5

AN INTRODUCTION TO PERT . . . OR . . .

NOW THAT WE'VE ALL FINALLY AGREED ON WHERE WE WANT TO GO, HOW DO WE ARRANGE TO GET THERE FROM HERE.

Suppose you wake up on Saturday morning and decide to take the family on a picnic.

Going through your head is a jumble of activities and tasks that need doing in order to get the picnic organized. "Coffee. Is the thermos clean? Remember this time to take some fly-spray. Do we have any beer? What kind of sandwiches would everyone like? "

How to accomplish all the preparations? Obviously, you need the help of the rest of the family. But if everybody is involved in the task, how will it be coordinated? How avoid two people getting the napkins and nobody remembering to get the first-aid box? How to assign responsibility for the can-opener? And how to decide what must be done first, and what can be done at any time?

These kinds of questions *could* be all answered by one person, who would assign tasks and maintain supervision, settle disputes and respond to the inevitable complaints about work-loads, tasks neglected, and so forth.

Or there could be a non-directed kind of process in which the family periodically stops what it is doing to argue about everything from where we want to go down to which kind of olives to take.

But there is a planning method that permits a group to . . .

Be mutually aware of the process and sub-goals. Contribute to and share in the decisions made about how, when and by whom activities are done

Make more efficient use of resources by concentrating effort and time on the *critical tasks* rather than devoting time to sub-tasks while tasks of greater priority lack hands.

Re-evaluate the project while it is underway, and re-allocate resources to cope with unexpected blocks to task accomplishment, or to take advantage of unanticipated success in meeting some sub-goal.

This planning method is called PERT, one of those acronyms to be sure, but no less valuable for that. It stands for Program Evaluation and Review Technique, and it has saved government and industry many millions of man-hours and dollars. A variation of PERT is known as CPM, or the Critical Path Method, a name that expresses something about how the thing is done. In this brief paper, we can only glimpse the bare outlines of PERT/CPM. Please consult the references for more detailed discussions.

PERT is a group analysis and flow-charting procedure that begins with identifying the sequences of dependent activities.

One begins, in true Lewis Carrol fashion, at the end.

Before we can arrive at the picnic grounds, we must travel there in the car. Before we can travel in the car, we must fill up with gas and check the oil. Before we can do that, we must have traveled to the service station. Before we can start out for the service station, we must have loaded all the supplies in the car . . . except ice, which we can get at the gas station.

The example we have given is thus seen to be trivial, indeed, but at the same time a paradigm of the planning process.

PERT is seen to be a tool of communication, and not just an abstract exercise performed only by the staff planners, thereafter executed under duress by the grumbling line.

PERT is a method that permits revision of the plan when things don't work out like the original plan said they should.

Plans never work out right.

But *the planning process is indispensable.*

The Psychological Corporation, 304 E. 45th Street, N.Y., N.Y. 10017.
Psychological Services, Inc., 4311 Wilshire Blvd., Los Angeles, Cal. 90005.
RBH, (Richardson, Bellows, Henry, and Company), 1140 Connecticut Avenue, N.W., Washington, D.C. 20036.
Science Research Associates, Inc., 259 E. Erie Street, Chicago, Ill. 60611.
Sheridan Supply Company, P.O. Box 837, Beverly Hills, Calif. 90213.
Stanford University Press, Stanford, Cal. 94305.
C.H. Stoelting Company, 424 North Homan Ave., Chicago, Ill. 60624.

Texts:

Buros, Oscar Krisen, ed., "The Seventh Mental Measurement Yearbook," Highland Park, N.J., Gryphon Press, 1972.
Stone, C. Harold and Kendall, William E., "Effective Personnel Selection Procedures," Englewood Cliffs, N.J., Prentice-Hall, 1956.

Cross References: *Executive Selection; Industrial Psychology; Personnel Testing.*

PERT (PROGRAM EVALUATION AND REVIEW TECHNIQUE)

The advancing technology of the Space Age brought an explosive growth of a new family of planning and control techniques. Much of the development work was done in the defense industry, but the construction, chemical, and other industries have also played an important part. Perhaps the best known of all the new techniques is Program Evaluation and Review Technique, commonly referred to as PERT.

