

Planning and Controlling Building Projects Using Microcomputers

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KEYWORDS

Building, CPM Management, Microcomputers, Planning, Scheduling.

ABSTRACT

This paper presents the results of monitoring the construction of a research facility by using microcomputers for project long-term planning, short-term scheduling and project completion forecasting. The steps adopted for implementing CPM Management are examined: scheduling specifications, scheduling training sessions, network elaboration meetings, and project coordination meetings. Important field observations concerning scheduling implementation are discussed and include Owner and Contractor response to CPM. Various schedule and progress reports used or generated as a result of the managerial effort will be presented for general use for building construction. The paper is a useful document for contractors and owners involved with building projects in a range of a \$20 million reinforced concrete structure.

Le Trace d'un Plan et La Surveillance des Projets des Batiments
Utilisant Les Microcomputers

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MOTS IMPORTANTS

Le Batiment, CPM Administration, Le Trace dun Plan, L'horaire.

ABREGE

Le report present les resultats du monitoring de la construction d'une institution de la recherche pai utilisant les micomputers pour le trace dun plan a longue date du project, l'horaire a court date, et la prevision du accomplissement du projet. Les demarches quon a adopte pour l'execution de la CPM administration sont, examine: les specifications de l'horaire, l'horaire pour les sessions de instruction, les assemblees de l'elaboration du reseau, et les assemblees de la coordination du projet. Les observations importants au site concernant l'execution de l'horaire sont discute et comprennent la reponse du proprietaire et l'entrepreneur a CPM. Des reports variables de l'horaire et de la progres utilises ou engendres comme un resultat de l'effort directorial seront present pour l'emploi general pour la construction des batiments. Le report est un document utile pour les entrepreneurs et les proprietaires embrouille avec des projets de la construction dans une classe dun batiment beton arme qui coute vers \$20 million.

INTRODUCTION

The usage of the critical path method (CPM) in time management computer programs can furnish prompt information for project planning and scheduling, and consequently constitutes an important control tool for construction. The computer technology of the 1980s has opened the way for microcomputers to perform construction management functions that only large and expensive computers performed a decade ago (5). This paper presents and examines the results of the implementation of a microcomputer program using CPM Scheduling and its impact on the administration of a building project.

PROJECT DESCRIPTION

The project consists of the erection of a main and a mechanical building on a 20 acre parcel at The University of Texas Balcones Research Center located in Austin, Texas. Both the buildings are concrete frame construction with concrete floor slabs and roofs. The mechanical building is a one-story structure with approximately 5,000 square feet of floor area. The main building contains 200,000 square feet, including four levels, a vault room basement, an auditorium, and a penthouse. Construction initiated late January of 1985, and completion is expected by mid-July of 1986, presently at the time of this writing (December 1985), one month behind contract completion date.

THE SCHEDULING APPROACH

The scheduling specifications are included in the Special Conditions of the Project Manual (2). The following issues are addressed by the Owner which refer to the work progress schedule:

1. The Contractor is required to participate with the Owner's representative in the development of the CPM network;
2. The CPM network must incorporate all the milestone dates submitted in the bid proposal as a basis for contract agreement;
3. The schedule must be in a precedence technique format and the network must include structural activities, mechanical, electrical, plumbing, finishes and the work of all subcontractors;
4. The progress of the work is to be monitored through updating meetings at the site. Such meetings shall take place once every two weeks for the first 12 months and once a week for the remaining construction duration;
5. Data processing is performed by the Owner through the CPM Management Team. Distribution of computerized reports and summary progress reports are responsibilities of the CPM Management Team;
6. PLANTRAC computerized scheduling system will be used to perform standard schedule calculations and to produce required CPM schedule reports; and

7. The CPM schedule costs are borne by the Owner.

The scheduling specifications establish that the CPM schedule assembled and monitored by the CPM Management Team is time control oriented only but, upon request, can be used by the Contractor or Subcontractors for resources or cost control.

