COST EFFECTIVENESS AND CONTROL:
LONG-TERM PROJECT MANAGEMENT USING PERT/CPM

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ABSTRACT

This paper addresses the use of PERT/CPM scheduling software as a workable solution to the management and control of complex conservation projects. For the Hood River Conservation Project, using a PERT/CPM system, over 330 activities including project operations and fifteen research studies have been optimally planned on the basis of time and resource logic over a three-year period.

A computerized system has enabled projections of different planning scenarios, comparison between potential schedules, and the successful elimination of a projected one-year Project overrun. In addition to planning and update capacity, the system offers several reporting functions including detailed graphics, status updating, time delay/benchmark contrast, and segmented reporting by selected category.

Beyond project planning and control, the system is able to document project delays and detail activity components. This documentation (in addition to time-frozen planning schedules) enables post-facto explanation and evaluation of delays, and facilitates more accurate future planning in areas of program replication.

These and other measures are explored in terms of efficiency, accuracy and cost-savings. Several versions of PERT/CPM scheduling software are available in both mainframe and personal computers, and offer a useful resource in the management of complex conservation projects.
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INTRODUCTION

The Hood River Conservation Project is a three and a half year intensive conservation research project taking place in Hood River, Oregon. This project is the collaborative result of several organizations involved in conservation or electric energy planning and use. The Bonneville Power Administration (BPA) has contracted with Pacific Power and Light Company (PPL) to manage and administer the Project in areas of weatherization, budget control, schedule and personnel management, and research and evaluation.

The research and evaluation portion of the Project is extensive, consisting of over fifteen separate research studies regarding energy savings, program evaluation, and project penetration and marketing analyses.

In the course of planning and administering these studies, several subcontractors have been enlisted to aid in the research effort. The inclusion of these contractors, in addition to the work being performed by the research and evaluation team itself creates a large and complex research program to be managed within the Project. In addition to the various entities working directly with research studies, the research coordination and management effort must take several other variables into account when planning its long term work load and scheduling.

Three of the major studies being undertaken in the Hood River Project involve the use of complex state of the art monitoring equipment. In addition, a newly designed computer data system has been installed to track Hood River data. Finally, the schedule by which various research studies will be undertaken is closely related to the weatherization timeline for the Project.

These components combine to create a complex group of varied activities. All of these are highly interrelated in the process of planning and maintaining a workable long term research and evaluation schedule. Unexpected and severe problems emerge in the context of such a large scale project, as deadlines are charted out only to be circumvented by related yet unforeseen problems in other areas.

In order to conduct accurate and logical long range planning, the Hood River Project staff turned to a PERT/CPM software package called Project 2. PERT is the Program Evaluation and Review Technique, and CPM refers to Critical Path Method. Both of these systems are network scheduling systems which were developed in the late 1950s, PERT in relation to the US Navy's Polaris system, and CPM by the Sperry Rand Corporation in relation to chemical plant management. Until the development of computer software based upon these systems, however, projects had to be scheduled by hand, often a long and arduous process.
THE METHOD

CPM is based upon the logical order in which a sequence of events must be performed. Given the estimated duration of each activity in a series, CPM software calculates the estimated duration of a project, and identifies the activities which control the overall length of the project.

PERT accentuates CPM by allowing the user to identify milestones or significant events, and project a schedule using both optimistic and pessimistic durations for an activity. It is then possible to determine the earliest possible and latest possible completion dates for a project.

Involved with both of these systems is PDM, or Precedence Diagramming Method. This allows the user to connect several activities which may occur in parallel schedule paths. If two activities must each be completed before a third may begin, PDM will determine the lag or slack time between the activity which should finish first, and the third activity which cannot start until the first two have been completed. (See Figure 1 below)

KEY CONCEPTS OF PERT/CPM

Some of the key concepts found in PERT/CPM are critical path, float, and milestones. Critical path, as previously mentioned, is the identification of the particular chain of activities whose delay will cause an automatic lengthening of the total project timeline. The critical path may be described as the taut string which reaches from beginning to end having several other loose strings connected (but not pulled taut).