The new techniques have several distinguishing characteristics:

(1) They give management the ability to plan the best possible use of resources to achieve a given goal within overall time and cost limitations.

(2) They enable executives to manage "one-of-a-kind" programs, as opposed to repetitive production situations.

(3) They help management handle the uncertainties involved in programs where no standard time data of the Taylor-Gantt variety are available.

(4) They utilize a so-called "time network analysis" as a basic method of approach to determine manpower, material, and capital requirements.

Development of PERT. Project managers increasingly noted that the techniques of Frederick W. Taylor and Henry L. Gantt, introduced during the early part of the century for large-scale production operations, were inapplicable for a large portion of the industrial effort of the 1960s and 1970s, an era that has aptly been characterized as the "Age of Massive Engineering."

The Special Projects Office of the U.S. Navy, concerned with performance trends on large military development programs, introduced PERT on its Polaris Weapon System in 1958, after the technique had been developed with the aid of the management consulting firm of Booz, Allen & Hamilton. Since that time, PERT has spread rapidly throughout the U. S. defense and space industry. Currently almost every major government and military agency concerned with Space Age programs is utilizing the technique, as are large industrial contractors in the field. Small businesses wishing to participate in national defense programs have found it increasingly necessary to develop PERT capability.

At about the same time the Navy was developing PERT, the duPont company, concerned with the increasing costs and time required to bring new products from research to production, initiated a similar technique known as CRITICAL PATH METHOD (CPM) which has spread quite widely, and is particularly concentrated in the construction industry. (For an overview discussion of the various control techniques, see INTEGRATED PROJECT MANAGEMENT.)

What PERT Is. In the early 1960s, PERT was in practice restricted largely to the area of time. (Later extensions are described below.) The basic requirements of PERT/time as established by the Navy were as follows:

(1) All of the individual tasks to complete a given program must be visualized in a clear enough manner to be put down in a *network*, which is comprised of *events* and *activities*. An event represents a specified program accomplishment at a particular instant in time. An activity represents the time and resources which are necessary to progress from one event to the next. Emphasis is placed on defining events and activities with sufficient precision so that there is no difficulty in monitoring actual accomplishment as the program proceeds. Exhibit I shows a typical operating-level PERT network from the electronics industry. Events are shown by the circles in the network, and activities are designated by the arrows leading from one event to its successor event or events.

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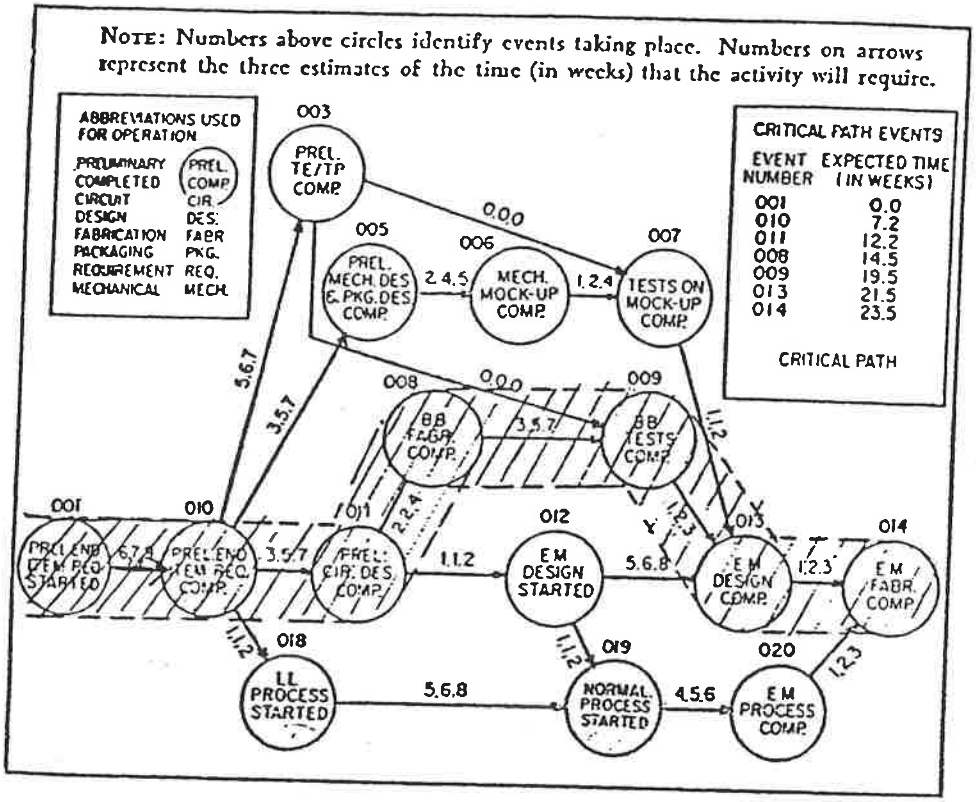
EXHIBIT I

