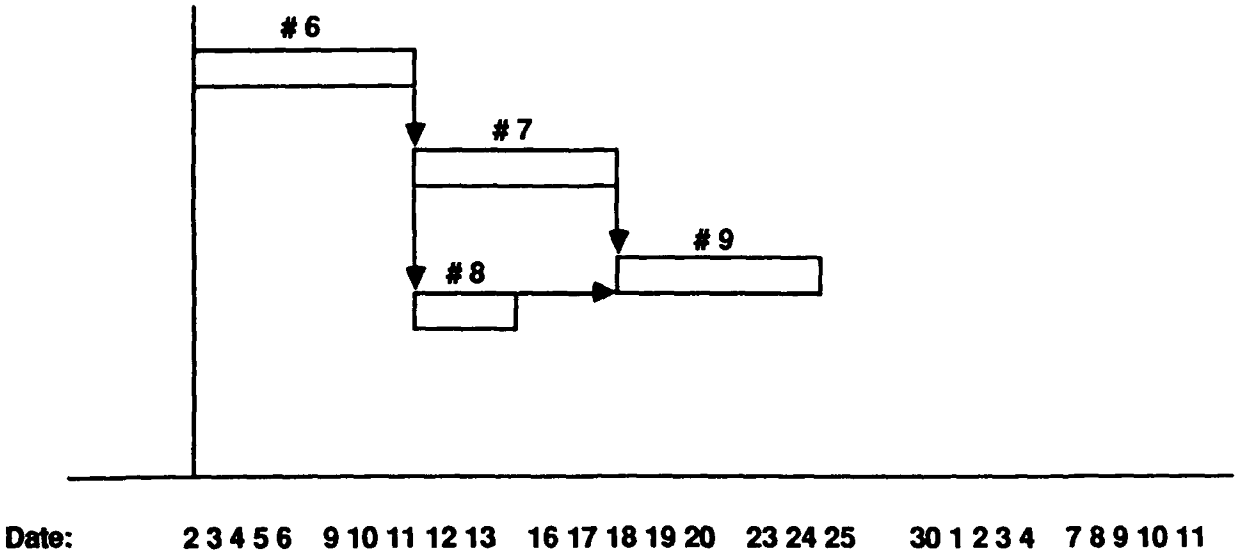


Figure 10. Logical calculation method for out-of-sequence progress.

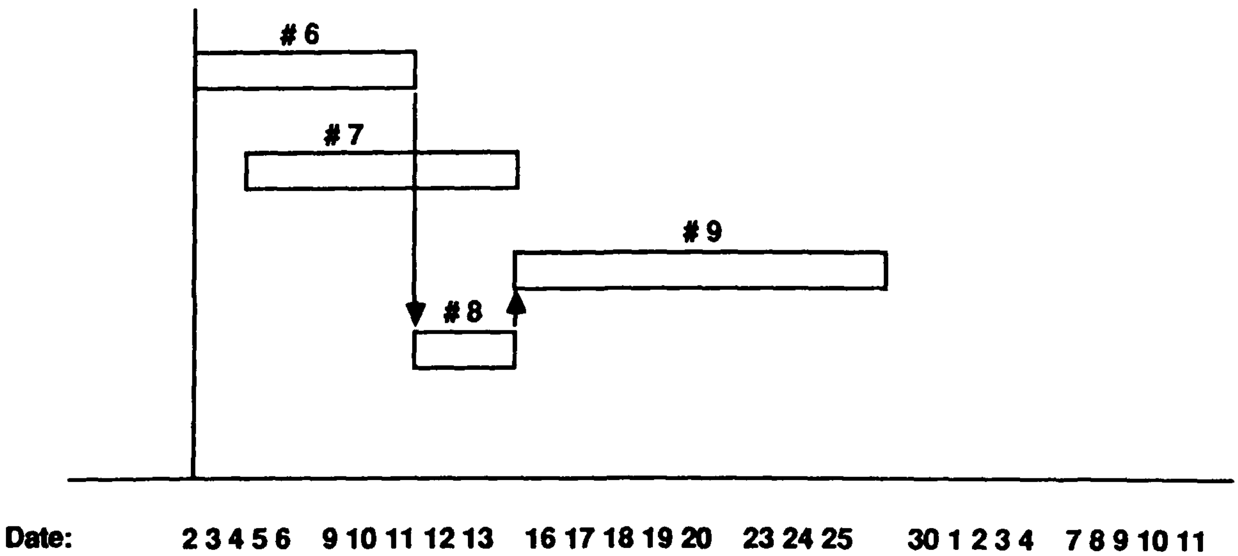


Figure 11. Progress calculation method for out-of-sequence progress.

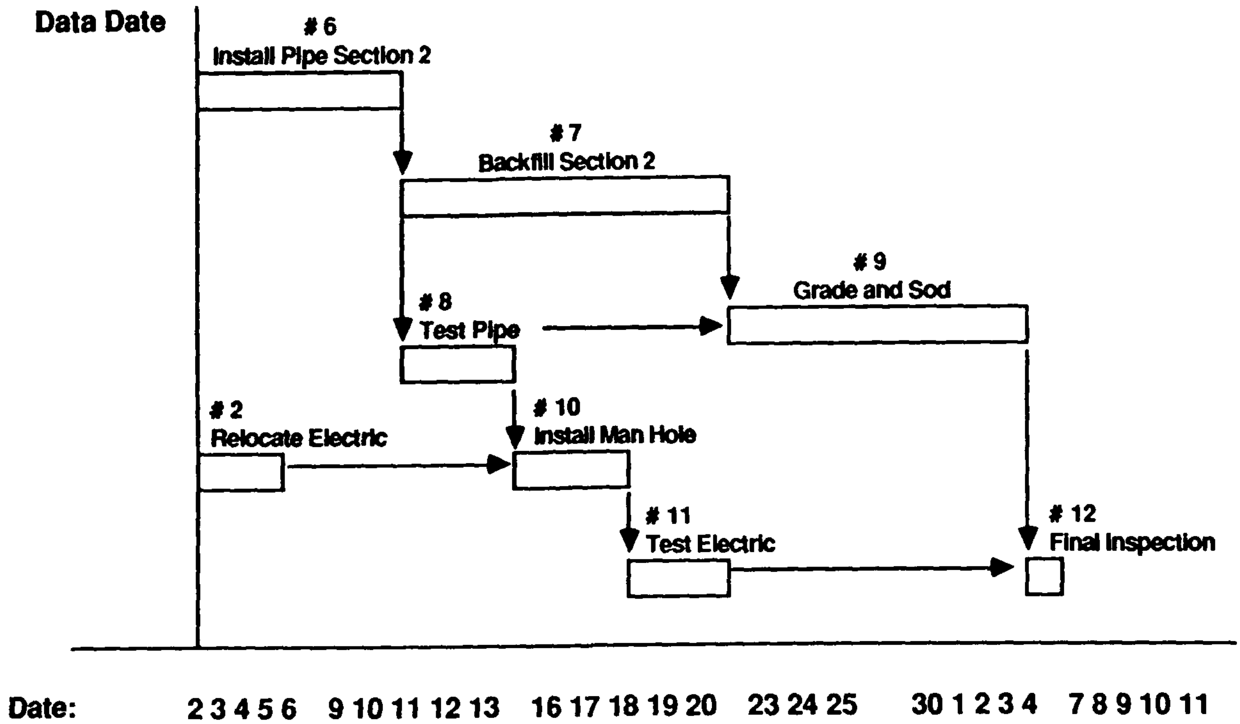


Figure 12. Project update chart.

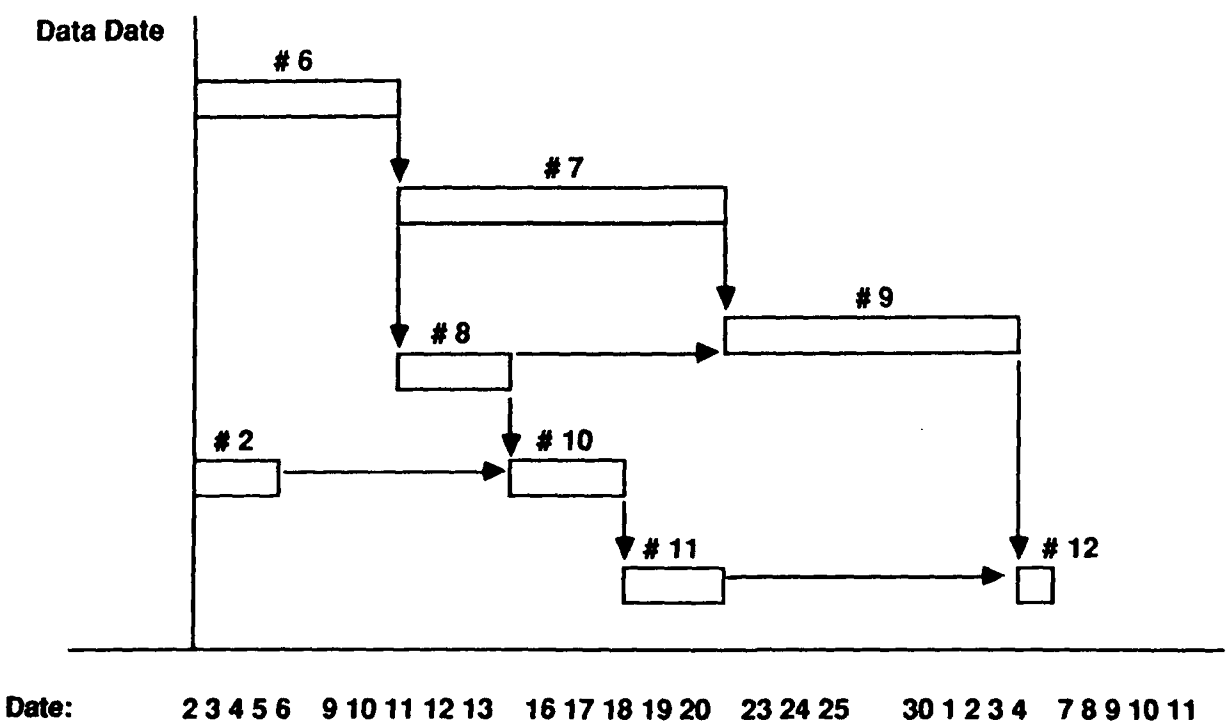


Figure 13. Example project using LCM.

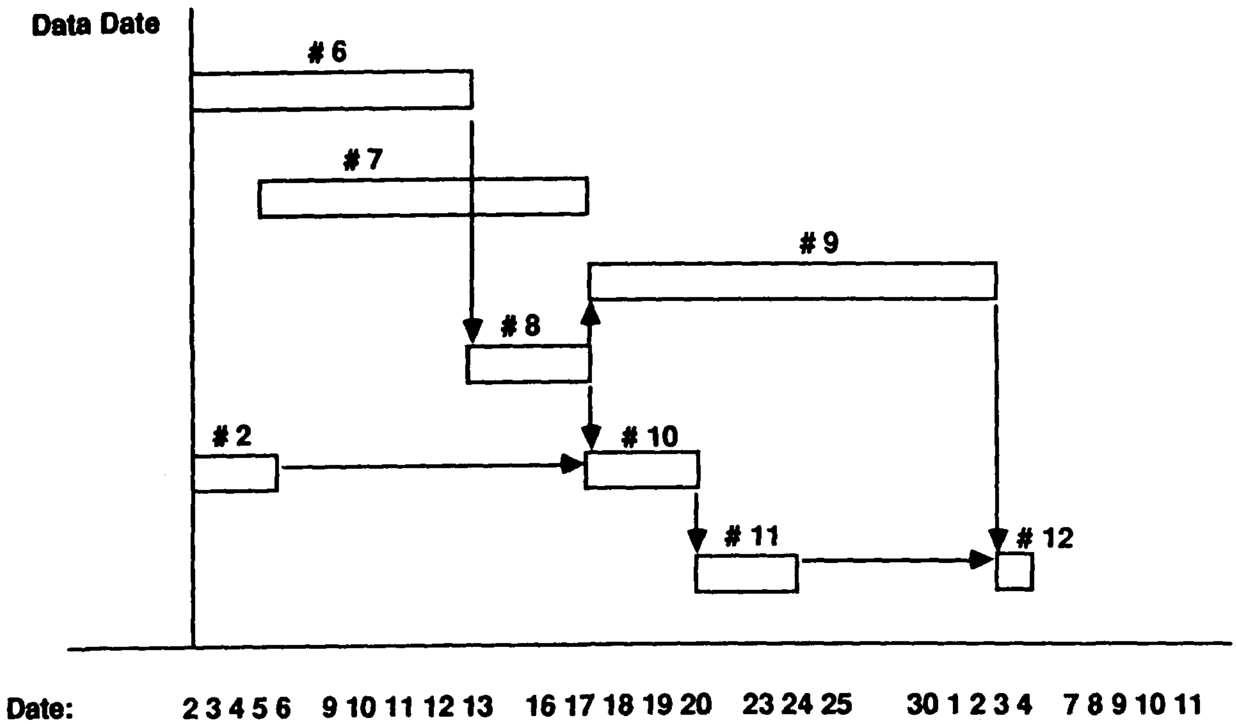


Figure 14. Example project using PCM.

reasons. First, most systems that use LCM do not allow out-of-sequence activities to be completed before their succeeding activities. Second, LCM will always leave less float on the critical path than PCM. The greatest PCM float is generally the difference between the early finish of the preceding activity and the data date. This is the time that is disregarded by the PCM and set as a temporary early start date in the LCM. One good way to motivate a contractor is to reduce the amount of float on the schedule by using the LCM.

It is important to remember that the schedules and all analyses made throughout the life of the project are legal documents. It is recommended that the resident office keep electronic and paper copies of the original project submission, all changes made for initial acceptance, all project updates, and any other changes to the schedule. These will be needed in the event of future claims or litigation.

Milestones and Target Dates

"Plugged" dates may be used in many PMSs to add realism to the construction model being created. Some examples of these dates are contract completion date, factory delivery dates, and intermediate notice to proceed on phased work. These examples will be reviewed to show how the scheduler might use a PMS to model real world constraints.

Table 7

Out-of-Sequence Schedule Report (LCM)

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Early Start/Finish	Late Start/Finish	Float
1/2,3	NTP	1	0	1 Oct 87 A	1 Oct 87 A	
2/10	Reloc Elec	6	3	8 Oct 87 A 3 Nov 87	 19 Nov 87	12
3/4	Excavate	3	0	5 Oct 87 A	9 Oct 87 A	
4/5,6	Pipe 1	10	0	12 Oct 87 A	23 Oct 87 A	
5/7	Backfill 1	5	0	26 Oct 87 A	30 Oct 87 A	
6/7,8	Pipe 2	12	7	26 Oct 87 A 10 Nov 87	2 Nov 87 10 Nov 87	0
7/9	Backfill 2	8	8	28 Oct 87 A 17 Nov 87	 17 Nov 87	0
8/9,10	Test Pipe	3	3	11 Nov 87 13 Nov 87	13 Nov 87 17 Nov 87	2
9/12	Grade & Sod	7	7	18 Nov 87 30 Nov 87	18 Nov 87 30 Nov 87	0
10/11	Man Hole	3	3	16 Nov 87 18 Nov 87	20 Nov 87 24 Nov 87	4
11/12	Test Elect	2	2	19 Nov 87 20 Nov 87	25 Nov 87 30 Nov 87	4
12	Inspect	1	1	1 Dec 87 1 Dec 87	1 Dec 87 1 Dec 87	0

The first step in attempting to plug predetermined dates into a PMS is to consider the effect of the particular constraint on the project. In the first example, contract completion date, the project must be completed no later than the given completion date. Three cases could occur when discussing the contract completion date. If the project shows completion before or on this date, there is no problem as the contractor has the option of completing the project anytime within the contract period. However, if the project extends past this date, all parties to the construction contract should be alerted as soon as possible. The scheduler must then determine if a portion of the schedule calculation should be "fixed" to ensure that a milestone may be met. In this case, the warning signal should go up if the "earliest the schedule can finish" exceeds the contract completion date.

