PMWorldToday

Published in PM World Today - March 2008 (Vol. X, Issue III)

PM WORLD TODAY – FEATURED PAPER – MARCH 2008

Contemporary Aspects of Critical-Path Planning and Scheduling
Part I

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Introduction & Summary:

A characteristic of contemporary project scheduling is the over-simplification which stems from the inability of unaided human beings to cope with sheer complexity. Even though we know that a detailed plan is necessary, we also know that management need only act when deviations from the plan occur. To resolve this situation we undertook to develop a technique that would be very simple but yet rigorous in application. One of the difficulties in the traditional approach is that planning and scheduling are carried on simultaneously.

Our first step was to separate the functions of planning from scheduling. The basic elements of a project are activities and resource expenditures and execution times are associated with each activity in the project. These factors, combined with technological relations, produce schedules proposing varying completion dates. Management comes into possession of a spectrum of possible schedules, each having an engineered sequence, a known elapsed time span, a known expenditure function, and a calendar fit. (In R&D projects, one obtains 'most probable' schedules).

Analysis of a Project

For the scheduling aspects of project work, it is necessary to consider the environment of each activity, i.e. working space, safety hazard, etc. A project activity diagram is built up by sections and the individual sections are then connected to form the complete project network diagram.

Diagramming project work has given planners several benefits:

- discipline
- a clear picture of the scope
- a vehicle for evaluating alternative strategies
- tends to prevent the omission of activities that belong to the project
- it pinpoints responsibilities
- can be an aid to refining the design of a project
- an excellent vehicle for training project personnel

The duration of each activity is a variable taken from an approximately known distribution. This information is important not only for putting a schedule on the calendar, but also for establishing rigorous limits to guide field personnel.

We may compute the latest time at which each event [node] in the project may occur relative to a fixed completion time. If the maximum time available for an activity equals its duration the activity is called *critical*. If the maximum time available for an activity exceeds its duration the activity is called a *floater*. Some floaters, if displaced, will start a chain reaction of displacements downstream in the project.

To proceed further we must introduce the notion of 'risk' in defining the criticalness of an activity. The elapsed time duration of an activity may change as the number of men put on it changes, as the type of equipment or method used changes, as the workweek changes from 5 to 6 or 7 days, etc. Exogenous conditions may require that an activity be expedited. This may be done in a variety of ways. But in any case there is a limit as to how fast an activity may be performed. This lower bound is called the *crash* duration. We must assume that the approximate expenditure functions are a piecewise linear, as in practice insufficient data is available to make more than a linear approximation. We can now force a reduction in the project completion time by expediting certain of the critical activities – those activities that control project completion time.

Manpower Leveling.

Considerations of available manpower, materials, and equipment would be conspicuous by their absence. The equipment, materials, and manpower requirements, for a particular schedule may exceed those available or may fluctuate violently with time. A means of handling these difficulties must therefore be sought -–a method which 'levels' these requirements. One should not use the maximum number of men available at one instant in time and very few the next instant of time. The difficult part of treating the manpower-leveling problem is the lack of any explicit criteria with which the 'best' use of manpower can be obtained.

Incorporating Manpower Sequences; it is possible to incorporate manpower availability in the project diagram. However, this approach can cause considerable difficulty and may lead to erroneous results therefore it is recommended that this approach be dropped from consideration. For example, three activities, A, B, & C, can occur concurrently and each activity requires the same crew. We can avoid the possibility that they occur simultaneously by requiring that A be diagrammed to be followed by B, followed by C. It is also possible to state 5 other combinations.

However, by incorporating manpower sequences, we would never really know the true scheduling possibilities. One criteria would be to displace the activities with the least float first.and sub-totals kept by craft to ensure that, even though total force may be all right, craft restrictions also are met.

<u>1st Test:</u>

The whole project was divided into WBS work packages. The scope of work in each was analysed and broken down into individual work blocks or activities. The updating which took place required only about 10% of the effort it took to set up the original plan and schedule. With only 30% design information, the total manpower force curve was predicted with high correlation.

For only 1% increase in the variable direct cost of the project an additional two months improvement could be gained. If the project manager were asked for improvement in the project duration and he had no knowledge of the project expense curve, he would first vigorously protest that he could not do it.