TYPICAL OPERATING-LEVEL PERT NETWORK



NOTE: Numbers above circles identify events taking place. Numbers on arrows represent the three estimates of the time (in weeks) that the activity will require.

(2) Events and activities must be sequenced on the network under a highly logical set of ground rules which allow the determination of important critical and subcritical *paths*. These ground rules include the fact that no successor event can be considered completed until all of its predecessor events have been completed, and no "looping" is allowed, i.e., no successor event can have an activity dependency which leads back to a predecessor event.

(3) Time estimates are made for each activity of the network on a three-way basis, i.e., *optimistic*, *most likely*, and *pessimistic* elapsed-time figures are estimated by the person or persons most familiar with the activity involved. The three time estimates are required as a gauge of the "measure of uncertainty" of the activity, and represent full recognition of the probabilistic nature of many of the tasks in development-oriented and nonstandard programs. It is important to note, however, that, for the purposes of computation and reporting, the three time estimates are reduced to a single expected time (t_e) and a statistical variance (σ^2).

(4) *Critical path* and *slack times* are computed. The critical path is that sequence of activities and events which will require the *greatest expected time to accomplish*. Slack time is the difference between the total expected activity time required for any specific path and the total for the critical path. Thus for any event it is a measure of the spare time that exists at the moment in each of its subsequent sequence of events.

If the size and complexity of the network call for them, computer routines are available to calculate the critical path, as well as the amount of slack for all events and activities not on the critical path. If total expected activity time along the critical path is greater than the time available to complete the project, the program is said to have *negative slack*. Negative slack time is a measure of how much acceleration is required to meet the schedule objective dates.

Time Estimates. Interpretation of the concepts of optimistic, most likely, and pessimistic elapsed times has varied. The definitions which represent a useful consensus are as follows.

Optimistic—An estimate of the *minimum* time an activity will take, if unusual good luck is experienced and everything "goes right the first time."

Most likely—An estimate of the *normal* time an activity will take, a result which would occur most often if the activity could be repeated a number of times under similar circumstances.

Pessimistic—An estimate of the *maximum* time an activity will take, if unusually bad luck is experienced. It should reflect the possibility of initial failure and fresh start, but should not be influenced by such factors as "catastrophic events"—strikes, fires, power failures, and so on—unless these hazards are inherent risks in the activity.

Averaging formulas have been developed by which the three time estimates are reduced to a single expected time (t_e), variance (σ^2), and standard deviation (σ). Thus (approximately):

$$t_e = \frac{a + 4m + b}{6}$$

$$\sigma = \frac{b - a}{6}$$

where a is the most optimistic time, b is the pessimistic time, and m is the most likely time. The choice of probability distribution and the approximations involved in these formulas are subject to some question, but they have been widely used and seem appropriate enough in view of the inherent lack of precision of estimating data. The variance data for an entire network make possible the determination of the *probability of meeting an established schedule date*, as shown in the Appendix at the end of this article.

Exhibit II contains data on the critical path and slack times for the sample network of Exhibit I. The data are shown in the form of a *slack order report* (lowest to highest slack), perhaps one of the most important of PERT reports. Other output reports, such as event order and calendar time order reports, are also available.

Review and action by responsible managers, generally on a biweekly basis, are required, concentrating on important critical path activities. Where required, valid means of shortening lead times along the critical path must be determined by applying new resources or additional funds, obtained from those activities that can "afford" them because of their slack. Alternatively, sequencing of activities along the critical path may be changed. A final alternative may be, perforce, a change in the scope of the work of the critical path to meet a given schedule.