The second example, factory delivery dates, is typically used to provide the latest date the equipment may be delivered and not delay the project. This type of constraint may be referred to as a "finish on" constraint because the equipment delivery may be early, but it cannot finish later than a given date. This type of constraint may be particularly important when a contractor plans to include a large piece of equipment within a room with limited access.

Intermediate notices to proceed, the third example of a constraint, provides information about when the contractor may start an activity. This type of constraint is referred to as a "start no earlier than" constraint because the activity may start no

Table 8

Out-of-Sequence Schedule Report (PCM)

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Early Start/Finish	Late Start/Finish	Float
1/2,3	NTP	1	0	1 Oct 87 A	1 Oct 87 A	
2/10	Reloc Elec	6	3	8 Oct 87 A 3 Nov 87	 23 Nov 87	9
3/4	Excavate	3	0	5 Oct 87 A	9 Oct 87 A	
4/5,6	Pipe 1	10	0	12 Oct 87 A	23 Oct 87 A	
5/7	Backfill 1	5	0	26 Oct 87 A	30 Oct 87 A	
6/7,8	Pipe 2	12	7	26 Oct 87 A 10 Nov 87	 10 Nov 87	0
7/9	Backfill 2	8	8	28 Oct 87 A 6 Nov 87	 13 Nov 87	5
8/9,10	Test Pipe	3	3	11 Nov 87 13 Nov 87	11 Nov 87 13 Nov 87	0
9/12	Grade & Sod	7	7	16 Nov 87 24 Nov 87	16 Nov 87 24 Nov 87	0
10/11	Man Hole	3	3	16 Nov 87 18 Nov 87	18 Nov 87 20 Nov 87	2
11/12	Test Elect	2	2	19 Nov 87 20 Nov 87	23 Nov 87 24 Nov 87	2
12	Inspect	1	1	25 Dec 87 25 Dec 87	25 Dec 87 25 Dec 87	0

earlier than the notice to proceed. Table 9 shows the eight types of dates that may be plugged into a schedule. Not all of these dates are available in all systems.

Three different levels of schedule constraint may be applied to model a particular situation. Each level provides greater control over the schedule than the previous level. The minimum control available is the "target" date. These plug dates do not affect the schedule; they provide a reference for comparison. A user may control the schedule at an intermediate level by forcing the use of a plug date if the PMS calculates a date that does not meet the necessary conditions. The intermediate level of control is provided by the "no earlier than" and "no later than" dates.

If the user wants to require that an event occur on a certain date, regardless of the calculated dates, the third level of schedule constraint (the "start on" and "finish on" dates) is available. This is the maximum control the user may exert on the network. Caution should be exercised when using this constraint since the network logic will be ignored if there is a potential conflict. Given the correct circumstances, this may force an activity to be scheduled complete before its calculated start date. When controlling the schedule with this constraint, the user should be concerned with the potential disruption to succeeding activities.

Table 9

Types of Plugged Dates

Name of Milestone Date	Effect on Schedule Calculation
Target start	Does not affect the early or late start date but may be shown in reports to allow user comparisons.
Target finish	Does not affect the early or late finish date but may be shown in reports to allow user comparisons.
Start no earlier than	If the scheduled early start date is before the plug date, the plug date replaces the early start date.
Finish no earlier than	If the scheduled early finish date is before the plug date, the plug date replaces the early finish date.
Start no later than	If the scheduled late start date is past the plug date, the plug date replaces the late start date.
Finish no later than	If the scheduled late finish date is past the plug date, the plug date replaces the late finish date.
Start on	Replaces both the calculated early and late start dates.
Finish on	Replaces both the calculated early and late finish dates.

When using any of these scheduling constraints, it is also important to make sure the plug date is a workday. Although some systems may allow the user to enter a non-workday date, this date will not be meaningful to the people who have to use the report. The network's credibility would substantially decrease if, for example, a particular phase of construction were scheduled to start on December 25th.

Since the use of the "no earlier than," "no later than," "start on," and "finish on" dates will affect the results the PMS provides, these dates should be used carefully. The use of these dates often requires trial and error to create the desired effect on the schedule calculation. One reason trial and error is needed is because some systems may not follow the definitions provided in Table 4. If a contractor wishes to use these dates, the resident office should completely understand the effect of these dates on the schedule.

One date that should be plugged into a schedule, however, is the contract completion date. The first update of the example network, shown in Table 6, indicated the contractor was 3 days behind schedule. The use of plug dates allows this delay to appear as negative float. If the schedule report had been run with the original completion date of 1 December 1987 as the "finish no later than" date, the result would appear as shown in Table 10. These plug dates, under the right circumstances, are a very effective project management tool.

Posting Cost Progress

Two common approaches to assigning cost information to activities are (1) from the construction contractor's perspective and (2) from the Corps of Engineers', or owner's perspective. These two approaches are very different; however, the terminology of each approach is liberally mixed in most PMSs. This section introduces and defines a consistent terminology that may help the resident office communicate about cost information and isolate problems that may occur as a result of misinterpretations.

From the contractor's point of view, there are three categories of cost associated with any one activity on a military construction project. These categories reflect the iterative process most contractors use to arrive at project costs. The first category is an "estimated cost" to complete an activity. This may be a rough breakdown from a building system, such as an air-conditioning system, that was determined as a lump sum cost in the contractor's bid. The "budgeted cost" is what the contractor feels the activity may cost. The "actual cost" is what the contractor actually spends in the process of construction.

From the Corps' perspective "activity cost" refers to the fixed amount that the resident engineer has agreed to pay the contractor in return for completing the work described by an activity. The cost is generally assumed to be spread evenly over each day of an activity. This type of cost allocation is called "earned value." When the activity cost does not have a constant dollar per day rate, the contractor has two other alternatives for obtaining financial compensation. The first alternative, "fiscal completion," is typically used when the contractor has a large dollar investment to make before actually beginning the work. The primary use of fiscal completion is to pay the contractor for materials on site. The other alternative, "physical completion," occurs when the contractor actually completes most of the work at the beginning of an activity. One example of this type of activity is concrete placement. Most of the work is completed shortly after the concrete is placed inside the forms. Figure 15 shows the dollar per day allocation of each of the three types of cost.

Table 10

Updated Schedule Using a Plugged Completion Date

Activity/ Successors	Description	Original Duration (days)	Remaining Duration (days)	Early Start/Finish	Late Start/Finish	Float
1/2,3	NTP	1	0	1 Oct 87 A	1 Oct 87 A	
2/10	Reloc Elec	6	3	8 Oct 87 A 3 Nov 87	19 Nov 87 23 Nov 87	14
3/4	Excavate	3	0	5 Oct 87 A	9 Oct 87 A	
4/5,6	Pipe 1	10	0	12 Oct 87 A	23 Oct 87 A	
5/7	Backfill 1	5	0	26 Oct 87 A	30 Oct 87 A	
6/7,8	Pipe 2	12	7	26 Oct 87 A 10 Nov 87	10 Nov 87	-3
7/9	Backfill 2	8	8	11 Nov 87 20 Nov 87	11 Nov 87 20 Nov 87	-3
8/9,10	Test Pipe	3	3	11 Nov 87 13 Nov 87	18 Nov 87 20 Nov 87	2
9/12	Grade & Sod	7	7	23 Nov 87 3 Dec 87	23 Nov 87 3 Dec 87	-3
10/11	Man Hole	3	3	16 Nov 87 18 Nov 87	25 Nov 87 1 Dec 87	4
11/12	Test Elect	2	2	19 Nov 87 20 Nov 87	2 Dec 87 3 Dec 87	4
12	Inspect	1	1	4 Dec 87 4 Dec 87	4 Dec 87 4 Dec 87	-3

Because of the different philosophies construction companies use in allocating costs to an activity, the assignment of costs depends on the interpretation of these philosophies by the PMS vendor. Some programs allow the activity cost to be entered with the activity identification and logical relationship descriptions. Others require that some form of resource or cost accounts be set up to monitor costs more closely.

While the variety of approaches to cost may be of great benefit to the contractor, the resident office staff who regularly use the PMS must become familiar with the features that meet the Corps requirements and should carefully review the contractor's use of these cost fields.

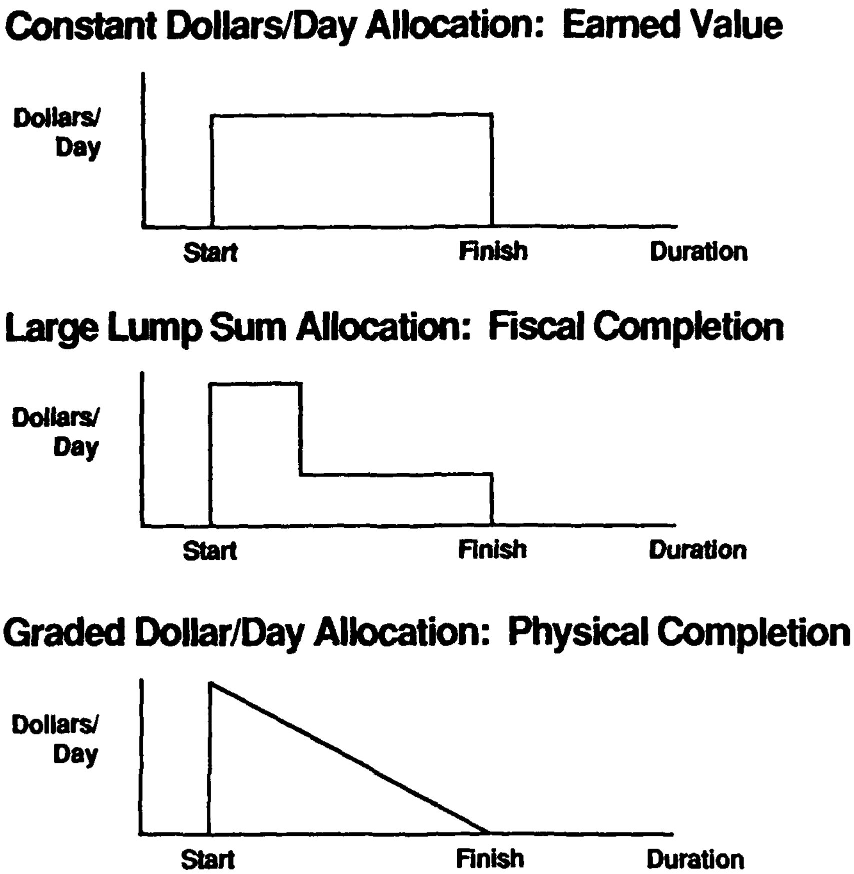


Figure 15. Cost allocation over activity duration.

While it is generally assumed that an activity should be billed to the government in accordance with the time-based completion of the activity, most PMSs also recognize the other two methods of reporting cost completion of an activity. Since most programs are oriented toward the contractor's monitoring of estimated, budgeted, and actual cost, reporting cost is another area that the resident office and contractor should agree on before submission of the initial schedule.

Several systems calculate the payment due the contractor through a series of three default settings: time-based percent complete, physical percent complete, and fiscal completion. The initial default value, time-based percent complete, is determined by dividing the expended duration by the original duration. Earned value will be calculated, in this case, as the product of the activity cost and the time-based percent complete.

If percent complete is entered, some systems assume that this data represents the physical completion of the activity. In this case, the time-based percent complete is not calculated and the physical percent complete is used to calculate the earned value.

The final tier of the default cost scheme would be entering an actual dollar amount to represent the payment due the contractor for the earned value of work in place. This is referred to as fiscal completion. Figure 16 illustrates the way this hierarchy might work for several activities on the example schedule. Table 11 shows the cost progress posted along with the latest update of the example construction schedule.

Cost completion is a very program-dependent issue for PMSs. While the hierarchy presented for determining a contractor's payment is the most common among the systems surveyed, there are many other approaches to determining earned value. Some of the other approaches

- require the user to provide completely separate cost and time data without any default values
- provide the user with multiple cost accounts per project
- provide a data field for materials on site
- provide a data field for changes in the original cost of an activity due to contract modification, and
- allow the user to manipulate unit cost and activity quantities.

Depending on the needs of the contractor and resident office, these may be important features; they are not as important, however, as the need for an agreement between the resident office and contractor on the way that time-based, physical, and fiscal completion will be modeled during the contract.

TIME-BASED PERCENT COMPLETE:

Example Activity: #2, Relocate Electrical
Original Duration = 6 Days; Remaining Duration = 3 Days
Time-Based Completion = Days Expended / Days Remaining = 50%
Earned Value = Activity Cost * Time-Based % Complete
$4,200 * 50% = $2,100

PHYSICAL PERCENT COMPLETE:

Example Activity: #6, Pipe Section Two
Time-Based Percent Complete = 6 / 12 = 50%
Physical Percent Complete = 70%
Earned Value = Activity Cost * Physical Completion
$14,400 * 70% = $10,080

FISCAL COMPLETION:

Example Activity: #10, Manhole
Time-Based Percent Complete = 0%
Actual Dollar Amount Entered = $1,000
Earned Value = Actual Dollar Amount / Activity Cost
$1,000 / $3,000 = 33%

Figure 16. Earned value hierarchy.

Reporting and Analysis

Unless a resident office is skilled in obtaining reports from a project management system, all the work that went into developing the schedule will be for nothing. This section describes how the resident office can gain extremely useful information from a contractor's schedule.

The ability to obtain useful information from PMSs has increased significantly since the mainframe scheduling programs that only allowed "standard" reports. These reports were generally limited to the activity number sort, the early start sort, and the total float sort. These voluminous paper reports, while providing "hard copy" documentation for the file, have very limited usefulness for the resident office analysis of a contractor's schedule and are typically used only when the contractor requests payment.

Table 11

Posted Cost Data

Account Number	Description	Activity Cost	Original Duration	Rem Duration	Phy Pct* Complete	Earned Value
1	NTP	0	1	0		$0
2	Reloc Elec	4,200	6	3		$2,100
3	Excavate	3,000	3	0		$3,000
4	Pipe 1	12,000	10	0		$12,000
5	Backfill 1	3,500	5	0		$3,500
6	Pipe 2	14,400	12	6	70	$10,080
7	Backfill 2	5,600	8	6		$1,400
8	Test Pipe	1,500	3	3		
9	Grade & Sod	2,100	7	7		
10	Man Hole	3,000	3	3		$1,000
11	Test Elect	6,000	2	2		
12	Inspect	0	1	1		
		$55,300			overall 60	$33,080

*Physical percent complete.

The resident office needs answers to the following questions regarding a contractor's schedule.

- Does the contractor's initial schedule show the project being completed within the contract limits?
- Has the contractor included all important features of the project in the schedule?
- Is the sequence of construction reasonable?
- Are activities that require specific coordination with the resident office included in the schedule?
- Are weather sensitive activities scheduled during periods of poor weather?
- When should prepatory inspections be conducted?
- What should the contractor be working on this week?
- Will the contractor's progress be sufficient to allow the project to be completed on time?

The following paragraphs discuss how to obtain some of the answers. The methods are also applicable to many other reports that must be generated to monitor a large construction project adequately.

As an example of a large network, the Dispensary Project from the Corps of Engineers Network Analysis System PROSPECT course has been chosen. This project was chosen because many workers at resident offices have taken the Network Analysis System course and will, therefore, have some familiarity with this project. Table 12 provides the initial schedule data, shown in order of "i" and "j" nodes, for this project. Figure 17 is a reduced network diagram that graphically presents the data in Table 12. This schedule was calculated with a 7-day workweek and no holidays.

The first question the resident office might ask when reviewing this schedule is, "Does the schedule show the construction being completed by the contract completion date?" Using Table 8, the reviewer can search through the pages of the report until the activity with the latest early finish is found. As expected, the activity that completes the network is on the last page of the schedule. This, however, may not always be the case. Several types of reports may be used to find the planned completion date without requiring the reviewer to look through reams of paper. The best way would be to request a report that sorts the activities with the latest early finish date listed first.

