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ABSTRACT

This report describes the critical path method (CPM), a system for planning and scheduling work to get the best time-cost combination for any particular job. With the use of diagrams, the report describes how CPM works on a step-by-step basis. CPM uses a network to show which parts of a job must be done and how they would eventually fit together to complete the entire job. These parts of a job are called activities. At the beginning and end of each activity there is a numbered event. The major benefit of CPM is seeing all of the related things required to complete a job being put down on paper in the order in which they must be done. (Author/CS)

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DO-IT-YOURSELF

Critical Path Method

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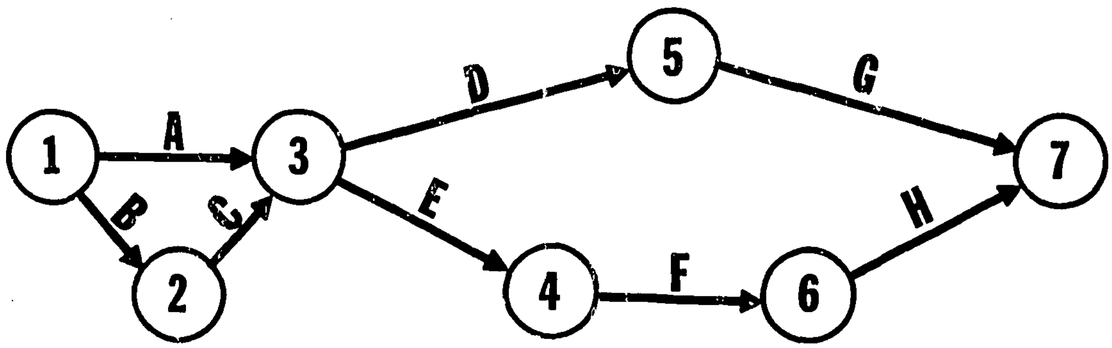
DO-IT-YOURSELF CPM

Recently added to the growing list of tools to help you in making decisions is the powerful, but basically simple, *critical path method* (CPM). CPM is an orderly system for planning and scheduling your work which makes it possible to get the best time-cost combination for any particular job. You can use it for any size job--from building one house to building a large tract of houses; from planning a new product to building a plant to produce all your products.

CPM NETWORK

CPM uses a network to show which parts of a job must be done and how they would eventually fit together to complete the entire job. These parts of a job are called *activities* and are shown as arrows in the following diagram. An activity must be of the type that you can tell when it is completed. A simple activity example is "dig a hole". An example of an activity which is hard to predict completion of is "promote the general welfare." In a CPM network an *event* is shown as a circle. At the beginning and end of each activity there is a numbered event. A simple CPM network is illustrated on the following page.

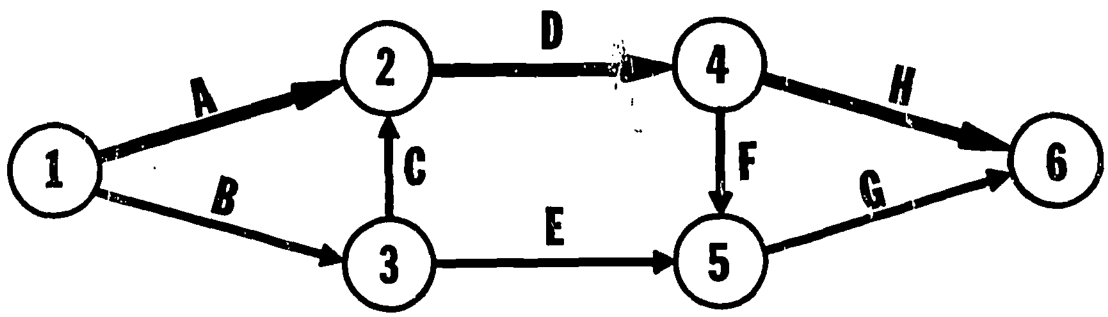


Event 1 is "start job" and event 7 is "job finished". The activity called A is a part of the job which must be done before activities D and E can be started. B must be done before C can be started. C must also be done before D can be started. For example, a job may be "planting a fence post" using two men. Activity B is "get post-hole digger". While this is being done, activity A is "get fence post". Activity C is "dig hole". Activity D is "put post in hole". Activity G is "hold post in hole". Activity H is "tamp dirt in hole".