EXHIBIT II
SLACK ORDER REPORT

PERT SYSTEM
Airborne Computer– Slack Order Report
Date 7/12/73 Week 0.0 Time in Weeks Page 1

Event	T_E	T_L	T_L-T_E	T_s	*pr*
001	0.0	0.0	0		
010	7.2	7.2	0		
011	12.2	12.2	0		
008	14.5	14.5	0		
009	19.5	19.5	0		
013	21.5	21.5	0		
014	23.5	23.5	0	23.5	.50
020	20.6	21.5	+ .9		
019	15.6	16.5	+ .9		
012	14.4	15.3	+ .9		
018	9.4	10.3	+ .9		
007	18.2	20.3	+2.1		
006	16.0	18.1	+2.1		
005	13.2	14.3	+2.1		
003	14.2	19.5	+5.3		

T_E = Expected event date
T_L = Latest allowable event date
T_L-T_E = Event slack
T_S = Scheduled event date
P_r = Probability of achieving T_S date

PERT requires constant updating and reanalysis, since the outlook for the completion of activities in a complex program is in a constant state of flux. Highly systematized methods of handling this aspect of PERT have been developed.

Benefits Gained. A big advantage of PERT is the kind of planning required to create a major network. Network development and critical path analysis reveal interdependencies and problem areas which are either not obvious or not well defined by conventional planning methods.

Another advantage, especially where there is a significant amount of uncertainty, is the three-way estimate. If the decision maker is statistically sophisticated, he can examine the standard deviation and probability of accomplishment data. If there is a minimum of uncertainty, the single-time approach may, of course, be used, while retaining the advantages of network analysis.

Finally, PERT allows a large amount of data to be presented in a highly ordered fashion, bringing the management-by-exception principle to an area of planning and control not hitherto readily susceptible to it. Additionally, many individuals in different locations can easily determine the total task requirements of a large program.

Implementation Techniques. When a well-thought-through network is developed in sufficient detail, the first activity time estimates made are as accurate as any, and these should not be changed unless a new application of resources or a trade-off in goals is specifically determined. Further, the first time estimates should not be biased by some arbitrarily established schedule objective, or by the assumption that a particular activity does not appear to be on a critical path. Schedule biasing of this kind, while it obviously cannot be prevented, clearly atrophies some of the main benefits of the technique—although it is more quickly discovered with PERT than with any other method.

In the case of common resource centers, it is generally necessary to undertake a loading analysis, making priority assumptions and using the resulting data on either a three-time or single-time basis for those portions of the network which are affected. It should be pointed out that the process of network development forces more problems of resource constraint or loading analysis into the open for resolution than do other planning methods.

Application to Production. It is sometimes viewed as a disadvantage of the PERT technique that it is not applicable to all manufacturing effort. PERT deals in the time domain only and does not contain the quantity information required by most manufacturing operations. Nevertheless, PERT can be, and has been, used very effectively through the preliminary manufacturing phases of production prototype or pilot model construction, and in the assembly and test of final production equipments which are still "high on the learning curve." After these phases, established production control techniques which bring in the quantity factor are generally more applicable.

It should be noted, however, that many programs of the Space Age never leave the preliminary manufacturing stage, or at least never enter into mass production. Therefore, a considerable effort is going forward to integrate the techniques of PERT within some of the established methods of production control, such as LINE-OF-BALANCE or similar techniques that bring in the quantity factor.

PERT and Computers. There is a common impression that the technique is only applicable when large-scale data-processing equipment is available. This is certainly true for large networks, or aggregations of networks, where critical path and slack computations are involved for several hundred or more events.

However, several ingenious manual methods have been developed, ranging from simple inspection on small networks to more organized but clerically oriented routines for determination of critical path, subcritical path, and slack times on networks ranging from fifty to several hundred events. Exhibit I shows the network for a relatively small electronics program. Developed in less than a day, the whole network required only two hours for manual computation.

PERT Extensions. A considerable amount of research has been put into the extension of PERT into the areas of manpower, cost, and capital requirements. The ultimate objective is the determination of "trade-off" relationships between time, cost, and product or equipment performance objectives.