Although the [illegible]n mind can make sense out of complex and interrelated problems, keeping tr[illegible] of every activity of a large construction schedule is rather difficult. Using two project management features (activity code capacity and sort and select ability), the user may untangle a large project into manageable pieces. This is done by grouping activities that match specific criteria.

The second question that might be asked is, "Has the contractor included all important features of the project in the schedule?" If the schedule reviewer were to use only the nine pages of the original schedule, arriving at an answer to this question would be very tedious. Unfortunately, field office personnel must often choose between performing a detailed analysis or visiting the construction site.

Table 12

Initial Schedule: Dispensary, Lackland AFB

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
1	5	1	Ntp	1 Jul76	1 Jul76	
				1 Jul76	1 Jul76	0
5	10	7	Mob & Layout	2 Jul76	8 Jul76	
				27 Jul76	2 Aug76	25
5	20	30	Submit & Approve Mechanical	2 Jul76	31 Jul76	
			& Electrical Rough-In Mtls	3 Jul76	1 Aug76	1
5	25	20	Submit Pan Form Shop Drawings	2 Jul76	21 Jul76	
				17 Aug76	5 Sep76	46
5	30	20	Submit Metal Door Buck Shop	2 Jul76	21 Jul76	
			Drawings	22 Aug76	10 Sep76	51
5	35	30	Submit Structural Steel	2 Jul76	31 Jul76	
			& Joist Shop Drawings	12 Aug76	10 Sep76	41
5	40	45	Submit & Approve Masonry Matls	2 Jul76	15 Aug76	
				12 Nov76	26 Dec76	133
5	45	30	Submit Metal Window Shop Dwgs	2 Jul76	31 Jul76	
				10 Sep76	9 Oct76	70
5	50	30	Submit Hardware	2 Jul76	31 Jul76	
			Schedule and Samples	12 Sep76	11 Oct76	72
5	55	45	Submit Alum Entrance & Metal	2 Jul76	15 Aug76	
			Door Shop Drawings	7 Oct76	20 Nov76	97
5	60	45	Submit Lath & Plaster Data	2 Jul76	15 Aug76	
				25 Dec76	7 Feb77	176
5	65	45	Submit Ceramic Tile Data	2 Jul76	15 Aug76	
			& Samples	13 Dec76	26 Jan77	164
5	70	45	Submit Toilet Partition	2 Jul76	15 Aug76	
			& Accessory Schedule	12 Feb77	28 Mar77	225
5	75	30	Submit Plumbing & Mechanical	2 Jul76	31 Jul76	
			Fixtures & Equipment Schedule	20 Oct76	18 Nov76	110
5	80	30	Submit Electrical Fixtures,	2 Jul76	31 Jul76	
			Data, & Schedule	17 Dec76	15 Jan77	168
5	85	45	Submit & Approve Misc Metals	2 Jul76	15 Aug76	
			Shop Drawings	4 Nov76	18 Dec76	125
5	90	35	Submit & Approve Reinf Steel	2 Jul76	5 Aug76	
			Shop Drawings	2 Jul76	5 Aug76	0
5	95	45	Submit & Approve Roof Deck	2 Jul76	15 Aug76	
			Shop Drawings	26 Oct76	9 Dec76	116
5	100	30	Submit Roof & Sheetmetal	2 Jul76	31 Jul76	
			Shop Drawings	8 Oct76	6 Nov76	98
5	105	30	Submit X-ray Protection Data	2 Jul76	31 Jul76	
				23 Oct76	21 Nov76	113
5	110	45	Submit & Approve Door Canopies	2 Jul76	15 Aug76	
			Signs	26 Mar77	9 May77	267
5	115	30	Submit Paint Certification	2 Jul76	31 Jul76	
			& Samples	19 Jan77	17 Feb77	201

Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
5	120	30	Submit Vinyl Wall Covering Data	2 Jul76	31 Jul76	
			& Samples	22 Mar77	20 Apr77	263
5	125	30	Submit Millwork Shop Drawings	2 Jul76	31 Jul76	
				25 Dec76	23 Jan77	176
5	130	30	Submit Resilient Floor Samples	2 Jul76	31 Jul76	
				23 Feb77	24 Mar77	236
5	135	45	Submit Casework Shop Drawings	2 Jul76	15 Aug76	
				27 Nov76	10 Jan77	148
5	140	45	Submit Hospital & Misc Building	2 Jul76	15 Aug76	
			Equipment Data	17 Oct76	30 Nov76	107
5	145	30	Submit Misc Building Equipment	2 Jul76	31 Jul76	
			Data	2 Mar77	31 Mar77	243
5	150	15	Submit Certified Concrete	2 Jul76	16 Jul76	
			Design Mix	6 Aug76	20 Aug76	35
5	330	30	Prequalify Welders	2 Jul76	31 Jul76	
				30 Nov76	29 Dec76	151
5	600	45	Submit & Approve Exterior	2 Jul76	15 Aug76	
			Electrical and Plumbing			
			Shop Dwgs	3 Nov76	17 Dec76	124
10	15	14	Rough Grading & Excavation	9 Jul76	22 Jul76	
				3 Aug76	16 Aug76	25
10	605	32	Demo & Site Grading	9 Jul76	9 Aug76	
				31 Dec76	31 Jan77	175
15	155	0	Dummy	23 Jul76	23 Jul76	
				17 Aug76	17 Aug76	25
15	265	0	Dummy	23 Jul76	23 Jul76	
				21 Aug76	21 Aug76	29
20	155	15	Deliver Initial Mechanical	1 Aug76	15 Aug76	
			& Electrical Rough-In			
			Materials	2 Aug76	16 Aug76	1
25	160	15	Gov't Approve Pan Forms	22 Jul76	5 Aug76	
				6 Sep76	20 Sep76	46
30	165	15	Gov't Approve Metal Door Bucks	22 Jul76	5 Aug76	
				11 Sep76	25 Sep76	51
35	170	20	Gov't Approve Structural Steel	1 Aug76	20 Aug76	
			& Joist Shop Drawings	11 Sep76	30 Sep76	41
40	175	45	Deliver Masonry Materials	16 Aug76	29 Sep76	
				27 Dec76	9 Feb77	133
45	180	20	Gov't Approve Metal Windows	1 Aug76	20 Aug76	
				10 Oct76	29 Oct76	70
50	185	30	Gov't Approve Hardware	1 Aug76	30 Aug76	
				12 Oct76	10 Nov76	72
55	190	20	Gov't Approve Aluminum Entrance	16 Aug76	4 Sep76	
			& Metal Doors	21 Nov76	10 Dec76	97

Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
60	195	15	Gov't Approve Lath & Plaster	16 Aug76	30 Aug76	
				8 Feb77	22 Feb77	176
65	200	30	Gov't Approve & Select Ceramic	16 Aug76	14 Sep76	
			Tile Color	27 Jan77	25 Feb77	164
70	205	20	Gov't Approve Toilet Partitions	16 Aug76	4 Sep76	
			& Accessories	29 Mar77	17 Apr77	225
75	210	30	Gov't Approve Plumbing &	1 Aug76	30 Aug76	
			Mechanical Fixtures &			
			Equipment	19 Nov76	18 Dec76	110
80	215	30	Gov't Approve Elec Fixtures	1 Aug76	30 Aug76	
			& Equipment	16 Jan77	14 Feb77	168
85	305	45	Fab & Deliver Misc Metals	16 Aug76	29 Sep76	
				19 Dec76	1 Feb77	125
90	150	15	Deliver Reinforcing Steel	6 Aug76	20 Aug76	
				6 Aug76	20 Aug76	0
95	350	30	Deliver Roof Deck Materials	16 Aug76	14 Sep76	
				10 Dec76	8 Jan77	116
100	220	15	Gov't Approve Roof & Sheetmetal	1 Aug76	15 Aug76	
			Shop Drawings	7 Nov76	21 Nov76	98
105	225	20	Gov't Approve X-ray Protection	1 Aug76	20 Aug76	
				22 Nov76	11 Dec76	113
110	500	75	Deliver Door Canopies & Signs	16 Aug76	29 Oct76	
				10 May77	23 Jul77	267
115	230	30	Gov't Test, Approve & Select	1 Aug76	30 Aug76	
			Paint Color	18 Feb77	19 Mar77	201
120	235	30	Gov't Approve & Select Vinyl	1 Aug76	30 Aug7	
			Wall Covering Color	21 Apr77	20 May7.	263
125	240	20	Gov't Approve Millwork	1 Aug76	20 Aug76	
				24 Jan77	12 Feb77	176
130	245	30	Gov't Approve & Select	1 Aug76	30 Aug76	
			Resilient Floor Color	25 Mar77	23 Apr77	236
135	250	30	Gov't Approve Casework	16 Aug76	14 Sep76	
				11 Jan77	9 Feb77	148
140	255	30	Gov't Approve Hospital & Misc	16 Aug76	14 Sep76	
			Equipment	1 Dec76	30 Dec76	107
145	260	20	Gov't Approve Misc Bldg	1 Aug76	20 Aug76	
			Equipment	1 Apr77	20 Apr77	243
150	265	0	Dummy	21 Aug76	21 Aug76	
				21 Aug76	21 Aug76	0
150	275	0	Dummy	21 Aug76	21 Aug76	
				27 Aug76	27 Aug76	6
155	275	10	Rough-In Under Basement	16 Aug76	25 Aug76	
				17 Aug76	26 Aug76	1
160	315	45	Deliver Pan Forms	6 Aug76	19 Sep76	
				21 Sep76	4 Nov76	46

Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
165	325	90	Fab & Deliver Metal Door Bucks	6 Aug76	3 Nov76	
				26 Sep76	24 Dec76	51
170	325	45	Fab & Deliver Steel Columns	21 Aug76	4 Oct76	
				10 Nov76	24 Dec76	81
170	330	90	Fab & Deliver Structural Steel	21 Aug76	18Nov76	
			& Joists	1 Oct76	29 Dec76	41
175	335	2	Construct Sample Masonry Panel	30 Sep76	1 Oct76	
				10 Feb77	11 Feb77	133
180	360	90	Fab & Deliver Metal Windows	21 Aug76	18 Nov76	
				30 Oct76	27 Jan77	70
185	345	120	Deliver Hardware	31 Aug76	28 Dec76	
				11 Nov76	10 Mar77	72
190	345	90	Fab & Deliver Aluminum Entrance	5 Sep76	3 Dec76	
			& Metal Doors	11 Dec76	10 Mar77	97
195	385	30	Deliver Lath & Plaster	31 Aug76	29 Sep76	
			Materials	23 Feb77	24 Mar77	176
200	405	45	Deliver Ceramic Tile Materials	15 Sep76	29 Oct76	
				26 Feb77	11 Apr77	164
205	425	90	Deliver Toilet Partitions	5 Sep76	3 Dec76	
			& Accessories	18 Apr77	16 Jul77	225
210	440	150	Deliver Plumbing & Mechanical	31 Aug76	27 Jan77	
			& Fixtures & Equipment	19 Dec76	17 May77	110
215	450	120	Deliver Electrical Fixtures	31 Aug76	28 Dec76	
			& Equipment	15 Feb77	14 Jun77	168
220	355	60	Fab & Deliver Sheetmetal	16 Aug76	14 Oct76	
			& Roof Materials	22 Nov76	20 Jan77	98
225	370	75	Deliver Materials to Protect	21 Aug76	3 Nov76	
			Items Stored On Site	12 Dec76	24 Feb77	113
230	430	45	Deliver Paint Matls	31 Aug76	14 Oct76	
				20 Mar77	3 May77	201
235	460	60	Deliver Vinyl Wall Covering	31 Aug76	29 Oct76	
				21 May77	19 Jul77	263
240	465	120	Fab & Deliver Millwork	21 Aug76	18 Dec76	
				13 Feb77	12 Jun77	176
245	470	45	Deliver Resilient Floor Matl	31 Aug76	14 Oct76	
				24 Apr77	7 Jun77	236
250	485	150	Deliver Casework	15 Sep76	11 Feb77	
				10 Feb77	9 Jul77	148
255	490	180	Deliver Hospital & Misc Equip	15 Sep76	13 Mar77	
				31 Dec76	28 Jun77	107
260	495	90	Deliver Misc Bldg Equip	21 Aug76	18 Nov76	
				21 Apr77	19 Jul77	243
265	270	16	Footings & Plinths	21 Aug76	5 Sep76	
				21 Aug76	5 Sep76	0

Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
270	300	30	Grade Beams	6 Sep76	5 Oct76	
				6 Sep76	5 Oct76	0
275	290	14	Basement Foundation, Slab	26 Aug76	8 Sep76	
			& Beams	27 Aug76	9 Sep76	1
280	285	21	Basement Walls	9 Sep76	29 Sep76	
				10 Sep76	30 Sep76	1
285	300	5	Dampproofing	30 Sep76	4 Oct76	
				1 Oct76	5 Oct76	1
300	305	0	Dummy	6 Oct76	6 Oct76	
				2 Feb77	2 Feb77	1
300	310	10	Backfill and Grade Under	6 Oct76	15 Oct76	
			Building	6 Oct76	15 Oct76	0
305	335	10	Basement Steps & Landings	6 Oct76	15 Oct76	
				2 Feb77	11 Feb77	119
310	315	20	30% Mechanical & Electrical	16 Oct76	4 Nov76	
			Rough-In Under Floor	16 Oct76	4 Nov76	0
315	320	50	Formed In Place Concrete	5 Nov76	24 Dec76	
			Slabs & Beams	5 Nov76	24 Dec76	0
315	325	50	70% Mechanical & Electrical	5 Nov76	24 Dec76	
			Rough-In Under Floor	5 Nov76	24 Dec76	0
320	325	0	Dummy	25 Dec76	25 Dec76	
				25 Dec76	25 Dec76	0
320	370	18	Concrete Topping Fill	25 Dec76	11 Jan77	
				7 Feb77	24 Feb77	44
320	375	63	Complete Electrical Rough-In	25 Dec76	25 Feb77	
			Inside Building	4 Feb77	7 Apr77	41
320	395	70	Complete Mechanical & Plumbing	25 Dec76	4 Mar77	
			Rough-In Inside Building	28 Jan77	7 Apr77	34
325	330	5	Erect Steel Columns & Metal	25 Dec76	29 Dec76	
			Door Bucks	25 Dec76	29 Dec76	0
330	335	0	Dummy	30 Dec76	30 Dec76	
				12 Feb77	12 Feb77	44
330	350	10	Erect Structural Steel & Joists	30 Dec76	8 Jan77	
				30 Dec76	8 Jan77	0
335	340	27	Exterior Masonry Walls	30 Dec76	25 Jan77	
				12 Feb77	10 Mar77	44
340	345	0	Dummy	26 Jan77	26 Jan77	
				11 Mar77	11 Mar77	44
340	500	0	Dummy	26 Jan77	26 Jan77	
				24 Jul77	24 Jul77	179
340	645	0	Dummy	26 Jan77	26 Jan77	
				25 Jul77	25 Jul77	180
345	385	14	Inst Aluminum Entrance	26 Jan77	8 Feb77	
			& Metal Doors	11 Mar77	24 Mar77	44

Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
350	355	12	Roof Deck	9 Jan77	20Jan77	
				9 Jan77	0 Jan77	0
355	365	21	Roofing & Sheetmetal	21 Jan77	10 Feb77	
				21 Jan77	10 Feb77	0
360	365	14	Inst Metal Windows	19 Nov76	2 Dec76	
				28 Jan77	10 Feb77	70
365	370	0	Dummy	11 Feb77	11 Feb77	
				25 Feb77	25 Feb77	14
365	385	0	Dummy	11 Feb77	11 Feb77	
				25 Mar77	25 Mar77	42
365	395	56	AC Ductwork	11 Feb77	7 Apr77	
				11 Feb77	7 Apr77	0
370	390	42	Interior Partition	11 Feb77	24 Mar77	
				25 Feb77	7 Apr77	14
375	395	0	Dummy	26 Feb77	26 Feb77	
				8 Apr77	8 Apr77	41
385	390	14	Stucco	11 Feb77	24 Feb77	
				25 Mar77	7 Apr77	42
390	395	0	Dummy	25 Mar77	25 Mar77	
				8 Apr77	8 Apr77	14
390	420	14	Plaster Walls	25 Mar77	7 Apr77	
				20 Apr77	3 May77	26
395	410	14	Ceiling Suspension System	8 Apr77	21 Apr77	
			& Insulation	8 Apr77	21 Apr77	0
405	420	22	Ceramic Tile	30 Oct76	20 Nov76	
				12 Apr77	3 May77	164
410	430	12	Plaster Ceiling	22 Apr77	3 MAY77	
				22 Apr77	3 May77	0
410	445	35	Acoustic and Other Ceilings	22 Apr77	26 May77	
				27 Apr77	31 May77	5
420	425	0	Dummy	8 Apr77	8 Apr77	
				17 Jul77	17 Jul77	100
420	430	0	Dummy	8 Apr77	8 Apr77	
				4 May77	4 May77	26
425	510	17	Toilet Partitions & Accessories	8 Apr77	24 Apr77	
				17 Jul77	2 Aug77	100
430	440	0	Dummy	4 May77	4 May77	
				18 May77	18 May77	14
430	445	28	30% Paint & Finish	4 May77	31 May77	
				4 May77	31 May77	0
440	650	70	Inst Mech Equip	4 May77	12 Jul77	
				18 May77	26 Jul77	14
445	450	0	Dummy	1 Jun77	1Jun77	
				15 Jun77	15 Jun77	14

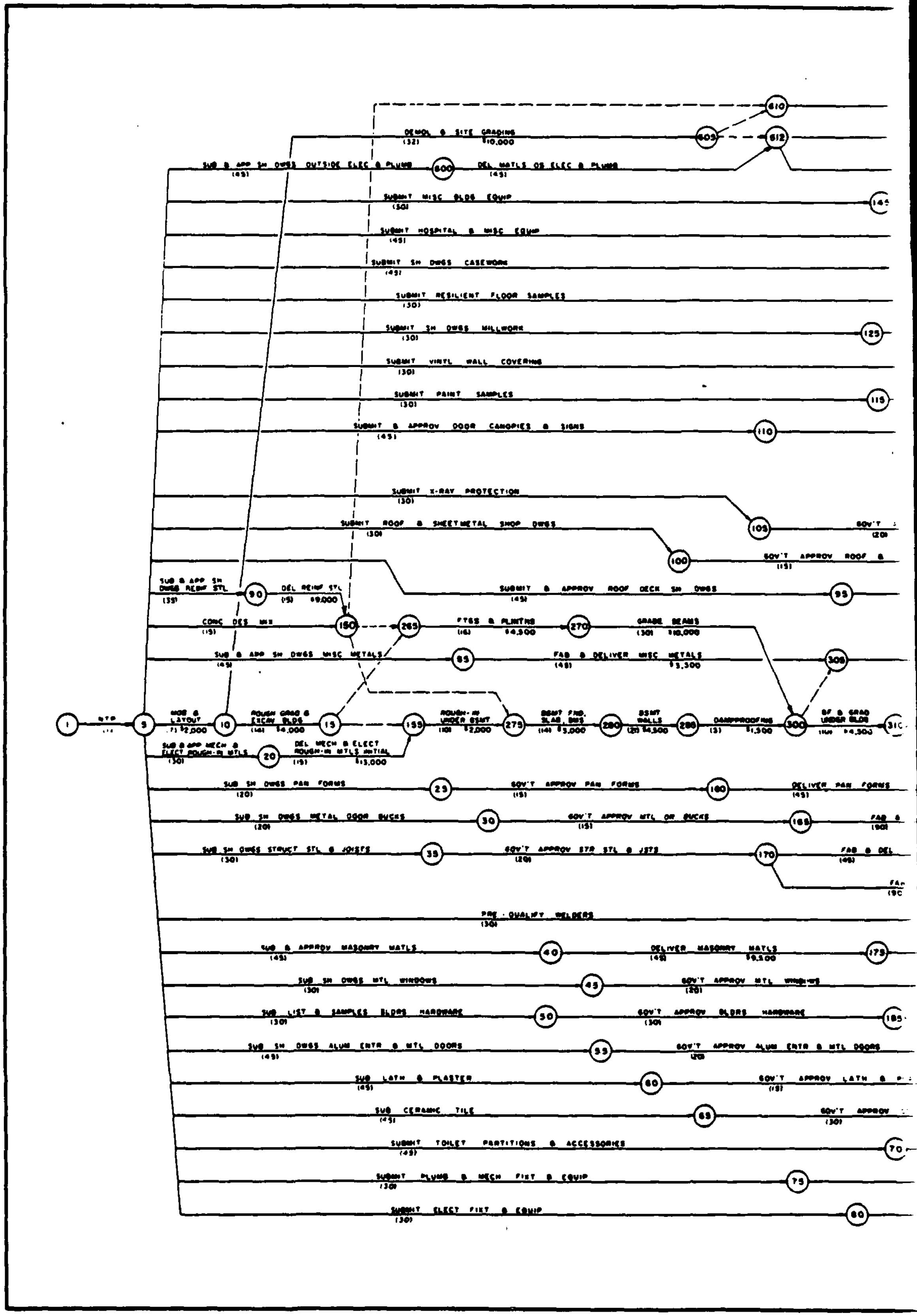
Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
445	455	0	Dummy	1 Jun77	1 Jun77	
				27 Jun77	27 Jun77	26
445	460	0	Dummy	1 Jun77	1 Jun77	
				20 Jul77	20 Jul77	49
445	465	0	Dummy	1 Jun77	1 Jun77	
				13 Jun77	13 Jun77	12
445	470	0	Dummy	1 Jun77	1 Jun77	
				8 Jun77	8 Jun77	7
445	505	45	50% Paint & Fin	1 Jun77	15 Jul77	
				1 Jun77	15 Jul77	0
450	650	42	Inst Elec Fixt & Equip	1 Jun77	12 Jul77	
				15 Jun77	26 Jul77	14
455	650	30	Inst Plumb & Mech Fixt	1 Jun77	30 Jun77	
				27 Jun77	26 Jul77	26
460	510	14	Vinyl Wall Covering	1 Jun77	14 Jun77	
				20 Jul77	2 Aug77	49
465	475	16	50% Millwork	1 Jun77	16 Jun77	
				13 Jun77	28 Jun77	12
470	480	21	Resilient Floor	1 Jun77	21 Jun77	
				8 Jun77	28 Jun77	7
475	480	0	Dummy	17 Jun77	17 Jun77	
				29 Jun77	29 Jun77	12
475	505	16	Complete Millwork	17 Jun77	2 Jul77	
				30 Jun77	15 Jul77	13
480	485	0	Dummy	22 Jun77	22 Jun77	
				10 Jul77	10 Jul77	18
480	490	0	Dummy	22 Jun77	22 Jun77	
				29 Jun77	29 Jun77	7
480	495	0	Dummy	22 Jun77	22 Jun77	
				20 Jul77	20 Jul77	28
480	510	3	Gov't Test X-ray Protection	22 Jun77	24 Jun77	
				31 Jul77	2 Aug77	39
485	510	24	Inst Casework	22 Jun77	15 Jul77	
				10 Jul77	2 Aug77	18
490	510	35	Inst Hospital & Misc Equip	22 Jun77	26 Jul77	
				29 Jun77	2 Aug77	7
495	510	14	Inst Misc Bldg Equip	22 Jun77	5 Jul77	
				20 Jul77	2 Aug77	28
500	510	10	Inst Door Canopies & Signs	26 Jan77	4 Feb77	
				24 Jul77	2 Aug77	179
505	510	18	Complete Paint & Finish	16 Jul77	2 Aug77	
				16 Jul77	2 Aug77	0
510	655	7	Clean Bldg	3 Aug77	9 Aug77	
				3 Aug77	9 Aug77	0

Table 12 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
600	612	45	Deliver Exterior Elec	16 Aug76	29 Sep76	
			& Plumbing Materials	18 Dec77	31 Jan77	124
605	610	0	Dummy	10 Aug76	10 Aug76	
				3 Mar77	3 Mar77	205
605	612	0	Dummy	10 Aug76	10 Aug76	
				1 Feb77	1 Feb77	175
610	620	60	Deliver & Install Storm			
			Drainage	10 Aug76	8 Oct76	
				3 Mar77	1 May77	205
612	615	45	Exterior Plumbing	30 Sep76	13 Nov76	
				18 Mar77	1 May77	169
612	619	90	Exterior Electrical	30 Sep76	28 Dec76	
				1 Feb77	1 May77	124
615	620	0	Dummy	14 Nov76	14 Nov76	
				2 May77	2 May77	169
615	650	0	Dummy	14 Nov76	14 Nov76	
				27 Jul77	27 Jul77	255
619	620	0	Dummy	29 Dec76	29 Dec76	
				2 May77	2 May77	124
619	650	0	Dummy	29 Dec76	29 Dec76	
				27 Jul77	27 Jul77	210
620	625	42	Subgrade & Base for Paving	29 Dec76	8 Feb77	
				2 May77	12 Jun77	124
630	630	21	Curb & Gutter	9 Feb77	1 Mar77	
				13 Jun77	3 Jul77	124
630	635	21	Walks	2 Mar77	22 Mar77	
				4 Jul77	24 Jul77	124
630	650	10	Asphalt Paving	2 Mar77	11 Mar77	
				17 Jul77	26 Jul77	137
635	645	0	Dummy	23 Mar77	23 Mar77	
				25 Jul77	25 Jul77	124
645	655	16	Topsoil & Fine Grading	23 Mar77	7 APR77	
				25 Jul77	9 Aug77	124
650	655	14	Test Mech & Elec Systems	13 Jul77	26 Jul77	
				27 Jul77	9 Aug77	14
655	660	5	Final Inspection	10 Aug77	14 Aug77	
				10 Aug77	14 Aug77	0

Although PMSs do not answer the user's questions directly, they may provide the data needed to judge the accuracy and completeness of the schedule within minutes rather than hours. Current microcomputer technology allows the reviewer to select and sort activities according to predefined activity codes. The activity codes referred to in this discussion were defined in Table 5. (Readers may wish to review these codes before proceeding.)



DEMOL & SITE GRADING (32) $10,000
SUB & APP SH DWGS OUTSIDE ELEC & PLUMB (45)
DEL MATLS OS ELEC & PLUMB (45)
SUBMIT MISC BLDG EQUIP (30)
SUBMIT HOSPITAL & MISC EQUIP (45)
SUBMIT SH DWGS CASEWORK (45)
SUBMIT RESILIENT FLOOR SAMPLES (30)
SUBMIT SH DWGS MILLWORK (30)
SUBMIT VINYL WALL COVERING (30)
SUBMIT PAINT SAMPLES (30)
SUBMIT & APPROV DOOR CANOPIES & SIGNS (45)
SUBMIT X-RAY PROTECTION (30)
SUBMIT ROOF & SHEETMETAL SHOP DWGS (30)
GOV'T APPROV ROOF & (15)
SUB & APP SH DWGS REINF STL (35)
DEL REINF STL (15) $9,000
SUBMIT & APPROV ROOF DECK SH DWGS (45)
CONC DES MIX (15)
FTGS & PLINTHS (16) $4,500
GRADE BEAMS (30) $10,000
SUB & APP SH DWGS MISC METALS (45)
FAB & DELIVER MISC METALS (45) $3,300
NTP
MOB & LAYOUT (7) $2,000
ROUGH GRAD & EXCAV BLDG (14) $4,000
ROUGH-IN UNDER BSMT (10) $2,000
BSMT FND. SLAB, BMS (14) $3,000
BSMT WALLS (21) $4,500
DAMPPROOFING (3) $1,500
BF & GRAD UNDER BLDG (14) $4,500
SUB & APP MECH & ELECT ROUGH-IN MTLS (30)
DEL MECH & ELECT ROUGH-IN MTLS INITIAL (15) $13,000
SUB SH DWGS PAN FORMS (20)
GOV'T APPROV PAN FORMS (15)
DELIVER PAN FORMS (45)
SUB SH DWGS METAL DOOR BUCKS (20)
GOV'T APPROV MTL DR BUCKS (15)
SUB SH DWGS STRUCT STL & JOISTS (30)
GOV'T APPROV STR STL & JSTS (20)
FAB & DEL (45)
PRE-QUALIFY WELDERS (30)
SUB & APPROV MASONRY MATLS (45)
DELIVER MASONRY MATLS (45) $9,500
SUB SH DWGS MTL WINDOWS (30)
GOV'T APPROV MTL WINDOWS (20)
SUB LIST & SAMPLES BLDRS HARDWARE (30)
GOV'T APPROV BLDRS HARDWARE (30)
SUB SH DWGS ALUM ENTR & MTL DOORS (45)
GOV'T APPROV ALUM ENTR & MTL DOORS (20)
SUB LATH & PLASTER (45)
GOV'T APPROV LATH & (15)
SUB CERAMIC TILE (45)
GOV'T APPROV (30)
SUBMIT TOILET PARTITIONS & ACCESSORIES (45)
SUBMIT PLUMB & MECH FIXT & EQUIP (30)
SUBMIT ELECT FIXT & EQUIP (30)