You would be wasting your time to plant only one fence post using CPM, but this shows how activities and events fit together in a network. The hardest part involved when using CPM, but the most useful, is simply putting down on paper what must be done in what order.

FINDING THE CRITICAL PATH

After deciding upon a network of activities and events which are necessary to complete a job, two time and cost estimates must be made for each activity. These estimates are referred to as *normal* (minimum-cost maximum-time estimate) and *crash* (minimum-time maximum-cost estimate). To get the best results from CPM, estimates must be based on jobs with which times and costs can be drawn with a large amount of confidence. Let us try this with the network shown below:



The estimates can be entered in a table showing each activity and its two estimates.

ACTIVITY	NORMAL		CRASH	
	Time	*Cost*	*Time*	*Cost*
A	12	$ 280	6	$1,000
B	6	260	2	820
C	4	160	2	360
D	10	220	6	620
E	4	160	2	240
F	4	100	2	260
G	6	260	2	820
H	12	280	6	1,000
		$1,720		$5,120

Now, let us look at the following different paths that are indicated on the network.

PATH	*NORMAL TIME*
ADH	12 + 10 + 12 = 34
BCDH	6 + 4 + 10 + 12 = 32
BCDFG	6 + 4 + 10 + 4 + 6 = 30
ADFG	12 + 10 + 4 + 6 = 32
BEG	6 + 4 + 6 = 16

The *critical path* is defined as the path which takes the longest normal time to complete. It is identified by the heavy black series of arrows. ADH is the critical path in the previous network. The cost is $1,720 to complete the total job in the 34 days indicated. If we put all the activities on a crash basis we could get the job done in 18 days, however, the cost would be $5,120.

COSTING AND SCHEDULING

To determine which activity could be reduced in time at a minimum of cost, we need to compute the *cost-slope formula* for each activity in the network. The *cost-slope formula* is shown below.

$$\text{COST SLOPE} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

You can also think of the cost-slope as "dollars per day increase" for reducing scheduling time.

Now, how do we reduce schedule time? A simple rule is to look at the critical path activity which has the lowest cost-slope. In ADH, activities A and H have a cost-slope of 120. D has a cost-slope of 100. Looking at our cost/time table, we find that D is common to all paths except BEG and that it can be reduced to a minimum of 6 days. If we do this, our cost will rise $100 per day or $400 to a total of $2,120.

Our new path/time table will look like this:

PATH	*NORMAL TIME*
ADH	12 + 6* + 12 = 30
BCDH	6 + 4 + 6* + 12 = 28
BCDFG	6 + 4 + 6* + 4 + 6 = 26
ADFG	12 + 6* + 4 + 6 = 28
BEG	6 + 4 + 6 = 16

**minimum or crash time*

ADH is still the path to work on. We cannot reduce D any more, so we have to work on A or H. Let us pick A and reduce it by two days at $120/day. For $240 we can reduce path ADH to 28 days. Our total project time is now 28 days; our total cost $2,360. Our new path/time table is:

PATH	*NORMAL TIME*
ADH	10 + 6* + 12 = 28
BCDH	6 + 4 + 6* + 12 = 28
BCDFG	6 + 4 + 6* + 4 + 6 = 26
ADFG	10 + 6* + 4 + 6 = 26
BEG	6 + 4 + 6 = 16