PERT/Cost. Most job-costing structures in industry on complex development programs need a great deal of interpretation to relate *actual costs* to *actual progress.* They are rarely, if ever, related in any explicit manner to the details of the scheduling plan. Yet cost constraints either in the form of manpower shortages or funding restrictions have a great deal to do with the program's success. For this reason, an approach called basic PERT/cost was developed. This involves establishing job cost estimates *directly from an activity or group of activities on a time network* [1]. The networks themselves are based upon the framework of a *work breakdown structure* for the complete program.

Regarding development of actual cost figures in basic PERT/cost, an estimate of manpower requirements, segregated by classification, is usually the easiest place to start, since these requirements were presumably known at the time the network was established. A single-valued scheduled time figure generally replaces t_e in the basic PERT/cost approach, as a matter of convenience in developing manpower leveling data. The summation of such data often reveals a manpower or funding restriction problem, and forces a replanning cycle if no alternatives are available.

SECTION 8

GLOSSARY OF PERT TERMS WITH PAGE REFERENCES

	Text Pages
ACTIVITY: A time-consuming element of a project which is represented on a chart as an arrow between two events. An activity cannot be started until the event leading it has been accomplished. A follower event cannot be accomplished until all activities leading it are complete. The arrowhead points toward the follower event.	1-3 to 1-9
ACTIVITY, DUMMY: A zero-time activity which constrains its follower event by requiring its leader be completed first. The dummy activity is represented on the chart by a dash-line arrow.	4-1 to 4-7
CHAINING, BACKWARD: The predicting and listing of a sequence of activities in reverse order. Generally used to prevent inadvertent ommission of necessary steps or requirements.	1-1 to 1-5
CHART, PERT: A visual representation showing the logical sequence and relationships among the various activities and events in a project.	1-15 to 1-19
CONSTRAINT: The relationship of activities to their follower events showing that an event cannot occur until all the activities leading it have been completed. Also, the term is used to indicate the relationship of an event to following activities wherein the activities may not start until their leader event has occurred.	4-3
CRITICAL PATH: The sequence of activities in a project that forms the longest time path from the first to the last event. If the project has a scheduled completion date, the critical path will be that path which has the greatest amount of negative slack, least amount of positive slack, or zero slack.	3-25 to 3-28
EVENT: A specific definable accomplishment in the project plan, which is recognizable as a particular instant in time when activities start or finish. Events do not consume time or resources and are represented in the chart by numbered circles.	1-5 to 1-13
EVENT FIRST: The start of all activities leading to the achievement of the project's goals.	1-10

	Text Pages
EVENT, FOLLOWER: The event which denotes the accomplishment of an activity. The number of this event is the second of the two numbers used to identify an activity.	1-8
EVENT, LAST: The event which marks the achievement of the project goals.	1-10
EVENT, LEADER: The event which establishes the beginning of the actual work that occurs during an activity. The number of the leader event is the first of the two numbers used to identify an activity.	1-8
LOOP: An impossible condition in a PERT chart formed by activity arrows arranged in a closed sequence. Since no activity can begin until its leader event has occurred, this arrangement prevents the accomplishment of any activity in the loop, and destroys the meaning of the chart.	2-21 to 2-22
MILESTONE: An important event in the project. Milestones are chosen by those persons planning the project. As a general rule, the first and last event of the project would be considered as milestones, or any event which marks the completion or start of several activities.	1-12 to 1-13
SLACK, NEGATIVE: The time value when the expected completion date is later than the latest allowed (or scheduled) date. This results in a critical path with negative slack value ($T_L - T_E = S$). The critical path will have the largest negative slack.	5-9 to 5-19
SLACK, POSITIVE: The time value when the expected date is earlier than the computed latest allowable (or scheduled) date. The critical path will have the least amount of positive slack.	4-9 to 4-30 and 5-13 to 5-17
SLACK, ZERO: The time value when the expected date is equal to the computed latest allowable date for an event. In this case, the critical path has zero slack.	4-9 to 4-30
TIMES, PERT: (t_e) Estimated activity time. The estimate in days or (or other unit of time) of the time necessary to complete an activity or a chart path in a specified manner.	3-1
(T_E) Estimated time for event to occur. It is measured in units of elapsed time from any event back to the first event or milestone.	3-23
(T_L) Latest allowed time for event to occur which will not delay completion of the project beyond the time indicated by the critical path. Latest allowed time (T_L) minus estimated time (T_E) equals slack time (S).	4-15

GANTT CHART

The Gantt Chart is a visual management control device developed during World War I by HENRY L. GANTT, one of the pioneers in scientific management. It is a linear calendar on which future time is spread horizontally and work to be done is indicated vertically.

