VII. PERT AS AN AID TO COST REDUCTION

1. PERT and Allied Techniques

1.1. PERT-Programme Evaluation Review Technique-is a powerful Dynamic Management aid for cost reduction. Whenever the execution or completion of projects is delayed, the benefits expected from these projects are postponed. In other words, the anticipated return on investment in these projects will not be realised. Secondly, the cost of these projects which are not completed in the scheduled time are found to be several times more, on completion, than the original estimated costs. A way must, therefore, be found whereby the time taken to complete these projects could be reduced or compressed, and the costs are also controlled.

1.2. If the time required to complete a programme could be reduced, it will be relatively easy to control the costs of the programme. The techniques available to achieve the twin objects of schedule and cost control are PERT, CPM, and LOB. These are essentially planning and control techniques.

1.3. Basically, there is not much of a difference between Critical Path Method and PERT, except for the fact that these two have been independently developed within a time interval of one year. The development of network is common to both these techniques. The differences between these two methods are:

(i) Critical Path Method lacks the feature which PERT has, viz., probabilities for the estimates of task durations.

(ii) 'PERT lacks the cost-time function of Critical Path Method, which is an important factor in maintaining complete project control.

1.4. The line of Balance Technique has been developed during World War II. PERT and LOB have certain similarities, but the framework of application is different. There are no predictive features in LOB; in other words, there are no projections concerning potential trouble spots in the future. Owing to this drawback, viz., lack of flexibility and predictive features, Line of Balance has not been used in non-

repetitive programmes. Let us now consider the technique of PERT, in explicit relationship with costs, in greater detail.

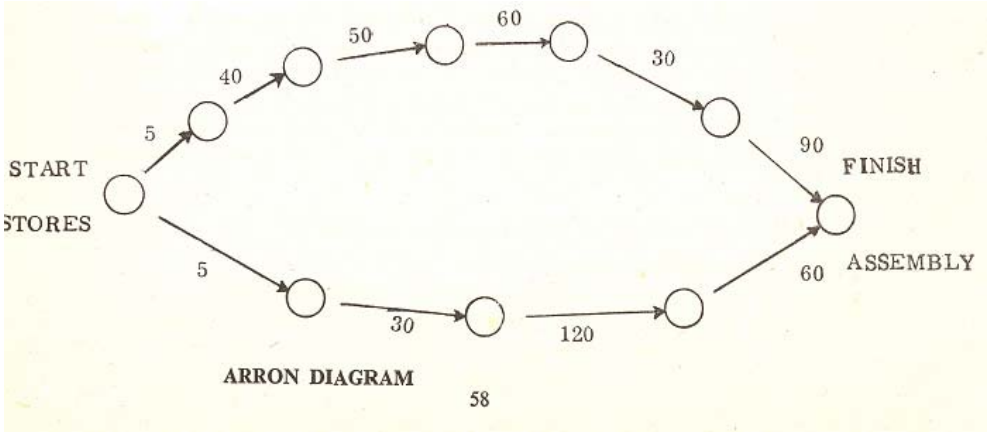
1.5. PERT consists in obtaining or finding out the critical path in a given flow of work, so that, with the help of this knowledge, optimum use of resources can be achieved by such allocation and reallocation as would give rise to improved results and efficiency.

1.6. For the diagrammatic representation of flow 'of work and its analysis, this technique uses arrow diagrams. The arrow diagram method of work planning and. analysis is flexible in that it permits adjustments, later, without difficulty,. in the presentation of work plans.

1.7. Let us take a very simple example to illustrate this method, using the arrow diagram, and explain the terms involved in it. Let the proposition be manufacture of motor bus seats. The operations involved are, say-

		Time taken
(i)	(a) Obtaining materials from stores	5 minutes
	(b) Cutting the steel pipes	40 "
	(c) Bending the pipes	50 "
	(d) Drilling holes for riveting	60 "
	(e) Riveting	30 "
	(f) Welding at required places	90 "
(ii)	(a) Obtaining maternal from stores	5 "
	(b) Cutting the upholstery to size	30 "
	(c) Switching the upholstery	120 "
	(d) Assemble together cushions & upholstery	60 "

1.7.1. Assemble both (i) & (ii) to form a complete seat. The arrow diagram for the above is shown below:



ARRON DIAGRAM

1.7.2. In the diagram the circ1e denotes an event, and the arrow an activity. The activity times are placed the corresponding arrows. The length the arrow has no. relation to the time taken by the activity. In any given piece of work there is a 'Start' and a 'Finish' paint indicating the commencement and completion of work respectively.