*minimum or *crash time*

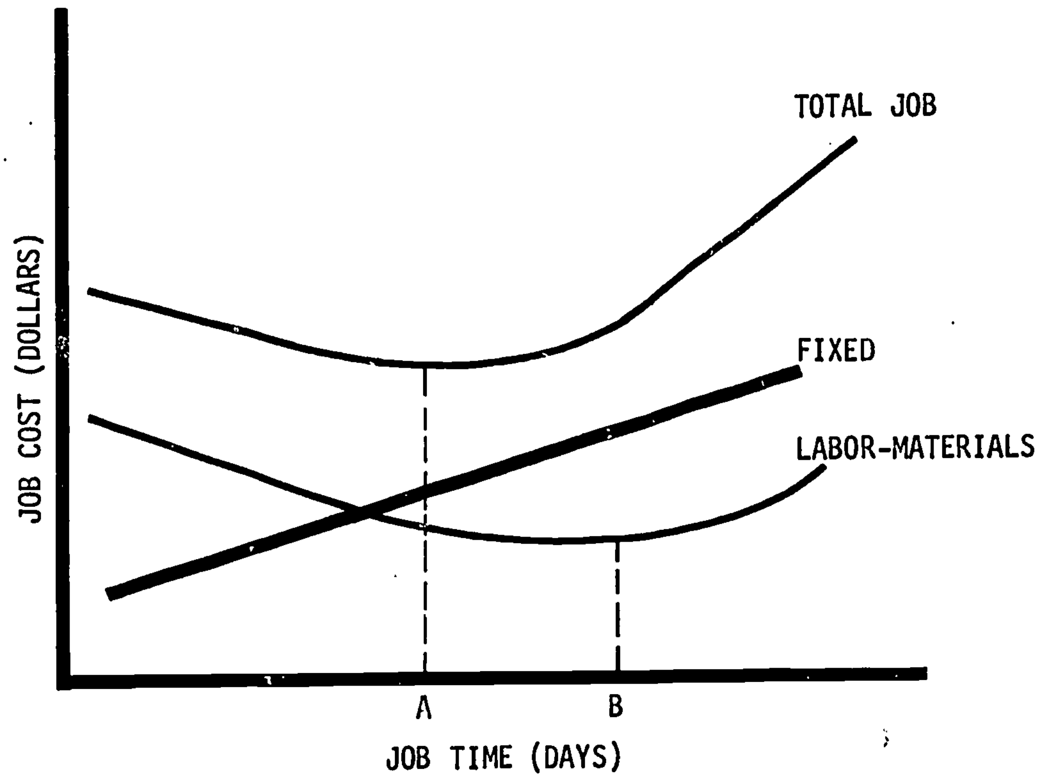
Now we have to look at the two paths ADH and BCDH since they are both 28 days. Which activity has the lowest cost slope? C and D each have one of 100. We cannot reduce D any further. C should be the best choice by our rule. But is it in this case?

If we reduce C, then ADH is still 28 days and we have not reduced the total project time. H will have to be our choice because by reducing H we reduce both paths. We already have two paths of 26 days, so H should not be reduced by any more than 2 days at $120/day. We now have a total project time of 26 days at a total cost of $2,600. We have 4 paths of 26 days each in which all activities must be done on time.

This exercise has indicated how you could cut 8 days from the schedule at a cost of $880. If you have a bonus-type contract, some perishable crop depending upon your project, or future business will be gained, this type of do-it-yourself CPM can really pay off.