In any activity, the only constant is time, and therefore the scale of the Gantt chart is time—future time—the calendar spread horizontally across a sheet. Any suitable divisions and subdivisions of time can be used—months, weeks, days, or hours.

The Planning Chart. There are two basic types of Gantt chart. In the first form, the "planning" chart, the things to be done are entered in symbols and descriptions under the portions of the calendar in which it is planned to do them. (See Exhibit I.) (The standard symbols are described in Exhibit Ia.)

It should be noted that the heavy progress line always starts at the opening angle and never runs beyond the closing angle. The heavy progress line does not necessarily bear any relationship to the *amount* of time actually spent or to *when* it was spent. The chart has no value as a historical record and is usually thrown away after all operations are completed. The important thing in reviewing progress is the position of the ends of the progress lines in relation to the current date (V).

The Progress Chart. This form is used in production control to show cumulative work against time in relation to schedules. In Exhibit II, for example, figures in the upper left-hand corners are outputs in units scheduled for that particular period (in this case charting is done by five-day weeks). Figures in the upper right-hand corners show the cumulative schedule. As work progresses, a light bar is drawn in each period, its length proportional to the percentage of the work scheduled for that period completed in that period. (Note that for week 8-4, 20% more work was done than was scheduled for that week, represented by the double light line.) In this illustration, "today" is the end of Week 8-4. A vertical chain or weighted string can be suspended from hooks at the top of a Gantt wall chart and readily moved to today's date to show status at any time.

EXHIBIT Ia
STANDARD SYMBOLS FOR GANTT PLANNING CHART

┌ = the "opening angle," entered under the date when an operation is planned to start.

┐ = the "closing angle," entered under the date when an operation is planned to finish.

┌──┐ = the time span during which the operation is to be active.

┌━━ ┐ = the state of progress, as shown by the length of the heavy line compared to the planned. In R&D, the length of the heavy line is determined by reestimating the time still needed for completion and then measuring back (toward the left) from the closing angle—in other words, the open space between the end of the heavy line and the closing angle is the time still needed to complete the work.

V = the date when progress was posted, and is entered at the top of the calendar columns.

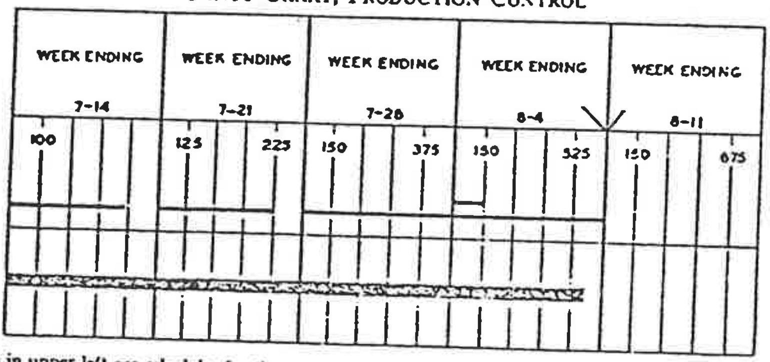
Opening and closing angles are not used. The heavier bar at the bottom shows *cumulative amount finished*. This line is posted at the scale of the week through which it passes.

On individual projects, the chart can be used to show *and watch* expenditures of man-days or dollars in relation to budgets. A project budget might be $1,000 per month, but it can (and probably does) build up to a period of greatest activity and then taper off—e.g., $500 in the first month, $750 in the second, three months at $1,500, then down to $1,000 or $500.

Actual figures are not shown on the chart but are included in an accompanying tabulation, usually bound facing the chart. The actual figures are of little consequence and need not be referred to, except in cases of significant overrun or underrun (end of heavy line to the right or left of the V).