Float represents the amount of slack time existing between activities before they become critical. If activity 3 is to take ten (10) days, activity 4, five (5) days, and both must be completed before activity 5 which will start on day activity 4 five (5) days free float. See figure 1.

Figure 1. Example of Precedence Diagramming Method, various types of Float, and the Critical Path within a schedule diagram.
Some activities are directly tied to activities on the critical path. In the case that they are delayed and use up all their float, they will become part of the critical path. There are three types of float. Direct Float shows which activity controls its successor in the project schedule, Free Float involves the amount of internal float an activity has before it begins to affect another related activity, and Total Float lists how much float exists between an activity and the critical path.

Milestones are the major events which occur in the course of most projects. In the case of the Hood River Project, milestones include contract deliverable dates, final copies of reports, and weatherization or equipment installation deadlines.

PROJECT 2 - HOW IT WORKS

One of the many PERT/CPM software scheduling systems on the market today is Project 2. This program utilizes components of PERT, CPM, and PDM. In order to provide as clear a picture of Project 2 as possible, it is necessary to outline a few of the primary concepts used in building and maintaining a Project schedule.

Basic Structure

Project 2 allows the user to take a large project and break it down into smaller parts. Take for instance, the construction of a tall building. Though it is one project as a whole, it can easily be broken down into smaller parts according to types of tasks. There might be categories for masonry, electrical work, glass installation, concrete work, and framing. This allows the user to separate tasks by their nature, yet maintain the overall perspective of inter-relation between these tasks. These sub-categories are called codes.

Within these codes, tasks are broken down into specific activities. The process of pouring concrete (one code), for instance, might be broken down into activities such as: order cement, ship cement, receive cement, mix concrete, pour concrete, allow concrete to settle, cure concrete, and remove forms. If concrete is being poured in five places, this process, or one similar to it, would be repeated five different times, all in the same code. See figure 2.

<table>
<thead>
<tr>
<th>Codes</th>
<th>Glass</th>
<th>Electrical</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks</td>
<td>Install 1st floor windows</td>
<td>Install EXIT signs</td>
<td>Outside concrete fixtures</td>
</tr>
<tr>
<td>Activities</td>
<td>List all 1st floor window measurements</td>
<td>Order 58 EXIT signs</td>
<td>Pour front sidewalk</td>
</tr>
</tbody>
</table>

Figure 2. Project 2 breakdown of general work areas to codes and activities.
The use of codes allows for the definition of basic activity categories. Likewise, the use of activities delineates specific tasks, and usually implies what party is responsible for the completion of each task. The primary structure of Project 2 then, involves codes (concrete work), tasks (pour concrete for north side), and finally, specific activities which make up the process (mix concrete).

**Data Bases**

Project 2 provides the user with several data bases. These include the Planning Schedule, Target Schedule, and Current Schedule. The Planning Schedule is the cornerstone of the Project Schedule. It reflects the user's conception of the activities involved in the project, their probable duration, and their relationships to each other in terms of precedence and ordering. Once the user has input this data, Project 2 will create a schedule which lists each activity in order of occurrence with its early start date, late start date, early and late finish dates. It also calculates the amount of float existing for each activity, and delineates the critical path. Once this schedule has been developed (though it may be revised at a later date) the user knows when activities are scheduled to occur, how long the project is scheduled to last, and which activities are critical and therefore must be watched in order to avoid time overruns.

Typically, more than one planning option may be offered. Project 2 allows the user to experiment with different scenarios in order to arrive at the most efficient order and mix of activities possible for the project as a whole.

In the course of developing the Planning schedule, it is possible to freeze schedules at different stages in the process. These schedules are referred to as Target Schedules, and several may be saved in one data bank. This allows the user to "save" several planning options for future comparison. These frozen schedules are stored by the system and may be used as benchmark schedules in comparison with the final Planning schedule as it evolves.