SCHEDULING TRAINING SESSIONS

The CPM Management Team consists of an associate professor from The University of Texas at Austin and a graduate student from the construction engineering and project management program. A couple of weeks prior to the opening of bids, the CPM Management Team prepared and developed scheduling training sessions for the Owner representatives directly involved in the management of the construction phase of project: the Head of the Construction Division, the Project Coordinator and the Resident Construction Manager. Such effort took place during three days working two hours and a half each day.

During the first day the precedence technique logic was explained to the Owner representatives. Main features included contents of activity lists and milestone lists, diagram format and organization, distribution of the network diagrams and updating procedures.

During the second day, several programs of the PLANTRAC CPM software package were illustrated: file management, network formulation and amendment, loop detector, time analysis, and schedule reports in tabular form and bar charts. A planning and network scheduling system for the project was discussed.

The last day was a workshop which included the development and input of a network to an IBM/XT microcomputer using PLANTRAC. An updating session was simulated and several scheduled reports were produced. Consequently, the CPM Management Team and the Owner defined the format and content for the different schedule reports to be distributed among the contractual parties.

Upon award and execution of the contract, the CPM Management Team contacted the Contractor to determine the procedure for developing the CPM Master Schedule. It was agreed to meet twice a week for a period of five weeks. Each week was used to cover a major network (structural, electrical, mechanical, finishes and submittals). Mondays were for developing the network, Fridays were for revisions. This period proved to be too long and it is suggested that the network development and elaboration phase should be shortened to two to three weeks.

Prior development of the major construction networks, the CPM Management Team spent one morning presenting the features of PLANTRAC to the General Contractor's Project Manager. In addition, the Project Manager created a sample network in the computer in order to get directly involved with the program and the precedence technique logic.

NETWORK ELABORATION

All network elaboration meetings between the Project Manager and the CPM Management Team were held at the General Contractor's home office. The Master Schedule was divided into work packages corresponding to five construction networks:

1. Structural network
2. Mechanical network
3. Electrical and Security Audio Visual (SAV) network
4. Finishes network
5. Submittals network

The Structural network was the first one developed. It included site mobilization, excavation, piers, slabs on grade, columns and elevated slabs for every level. Each elevated slab was divided into three major concrete pours. Milestones were attached to the completed pours at each level.

The Mechanical network was next. It included all rough-in operations for sprinkler piping, plumbing, HVAC piping and ductwork, and installation of sprinkler heads, drops, grilles, and diffusers. Site activities involving underground piping work were also included.

The Electrical and SAV network included rough in and installation of electrical, fire alarm security and temperature control fixtures and devices. Site activities included underground electrical and security, permanent power, and site lighting.

The Finishes network contained the major bulk of construction activities for the project. Like the Mechanical and the Electrical and SAV networks, activities were to be performed on a level by level basis, with milestones attached upon completion for all levels.

The Submittals network was the last to be developed. It included main submittal items and activities were of three types: submittal, approval, and delivery to the site. Milestones related to major equipment deliveries were included in this network. All deliveries were tied into the construction activities of the other main networks.

All construction activities contained the following information: an activity number with the first two digits corresponding to a CSI division number, activity description, duration, responsibility, and location code. All milestones contained a milestone number from the bid proposal, a milestone description, and a responsibility code. Milestones in this CPM network did not contain any duration.

It is important to state that the Project Manager was developing his bar chart at the same time the networks were being done. The CPM networks were elaborated and adjusted as much as possible to match the logic and sequence of the activities in the bar chart. After drawing the precedence network diagrams and performing the data entry into the computer, several computer runs were made in order to adjust the project schedule to the milestone bid dates and the contract completion date. Finally, the computer schedule

dates for all milestones were confirmed and validated by the Owner and the General Contractor.

PROJECT COORDINATION MEETINGS

Following the preconstruction conference meeting, a series of regular meetings have been held at the jobsite:

1. Updating Meetings: Held every two weeks, the purpose of the updating meetings is to record construction progress through the CPM network. The CPM Management Team, the Project Manager, the Project Coordinator and Resident Construction Manager meet at the Contractor's job office. Sometimes major subcontractors and the Associate Architect (the A/E Contract Administrator) attend the update meetings. Activities in progress or due to start are recorded by writing the start date, the percentage of completion or the remaining duration. Finish dates are recorded for all completed activities on the network diagrams.