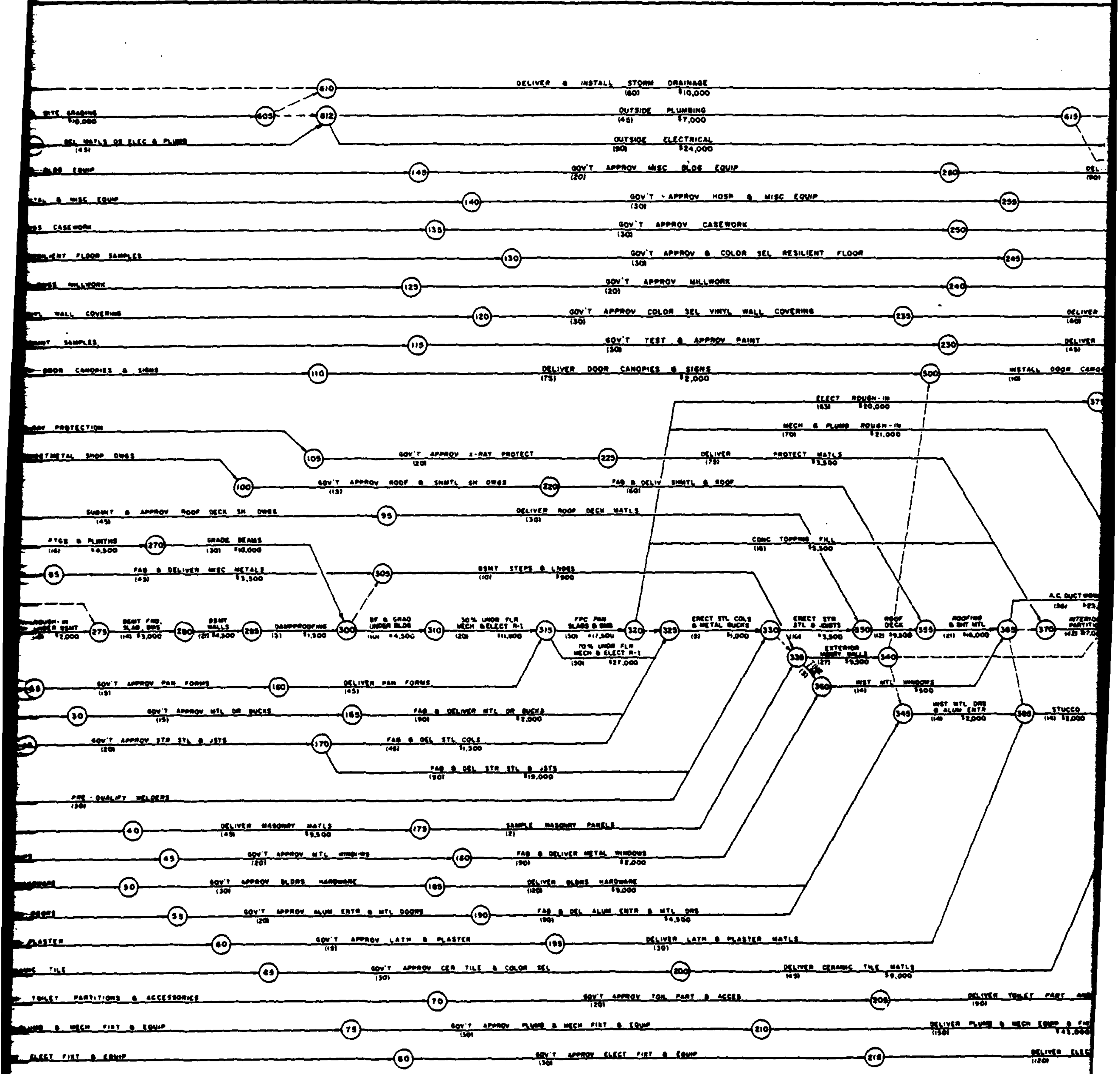
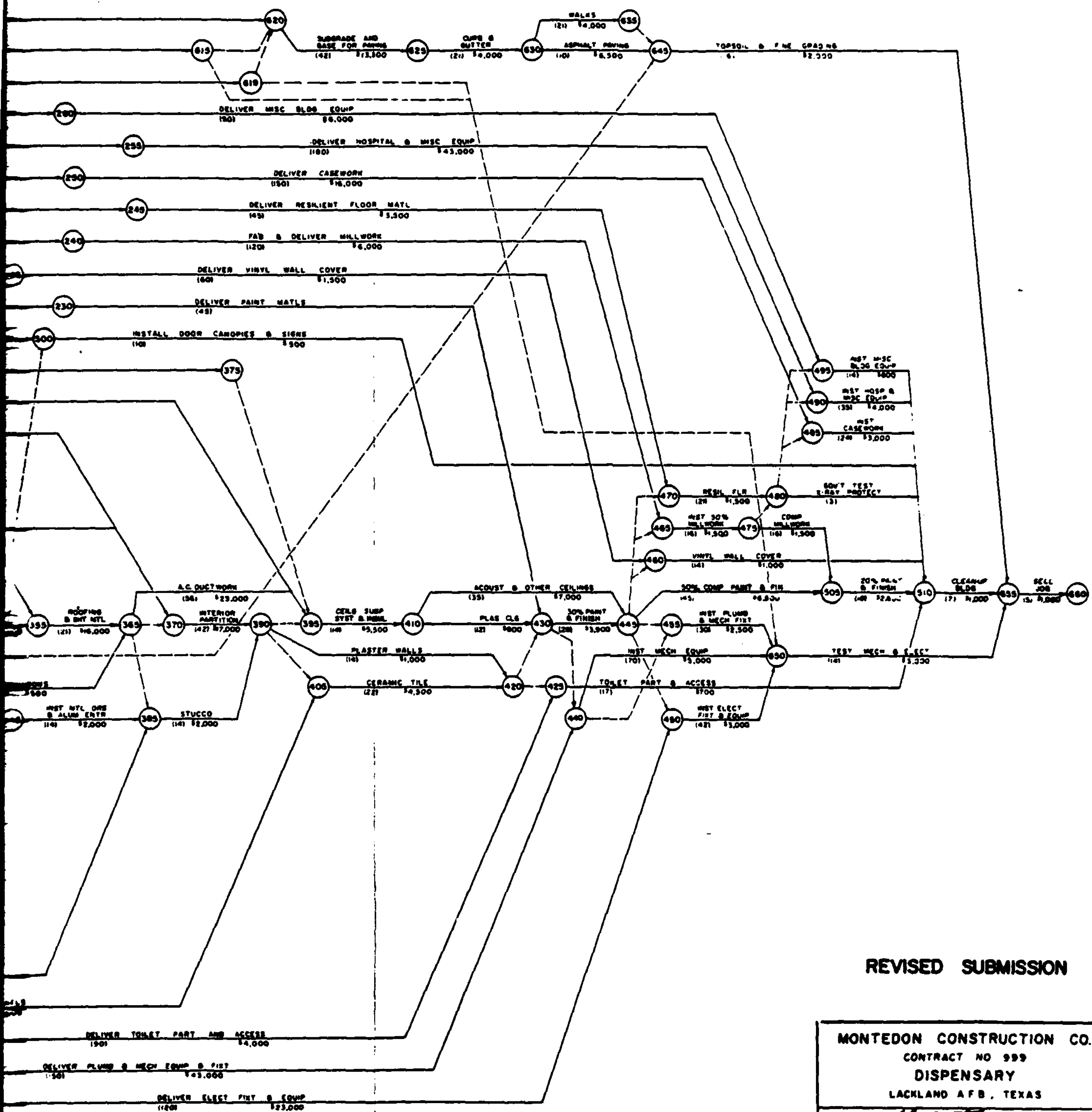


Figure 17. A reduced network diagram.



REVISED SUBMISSION

MONTEDON CONSTRUCTION CO.
CONTRACT NO 999
DISPENSARY
LACKLAND A F B , TEXAS

SUBMITTED BY	DATE 15 Jul '76
RECOMMENDED BY	DATE 20 July '76
APPROVED BY	DATE 30 July '76

…k diagram.

On any construction project, there are activities in addition to those on the critical path that may require special attention due to their potential impact on project completion. In a dispensary, as with other hospital projects, the equipment is very specialized and often creates problems during construction. Therefore, on any hospital project the resident office should check that the contractor included this equipment in the schedule.

The review is conducted by comparing the contract requirements for the hospital equipment with the schedule's activities concerning this equipment. Since the computerized version of the schedule has the Construction Specification Index (CSI) coded with each activity, the data needed for the review of any particular part of the schedule is very simple. The PMS user will instruct the computer to list only those activities in the specification sections for hospital equipment. These two sections are the Specialties and Equipment section. Hospital toilet partitions and materials for x-ray protection are included in the Specialties section as shown in Table 13. Table 14 provides a list of other hospital equipment included in the Equipment section.

Once these activities have been identified, the user is able to rapidly determine the need for schedule revisions. Rather than spend a half-hour looking through a long report, the resident office, through current PMS technology, may have a list of all activities pertaining to any needed specification section within 1 minute.

The third question on the list is, "Is the sequence of construction reasonable?" Of the many ways to approach this question, only two will be illustrated here: activities on the critical path, and activities within a class of building system.

Table 15 presents a report with a selection of activities that had 1 week or less float. Since the schedule was calculated on a 7-day workweek, the user may instruct the PMS to provide all activities having a float of less than or equal to 7 days.

Another way to analyze the schedule is to select those activities that fit within a building system such as "exterior closure." With this list of activities, the user can determine if the contractor included all the activities that are logically necessary to provide a completed building system. The Building Systems Index (BSI) provides a coding scheme that may be used to categorize activities into types of building systems. The use of this, in addition to the CSI, is important because this coding scheme cuts across many specification sections. Table 16 contains activities belonging to several different specification sections, but all are part of the BSI for exterior closure.

The use of the BSI allows the user to create a mental picture of the way the contractor is planning to construct the facility. Creating a mental three-dimensional model of the construction activities listed on a page is essential for not only a proper schedule review, but also for understanding and communicating about the construction plan.

Once the contractor's planned construction sequence appears complete and reasonable, the resident office may then ask the fourth question, "Are activities that require specific coordination with the resident office included in the schedule?" By selecting activities according to the coding scheme previously presented, the answer may be obtained quickly. One of the activity codes, "TYPE", allows designation of government approval activities. Table 17 is a report of government approval activities from the dispensary project.

Table 13

Specialties (Construction Specification Index 10000-11000)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
5	70	45	Submit Toilet Partition	2 Jul76	15 Aug76	
			& Accessory Schedule	12 Feb77	28 Mar77	225
5	105	30	Submit X-ray Protection Data	2 Jul76	31 Jul76	
				23 Oct76	21 Nov76	113
0	205	20	Gov't Approve Toilet Partitions	16 Aug76	4 Sep76	
			& Accessories	29 Mar77	17 Apr77	225
105	225	20	Gov't Approve X-ray Protection	1 Aug76	20 Aug76	
				22 Nov76	11 Dec76	113
205	425	90	Deliver Toilet Partitions	5 Sep76	3 Dec76	
			& Accessories	18 Apr77	16 Jul77	225
425	510	17	Toilet Partitions & Accessories	8 Apr77	24 Apr77	
				17 Jul77	2 Aug77	100
480	510	3	Gov't Test X-ray Protection	22 Jun77	24 Jun77	
				31 Jul77	2 Aug77	39

Table 14

Equipment (Construction Specification Index 11000-12000)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
				27 Nov76	10 Jan77	148
5	140	45	Submit Hospital & Misc Building	2 Jul76	15 Aug76	
			Equipment Data	17 Oct76	30 Nov76	107
5	145	30	Submit Misc Building Equipment	2 Jul76	31 Jul76	
			Data	2 Mar77	31 Mar77	243
140	255	30	Gov't Approve Hospital & Misc	16 Aug76	14 Sep76	
			Equipment	1 Dec76	30 Dec76	107
145	260	20	Gov't Approve Misc Bldg	1 Aug76	20 Aug76	
			Equipment	1 Apr77	20 Apr77	243
255	490	180	Deliver Hospital & Misc Equip	15 Sep76	13 Mar77	
				31 Dec76	28 Jun77	107
260	495	90	Deliver Misc Bldg Equip	21 Aug76	18 Nov76	
				21 Apr77	19 Jul77	243
490	510	35	Inst Hospital & Misc Equip	22 Jun77	26 Jul77	
				29 Jun77	2 Aug77	7
495	510	14	Inst Misc Bldg Equip	22 Jun77	5 Jul77	
				20 Jul77	2 Aug77	28

Table 15

Zero Float Sort

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
1	5	1	Ntp	1 Jul76	1 Jul76	
				1 Jul76	1 Jul76	0
5	90	35	Submit & Approve Reinf Steel	2 Jul76	5 Aug76	
			Shop Drawings	2 Jul76	5 Aug76	0
20	155	15	Deliver Initial Mechanical & Electrical Rough-In	1 Aug76	15 Aug76	
			Materials	2 Aug76	16 Aug76	1
90	150	15	Deliver Reinforcing Steel	6 Aug76	20 Aug76	
				6 Aug76	20 Aug76	0
150	265	0	Dummy	21 Aug76	21 Aug76	
				21 Aug76	21 Aug76	0
150	275	0	Dummy	21 Aug76	21 Aug76	
				27 Aug76	27 Aug76	6
155	275	10	Rough-In Under Basement	16 Aug76	25 Aug76	
				17 Aug76	26 Aug76	1
265	270	16	Footings & Plinths	21 Aug76	5 Sep76	
				21 Aug76	5 Sep76	0
270	300	30	Grade Beams	6 Sep76	5 Oct76	
				6 Sep76	5 Oct76	0
275	290	14	Basement Foundation, Slab	26 Aug76	8 Sep76	
			& Beams	27 Aug76	9 Sep76	1
280	285	21	Basement Walls	9 Sep76	29 Sep76	
				10 Sep76	30 Sep76	1
285	300	5	Dampproofing	30 Sep76	4 Oct76	
				1 Oct76	5 Oct76	1
300	305	0	Dummy	6 Oct76	6 Oct76	
				2 Feb77	2 Feb77	1
300	310	10	Backfill and Grade Under	6 Oct76	15 Oct76	
			Building	6 Oct76	15 Oct76	0
310	315	20	30% Mechanical & Electrical	16 Oct76	4 Nov76	
			Rough-In Under Floor	16 Oct76	4 Nov76	0
315	320	50	Formed In Place Concrete	5 Nov76	24 Dec76	
			Slabs & Beams	5 Nov76	24 Dec76	0
315	325	50	70% Mechanical & Electrical	5 Nov76	24 Dec76	
			Rough-In Under Floor	5 Nov76	24 Dec76	0
320	325	0	Dummy	25 Dec76	25 Dec76	
				25 Dec76	25 Dec76	0
325	330	5	Erect Steel Columns & Metal	25 Dec76	29 Dec76	
			Door Bucks	25 Dec76	29 Dec76	0
330	350	10	Erect Structural Steel & Joists	30 Dec76	8 Jan77	
				30 Dec76	8 Jan77	0
350	355	12	Roof Deck	9 Jan77	20 Jan77	
				9 Jan77	0 Jan77	0

Table 15 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
355	365	21	Roofing & Sheetmetal	21 Jan77	10 Feb77	
				21 Jan77	10 Feb77	0
365	395	56	AC Ductwork	11 Feb77	7 Apr77	
				11 Feb77	7 Apr77	0
395	410	14	Ceiling Suspension System	8 Apr77	21 Apr77	
			& Insulation	8 Apr77	21 Apr77	0
410	430	12	Plaster Ceiling	22 Apr77	3 May77	
				22 Apr77	3 May77	0
410	445	35	Acoustic and Other Ceilings	22 Apr77	26 May77	
				27 Apr77	31 May77	5
430	445	28	30% Paint & Finish	4 May77	31 May77	
				4 May77	31 May77	0
445	505	45	50% Paint & Fin	1 Jun77	15 Jul77	
				1 Jun77	15 Jul77	0
470	480	21	Resilient Floor	1 Jun77	21 Jun77	
				8Jun77	28 Jun77	7
480	490	0	Dummy	22 Jun77	22 Jun77	
				29 Jun77	29 Jun77	7
505	510	18	Complete Paint & Finish	16 Jul77	2 Aug77	
				16 Jul77	2 Aug77	0
510	655	7	Clean Bldg	3 Aug77	9 Aug77	
				3 Aug77	9 Aug77	0
655	660	5	Final Inspection	10 Aug77	14 Aug77	
				10 Aug77	14 Aug77	0

With this type of report, the resident office may make sure that the contractor is in compliance with the contract's submittal requirements, verify the accuracy of the contractor's submittal register, and determine resource requirements needed for submittal review. Since one of the most frequent problems to occur on construction projects is that submittals were not submitted and reviewed in a timely fashion, this report is very basic to analyzing a contractor's schedule.

Many contractors object to including submittal information on a construction schedule. One of the favorite arguments has been that including the submittal activities in a network creates a schedule that is too big to use on the construction site. Fortunately, the use of codes allows the administration and construction activities to be separated into ad hoc parts that can be selected by different users.

In addition to those items that the government must approve, many items must be certified by the contractor as meeting the specifications. Therefore, only this certification must be submitted. The same code that identified the government approval activities, "TYPE", may be used to find all of the contractor's submittal activities. Table 18 is a report of all submittal activities in the dispensary project.

