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PERT/Cost: Its Values and Limitations

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The methods devised for applying PERT to the control of costs as well as completion times of complex projects seem to have real potential for management. However, some problems have arisen in actual use.

PERT/COST: ITS VALUES AND LIMITATIONS

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PERT, NETWORK diagraming, critical path scheduling, and similar planning and control techniques have proved highly useful in the scheduling and controlling of the time elements of large projects. Only recently, however, has a system been evolved to integrate both time and cost on a common framework.

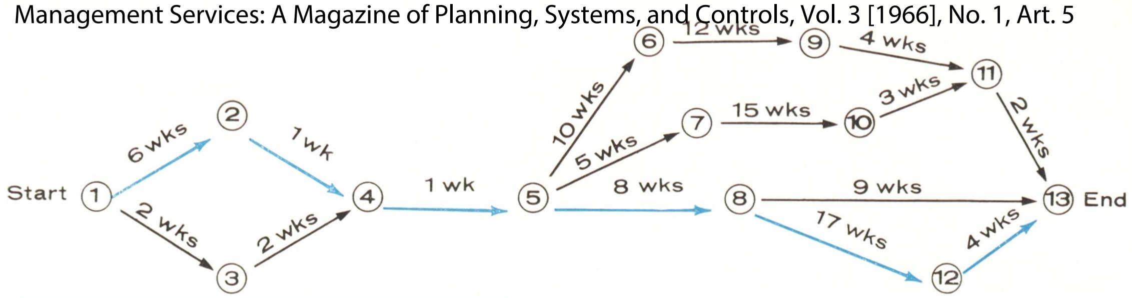
The PERT/Cost system was developed in 1962[1] for the specific purpose of integrating time data with the associated financial data of project accomplishment. Schedule slippages and the consequent cost overruns of many projects had made it necessary to add the resources dimension (manpower, materials, machines) to PERT/Time. Although PERT/Time provided the means of monitoring, coordinating, and controlling a project's time progress at various levels, it provided no means of measuring the project's financial status along with its physical accomplishment.

PERT/Cost is not yet old enough to have won a firmly established place in project management. Although it seems to have real potential as a means of cost control, it is more difficult to apply than PERT/Time. A number of problems have arisen in actual use. Some of them may disappear as users gain more experience with the technique and its application. Others may prove to be inherent limitations, however.

The use of PERT/Cost unquestionably has many advantages. It greatly facilitates the assessment of project status in relation to financial planning. It highlights the interrelationships of time and costs and the financial effects on the project of possible changes in resources and/or schedules. It permits evaluation of progress from multiple sources of information, and it provides a single set of reports for appraising both the financial and the physical status of a project.

Other values

PERT/Cost also aids in conceptual planning by financially quan-



SAMPLE PERT NETWORK

What PERT Is

PERT (Program Evaluation and Review Technique) is a method for planning, controlling, and monitoring the progress of complex projects. The emphasis is on time scheduling. A project is broken down into its component steps. These steps are represented graphically in the form of a network showing the dependencies among them. The times required to complete each step are estimated and potential bottleneck steps are identified. Then the planner is in a position to reassign manpower and resources to speed up the steps that might cause the project to fall behind schedule.

PERT, originated to coordinate the work of a large number of subcontractors engaged in the development of the Navy's Polaris missile, is credited with having cut two years off the time span of that project. Because PERT incorporates a method for estimating the time it will take to do something that has not been done before — and for which, therefore, no time standards exist — it is particularly useful in the scheduling of research and development projects. It has been widely applied in the space and defense industries.

PERT works this way:

All the individual tasks required to complete a given project must be identified and put down in a network. A network is composed of events and activities. An event represents a specific project accomplishment at a particular point in time. An activity represents the actions required to progress from one event to another.

Events and activities are sequenced on a network diagram. Activities are represented by arrows connecting two events. The direction of the arrow shows which event must precede the other. For example, on the sample network shown on this page, Events 2 and 3 both precede Event 4; Events 6, 7, 9, and 10 must precede Event 11; and Events 8, 11, and 12 must precede Event 13.

Sequencing must follow a rigorous set of rules. No successor event can be considered completed until all of its predecessor events have been completed. No "looping" is allowed; that is, no successor event can be a predecessor of one of its predecessors.

Time estimates are made for each activity on the network. Because completion times are assumed to be uncertain, three time estimates are sometimes made for each activity — optimistic, pessimistic, and most likely — and the expected time is calculated from these by means of a probability formula.