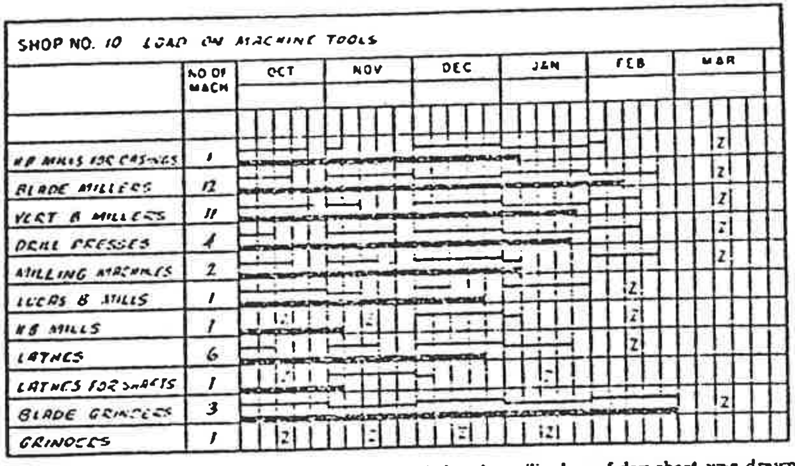
When this form is used for presenting load, the figures represent capacity in man-days or man-weeks. The V is not used here, because all time is future (the chart is redrawn periodically with the first future month at the left.) The light lines show overloads or unused capacity, *in the months in which they will occur.* The heavy line indicates the date when a department or section would be "out of work" if no new work came in. Experience usually leads to discovery of a normal or optimum total load—one in which adequate service can be rendered without idle staff or equipment. Exhibit III, for example, shows how far into the future machine tools in a certain shop will be kept busy by orders in the plant at the time it is drawn up. The heavy bars show the total amount of work ahead of the machines. "Z" indicates months in which no work is scheduled.

EXHIBIT II
GANTT CHART, PRODUCTION CONTROL



Figures in upper left are schedules for the week shown; figures in upper right are cumulative schedules. Light bars are actual production. Heavy bar is cumulative production as of end of week 8-4. Complex schedules covering large numbers of parts and assemblies can readily be controlled.

EXHIBIT III
GANTT LOAD CHART



Light lines indicate portion of month machines are scheduled to be utilized as of day chart was drawn. Heavy bars are cumulative load ahead of machines. "Z" means no work scheduled for that month. (Cf. Clark, Wallace, "The Gantt Chart.")

On Gantt planning charts, new work can readily be added without erasure to take precedence over work already planned—in fact, no erasing is ever required. The charts are "self-adjusting" for delays or inaccurate time estimates.

The use of the Gantt chart makes a definite plan for each project necessary. This is one of its advantages. It forces the thinking through of the things that will be encountered and must be provided for.

Percentage-Complete Progress Measure. The most common method of measuring progress is estimating the percentage complete. If one is dealing with the production of common units—the fabricating of a quantity of identical machines or machine parts—the numerator and denominator for the percentage are readily at hand. A project in research or development, however, is not composed of a number of identical parts—there is no common denominator applicable to both the portion completed and the portion uncompleted. Lacking any recourse other than a "blue-sky" guess, the tendency is to assume that the project is moving in relation to the allotted time plan—until the allotted time is nearly exhausted. Successive periodic reports of "percentage complete" sometimes appear like this: 25, 33, 50, 75, 90, 91, 92, 93, 94, etc. Since the figures were given at equal periods of time, it is fair to assume either that the earlier figures were too optimistic or that unforeseen difficulties have arisen in the later periods. At best, management has no assurance that the next reports may not be 94.5, 95, 95.25, etc.; and it cannot forecast *when* the project will be completed.

Where man days or man-hours can be pre-estimated, hours can be used as units of measurement, and the percentage complete can be calculated:

$$\frac{\text{Hours spent to date}}{\text{Total hours estimated}} = \%$$

This does, however, require a timekeeping and reporting system. Also, it is accurate only when the original total estimate is accurate. This objection can be overcome by using the formula:

$$\frac{\text{Hours spent to date}}{\text{Hours spent to date} + \text{Hours estimated necessary to complete}} \% =$$

Re-estimating Progress Measure. The status or position versus plan is also secured in another way where Gantt planning charts are in use. This method is: first, to estimate the *time still necessary to complete*; and second, to subtract this time from the planned date of completion. This gives a date, on the plan, to which the project has progressed.