Changes in network logic are discussed, as well as forecasted schedules. Problem areas, delivery items and subcontractor interfaces are also brought up at the meeting. The CPM Management Team is responsible for recording all progress data and issues which have an impact on the schedule.

Following the data processing, based on the progress data, the CPM Management Team analyzes the new computer reports. After making corrections, if any, the final data processing is done and the CPM Management Team prepares the summary progress reports. The contents of these reports are:

- a) Project Schedule: The important network logic changes, the computed completion date, project status and a brief explanation of key issues affecting the project schedule are addressed in this section of the report.
- b) Subcontractor Interface: This section is used if there are problems concerning subcontractors or work from other contractors near the site.
- c) Submittals: Status of the important submittals are addressed in this section, recording if a submittal, approval or a delivery at the site has been achieved.
- d) Change orders: The number of change orders, accumulated time extensions and current contract completion date are included in this section of the report. Change orders being processed and approved time extensions not in completed change orders are also addressed. Upon approval of time extensions the CPM Management Team defers the remaining milestone and project latest finish dates.

- e) Key Milestones: The milestone list, sorted by milestone number, is attached to the report. This section also includes Milestones completed between update periods milestones with negative floats and a forecast of milestones to be completed by the next update.

The summary progress reports are no more than five pages in length, including the two page milestone report.

2. General Monthly Meetings: Known also as job conference meetings, these meetings are conducted by the Project Architect to discuss construction progress problems. The people who attend these meetings are the Project Architect, the Associate Architect, the Project Coordinator, the Resident Construction Manager, the Project Manager, the CPM Management Team, major subcontractors, and/or any subcontractors or suppliers having problems. A consulting engineer is brought by the Project Architect if needed in the meeting.

The monthly project meetings follow an agenda which includes:

- a) Submittal status
- b) RFI/CI (Request for Information/Clarification)
- c) Change Proposal/Change Order Status
- d) Coordination problems
- e) Progress report/Forecast for the next period
- f) Workmanship/Quality Control/Safety/Clean-up
- g) Outages
- h) Pay Estimate/Completion Date Forecast
- i) Next monthly project meeting
- j) Miscellaneous/Other opportunities

Documents distributed in this meeting are:

Project monthly meeting agenda - by the Associate Architect
Change Proposal/Change Order Status (Contract Change Log) - by the Project Architect
Summary progress report - by the CPM Management Team
Pay estimates - by the Owner (the Project Coordinator)
Shop Drawings/Submittals - by the Project Architect and/or the consulting engineer.
Change Orders - by the Project Architect

The general monthly meeting report is prepared by the Associate Architect. The contents of this report are the agenda items discussed at the meeting. The summary progress report and the contract change log are attached.

SCHEDULING IMPLEMENTATION - FIELD OBSERVATIONS

The official document concerning the project status is the summary progress report prepared by the CPM Management Team after each updating meeting held every two weeks. Computer reports, in addition to the milestone report

attached to the summary progress report, are distributed to the Project Manager and occasionally to the Resident Construction Manager. Typical computer reports include:

- a) A schedule report for activities in progress and activities to be performed within the next two weeks. Activities are sorted by earliest start and total float. The format of these reports consists mainly of bar charts and/or tabular forms.
- b) A report containing the critical activities. Such a report includes the current critical path and activities with negative floats affecting milestones completion dates. Activities are also sorted by earliest start and total float.