OPTIMUM SCHEDULE

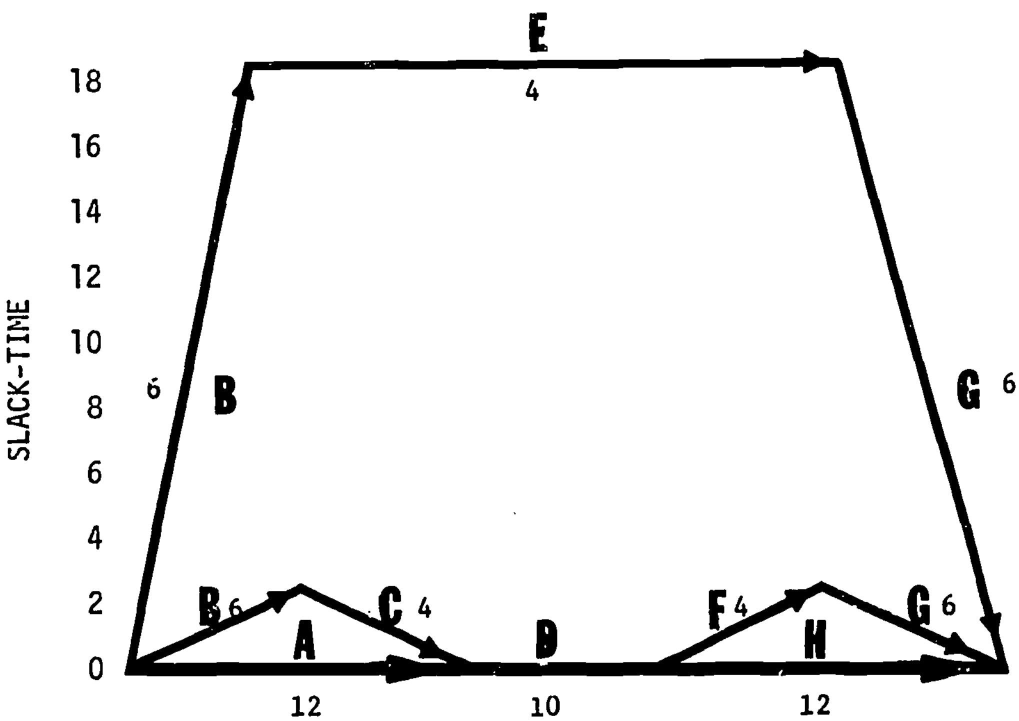
Reducing the schedule of a job to the point in time where it can be done for the lowest cost per day depends upon looking at all costs. In our crash and normal cost figures we just look at labor, materials and time. We arrived at a time by stopping with 4 equal paths. In most jobs there are fixed costs that have to be figured such as rent, insurance, and interest being paid. These combined costs might look like the following figure. As the figure shows, doing the job at point A would produce the lowest total job cost rather than at point B which is the lowest direct cost point. If you do not know what the fixed and direct costs are on any particular job, you are then in a poor position to decide the least cost point for the total job.



SLACK PATH ANALYSIS

We have shown you how to reduce total job time to a minimum at a minimum increase in cost. The lowest daily cost versus schedule time was also discussed. You have seen that to reduce total job time you have to work on activities that are on the critical (longest) path. Now, let us look at a crude method of determining the normal-time minimum-cost job and how much you could delay the starting of activities which are not on the critical path. In other words, where can you spare the labor to put on critical path activities if you want to reduce total job time at the least cost.

In the figure below, the critical path activities (A, D, H) are plotted on the base line. Activities B and C total 10 days. These have to be completed in the same time as A which is 12 days. The slack time for the BC path is, therefore, 2 days A - (B + C). Either B or C can be delayed 2 days without delaying the total job.



The same holds true for the FG path H - (F + G). The BEG path has 18 days slack time, (A + D + H) - (B + E + G). Neither B or G can be delayed more than 2 days each because of their A and H relationship. This means that activity E could plan to be delayed at least 18 - (2 + 2) or 14 days at normal-time and not hold up the total job.

COMPUTER ASSISTANCE

Many critical paths can be solved by hand, using the methods shown earlier. There are practical problems of time when a network becomes very large. For a network involving 200 activities a computer would probably be required to provide a solution in a reasonable length of time. One small-computer package requires a running time of three minutes for a network of 271 events and 340 activities. Some packages are available to handle thousands of activities.

Initially, the computer finds a normal time for each critical-path activity and computes a maximum-time schedule. Then a computer review of activities on a cost-slope basis is performed. The computer then prepares a new schedule with selected activities crashed. This is repeated until a best time/cost combination is found.

Once a final schedule has been decided upon, earliest start and finish dates are found for critical and slack path activities and the manager is then given enough information to provide control over time and costs. As work goes on, *slippages* and *alternate ways* must be included to adjust the schedules.

SUMMARY

The CPM is a powerful tool to use in planning any type of job. Whether the CPM schedule is prepared by hand or with a computer, the end result cannot be any better than the cost and item estimates that were used. The major benefit of CPM is seeing all of the related things required to complete a job being put down on paper in the order in which they must be done. The outstanding feature is the time-cost relationship which helps you to save on time at the smallest cost, and to know when further savings in time become a losing proposition.

CPM will not solve all of your problems but it is a good tool to have in your manager's planning kit.