Where Gantt charts are used, the estimated weeks necessary to complete are counted back from the planned "closing angle" (⅂) to a point at which the heavy progress line is to be terminated. The advantage of this method is that it does not, in itself, alter the original plan, but compensates for inaccuracy in it (based on latest knowledge). Progress is indicated ahead of or behind the plan, and by how much.

Rescheduling. Where formal methods of planning have been introduced, the tendency has been to change schedules almost as soon as performance fails to meet the schedules. It is obvious that this will lead to complacency with any performance. It is possible to be "on schedule" always, if the schedule is changed to conform with current progress. The habit of frequently revising schedules also leads to lack of thoroughness in thinking through the original plan for a project.

Of course, a change in direction, objective, area of investigation, or general method requires a new plan. However, changing schedules because of overoptimism in the original planning or failure to pursue the plan with vigor destroys the very usefulness of planning: It accomplishes nothing—that is, it does not expedite the project: and it weakens the confidence of management in information furnished for its plans.

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Information References

Camp, William E., "Executive Direction of Projects," Ch. 8 in "Handbook of Industrial Research Management," Heyel, C., 2nd ed., New York, Reinhold, 1968.

Clark, Wallace, "The Gantt Chart," 3rd ed., London, Pitman, 1952.

Clark, Mrs. Wallace, "The Gantt Chart," Ch. 7–3, in "Industrial Engineering Handbook," Maynard, H. B., ed., 2nd ed., New York, McGraw-Hill, 1963.

Cross References: *Integrated Project Management (and cross references there given).*

GANTT, HENRY L.

Henry Laurence Gantt (1861–1919), a pioneer American industrial and management engineer, taught natural sciences and mechanics, worked as a draftsman, and held a succession of increasingly responsible technical and executive positions in industry from 1887 through 1901. From 1902 until his death he served as a consultant. In 1917 he relinquished his private activity to accept a Government assignment in the Frankford Arsenal, and later in the building of ships for the Emergency Fleet Corporation. A contemporary of Taylor in the MANAGEMENT MOVEMENT, Gantt was one of the earliest to give major attention to human-relations aspects in industry, as distinguished from Taylor's primary emphasis on financial incentives. At the Midvale Steel Co. in Philadelphia (1887–93) he became Assistant to the Chief Engineer (F. W. Taylor) and then Superintendent of the Casting Department. There he made his first original contribution to management with his "task and bonus" system wage payment, which worked successfully at Midvale Steel earlier than Taylor's differential piece-rate system, and won acceptance long afterwards because it was simple, generally applicable, and less severe than Taylor's when the worker failed to attain standard. The GANTT CHART for which his name is now so widely known, was a revolutionary improvement in the planning and control of production in terms of time as well as quantity. But more enduring than his techniques is the new outlook he brought to bear upon industrial leadership. "In his later years, his influence in bringing American industry, and particularly the American engineering profession, to accept the new concepts of management was enhanced by his success in insisting that the training of workers should become a responsibility of management. In 1908 he was putting forward views not generally accepted until the end of the First World War. By then he was already thinking further ahead, to 'democracy in industry' and the humanizing of the science of management. In his later writings he rose to philosophical stature in his proposals for equality of opportunity in industry, and for the identification of the interest of employers and employed on the basis of scientifically ascertained facts" [1]. Gantt's books include "Work, Wages, and Profits," 1910 (Engineering Magazine Co.): "Industrial Leadership," 1916, (Yale Univ. Press): and "Organizing for Work," 1919 (Harcourt, Brace, and Howe, New York). Important among the papers he read before the American Society of Mechanical Engineers are, "A Bonus System of Rewarding Labor," 1902 (*Transactions*, vol. 23); "A Graphical Daily Balance in Manufacture," 1903 (*Transactions*, vol. 24); "Training Workmen in Habits of Industry and Cooperation," 1908 (*Transactions*, vol. 30); "The Relations Between Production and Costs," 1915 (*Transactions*, vol. 37); and "Efficiency and Democracy," 1918 (*Transactions*, vol. 40). Gantt was a prolific writer and

Sample Gantt Chart

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