Once the project has actually begun, Project 2 becomes a management tool. As each activity occurs, actual starts and finishes are recorded. These starts and finishes, in addition to any known delay information, are applied to the Planning schedule by Project 2. The actual occurrence, or Current Schedule, is calculated and compared to the Planning Schedule. The Current Schedule presents the user with the actual progress versus planned progress. It delineates which activities are ahead of schedule, which are behind, and how many days remain for the on-time completion of activities which are in process. This data bank of reported progress may be updated at any time, usually in batch form.

**PLANNING AND DIAGNOSTIC REPORTS**

Project 2 offers various forms of output to aid the user in the process of creating and maintaining a project schedule. The two major output reports used in the planning and diagnostic process are the Planning Schedule and the Analyze Network.
The Planning schedule provides (by code if specified) a listing of all activities involved in the Project, their early and late start and finish dates, their calendar and project-day number, their duration, codes, and succeeding activities. These activities may be printed as one comprehensive unit, or broken down by code. This allows the user to pinpoint actual dates projected by Project 2, and to trace the chain of events within individual codes, and through the project as a whole. This report also provides the chronological listing of all activities occurring in the Project.

The Analyze Network accentuates the Planning Schedule by providing the user with a much more detailed account of all precedences and successors for each activity in a network. It also lists three types of Float related to each activity: direct float, free float and total float. The first involves how much internal float the activity has (before it begins to affect another related activity). The second details how much float remains before an activity affects on of its successors, and the third lists how much float exists between an activity and the critical path.

Each of these reports is available for the Planning or Current schedules. This allows the user to compare the actual float to the planned float (critical paths in Current schedules sometimes differ from those occurring in the Planning schedule), and create schedule modifications accordingly. In addition, activity relationships may be explored and compared between the two types of schedules in order to maintain a schedule which is as effective as possible for the user.

Though these reports are essential to the internal control of the Project schedule, they do not adequately serve as appropriate reporting tools for management or outside presentations. For these types of needs, Project 2 provides a spectrum of output reports which provide a clear picture of the Project schedule and status.

MANAGEMENT REPORTS

The Current schedule allows for several informative and useful reports for project management. One of these is the comparison between the Planning schedule and the Current schedule. This is available in printed or graphic form, and allows the user to check the overall Project time schedule with a minimum of effort. Another effective use of the Current schedule is the Current Status Report. This allows the user to request any period of time in the future - the next two weeks, a month, or August of next year. Project 2 will calculate a list of activities which, according to project logic, fall into three priorities of action for the period specified. They are activities which must be complete by the end of such period, must be in progress, or may be in progress during that period. This report allows a user to keep track of activities in several areas over a long period of time and allocate appropriate resources and priorities to each.
In addition to the Current Schedule reports, Project 2 offers several types of graphs. These include plots of the Planning, Target, or Current schedules, as a whole, or by code sections. Each of these reports may be printed with XXXs on normal computer paper, or in clear, crisp detail on a plotter. Project 2 will also print out its schedule logic in standard PERT/CPM format with the critical path delineated in red.

ADVANTAGES

By breaking an activity down into its logical parts, several ends are met. Responsibility is allocated — who performs this activity; and dates are set for completions of drafts and reviews. This allows resource planning, and early warning for parties who will be expected to perform a review. It also presents the research team with a tangible list of events which need to occur, and their order of priority.

In the case of equipment orders, when delays occur, they may be documented in terms of the exact location of the delay. This creates an early warning system for researchers who may develop contingency plans when needed equipment is delayed. This facility is especially important when administering a project in the context of one or more large organizations. Due to the specialization of various internal departments, communication is often inhibited, and delays may not be routinely flagged.

CAUTIONS

In light of all that Project 2 can do, it is easy to assume that its maintenance will become someone’s full time job over an extended period of time. The Hood River Evaluation team found that this is true only at the outset of Project scheduling. The complex logic and articulation of a schedule will take some time in the initial stages of developing a project schedule. However, once the initial Project planning has been completed and all necessary data input, the process of reporting progress and creating reports involves between one and two person hours every two weeks.