Once expected activity times are recorded on the network, it is easy to see the critical path (marked in color on the illustration). The critical path is the sequence of events that will require the greatest expected time to accomplish. Activities not on the critical path have slack time, which means that it would be safe to delay them somewhat by shifting resources from them to critical activities.

On a research project, for example, manpower can be shifted from Activities 1-3 and 3-4 to speed up Activities 1-2 and 2-4. Similar slack in Activities 5-7, 7-10, and 10-11 can be utilized to shorten the critical path 5-8, 8-12, and 12-13.

What PERT/Cost Is

PERT/Cost is an extension of PERT for planning, monitoring, and controlling the cost progress as well as the time progress of a project. Cost classifications are based upon project work breakdowns so that costs can be identified with the activities on the PERT network. The breakdowns serve as vehicles for both estimating and accumulating costs. Thus the PERT network, with costs tied to its activities, can be used for planning and performance evaluation in terms of both costs and time.

In addition, PERT/Cost provides a method of comparing the costs of alternative courses of action. The cost penalty as well as the time benefit of transferring resources to the critical path can be determined. And the lowest-cost allocation of resources among individual activities can be determined — for comparison with the least-time allocation. PERT/Cost and its application were described in more detail in an earlier issue of MANAGEMENT SERVICES (see M/S, May-June, 1964, p. 13).

tifying the project tasks to be performed and by assessing the adequacy of funding requirements for meeting total project costs. It provides a means for comparing time schedules and resource estimates of different departments or of different contractors. For example, with it the project manager can combine detailed information from engineering and manufacturing or fuse summary cost data from one contractor with in-house data and still have consistent program output information. Its outputs for network areas are useful even if one section is given in summary form and another in detailed network form.

By integrating PERT/Time and PERT/Cost one can determine whether the various-level managers are meeting their schedule commitments, cost estimates, and technical performance standards and, if not, decide how resources can be recombined so as to minimize costs.

In measuring the progress of a project, the sum of actual costs to date can be compared directly with funds authorized and the estimated cost of completion of the project. Such a comparison will reveal potential cost overruns and/or underruns and will pinpoint the segments of work that require cost control action.

Limitations

While PERT/Cost undoubtedly provides a substantial measure of cost control for large, complex projects, there are, nevertheless, shortcomings that somewhat limit its applicability.

Although the splintering up of large, unwieldy projects into smaller, more manageable units permits the sharing of exacting responsibility and the more precise delineation of multiple efforts, it also increases the overall problem of departmental coordination. Top management, of course, is concerned chiefly with summary reports. Much of the requisite on-the-spot control is delegated to departmental heads who have vested interests in the type and amount of information presented to top management. Just as time estimates in PERT/Time tend to be used for firm schedules (although they should not), so cost estimates in PERT/Cost eventually end up as budgets, and, despite the fact that cost estimates are subject to revision, there is a tendency to inflate the budget in the initial planning stage.

Padding

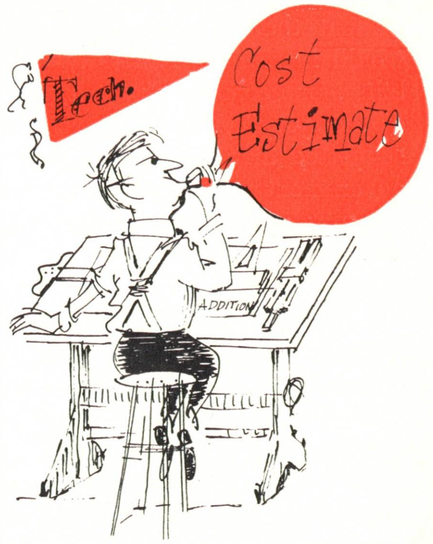
This tendency to "pad" does not necessarily represent any willful attempt to convey fraudulent or erroneous information but rather that all too human desire to "play it safe." Since time and cost are directly related, and since engineers tend to be somewhat pessimistic about time estimates, there is concomitant hedging on the cost side as well.

No department head wants to encounter cost overruns, which would reflect adversely on his performance. As a result, he is naturally tempted to pad the cost estimates so as to compensate for any possible error in the time estimates.

This problem is by no means limited to PERT/Cost systems, of course. It is always a hazard in budget formulation, regardless of the control technique employed.

It is ordinarily impractical to have each cost estimate independently recalculated — or have its components independently verified — by someone outside the department responsible for preparing the estimate. However, several steps can be taken to discourage "fudging."