1.7.3. Activities (i) and (ii) start at the same time, with materials being drawn far bath from the stares, and are carried an separately. The total time taken by (i) above is obtained by adding up all the contained activity times, and for (ii) also. the total time is similarly obtained. The critical path is the flow line of, work which takes the longest time. In our example, (i) takes longer time, and so. it is the critical path. The difference in the total time taken by (i) and (ii) is called the 'float' time. The event to Which this float time is related is called the slack event.

1.7.4. The times taken by each activity are determined from past experience or by means of technical studies. For the sake of simplicity the times indicated in the given illustration are taken hypothetically, though they may not bear true relationship to reality.

1.7.5. The total time taken for work flow in (i) above is 275 minutes, and for that in (ii), is 215 minutes. The time taken by the flow line of work in (i) is 60 minutes more than that in (ii), and therefore (i) is the critical path.

1.7.6. When work is tarted simultaneously both on (i) and (ii), it can be seen that a minimum of 275 minutes must elapse for the whole work to be ready at 'finish' for final assembly. But if we consider the time taken by (ii) alone to reach the finishing stage, it is 215 minutes only, i.e., less by 60 minutes than that taken by (i). Thus, activity (i) controls the total time required for making the final seat, and that is why it is called critical.

1.7.7. Now the attempt in all this is to use the float time in (ii) by transfer of resources from (ii) to. (i) so as to reduce the overall total time required for reaching the 'finish'. By transfer of resources, it is meant, that some labium hours or machine hours, etc., manifesting in (ii) as 'float' time, be advantageously utilised for speeding up work in (i). But the basic proviso here is that these resources are interchangeable or adaptable to Slight variations in the nature of work. This does not seem to. be really possible in the illustration given here, but it explains the method of using the float time.

1.7.8. The above objective requires a careful consideration of:

(a) Availability of resources;

(b) Adaptability or suitability of r«sources for inter-allocation or transfer;

(c) The costs involved in such reallocation or transfers with a view to achieving economy in costs and cost control.

1.8. The example given above is very simple, involving few activities. :Rut it is quite usual to face, in actual practice, planning problems involving a very large number of activities. In the latter case computers may have to be used for determining the critical path, and for further analysis, to reduce total time of work. This should finally lead to the finding of the best possible methods and ways of doing work from the start to finish.

2. Applications

2.1. There are two types of programmes, which emphasise the application of new management techniques such as PERT:

(i) Capital or construction programmes in which many diverse elements are· required to be brought together to meet an end objective, and

(ii) those new product or defense programmers which involve extensive research and development to reach the end objective. Once the end objective(s) are established, these two programmes have in common the following:

(a) The need to identify all the activities required to meet the end objective(s);

(b) The need to show complex interrelationship or constraints between these activities;

(c) The need to project the outcome, in time and cost, of executing auk these activities;

(d) The need to optimise or allocate limited resources in the best possible manner between activities; and

(e) The need for flexibility, i.e., ability to undertake the programme under changed conditions.

2.2. PERT acts as Manager's tool for defining and co-ordination what must be done to accomplish successfully the objectives of a project on time. It can: be applied to any field of endeavor which requires planned, controlled, and integrated work efforts to accomplish established goals and complete a programme on time. PERT is a technique that aids the decision-maker, but does not make decisions for him. It provides statistical information regarding the uncertainties faced in completing the different activities associated with a project. It is a method of focusing managerial attention on latent problems that require decisions and/or solutions. It reveals to the Management the procedures and adjustments required regarding time, resources or performance which may improve the capacity of meeting the target dates.