Table 16

Exterior Closure (Building Systems Index 04000-05000)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
5	30	20	Submit Metal Door Buck Shop	2 Jul76	21 Jul76	
			Drawings	22 Aug76	10 Sep76	51
5	40	45	Submit & Approve Masonry Matls	2 Jul76	15 Aug76	
				12 Nov76	26 Dec76	133
5	45	30	Submit Metal Window Shop Dwgs	2 Jul76	31 Jul76	
				10 Sep76	9 Oct76	70
5	55	45	Submit Alum Entrance & Metal	2 Jul76	15 Aug76	
			Door Shop Drawings	7 Oct76	20 Nov76	97
5	110	45	Submit & Approve Door Canopies	2 Jul76	15 Aug76	
			Signs	26 Mar77	9 May77	267
30	165	15	Gov't Approve Metal Door Bucks	22 Jul76	5 Aug76	
				11 Sep76	25 Sep76	51
40	175	45	Deliver Masonry Materials	16 Aug76	29 Sep76	
				27 Dec76	9 Feb77	133
45	180	20	Gov't Approve Metal Windows	1 Aug76	20 Aug76	
				10 Oct76	29 Oct76	70
50	185	30	Gov'Approve Hardware	1 Aug76	30 Aug76	
				12 Oct76	10 Nov76	72
55	190	20	Gov't Approve Aluminum Entrance	16 Aug76	4 Sep76	
			& Metal Doors	21 Nov76	10 Dec76	97
110	500	75	Deliver Door Cancpies & Signs	16 Aug76	29 Oct76	
				10 May77	23 Jul77	267
165	325	90	Fab & Deliver Metal Door Bucks	6 Aug76	3 Nov76	
				26 Sep76	24 Dec 6	51
175	335	2	Construct Sample Masonry Panel	30 Sep76	1 Oct76	
				10 Feb77	11 Feb77	133
180	360	90	Fab & Deliver Metals Windows	21 Aug76	18 Nov76	
				30 Oct76	27 Jan77	70
185	345	120	Deliver Hardware	31 Aug76	28 Dec76	
				11 Nov76	10 Mar77	72
190	345	90	Fab & Deliver Aluminum Entrance	5 Sep76	3 Dec76	
			& Metal Doors	11 Dec76	10 Mar77	97
225	370	75	Deliver Materials to Protect	21 Aug76	3 Nov76	
			Items Stored On Site	12 Dec76	24 Feb77	113
335	340	27	Exterior Masonry Walls	30 Dec76	25 Jan77	
				12 Feb77	10 Mar77	44
345	385	14	Inst Aluminum Entrance	26 Jan77	8 Feb77	
			& Metal Doors	11 Mar77	24 Mar77	44
360	365	14	Inst Metal Windows	19 Nov76	2 Dec76	
				28 Jan77	10 Feb77	70
500	510	10	Inst Door Canopies & Signs	26 Jan77	4 Feb77	
				24 Jul77	2 Aug77	179

Table 17

Activities for Government Approval

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
25	160	15	Gov't Approve Pan Forms	22 Jul76	5 Aug76	
				6 Sep76	20 Sep76	46
30	165	15	Gov't Approve Metal Door Bucks	22 Jul76	5 Aug76	
				11 Sep76	25 Sep76	51
35	170	20	Gov't Approve Structural Steel	1Aug76	20 Aug76	
			& Joist Shop Drawings	11 Sep76	30 Sep76	41
45	180	20	Gov't Approve Metal Windows	1 Aug76	20 Aug76	
				10 Oct76	29 Oct76	70
50	185	30	Gov't Approve Hardware	1 Aug76	30 Aug76	
				12 Oct76	10 Nov76	72
55	190	20	Gov't Approve Aluminum Entrance	16 Aug76	4 Sep76	
			& Metal Doors	21 Nov76	10 Dec76	97
60	195	15	Gov't Approve Lath & Plaster	16 Aug76	30 Aug76	
				8 Feb77	22 Feb77	176
65	200	30	Gov't Approve & Select Ceramic	16 Aug76	14 Sep76	
			Tile Color	27 Jan77	25 Feb77	164
70	205	20	Gov't Approve Toilet Partitions	16 Aug76	4 Sep76	
			& Accessories	29 Mar77	17 Apr77	225
75	210	30	Gov't Approve Plumbing &	1 Aug76	30 Aug76	
			Mechanical Fixtures &			
			Equipment	19 Nov76	18 Dec76	110
80	215	30	Gov't Approve Elec Fixtures	1 Aug76	30 Aug76	
			& Equipment	16 Jan77	14 Feb77	168
100	220	15	Gov't Approve Roof & Sheetmetal	1 Aug76	15 Aug76	
			Shop Drawings	7 Nov76	21 Nov76	98
105	225	20	Gov't Approve X-ray Protection	1 Aug76	20 Aug76	
				22 Nov76	11 Dec76	113
115	230	30	Gov't Test, Approve & Select	1 Aug76	30 Aug76	
			Paint Color	18 Feb77	19 Mar77	201
120	235	30	Gov't Approve & Select Vinyl	1 Aug76	30 Aug76	
			Wall Covering Color	21 Apr77	20 May77	263
125	240	20	Gov't Approve Millwork	1 Aug76	20 Aug76	
				24 Jan77	12 Feb77	176
130	245	30	Gov't Approve & Select Resilient	1 Aug76	30 Aug76	
			Floor Color	25 Mar77	23 Apr77	236
135	250	30	Gov't Approve Casework	16 Aug76	14 Sep76	
				11 Jan77	9 Feb77	148
140	255	30	Gov't Approve Hospital & Misc	16 Aug76	14 Sep76	
			Equipment	1 Dec76	30 Dec76	107
145	260	20	Gov't Approve Misc Bldg	1 Aug76	20 Aug76	
			Equipment	1 Apr77	20 Apr77	243

Table 18 should contain the submissions for all activities, contractor certifications and those that are to be approved by the government. For example, submittal activity 5-105, SUBMIT X-RAY PROTECTION DATA, is normally followed by activity 105-225, GOV'T APPROVE X-RAY PROTECTION. The resident office may want to check that there are submittal activities for each government approval. To create such a report, a PMS would identify those activities that were coded as government approval activities, determine for each identified activity which of its preceding activities were coded as submittal activities, sort the activities according to their "i" and "j" node numbers, and print the activities. Project management systems that provide sophisticated searching of preceding activities are not yet commercially available. However, since this type of search may be very useful, this feature will probably be marketed. While there are limits to the power of commercially available PMSs, some systems allow interaction with a data base program, such as DBASE III+, which may be programmed to provide the appropriate algorithm.

The fifth question, "Are there weather-sensitive activities that are scheduled during periods of poor weather?" has also been answered by using activity codes. Rather than having the code's value be an abbreviation of a word, the weather-sensitive code is a "logical" code. Logical codes have only two values, for example, "true" or "false," or "yes" or "no." Another interesting feature of this type of coding is that the user only needs to enter the positive values (true or yes) since a blank would indicate that the activity is not weather sensitive. If, for example, there are 300 activities in the network and there are 35 weather-sensitive activities, then only the 35 would have to receive an entry. The other 265 activities could be blank or contain a negative code, indicating that the activity is not weather sensitive. Once such a coding scheme is in place, the PMS could select those activities that have the weather-sensitive coding and then, from that reduced group, print only those activities with start dates between bad weather periods.

Coding for weather sensitivity may be a very important feature, not only in the original review of the schedule, but also after construction begins. As the project proceeds, the original plan will be modified. The impact of these changes must be assessed to limit potential problems that may occur later on the job. Moving weather-sensitive activities into a bad weather period should be avoided if possible.

The sixth question, "When should prepatory inspections be conducted?" illustrates another way that quality assurance (QA) personnel can use the schedule during construction to keep one step ahead of the contractor. One of the most important reports that a PMS generates is a list of those activities that are to start within a given time period. In tne case of the preparatory inspection, the user would produce a report listing activities scheduled to start within the next week. Since the preparatory inspection must be held before the work begins, this report is a very good QA tool.

The seventh question, "What should the contractor be working on this week?" is very similar to the previous question. To answer this question, all activities that have progress without a finish date and start dates in a particular week may be printed. Of those activities scheduled to start, two categories really get to the intent of this question: activities which <u>may</u> start and activities which <u>must</u> start. Activities which may start are those with early start dates within the week's period. The must start activities are those with late start dates within the particular week's period. Unless the must start activities begin within the week, the project will fall behind schedule. The other point in this question (which activities have to be finished) uses the early and late finish dates to determine the may- and must-finish activities.

Table 18

Contractor Submittal Activities

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
5	20	30	Submit & Approve Mechanical & Electrical Rough-In Mtls	2 Jul76 3 Jul76	31 Jul76 1 Aug76	1
5	25	20	Submit Pan Form Shop Drawings	2 Jul76 17 Aug76	21 Jul76 5 Sep76	46
5	30	20	Submit Metal Door Buck Shop Drawings	2 Jul76 22 Aug76	21 Jul76 10 Srp76	51
5	35	30	Submit Structural Steel & Joist Shop Drawings	2 Jul76 12 Aug76	31 Jul76 10 Sep76	41
5	40	45	Submit & Approve Masonry Matls	2 Jul76 12 Nov76	15 Aug76 26 Dec76	133
5	45	30	Submit Metal Window Shop Dwgs	2 Jul76 10 Sep76	31 Jul76 9 Oct76	70
5	50	30	Submit Hardware Schedule and Samples	2 Jul76 12 Sep76	31 Jul76 11 Oct76	72
5	55	45	Submit Alum Entrance & Metal Door Shop Drawings	2 Jul76 7 Oct76	15 Aug76 20 Nov76	97
5	60	45	Submit Lath & Plaster Data	2 Jul76 25 Dec76	15 Aug76 7 Feb77	176
5	65	45	Submit Ceramic Tile Data & Samples	2 Jul76 13 Dec76	15 Aug76 26 Jan77	164
5	70	45	Submit Toilet Partition & Accessory Schedule	2 Jul76 12 Feb77	15 Aug76 28 Mar77	225
5	75	30	Submit Plumbing & Mechanical Fixtures & Equipment Schedule	2 Jul76 20 Oct76	31 Jul76 18 Nov76	110
5	80	30	Submit Electrical Fixtures, Data, & Schedule	2 Jul76 17 Dec76	31 Jul76 15 Jan77	168
5	85	45	Submit & Approve Misc Metals Shop Drawings	2 Jul76 4 Nov76	15 Aug76 18 Dec76	125
5	90	35	Submit & Approve Reinf Steel Shop Drawings	2 Jul76 2 Jul76	5 Aug76 5 Aug76	0
5	95	45	Submit & Approve Roof Deck Shop Drawings	2 Jul76 26 Oct76	15 Aug76 9 Dec76	116
5	100	30	Submit Roof & Sheetmetal Shop Drawings	2 Jul76 8 Oct76	31 Jul76 6 Nov76	98
5	105	30	Submit X-ray Protection Data	2 Jul76 23 Oct76	31 Jul76 21 Nov76	113
5	110	45	Submit & Approve Door Canopies Signs	2 Jul76 26 Mar77	15 Aug76 9 May77	267
5	115	30	Submit Paint Certification & Samples	2 Jul76 19 Jan77	31 Jul76 17 Feb77	201
5	120	30	Submit Vinyl Wall Covering Data & Samples	2 Jul76 22 Mar77	31 Jul76 20 Apr77	263
5	125	30	Submit Millwork Shop Drawings	2 Jul76 25 Dec76	31 Jul76 23 Jan77	176

Table 18 (Cont'd)

"i" Node	"j" Node	Orig Dur	Activity Description	Early/ Late St	Early/ Late Fn	Tot Flt
5	130	30	Submit Resilient Floor Samples	2 Jul76	31 Jul76	
				23 Feb77	24 Mar77	236
5	135	45	Submit Casework Shop Drawings	2 Jul76	15 Aug76	
				27 Nov76	10 Jan77	148
5	140	45	Submit Hospital & Misc Building	2 Jul76	15 Aug76	
			Equipment Data	17 Oct76	30 Nov76	107
5	145	30	Submit Misc Building Equipment	2 Jul76	31 Jul76	
			Data	2 Mar77	31 Mar77	243
5	150	15	Submit Certified Concrete	2 Jul76	16 Jul76	
			Design Mix	6 Aug76	20 Aug76	35
5	330	30	Pre-Qualify Welders	2 Jul76	31 Jul76	
				30 Nov76	29 Dec76	151
5	600	45	Submit & Approve Exterior	2 Jul76	15 Aug76	
			Electrical and Plumbing			
			Shop Drawings	3 Nov76	17 Dec76	124

When using a PMS to provide data to analyze a schedule the resident office reviewer must understand the way the data may be manipulated within the program. The methods presented thus far use activity codes and activities' dates. There are, however, other ways for a PMS to assist the review of a construction schedule.

The final question points to several features that might be incorporated by future PMSs: "Has the contractor's progress been sufficient to allow the project to be completed on time?" Currently, several systems provide "target" schedules. These systems allow the direct comparison of two or more schedules to inform the user of the change in float of each activity compared to another, presumably earlier, schedule. This type of report is excellent for rapid analysis of any changes that have occurred to the schedule due to change orders or claims.

Although knowing that a particular activity's float decreased and affected the critical path is very important, it is limited to "what if" projections. The resident office needs to know more than that an activity became critical over the past month. The following steps will help determine how an activity became critical and what the contractor must do to correct the situation.

1. Create a list of the activity predecessors
2. Check past versions of the schedule to gather data
3. Compare the original duration with the actual duration
4. Select those activities that had delays
5. Attempt to identify a pattern to explain the delay(s)

6. Project future performance from past performance and

7. Prepare a report that shows the results of this analysis.

Unfortunately, there are several important differences between a program that can perform these steps and the programs that are commercially available today. These are (1) statistical and (2) recursive analysis.

While it is possible that the program used to "drive" a limited portion of the statistical analysis module could be a commercially available data base program such as DBASE III+, more sophisticated programming is necessary before attempting to use automation to help create alternative plans for future action. Research efforts at several universities and laboratories are, however, using more powerful tools to develop broader scheduling applications, including program-initiated "what if" analysis to judge the effectiveness of potential solutions.

Graphic Output

The ability to provide time-scaled network diagrams, while not essential to the effective use of a PMS, is a feature that many resident offices believe should be required. This requirement should be evaluated in terms of the currently available equipment, monies, and staff resources. Network diagram programs that prepare diagrams that can be used in presentations require an additional purchase of software and hardware generally totaling around $15,000. These graphics are used very effectively for presentations. The time required to learn to use, maintain, and obtain a "visually pleasing" graphic should be heavily factored into any decision to purchase plotting features.

A much more important type of simple graphic report can be created by sorting a group of activities by their activity codes and then combining all similarly coded activities into one "activity." The presentation of these new super-activities in a bar chart format is very effective in monitoring the job's progress.

Data Exchange

One of the greatest resource drains on the field office is the need to manually enter project data into PMSs. Several systems now allow data to be input from a file that may be copied from floppy disks. Including the exchange of a contractor's data file in the specifications will greatly reduce the time required for manual data analysis.

The drawback of the data exchange specification is that there is currently no industry standard file format. In an effort to investigate the willingness of software vendors to develop a routine that would produce a file in a standard format, researchers sent a letter of request to several system vendors. This letter presented a possible format (Appendix). Most vendors expressed an interest in developing some type of standard data exchange file.

3 CONCLUSIONS

The following features allow easier implementation of project management systems within the Construction Field Office:

- Most systems have sophisticated user-interfaces that allow the user to create menus. Some systems even define commands that automate many functions and allow the user to customize data entry screens.
- The systems allow the user to produce reports, analyze the schedule, and prepare graphics based on information in the data base.
- The systems allow the user to post cost progress and calculate payment based on progress
- In most cases, dates can be plugged into the system to define constraints.
- Some systems provide a method of allocating resources and also provide algorithms to help plan an efficient schedule.
- Several systems allow data to be input from a floppy disk. This may facilitate data exchange between the contractor and the Field Office.

This research identified the following potential scheduling problems that may be discovered when analyzing the contractor's progress schedule:

- If the work schedule (hours per day, days per week, and holiday time) is not coordinated in advance, the completion date calculated by the Field Office will not match that calculated by the contractor.
- Using system default dates instead of the actual dates will mask the real progress level of the project, and should be discouraged.
- Routine changes in the schedule can result in out-of-sequence progress that should be rescheduled using the Logical Calculation Method.

CITED REFERENCES

Buyer's Guide to Project Management Software, Kenneth M. Stepman, Ed. (New Issues Inc., 1987).

Engineer Regulation (ER) 1-1-11, *Network Analysis System* (U.S. Army Corps of Engineers, 15 October 1985).

UNCITED REFERENCES

East, E. William, "A Knowledge-Based Approach for Project Scheduling System Selection," *Journal of Computering in Civil Engineering*, (American Society of Civil Engineers [ASCE], October 1988).

East, E. William, "Approaches to Selecting Project Management Systems," *Proceedings of the Fifth Annual Conference on Microcomputers in Civil Engineering* (ASCE, March 1988).

Harris, Robert B., *Precedence and Arrow Networking Techniques for Construction* (Wiley and Sons, 1978).

Johnston, David W., "Linear Scheduling Method for Highway Construction," *Journal of the Construction Division* (ASCE, June 1981), pp 247-261.

Levine, Harvey A., *Project Management Using Microcomputers* (McGraw Hill, 1986).

Melin, John W., and Barry Whiteaker, "Fencing a Bar-Chart," *Journal of the Construction Division* (ASCE, September 1981), pp 497-507.