Complete work packages or spe-



cific activities within a work package can be selected at random for review and verification by the project manager. This review can be performed either during the planning stage of the project, in which case the validation is of time and cost estimates, or during the execution stage of the project, in which case actual times and costs may be available for comparison with estimates. These checks provide clues to estimator bias; they also act as psychological deterrents to fudging.

This review by the project manager is itself a kind of audit. However, it is also possible to have an internal audit by an accounting department or some other independent staff, performed randomly on work packages or at a summary level. On some government projects an external government agency routinely performs such an audit. An internal audit helps to provide control since it measures deviations from a standard; more important, however, the threat of an audit or close review "disciplines before it acts."

Changes in estimates

Usually, as a project develops, changes are made in the product or system under design because unforeseen technical difficulties are

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encountered [illegible] becomes evident that certain modifications would increase the stability, reliability, or economy of the product or the system. Indeed, it has been suggested that out of thousands of government projects fewer than one per cent fail to undergo significant alterations.

Cost estimates, of course, change accordingly. Such changes are particularly characteristic of cost-plus government contracts, for under such contracts there is little or no penalty for underestimation of costs. Thus, contractors tend to understate costs in order to win the contracts and then make little effort to control costs.

Cost-plus psychology

This tendency to understate costs seems to be the rule rather than the exception. Reports of final incurred costs tend to play down or omit earlier cost estimates, thus making it difficult to verify the original estimates. Revisions partially absolve the individual responsible for the original estimates since the final costs are really for a new program, not for the one whose cost estimates he formulated. Furthermore, by the time the project is completed, it is usually impossible to demonstrate what the original program would have cost if it had not been altered.

On many projects the margins of error have been significant, even startling. Cost increases of 200 to 300 per cent and extensions of development time by one-third to one-half are not uncommon.[2] The degree of error in estimates depends to some extent on the type of program. Programs that incorporate many new technological innovations are particularly subject to large margins of error. For instance, on six missile projects in which The Rand Corporation played a major role, the actual cumulative costs ranged from 1.3 to 57.6 times the initial projected costs,[3] with a mean of 17.1; in other words, the final costs were on the average 17.1 times as great as the earliest available estimates.[4]

Cost uncertainties

Even if changes in cost estimates are not forced by external or project changes, they are likely to become necessary as a project moves along and estimating errors become apparent. Because PERT by its very nature deals so much with uncertainties, it is difficult to extrapolate from previous cost patterns. Nor do project costs always react in a linear fashion.

Thus, the assumption that a particular course of action will result in a least-cost situation may prove highly unrealistic. It is true that a computer can theoretically minimize costs and optimize resource allocation. In actual application, however, many of these costs are so difficult to estimate that the optimum allocation of resources remains a guess.

In the stage of project planning when entire networks are being visualized and computer programs are being prepared, it is often too early to subject cost patterns to precise mathematical determination. This is not to imply that costs are not predictable for discrete situations or that PERT/Cost does not provide a sound framework for cost control. But the difficulty of obtaining reliable cost estimates is certainly a limitation on the effectiveness of the technique.

Allocations

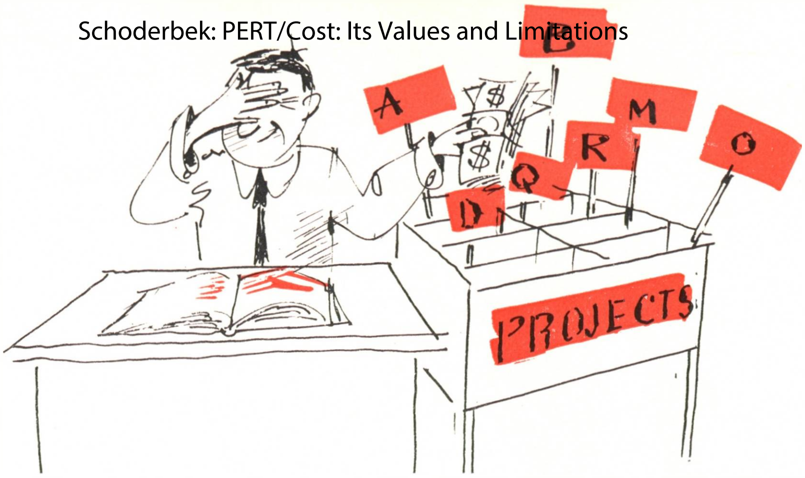
Cost allocation is a major problem. Work packages are usually made up of activities involving several different departments. An engineering department, for example, is frequently involved in many aspects of a program, while the production department may be concerned with the major assemblies only. It is frequently difficult, if not impossible, to assign departmental expenses accurately among projects, and for control purposes an arbitrary allocation is about as useful as none.