There are, however, some potential problems which accompany Project 2’s use in management. It is important not to overburden the system by breaking activities down into minute parts. It is best to maintain a comparable level of detail throughout the activities catalogued in Project 2. The more activities in the system, the more logical precedences and successors involved, the more cumbersome it becomes to make changes and diagnose critical path elements.

It is also essential to keep in mind the fact that Project 2 is a scheduling tool that reflects the logic it has been given. Users may be tempted to beat the system by placing activities in the order which best suits the internal structure of the project, rather than in the logical order in which they must be completed. Project 2 does not correct these sequences, nor will it complete logic sequences which have only been partially articulated by the user.
ly, Project 2 is a computer software system, not a reasoning staff member. The schedule it has created is a product of program input, and Garbage in will equal Gospel Out.

Therefore, the products of Project 2 must be examined in those terms. The priority given certain activities is often a reflection of initial planning rather than actual reality. Likewise, it is necessary to periodically reassess the reasoning behind the original Planning schedule in order to assure that Project 2's schedules are as reflective of actual Project occurrences as possible.

IMPLEMENTATION: THE HOOD RIVER CONSERVATION PROJECT

How has Project 2 worked within the Hood River Conservation Project? In less than one year of utilization, Project 2 has been instrumental in the creation of a Project schedule, the reduction of a significant projected time overrun, and the day to day management and documentation of the Project.

Schedule Construction

In the construction of a Project schedule for the Hood River Project, activities were broken down into 18 codes. These included separate codes for each of the research studies, categories for internal management, both in the Portland Headquarters and the Hood River field office and finally, data collection and weatherization activities which are tied to the various studies.

The Hood River Project schedule consists of over 300 different tasks connected by over 400 precedence/successor relationship ties. In the process of planning the Project, and through the early months of its implementation, these activities were clarified and reworked to best represent the actual workings of the Project.

Typical examples of research studies include the process of drafting and reviewing reports, or the ordering, receipt and installation of research equipment.

In the case of report writing, a particular study is defined by one code area. Within this area, the study is broken down into activities detailing data collection, initial draft, review by PPL and/or the BPA, revision, final reviews and approvals. Equipment orders are similarly handled, divided into activities for the ordering and shipping of material, its testing, and finally, installation.

Using P/2 To Regain Control

The Hood River Project contract was originally set for a time period of 1300 days. By the sixth month of the Project, delays in the shipping of equip-
ment and various contract negotiations had caused a change in the entire research plan which would mandate the addition of almost a year to the project timeline in order to compensate for lost data collection time.

The Planning schedule for Project 2 had gone from a tidy 1300 days to a 1631 day schedule—almost a year overrun. Using the various tools provided by Project 2, the research and evaluation staff began to re-examine some of the underlying assumptions behind the Planning schedule. The goal in this process was to create a Project schedule as close as possible to the original 1300 day schedule without placing impossible time constraints on crucial activities.

A good example of the type of cost and resource effective trimming that occurred is the report review process. In the original schedule, most reports consisted of a draft, two consecutive reviews, revision, two consecutive final reviews, and two consecutive approvals, one by the contractee (BPA), the other by the contractor (PPL). In the process of economizing the time available, the report reviews were made concurrent. Given two thirty day review periods per party, this reduced the total review time from 120 days to 60.

Other changes included the matching of work to be completed to resources available. For instance, two major deliverables to be completed by one subcontractor had been placed consecutively so as not to overburden their staff. It became apparent that there was ample human resource to complete both reports simultaneously. Because these reports were both on the Project schedule's critical path, this change significantly reduced the overall Project timeline.

An important Project 2 facility has been essential in many of these changes. This is the ability to overlap activities in cases where the first need not be fully completed before the second may begin. In the case of data collection and report drafting, the draft may begin up to 60 days before all data have been collected. This function was used to recover a time savings of 60 days in several Project research studies.

In retrospect, many of these modifications seem obvious. However, it is the cumulative effect of all these changes which enabled such drastic reduction in the overall Project schedule. After periodic revisions such as these over a period of four months, the project timeline had been reduced from 1631 days back to the original 1300. This occurred with no loss of quality in reports due, and the maintenance of a reasonable timeframe for each Project deliverable.