3. Planning Value of PERT

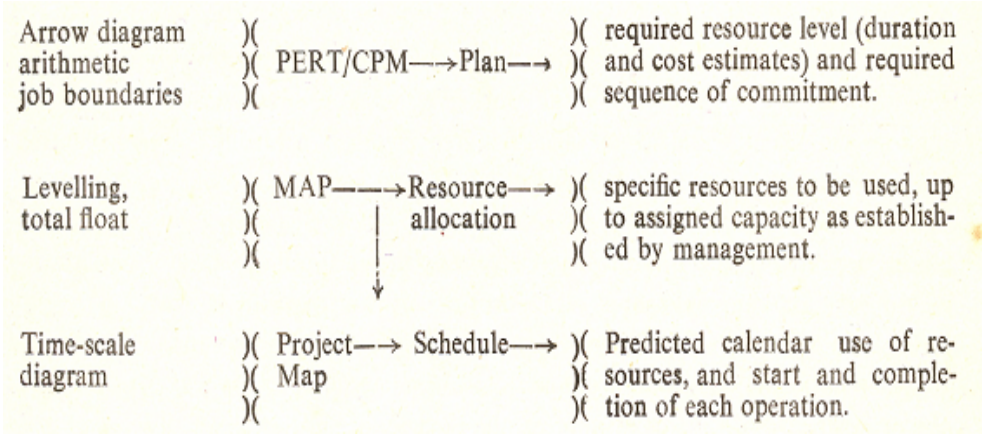
3.1. There are three major initial planning values derived from PERT. They are the improved planning action, improved orientation of planning to the fundamentals of the business, and an improved basis for evaluating the plan in terms of its ability to meet management objectives.

3.2. Top management is rightly critical of a great deal of planning because of its high theoretical content. PERT provides a practical methodology, and the very elements of project success, time and costs are competently estimated and become part of the plan. If the network is sufficiently detailed, each activity can be represented by a budget number.

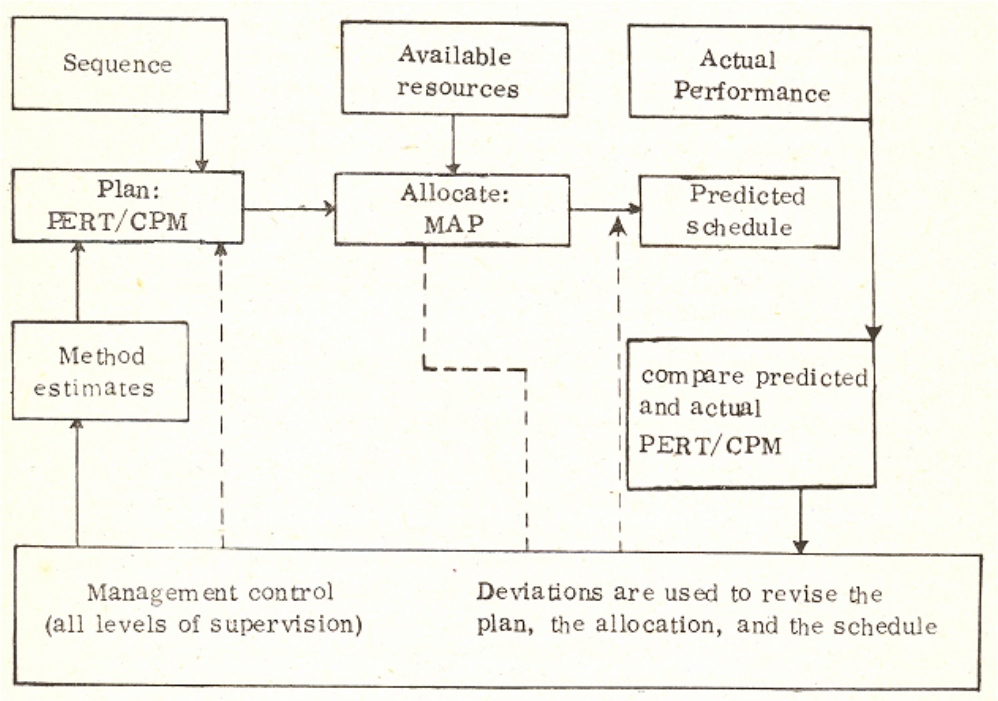
3.3. One of the most useful yields of PERT is its progress reporting. PERT lays the basis for anticipating management action against trouble spots likely to appear. As activities are completed, the actual time and costs are substituted for the previous estimates. The system is then processed to determine the effects of these performances on the total project. The progress or lacks of progress of the project can thus beanalysed. PERT thus eliminates 'lag' reporting, and institutes anticipating reporting.