Moder, Joseph J., and Cecil R. Phillips, *Project Management with CPM and PERT, 2nd Ed.* (Van Nostrand Rienhold, 1970).

O'Brien, James J., "VPM Scheduling for High-Rise Buildings," *Journal of the Construction Division* (ASCE, December 1975), pp 895-904.

O'Brien, James J., *Scheduling Handbook* (McGraw Hill, 1969).

O'Connor, Michael J., Timothy A. Kruppenbacher, and Glenn E. Cowell, *Microcomputer Selection Guide For Construction Field Offices*, Technical Report (revised) P-146/ADA146615 (U.S. Army Construction Engineering Research Laboratory, September 1984).

Pallatto, John, "Project Management - A Real Juggling Act," *PC Week* (May 15, 1984), pp 37-45.

APPENDIX:

POTENTIAL DATA EXCHANGE FORMAT

Data Exchange Standard Goal

The goal of developing the project management system (PMS) data exchange standard is to allow a PMS to share information easily with other systems. The focus of the data exchange standard will be transferring scheduling data between systems. If this goal is achieved, several person-hours of data entry time can be saved every month for each project scheduled. The following represents the joint effort of Corps of Engineers personnel and commercial software vendors and serves as an initial standard.

Revised Design Assumptions

The revised assumptions used to shape the design of the proposed standard data exchange file format are as follows:

1. The standard should be able to be used with many systems with as little reprogramming as possible.

2. The standard should be flexible enough to be applicable to as many Corps of Engineer field offices as possible.

3. The scheduling needs of small construction projects are reflected in required data records. Optional records are provided to add the necessary level of detail for large construction projects.

4. Specific guidelines must govern the inclusion of optional items into the standard exchange format for individual construction specifications.

5. All specified records for a project will be transferred at every update period.

Revised Standard Organization

The proposed ASCII data file will be composed of 132-character, fixed field length records. Each record type is designated by a "record identifier" contained in positions 1 through 4. Numeric fields will be right justified. Character fields will be left justified.

To enhance understandability of date formats, all dates will be provided by two integers representing the day of the month, three letters representing the month, and two integers representing the year. The following will be used to abbreviate each month: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec. Although some systems use different schemes, the workshop attendees all felt that the format described here would be the most appropriate since some standard format needs to be agreed on. The most naturally understood format should be chosen.

The records on the following pages are included in the revised standard. Each data record and field is identified as either required or optional. Every data field will have a column position, maximum length of field, required (or default) values, field type, and justification.

Project Data Record

The first record of every file must contain all the following overall project data in the format listed below.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	PROJ	Alpha.	Filled
DATA DATE	6-12	7	-	ddmonyy	Filled
PROJECT IDENTIFIER	14-18	4	-	Alpha.	Left
PROJECT NAME	20-67	48	-	Alpha.	Left
CONTRACTOR NAME	69-104	36	-	Alpha.	Left
ARROW OR PRECEDENCE	106-106	1	A,P	Fixed	Filled
USER DEFINED	108-132	35			

The first four characters of this record must be PROJ. These four characters will signify that this record contains overall project information and the file contains schedule data that meets the standard file format.

The DATA DATE is the date on which the schedule was calculated.

The PROJECT IDENTIFIER is a short abbreviation or other unique designation for the project. Software vendors are encouraged to provide a feature to ensure that inputs of schedule updates do not overwrite existing schedules with the same PROJECT IDENTIFER.

The PROJECT NAME and CONTRACTOR NAME fields provide a maximum length for the data. PMS vendors will indicate their actual field lengths for use in developing guide specifications.

The ARROW OR PRECEDENCE field indicates if the activity identifiers use the Arrow Diagram Method (ADM) or Precedence Diagram Method (PDM) notation. More information on the exact impact of this field will be described in the activity record.

USER DEFINED space in the PROJ record allows individual users to transfer additional project data as required for individual projects.

Calendar Record

One mandatory calendar record and any optional calendar records must follow the initial project record. Guide specifications will provide the criteria for including optional records of this type in a particular project specification.

More than one mandatory calendar record will typically not be required. Multiple calendars are most often used by contractors to reflect different crew weeks. Since the transfer of calendar data must be determined based on the specifics of the contractor's schedule, specifications will indicate that data used by the contractor to manage the particular project should be transferred.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1- 4	4	CLDR	Alpha.	Filled
CALENDAR CODE	6- 9	4	-	Alpha.	Left
WORKDAYS	11- 17	7	NYYYYYYN	Alpha.	Filled
CALENDAR DESCRIPTION	19- 49	30	-	Alpha.	Left

The calendar record must always begin with CLDR, the four-character RECORD IDENTIFIER. One calendar record must occur in every data transfer. If only one calendar record is found, all activities will use this calendar.

If additional calendar records are required, then the activity CALENDAR CODE will indicate which calendar is applied to a given activity.

The specific calendar will be indicated by the WORKDAYS field. This field indicates by Y, for yes, and N, for no, which of the days of the week are workdays. The order of days in this seven-character field is Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday. An example of a 5-day work week with Saturday and Sunday as nonworkdays would be shown by NYYYYYN.

The CALENDAR DESCRIPTION is a field that may be used to explain the calendar.

Vendors should provide information on the number and type of calendars they support.

Holiday Record

Optional holiday data will follow the required calendar record and any optional records. Guide specifications will provide the criteria for including this record type into a particular project specification.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	HOLI	Alpha.	Filled
CALENDAR CODE	6-9	4	-	Alpha.	Left
HOLIDAY DATE	11-17	7	-	ddMONyy	Filled
HOLIDAY DATE	19-25	7	-	ddMONyy	Filled
HOLIDAY DATE	27-33	7	-	ddMONyy	Filled
HOLIDAY DATE	35-41	7	-	ddMONyy	Filled
HOLIDAY DATE	43-49	7	-	ddMONyy	Filled
HOLIDAY DATE	51-58	7	-	ddMONyy	Filled
HOLIDAY DATE	60-66	7	-	ddMONyy	Filled
HOLIDAY DATE	68-74	7	-	ddMONyy	Filled
HOLIDAY DATE	76-82	7	-	ddMONyy	Filled
HOLIDAY DATE	84-90	7	-	ddMONyy	Filled
HOLIDAY DATE	92-98	7	-	ddMONyy	Filled
HOLIDAY DATE	100-106	7	-	ddMONyy	Filled
HOLIDAY DATE	108-124	7	-	ddMONyy	Filled

In most schedules, the use of holidays is simply a device to keep an activity from starting on a clearly incorrect date such as Thanksgiving or New Year's Day. The use of holidays may be resricted to larger projects. Vendors are encouraged to comment on holiday data and the criteia for including the holiday record.

If a contractor uses holidays, this data should be included in the data exchange file.

The holiday record will always begin with HOLI, the four-character RECORD IDENTIFIER. The CALENDAR CODE indicates which calendar the given holiday is applied to.

To make it clear which specific days are holidays, every specific HOLIDAY DATEs will be provided for every nonworkday. Although the workshop attendees thought that every holiday should have a beginning and ending date, this approach seems to be more straightforward from a programming point of view. Additional holidays may be added in additional records.

The specifications should be structured so that if a contractor wishes to uses holidays, the information will be included in the transfer file.

Activity Description Record

Activity description records must follow the calendar/holiday record(s). There will be one activity description field for every activity in the network. Guide specifications will provide the criteria for including these optional data fields into particular project specifications.

If contractors are using optional data, this data should be included in the data exchange standard.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	ACTV	Alpha.	Filled
ACTIVITY IDENTIFICATION	6-15	10	-	Integer	*
ACTIVITY DESCRIPTION	17-66	50	-	Alpha.	Left
ACTIVITY DURATION	68-70	3	-	Integer	Right
ACTIVITY COST	72-79	8	-	Integer	Right
Optional Activity Data:					
START NO EARLIER THAN DATE	81-87	7	-	ddMONyy	Filled
FINISH NO LATER THAN DATE	89-95	7		ddMONyy	Filled
UNIT PRICE	97-104	8	#.00	Real	Right
ESTIMATED NUMBER OF UNITS	106-112	7	-	Integer	Right
UNIT DESCRIPTION	114-117	4	-	Alpha.	Left
CALENDAR CODE	119-122	4	-	Alpha.	Left

Each activity record must begin with the four-character ACTV code. The RECORD IDENTIFIER field is used for both the ADM and PDM.

The schedule is noted to be either ADM or PDM in the PROJ record's ARROW OR PRECEDENCE notation field (discussed earlier). If the field contains the letter 'A', then the ACTIVITY IDENTIFICATION field will be interpreted as two right justified fields of five integers each. This allows a maximum activity number of 99999.

If the PROJ record's ARROW OR PRECEDENCE notation field contains the letter 'P', then the ACTIVITY IDENTIFIER is used as one right justified field with a maximum activity number of 9,999,999,999. Only integers will be allowed in the activity identification field.

The ACTIVITY DESCRIPTION will be a maximum of 50 characters. This field will be modified as appropriate to ensure that the actual number of characters used does not exceed the field length for a particular PMS. Since the possibility of using add-on programs exists, punctuation in descriptions should be restricted because the punctuation may be read differently by these programs. Vendors have been asked to provide the maximum number of description characters and punctuation available for inclusion in the guide specifications.

The ACTIVITY DURATION contains the original duration for the activity. All progress data is provided in another record. The ACTIVITY COST similarly provides the original estimated value of the activity.

Several optional fields in this record reflect the needs of various types of systems and projects. The first two fields, START NO EARLIER THAN DATE and FINISH NO LATER THAN DATE affect the calculation of the critical path. The START NO EARLIER THAN DATE fixes the early start of an activity to the date provided, overriding the calculated date. The FINISH NO LATER THAN DATE fixes the late finish of an activity, overriding the calculated date.

The first activity in a schedule will always have a start no earlier than date equal to the contract notice to proceed date. The last activity in the network must also have the finish no later than date equal to the current contract completion date. Vendors may wish to provide automatic exception reports that flag these problems during schedule calculation.

UNIT PRICE and ESTIMATED NUMBER OF UNITS provide support for unit cost and/or bid item type projects. The description of the units may be "cyds", "sqft", "tons", or other appropriate designations. Readers are encouraged to provide their suggestions for a library of unit descriptions that will be included in the scheduling guide specifications.

There was some discussion in the workshop regarding ACTIVITY TYPE codes being included in the activity record. Since the items typically contained in these data fields are used to sort and select activities, the information in these fields is essentially an activity code. All activity codes will be grouped in the activity code record. If specialized activity type codes are needed, each office is encouraged to take advantage of the ample blank space set aside for user-defined codes.

Activity Code Record

The activity code records will follow all activity records. A minimum of three codes will be required on most projects. Guide specifications will assist in selecting optional codes for a particular project.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	CODE	Alpha.	Filled
ACTIVITY IDENTIFIER	6-15	10	-	Integer	*
RESPONSIBILITY	17-20	4	-	Alpha.	Left
MODIFICATION OR CLAIM NUMBER	22-25	4	-	Alpha.	Left
WORK AREA	28-31	4	-	Alpha.	Left
Optional Activity Code Data:					
HAMMOCK ACTIVITY	33-33	1	-	Alpha.	Y or blank
WORK BREAKDOWN	35-46	12	-	Alpha.	Left
WEATHER SENSITIVE	48-48	1	-	Alpha.	Y or N
ACTIVITY TYPE	50-53	4	-	Alpha.	Left
SPEC SECTION	55-62	8	-	Integer	Right
BUILDING SYSTEM	64-70	7	-	Integer	Right
CALENDAR CODE	72-75	4	-	Alpha.	Left
USER DEFINED	77-132	56	-	As Rqd.	

All activity coding information will be identified by CODE, the four-character RECORD IDENTIFIER. Activity identifiers will reflect the format described in the previous section (Activity Description Records).

The RESPONSIBILITY code will have a designation for who will perform the work. Coding should, as much as possible, be understandable without a coding dictionary. The following codes are provided as examples for use in this field:

Code	Definition
SITE	Sitework Subcontractor Activity
CONC	Concrete Subcontractor Activity
STEL	Steel Erection Subcontractor Activity
DRYW	Drywall Subcontractor Activity
ELEC	Electrical Subcontractor Activity
MECH	Mechanical Subcontractor Activity
PLUM	Plumbing Subcontractor Activity
BALC	Testing and Balancing Subcontractor Activity
CORP	Corps of Engineers Activity
AE	Architect/Engineer Firm Activity

The RESPONSIBILITY code may contain the above codes or any others that provide a clear meaning to contractor personnel. Where possible, the coding scheme used by the contractor should be adopted. Reviewers of this standard are encouraged to write in the RESPONSIBILITY codes that they feel should be included in an initial list of possible codes.

The MODIFICATION OR CLAIM NUMBER code will identify every activity that is changed by a modification or changed to justify any claimed time extensions. This code field should be required for most construction contracts. Specifications will provide that all claims must be accompanied by a set of revised schedule activities. These activities will be coded in a consistent scheme that coordinates the claimed item with the schedule activities. When modifications are settled, activities will be modified with both revised duration and logic as well as the appropriate code number.

The WORK AREA code will identify the location of the activity (e.g., a floor, building, or station number designation). The designation should be an integer that refers to the floor of the building or phase of the work. Numbers may also indicate the reaches of horizontal construction.

The WORK AREA code may also be indicated by selecting appropriate activity numbers, for example activities with identification numbers between 100 and 199 may be on the first floor. If this is the case, individual systems should incorporate a feature to translate this implicit activity coding scheme to an explict activity code for every activity.

The WORK AREA code must be understandable without the use of a data dictionary. Where possible, the coding scheme used by the contractor should be adopted. Readers are encouraged to provide additional WORK AREA definitions.

Optional activity codes may be used as required for a particular project. The criteria for using these codes will be listed in the PMS data exchange specification.

The HAMMOCK ACTIVITY code indicates that a particular activity does not have its own independent duration but takes its start date from the start date of the preceding activity (or node) and takes its finish date from the finish date of its succeeding activity (or node).

For large projects, certain hammock activities may be specified to represent significant portions of work. Readers are encouraged to assist in establishing criteria for the requirement to add HAMMOCK ACTIVITIES.

The WORK BREAKDOWN field may be used for a variety of contractor and owner cost accounting functions. This field will typically not be required on firm-fixed priced contracts. If this field is requried, the work breakdown used by the contractor should be implemented as much as possible.

The WEATHER SENSITIVE code will indicate if the activity is weather sensitive. This code is useful for schedule analysis of large or complex projects. This code will either be a Y, for yes, or N, for not weather sensitive.

The ACTIVITY TYPE code helps the system user separate procurement activities from construction activities. This code, in conjunction with the RESPONSIBILITY code, provides superior control over owner approval activities.

Activity Type Code	Definition
MOB	Mobilization Activity
SUBM	Submittal Activity
APRV	Approval Activity
PROC	Procurement Activity
DELV	Delivery Activity
TEST	Testing Activity
TIE	Tie-In Activity
ITER	Intermittent Activity

The ACTIVITY TYPE code should be required on large projects. Readers are encouraged to assist in adding to the above list of potential ACTIVITY TYPE codes. If possible, all ACTIVITY TYPE codes should be understandable without the use of a dictionary. ACTIVITY TYPE values used by the contractor should be adopted.

Two other codes useful for schedule analysis are the SPEC SECTION and BUILDING SYSTEM codes. These codes help validate the completeness and logic of the schedule. ANNEX A contains the Construction Specification Index (CSI) typically used for specification sections. Where possible, these SPEC SECTION codes should be used. ANNEX B contains the BUILDING SYSTEM codes used in the Corps of Engineers Computerized Estimating System (CACES). Where possible, these BUILDING SYSTEM codes should be used.

There is flexibility in the codes listed in the annexes. Most sections could be made more specific as necessary for any particular project. If a contractor is using a different numbering scheme to fill the code fields, the dictonary for this system must be supplied.

The CALENDAR CODE allows the system vendor to specify the calendar used for a particular activity. If this field is empty, the default calendar indicated in the single calendar record will be used for the activity.