It is likely that this modification could not have occurred without the aid of a sophisticated software program. Using the Planning schedule, various options and "what-if" scenarios were charted out and calculated by the system within minutes where it would have taken hours manually. The diagnostic tools provided by Project 2 allowed for the simple identification of critical activities which illuminated those areas most in need of reduced time allocations.
Project Management With P/2

Once the schedule seemed reasonably close to its final version, it became appropriate to report progress in order to ascertain exactly how close actual Project activities were to the Planning schedule timeline. The reporting of progress every two weeks allows for several types of management control.

Initially, there is the enforced necessity of becoming informed about project activities which are not directly connected to one's area of work, yet may potentially influence it. Project 2 provides the user with a printout which lists all activities which have not yet been started and their scheduled start dates. These may be broken down into the code categories discussed earlier. Brief phone calls to all those people responsible for certain activities allow the user to gain a clear understanding of any potential delays. Given an early warning of a potential delay, it is possible to run a projected scenario using Project 2. What will be affected if this equipment arrives six weeks late? This information makes it possible to troubleshoot in anticipation of potential problems, rather than relying upon patchups once the damage has occurred.

One of the most relevant purposes behind Progress Reporting is the control Information provided by the software system. The Project 2 Progress reports mentioned earlier are the Current Status Report, and the comparison of Planning Schedule to actual project occurrence (discussed above).

The Current Status report lists all activities which should be occurring according to schedule logic. This report has been used by the research and evaluation team, shared with other participants in the Project, and used by internal management as an indication of project status, and a tool for prioritization of tasks.

Included in this report is a listing of how much ahead or behind schedule the listed activities are as of the reporting date. This allows for early diagnosis of potential delays and a clear picture of how critical these delays might be in light of the Project timeline and research design as a whole.

Project Documentation

Progress reporting also allows the user to document all delays and their exact nature. When looking back at certain aspects of a long-term project such as Hood River, understanding the nature of various delays will be essential in evaluation and replication of such a major research effort. A brief update every two weeks allows for the segmented understanding of delays, rather than a post hoc construction of what occurred.

Project 2 provides a documentation function which allows the user to list activities or relevant information alongside the pertinent activities in the Project schedule. This listing need not be printed on any of the Project output other than those documents being used internally for Project documentation.
The organization of a project schedule by code, task and activity facilitates a level of documentation which takes each piece of the process into account. The maintenance of such detail will allow for a clear and organized picture of which parts of the project worked smoothly, which were delayed, and perhaps, which were unrealistically planned. This type of evaluation will be essential to the user and other potential users for the future planning of similar projects.

CONCLUSION

In communications with various research subcontractors, Project 2 has provided an easily understood and uncomplicated planning tool. It is possible to select any activities in the schedule in the construction of a report. This allows for the isolation of all activities pertaining to a certain research study. Shared with the appropriate subcontractor, a clear and tangible understanding of the expected schedule is reinforced. This removes any ambiguity from expected deliverable dates, and allows the subcontractor to place their work in the context of a larger schedule whose maintenance depends upon their timeliness.

This discussion has focused upon the uses of PERT/CPM software in the planning and management of a complex, long-term conservation research project. Project 2 provides an easily managed form of PERT/CPM to enable accurate projected scheduling, early warning for delays, experimentation for the optimum schedule, progress documentation and recordkeeping, and finally, a series of graphics and reports useful to internal staff, management, and external subcontractors.

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REFERENCES


4) Though this discussion has centered largely around the use of Project 2 software, it is important to note that there are several similar systems available for a variety of computer applications. Project 2 is presently available on the IBM mainframe, and will soon be available for IBM personal computers.

In addition to Project 2, software packages such as PMS-II and RMS-II from Wiley Professional Software, Milestone from Digital Marketing, the Harvard Project Manager, Lisap project from the Apple systems, Visischedule from Visicorp are available, providing several variations on the CPM/PERT theme for many types of user applications.