Sometimes on large projects it is possible to break the work packages down in the planning stages in such a way that each department with a major contribution to make to the project can be assigned a specific criterion to be met, for example, $100,000 or three months' effort. The assumption implicit in this technique is that the necessary resources for the execution of the work packages are present and available.

So long as departments operate on tight budgets, however, the haphazard reporting of labor classifications is likely. Suppose, for example, that the engineering department has ten man-months allocated for one work package, and it actually requires only five man-months. If a second work package begins to show signs of slippage, then it is to be expected that engineering resources will be traded off accordingly. Department heads are often indifferent about which accounts their costs are charged to so long as they stay within their own overall budgets. Thus, the seeming definiteness associated with the PERT/Cost system may be only an apparent one, for there is always ample scope for flexibility and manipulation in the reporting of cost figures.

Whatever the reason for the misallocation of costs, there always remains the danger that these misleading figures will be used as a basis of estimating the costs of future work packages of similar nature. Obviously such forecasting, based on false or at best dubious premises, is likely to prove highly erroneous.

Actually, of course, these problems are not unique to PERT/Cost.



It is frequently difficult, if not impossible, to assign departmental expenses accurately among projects, and for control purposes an arbitrary allocation is about as useful as none at all.

They existed before it was developed, and they continue to plague project managers and controllers whatever the management and control techniques used. The particular problem with PERT/Cost is that it seems to be so scientific and its results seem so definitive that managers may be tempted to forget that no control technique is any better than the data upon which it rests.

Evolution

PERT/Cost is not, after all, a complete departure from earlier techniques. Most of its elements existed before, often under other names. For example, the cost-to-complete estimates do not differ greatly from reports formerly titled future cost to be incurred, costs to terminate, or simply recosting. The organization status reports have been in use for years under the name of department work sheets or department budget reports. The manpower loading report goes back to the older manpower requirement report or the jobs skills form. Thus, most of the components of PERT/Cost are evolutionary rather than revolutionary; i.e., pre-existing ideas of management and control have been refined and linked with the use of new data processing equipment and computers.

One of the chief advantages of this evolution is increased speed. However, although the PERT/Cost reporting system is relatively rapid, it still may not be fast enough to be really useful.

While it is relatively easy to gather historical costs, it is much more difficult to estimate the costs of physical progress for projects in various stages of completion. The rule that the value of work performed to date is measured by the actual costs, divided by the latest estimate to complete, times the budget to date is not an accurate guide for evaluation, especially if progress is not on target. By this formula, increasing the budget for a work package automatically increases the value of work performed — which is patently fallacious.

Thus, while PERT/Cost does aid in assessing the financial progress of activities, it is not an infallible guide. For many projects costs can be accurately reported only after completion.

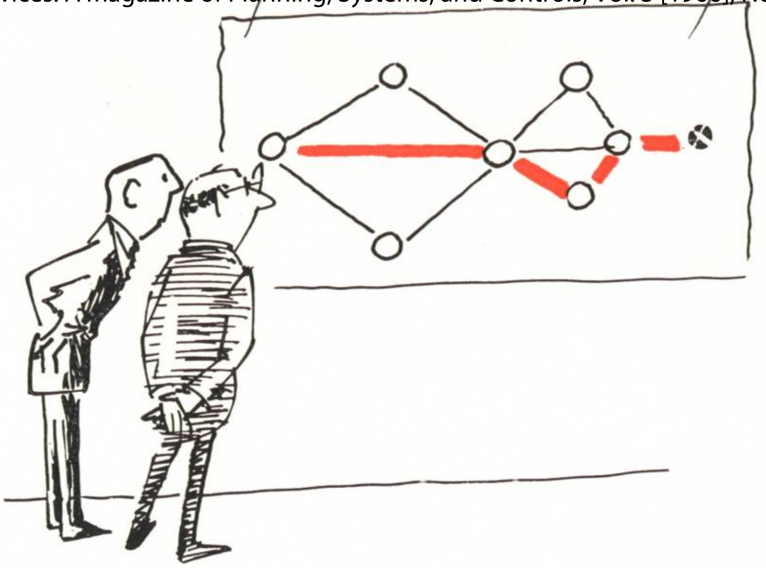
Future

Despite these limitations, there is no doubt that PERT/Cost has added a new dimension to the field of operations control. It has brought management closer to the ultimate goal of total systems control. As PERT/Time provides timely information helpful in achieving goals more rapidly, so PERT/Cost provides information that facilitates achieving these goals not only promptly but also efficiently and economically.