2nd Test Case

Planning will be done much earlier in the project life to incorporate more of the functions of engineering-design and procurement.

Applications to Maintenance Work

In the meantime, it was felt desirable to describe a project of much shorter duration. An ideal application for this purpose is in the shutdown and overhaul operation on an industrial plant. For purposes of testing the Critical-Path method, a plant shutdown and overhaul was selected. The basic difficulties encountered were in defining the plan of the shutdown. Because one never knows precisely what will have to be done to a reactor until it is actually opened up, it would be almost impossible to plan the work in advance. But the truth of the matter is that the majority of activities that can occur on a shutdown must be done every time a shutdown occurs. Another category that occurs with 100% assurance for each particular shutdown – scheduled design and improvement work.

The problem was how to handle the unanticipated work on a shutdown. This was accomplished in the following way: it was possible to absorb unanticipated work in the slack provided by the floaters.

Using the Critical-Path Method has cut the average shutdown time an average of 25%, mainly from the better analysis provided. This application has paid for the whole development of the Plan and Schedule effort five times over.

Current Plans.

The next project will include *all* design, procurement, and construction, starting with authorization, the point at which funds are authorized to proceed with sufficient design.
[aka Design-Build-Operate]

Computational Experience.

Generally computer usage represents only a small portion of the time it takes to carry through an application. Experience thus far shows that it may take six weeks to carry a project analysis through from start to finish. Fruitful use of parts of the Critical-Path Method does not require extensive computing facilities.

Conclusion

The Critical-Path Method should be used by the contractor in making the original contract schedule. In this way many of the unrealities of government project work would be sifted out at the start.

Extensions of the Critical-Path Method

The basic assumption is that adequate resources are available (this is an unrealistic assumption). Two extremes that need to be considered are: *one* project, *many* projects.

This may be called *intra*-project scheduling. In the second case, we run into difficulties in trying to share men and equipment among several projects which are running concurrently. We must now do inter-project scheduling.

The fundamental problem involved here is to find some way to define the many independent and combinatorial restraints involved into account: priorities, leveling manpower by crafts, shop capacity, material and equipment deliveries, etc. Study has indicated that this is a very difficult area of analysis and as such an extension may be purely academic.

Other Applications

Consider the underlying characteristics of a project – many series and parallel efforts directed toward a common goal. The Critical-Path Method was designed to answer pertinent questions about just this kind of activity. It can be used by the government to report and analyze subcontractor performance.

To be continued with Part II in the next issue of *PM World Today*

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Published in PM World Today - March 2008 (Vol. X, Issue III)

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Earl Glenwright, PE, has a career spanning 40+ years in construction project scheduling. Earl is certified as a Planning and Scheduling Professional [PSP] by the Association for the Advancement of Cost Engineering International [AACEi]. He is currently active with the PMI-College of Scheduling, and the AACEi Planning and Scheduling Committee. He frequently gives presentations at their annual conferences. Earl has both a BS in Civil Engineering and a MBA degree and is a Registered Professional Engineer. Earl's career has included multi-year positions in several countries including Brasil and Saudi Arabia, and shorter tours in Sudan. He currently lives in Bulgaria and Colorado. Prior to 1988 he was employed by the [US] Bureau of Reclamation and the [US] Army Corps of Engineers. After retiring in 1988 he has been a free-lance consultant for both contractor's construction scheduling and small business Enterprise Project Management. His experience includes large and very large [super-mega] construction projects, very small projects such as construction planning, and scheduling for home construction by his Habitat for Humanity affiliate. Through his extensive scheduling experience he has been recognized as a Subject Matter Expert [SME], a Master Scheduler, and an Expert Advisor. Earl has been active in the Project Management Institute for 30+years. He has presented "Time & Cost" training at PMI's annual seminar-symposia, and was a member of the initial PMBoK Guide Project Team, the 2000 update team, and the project team that prepared the 3rd edition. Earl has recently presented 'workshop/seminars' for Bulgarian project scheduling and controls persons which covers the 3 phases of scheduling: framework preparation/planning, schedule development, and schedule management and control. The work books are dual language English and Bulgarian. Earl can be contacted at earl_bg@yahoo.com.