The CPM Management Team has observed the Contractor and Owner response to CPM. Some important observations are:

1. Contractor's Usage of the CPM Reports: The Project Manager does not manage the project through CPM. His main control tool is his own bar chart which he has distributed to his subcontractors, the Resident Construction Manager and the CPM Management Team. Nevertheless the Project Manager is aware of the critical activities. Actually, one time extension was granted for delays due to accidents on activities belonging to the critical path. There is no indication that the subcontractors receive copies of the CPM reports other than the milestone reports distributed at the general monthly meetings.
2. Contractor's willingness to comply with the CPM network: As mentioned above, the Project Manager does not want to be controlled by the CPM schedule. He has been reluctant to commit himself to a structured pattern of work, partly due to the fact that the path of construction varies from the one planned. Furthermore, updated reports showing negative floats or delays have made the Contractor believe that the reports are unrealistic (3).
3. Actual Versus Planned Performance: Variations to the construction plan are inevitable. Day to day outputs tend to vary, due to changes in logic and activity durations, such as performance by subcontractors and suppliers, design changes, site conditions, and unavailability of optimal weather conditions (4). In such cases, work has been done in other tasks and overlapping activities have been frequent. In Figures 1 and 2, variations between planned percentage completed based upon contractor bar chart and actual percentage completed based on the CPM network show a difference of 24% by November 1985, nearly 7 months before the contract completion date.
4. Construction Progress: Difficulties also arise in determining progress for some activities, i.e. plumbing and ductwork rough-in. In fact, such activities may report a high percentage of completion, but many times the remaining duration is difficult to predict. The Project Manager is reluctant in reporting re-

maining duration and prefers to utilize percentage of completion based on planned activity duration. The CPM Management Team has resolved this problem by revising and adjusting durations for activities reporting percentage of completion.

5. CPM Management Team and the Project: It is important for the CPM Management Team to be acquainted with the project as much as possible. Prior to developing the construction networks, project documents were studied, mainly drawings, specifications, and communication flows established by the Owner. Site visits and field data collection between updating meetings are necessary for checking project status and progress of the work.
6. Owner reliability on the CPM: The Owner utilizes the summary progress reports and the network precedence diagrams from the updating meetings as official documents to measure construction progress. Original and updated schedules are critical to ascertaining the construction history of the project in the future (1). Hence, the CPM Management Team has kept copies of all reports and updates furnished. The CPM schedule, however, has not been instituted as a basis for progress payments.

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	A	B	C	D	E	F
1			PLANNED	ACTUAL	SBILLED	TOTAL
2	UPDATE NUMBER	DATE	% COMPLETE	% COMPLETE	REVENUE	PLAT
3	1	Mar-22	6	5	0	0
4	2	Apr-01	8	7		-7
5	3	Apr-17	10	9		-7
6	4	May-01	11	12	14	-3
7	5	May-15	12	13		10
8	6	May-29	13	15	19	9
9	7	Jun-12	14	18		5
10	8	Jun-26	17	22	29	11
11	9	Jul-10	20	23		6
12	10	Jul-24	24	23	36	6
13	11	Aug-14	32	30		-11
14	12	Aug-28	37	32	47	-14
15	13	Sep-11	45	34		-13
16	14	Sep-25	49	39	53	-10
17	15	Oct-17	59	45		-20
18	16	Oct-30	65	47	62	-16
19	17	Nov-13	70	50		-23
20	18	Nov-22	75	51	68	-30

Fig. 1 - Actual versus Planned Performance

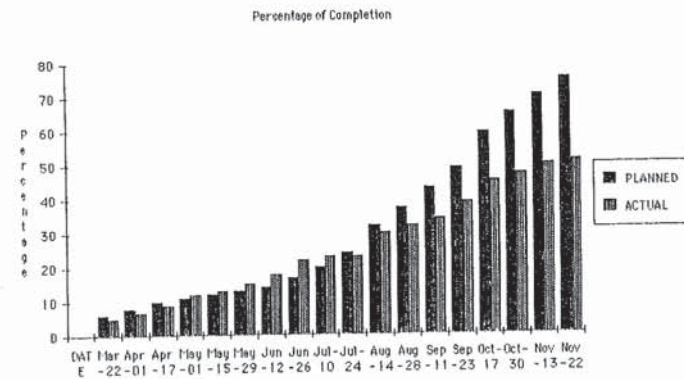


Fig. 2 - Actual versus Planned Percentage of Completion