Since there may be specific project needs that have not been addressed by this set of required and optional codes, there are 56 characters available for additional codes. These codes will be identified as required for each project.

Optional Resource Dictionary

Optional resource dictionary data will always follow all activity coding information. Guide specifications will provide the criteria for including this record type into a particular project specification. Use of resource information will generally not be required for firm-fixed price contracts.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	LIBR	Alpha.	Filled
RESOURCE IDENTIFIER	6-9	4	-	Alpha.	Left
DESCRIPTION	11-40	30	-	Alpha.	Left
UNIT PRICE	42-49	8	#.00	Real	Right
UNIT DESCRIPTION	51-54	4	-	Alpha.	Left
TOTAL ESTIMATED QUANTITY	56-62	7	-	Integer	Right
ACTUAL QUANTITY THIS PERIOD	64-70	7	-	Integer	Right
ACTUAL QUANTITY TO DATE	72-78	7	-	Integer	Right
START DATE	80-86	7	-	ddMONyy	Filled
END DATE	88-94	7	-	ddMONyy	Filled

All resources used in the resource code records must be identified in a resource dictionary record. While there is no inherent limit of resources in the specifications, vendors should provide maximum values for inclusion in the specifications.

The RESOURCE IDENTIFIER should be understandable without a dictionary. Readers are encouraged to suggest a possible library of codes for resources. The library developed will be included in the data exchange standard guide specification.

One of the most important points in this record is that there are two actual quantity fields: ACTUAL QUANTITY THIS PERIOD and ACTUAL QUANTITY TO DATE. These fields will allow cost accounting and earned value analysis for unit price items. While this feature is useful for certain projects, there could be some confusion when comparing the quantities and costs here to those in the activity and progress records.

If unit cost items are contained in this record, the activity record should contain an ACTIVITY COST equal to the TOTAL ESTIMATED QUANTITY times the UNIT COST. Since one resource may be used on many activities, the ACTUAL QUANTITIES TO DATE will be calculated by summing quantities for all activities of that resource type. If not calculated in a PMS, the feature should be added to the system interface program.

Another important feature of the proposed standard allows for the use of resources that have built-in time restrictions based on a start date and an end date. While there is no implicit limit to the number of time periods that a single resource may use, PMS vendors should provide their system limits.

The use of detailed resource information is potentially a complex data exchange requirement. The specification for the exchange of this data will be strictly limited to large projects that are not fixed price contracts. Readers are encouraged to assist in the further refinement of this optional field and in developing the criteria for specifying resource data transfer.

Optional Resource Data Record

Optional resource data will always follow activity coding information. Guide specifications will provide the criteria for including this record type in a particular project specification. Resource information will generally not be required for firm-fixed price construction contracts.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	RESC	Alpha.	Filled
ACTIVITY IDENTIFICATION	6-15	10	-	Integer	*
RESOURCE IDENTIFIER	17-21	4	-	Alpha.	Left
QUANTITY IDENTIFIER	23-23	1	blank,T,or D		
ESTIMATED QUANTITY	25-29	5	-	Integer	Right
ACTUAL QUANTITY THIS PERIOD	31-37	7	-	Integer	Right
ACTUAL QUANTITY TO DATE	39-45	7	-	Integer	Right

All resource data must begin with RESC, the RECORD IDENTIFER. There is no inherent limitation on the number of resources an activity may have allocated to it. Vendors should submit the number of resources per activity which they allow.

The resource record will be required only for activities that have resources allocated to them.

The QUANTITY IDENTIFER will show if the items should be interpreted as a Total (T) or Daily (D) cost.

The relationship between the ESTIMATED QUANTITY, ACTUAL QUANTITY THIS PERIOD, and ACTUAL QUANTITY TO DATE in this record and in the activity and progress records will need to be further specified to prevent any confusion that may result from apparently multiple fields for similar data. Readers are encouraged to provide suggestions.

Precedence Record

Precedence records must follow the resource records. If the project record indicates that the project is precedence, the activity information will be transferred through one record for each relationship which an activity has with another.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	PREC	Alpha.	Filled
ACTIVITY IDENTIFIER	6-15	10	-	Integer	*
SUCCESSOR ACTIVITY	17-26	10	-	Integer	Right
SUCCESSOR TYPE	28-28	1	either S, F, or C		
LAG DURATION	30-32	3	-	Integer	Right

This precedence information record must start with PREC, the four-character RECORD IDENTIFER. There is no limitation on the number of successor activities that a particular activity may have. Additional records may be added to supply additional successor activities.

Each set of successor activity information contains three parts. The first is the SUCCESSOR ACTIVITY. This field contains the activity that follows the ACTIVITY IDENTIFIER. The second field, SUCCESSOR TYPE, indicates the type of relationship that exists between the activities. The following types are allowed: start-to-start relationships will be represented by the letter S, finish-to-finish relationships will be represented by the letter F, and the conventional finish-to-start relationship will be represented by the letter C.

The relationships between activities may have durations. These durations are provided in the LAG DURATION field.

There is no inherent limit to the number of precedence information records that may be provided for a given ACTIVITY IDENTIFIER. Vendors should indicate any limitation on successors found in their products.

Progress Data Record

Progress data will follow all activity (and precedence) records. Guide specifications will provide the criteria for including these optional data fields in particular project specifications.

Description	Column Position	Max. Len.	Reqd. Value	Type	Just.
RECORD IDENTIFIER	1-4	4	PROG	Alpha.	Filled
ACTIVITY IDENTIFICATION	6-15	10	-	Integer	*
ACTUAL START DATE	17-23	7	-	ddMONyy	Filled
ACTUAL FINISH DATE	25-31	7	-	ddMONyy	Filled
REMAINING DURATION	33-35	3	-	Integer	Right
EARNED VALUE	37-39	3	-	Integer	Right
Optional Progress Data:					
UNITS PLACED THIS PERIOD	41-47	7	-	Integer	Right
UNITS PLACED TO DATE	49-55	7	-	Integer	Right

Every progress record will begin with PROG, the four-character RECORD IDENTIFIER. The ACTIVITY IDENTIFICATION for each activity that has had progress posted will match the format described in the activity record. Although many project management systems provide default calculations for various progress information, the data exchange standard must be explicit about the data that is being exchanged. Therefore the following requirements will govern the use of the progress record.

The ACTUAL START DATE is required for every in-progress activity. The ACTUAL START DATE must be less than or equal to the DATA DATE. The ACTUAL START DATE must also be greater than or equal to the notice to proceed date. A REMAINING DURATION is also required for every in-progress activity.

If the REMAINING DURATION of an activity is zero, there must be an ACTUAL FINISH DATE. The ACTUAL FINISH DATE must be less than or equal to the DATA DATE. The ACTUAL FINISH DATE must also be greater than or equal to the ACTUAL START DATE.

Cost progress is contained in the field EARNED VALUE. If there is an ACTUAL START DATE, there must also be some value for EARNED VALUE. The EARNED VALUE is not, however, tied to any other time-based value. For example, if the REMAINING DURATION is "0", the EARNED VALUE may only be 95 percent of the ACTIVITY COST to reflect 5 percent retainage for punch list items.

ANNEX A:

TYPICAL SPECIFICATION SECTIONS

01000 structure

01100	standard foundations
01200	special foundations
01300	slab on grade
01400	basement excavation
01500	easement walls

02000 structural frame

02100	floor construction
02200	roof construction
02300	stair construction

03000 roofing

03100	roofing

04000 exterior closure

04100	exterior walls
04200	exterior doors
04300	exterior windows

05000 interior construction

05100	interior partitionsa-afixed
05200	interior partitionsJa-amoveable
05300	interior doors
05400	interior windows

06000 interior finishes

06100	wall finishes
06200	flooring and floor finishes
06300	ceilings and ceilings finishes

0700 specialities

07100	toilet & bath specialities
07200	cabinetry
07300	shelving
07400	other specialties

0800 plumbing

08100	sanitary systems
08200	rainwater drainage
08300	special plumbing systems
08400	special plumbing fixtures

0900 H.V.A.C.

09100	energy supply system
09200	heating generation systems
09300	cooling generation systems
09400	air handling skystems
09500	ventilation systems
09600	exhaust systems
09700	special systems
09800	contrels & instrumentation
09900	testing,balance,etc.

10000 special mechanical systems

10100	fire protection systems
10200	pool systems
10300	pol systems
10400	refrigeration systems
10500	process systems
10600	water/waste treatment system
10700	chimneys and stacks
10800	other misc. systems

1100 interior electrical

11100	service & distrib. system
11200	power systems
11300	lighting systems
11400	grounding systems

12000 special interior elect. sys.

12100	sound systems
12200	alarm systems
12300	televevision systems
12400	control systems
12500	hospital systems
12600	time systems
12700	electric heating systems
12800	power generation systems

13000 equipment & conveying

13100	fixed & moveable equipment
13200	furnishings
13300	special construction
13400	conveying systems

14000 site preparation

14100	clearing 14200demolition
14300	site earthwork

15000 site improvements

15100	pavements
15200	site development
15300	landscaping

16000 site utilities

16100	water supply & distribution
16200	drainage & sewage systems
16300	heating distribution systems
16400	cooling distribution system
16500	gas distribution system
16600	exterior electrical

ANNEX B:

BUILDING SYSTEM CODES

00010	pre bid information
00100	instructions to bidders
00200	information available to midders
00300	bid forms
00400	supplements to bid forms
00500	agreement forms
00600	bonds and certificates
00700	general conditions
00800	supplementary conditions
00850	drawings and schedules
00900	agenda and modifications

specifications 01

01010	summary of work
01020	allownaces
01025	measurement and payment
01030	alternates/alternatives
01040	coordination
01050	field engineering
01060	regulatory requirements
01070	abbreviations and symbols
01080	identification systems
01090	reference standards
01100	special project procejures
01200	project meetings
01300	submittals
01400	quality control
01500	construction facilities and temporary controls
01600	material and equipment
01650	starting of systems commissioning
01700	contract closeout
01800	maintenance

division 02 site work

02010	subsurface investigation
02050	demolition
02100	site preparation
02140	dewatering
02150	shoring and underpinning
02160	cofferdams
02200	earthwork
02300	tunneling
02350	piles and caissons
02450	railroad work
02480	marine work
02500	paving and surfacing
02600	piped utility materials

02660	water distribution
02680	fuel distribution
02700	sewerage and drainage
02760	restoration of underground pipelines
02770	ponds and reservoirs
02780	power and communications
02800	site improvements
02900	landscaping

division 03 concrete

03100	concrete formwork
03200	concrete reinforcement
03250	concrete accessories
03300	cast in place concrete
03370	concrete curing
03400	precast concrete
03500	cementitious decks
03600	grout
03700	concrete restoration and cleaning
03800	mass concrete

division 4 masonry

04100	mortar
04150	masonry acessories
04200	unit masonry
04400	stone
04500	masonry restoration and cleaning
04550	refractories
04600	corrosion resistant masonry

division 6 wood and plastics

05010	metal materials
05030	metal finishes
06130	heavy timber construction
06150	wood metal systems
06170	prefabricated structural wood
06200	finish carpentry
06300	wood treatment
06400	architectural woodwork
06500	prefabricated structural plastics
06600	plastic fabrications

division 7 thermal and moisture protection

07100	waterproffing
07150	damproffing
07190	vapor and air retarders
07200	insulation
07250	fireproofing
07300	shingles and roofing tiles
07400	preformed roofing and cladding siding

07500	membrane roofing
07570	traffic topping
07600	flashing and sheet metal
07700	roof specialties and accessories
07800	skysights
07900	joint sealers

division 8 doors and windows

08100	metal doors and frames
08200	wood and plastic doors
08250	door opening assemblies
08300	special doors
08400	entrances and storefronts
08500	metal windows
08600	wood and plastic windows
08650	special windows
08700	hardware
08800	glazing
08900	glazed curtain walls

division 9 finishes

09100	metal support systems
09200	lath and plaster
09230	aggregate coatings
09250	gypsum board
09300	tile
09400	terrazzo
09500	acoustical treatment
09540	special surfaces
09550	wood flooring
09600	stone flooring
09630	unit masonry flooring
09650	resilent flooring
09680	carpet
09700	special flooring
09780	floor treatment
09800	special coatings
09900	painting
09950	wall coverings

division 10 specialities

10100	chalkboards and tackboards
10150	compartments and cubicles
10200	louvers and vents
10240	grilles and screens
10250	service wall systems
10260	wall and corner guards
10270	access flooring
10280	specialty modules
10290	pest control
10300	fireplaces and stoves

10340 prefabricated exterior specialties
10350 flagpoles
10400 identifying devices
10450 pedestrian control devices
10500 lockers
10520 fire protection specialties
10530 protective covers
10550 postal specialties
10600 partitions
10650 operable partitions
10670 storage shelving
10700 exterior sun control devices
10750 telephone specialties
10800 toilet and bath accessories
10880 scales
10900 wardrobe and closet specialties

division 11 equipment

11010 maintenance
11020 security and vault
11030 teller and service
11040 ecclesiastical
11050 library
11060 theater and storage
11070 instrumental
11080 registration
11090 checkroom
11100 mercantile
11110 laundry
11120 vending
11130 audioa-avisual
11140 service
11150 parking
11160 dock
11170 solida-awaste
11190 detention
11200 supply treatment
11280 gates
11300 fluida-awaste
11400 food
11450 residential
11460 kitchens
11470 darkroom
11480 athletic recretional and therapeutic
11500 industrial
11600 laboratory
11650 planetarium
11660 observatory
11700 medical
11780 morturary
11850 navigation

division 12 furnishings

12050	fabrics
12100	artwork
12100	manufactured casework
12500	window treatment
12600	furniture
12670	rugs and mats
12700	multiple seating
12800	plants

division 13 special construction

13010	aira-asupported
13020	integrated assemblies
13030	special purpose rooms
13080	sound vibration and seismic control
13090	radiation protection
13100	nuclear reactions
13120	prea-aengineered structures
13150	pools
13160	ice rinks
13170	kennels and animal shelters
13180	site constructed inceneratоrs
13200	liquid and gas storage tanks
13220	filter underdrains and media
13230	digestion tank covers and appurtenances
13240	oxygenation systems
13260	sludge conditioning systems
13300	utility control systems
13400	industrial and process control systems
13500	recording instrumentation
13550	transportation control instrumentation
13600	solor energy systems
13700	wind energy systems
13800	building automation systems
13900	fire suppression and supervisory systems

division 14 mechanical

14100	dumbwaiters
14200	elevators
14300	moving stairs and walks
14400	lifts
14500	material handling systems
14600	hoists and cranes
14700	turntables
14800	scaffolding
14900	transportation systems

division 15 mechanical

15050	basic mechanical materials and methods
15250	mechanical insulation

15300	fire protection
15400	plumbing
15500	heating ventilating and air conmditioning (HVAC)
15550	heat generation
15650	refrigeration
15750	heat transfer
15850	air handling
15880	air distribution
15950	controls
15990	testing adjusting and balancing

division 16 electircal

16050	basic electrical materials and methods
16200	power generation
16300	high voltage distribution (above 600 volt)
16400	service and distribution (600 volt and below)
16500	lighting
16600	special systems
16700	communications
16850	electric resistance heating
16900	controls
16950	testing

USACERL DISTRIBUTION

HQUSACE
ATTN: CECC-P
ATTN: CECW
ATTN: CEEC-C
ATTN: CEEC-CP
ATTN: CEEC-CM
ATTN: CEEC-CE
ATTN: CEIM-SL (2)
ATTN: CERD-L

US Army Engineer Districts (41)
ATTN: C/Const. Div. (5 ea)

US Army Engineer Divisions (13)
ATTN: C/Const. Div. (5 ea)

DLA ATTN: DLA WI 22304

General Services Administration
St. Louis, MO 63120
Kansas City, MO 64131

DNA ATTN: NADS 20305

NAVFAC
ATTN: Engineering Command (9)
ATTN: Division Offices (11)
ATTN: Naval Constr Battalion Ctr

Defense Technical Info. Center 22314
ATTN: DDA (2)

304
03/89