Although it is premature to pass final judgment on the success or failure of PERT/Cost, most companies that use it feel that it provides true management control by focusing attention on significant deviations from set goals. Just as operating personnel are forced by PERT/Time to examine schedule dates and accomplishments in detail, so PERT/Cost forces personnel to be equally cognizant of resources. This awareness of direct labor hours, material costs, computer time, and the like in turn aids in setting objectives for departments and managers at various levels of management.

PERT/Time and PERT/Cost will not make decisions for the manager. They will, however, aid him by revealing schedule and cost segments of programs that require his special attention. They also will pinpoint "crash" areas where acceleration may be essential if the project is to be completed on the target date.

Like other control techniques, PERT/Cost is no panacea. Its usefulness is directly dependent upon the usefulness of the data fed into the system, and this in turn depends upon the efficiency of the operating personnel. If unreliable data are fed into the PERT/Cost



PERT charts pinpoint "crash" areas where acceleration may be essential if the project is to be completed on the target date.

program, then haphazard information will be received from the computer.

Many of the current efforts to improve the PERT/Cost system are aimed at alleviating the difficulties in cost estimating, at tying cost reports more closely to time schedules, and at introducing other mechanical devices to complement the system. More attention, however, should be devoted to increasing the capabilities of the operating personnel who are responsible for the day-to-day functioning of the PERT/Cost system. Technical problems will – and should – not be neglected, but the need to solve more of the problems of human engineering apparently far outweighs any of the mechanical deficiencies of PERT/Cost.

One promising area of further development of the PERT/Cost system is that of Time/Cost estimating procedures. It may soon be possible to place manpower needs and costs directly on the detailed project networks. This would facilitate the control function by enabling the operations manager to formulate a more realistic program initially instead of making continual readjustments. Although many time and cost schedule revisions result from changes in the program objectives and from unexpected contingencies involving resource availability and the like, a substantial number are due to misestimations by PERT personnel in the first place.

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[1] Available at the present time are many manuals on PERT/Cost issued by private industries using PERT or by government agencies or departments. See especially U.S. Defense Department and National Aeronautics and Space Administration, *DOD and NASA Guide, PERT Cost, Systems Design,* U. S. Government Printing Office, Washington, D.C., 1962, and U.S. Department of the Navy, *An Introduction to the PERT/Cost System for Integrated Project Management,* Special Projects Office, Bureau of Naval Weapons, Washington, D.C., 1962. The following articles have also proved helpful: Richard E. Beckwith, "A Cost Control Extension of the PERT System," *IEEE Transactions of Engineering Management,* EM-9, December, 1962, pp. 147-149; Roderick W. Clarke, "Activity Costing – Key to Progress in Critical Path Analysis," *IRE Transactions on Engineering Management,* EM-9, September, 1962, pp. 132-136; Roland Frambes, "PERT and PERT/Cost in the RFP," *Aerospace Management,* V, May, 1962, pp. 24-26; J. Sterling Livingston, Willard Fazar, and J. Roland Fox, "PERT Gains New Dimensions," *Aerospace Management,* V, January, 1962, pp. 32-36; and Hillard W. Paige, "How PERT/Cost Helps the General Manager," *Harvard Business Review,* VI, November-December, 1963, pp. 87-95.

[2] A. W. Marshall and W. H. Meckling, *Predictability of the Costs, Time and Success of Development,* 2d ed., Rand Corporation, Santa Monica, Calif., 1959, p. 11.

[3] *Ibid.* The above figures are unadjusted both for price level changes and, more important, for modifications that have been made since the initial cost estimates. For example, on the above-mentioned missile project where the latest cost estimate was 57.6 times the initial one, this would be reduced to 14.7 if adjusted for the above factors. Even this margin of error is highly significant, this writer feels.

[4] In an effort to stimulate the profit motive and to cut costs for the government, "incentive" contracts have been made a policy for the Department of Defense since January, 1964. It is still too early to judge the effects of this policy. (See article in *The Wall Street Journal* which states that a "limited number of incentive contracts showed costs running about 50 per cent more than anticipated." See also "McNamara Cuts Costs, but Officials Wonder if Gain Is Exaggerated," *The Wall Street Journal,* June 11, 1964.) Some writers think that cost overruns will cease to be a problem with the advent of "incentive" contracts. However, while incentive contracts have undoubtedly reduced cost overruns in many instances, success has been far from complete; i.e., the controversial TFX project is currently expecting an overrun of about $.5 billion.