3.4. Thus the quality, timeliness, frequency, relationship, and anticipating characteristics of PERT distinguishes it from other conventional techniques, and helps management in establishing its responsibilities and in achieving its objectives.

3.5. As the primary purpose of applying PERT to any project is to create a plan and schedule, the steps in planning and scheduling a project are given below:



The new concept shown in the figure on page 62 represents the true approach the total approach-to the application of PERT to determine a 'plan' and a 'schedule'.


Sequence
Available resources
Actual Performance
Plan: PERT/CPM
Allocate: MAP
Predicted schedule
Method estimates
compare predicted and actual PERT/CPM
Management control (all levels of supervision)
Deviations are used to revise the plan, the allocation, and the schedule

4. PERT/Cost

4.1. PERT, when developed originally in connexion with the Polaris Missile Programme, was only time-oriented. It was during the period 1962-63 that the original time-oriented characteristic of PERT was extended to include manpower and cost elements. Now, we shall consider the most important developments in PERT Management systems, viz., the introduction of costs in an explicit relationship with the network. PERT/Cost cannot be considered independently of time-oriented PERT. In fact, PERT/Cost assumes the development of network before the costing phase can be completed. PERT/Cost to be effective requires those persons who had the experience of developing and implementing PERT/Time (time-oriented PERT). The central idea of PERT Cost is the direct association of programme costs with activities on an established time network. As in PERT/Time we are concerned in the use of PERT/Cost only with one-time-through programmes, such as capital· or construction programmes and Research and Development programmes, and not repetitive manufacturing programmes, where costs are associated with the number of units produced.

The fundamental objectives of PERT/Cost are twofold:

(i) to ascertain a significantly realistic programme cost estimate, and

(ii) once the programme is allowed to proceed, to achieve a marked improvement in control against the original estimate.

4.1.1. There are also potential areas of cost reduction or increase in efficiency made possible by the application of PERT Management systems. With these objectives, let us now consider the basic methodology of PERT/Cost.

4.2. The association of the cost factor with PERT requires the completion of network unlike in time-oriented PERT. All activities which carry direct cost must be indicated on the network. In order to provide a framework for complete networking, the work or Task Breakdown structure should be developed as the first step in any basic PERT/Cost analysis. The must significant feature of the work breakdown structure is to provide a foam work for identifying all the major tasks of a programme, the emphasis being on the product-oriented structuring of these tasks. The work breakdown structure is, therefore, generally product-oriented, in the sense that it is comparable to what is often known as unit assembly of a drawing breakdown sequence.

4.3 In the case of large programmes, there is widely varying consensus of opinion as to at what particular level the work breakdown structure should be functionally (i.e. organizationally) structured as against a product-oriented one. One of the main objectives of PERT/Cost, and in fact one of its new features, is to establish a time and Cost Correlation of tasks which are product-oriented. From the PERT/Cost, fune-

tionally-oriented budget and cost information can be derived, and it may be pointed that work breakdown structure can be partially structured on a functional basis, where product orientation is not significant, as in the case of programme management. The work breakdown structure, if properly developed, provides the key to an integrated programme management system for performance time and cost factors. If any areas in the initial work breakdown structure have not been fairly developed, provision for contingency End Item Subdivisions must be made.

4.4. It is desirable to develop the work breakdown structure through a number of levels, before reflecting the End Item Level, against which meaningful PERT networks can be developed. After carrying out a thorough analysis of PERT network covering all the End Item Subdivisions, the next step is to establish cost work packages, which are associated with the networks.

4.5. A cost-work package is established by aggregating a group of activities within the network. In establishing the cost-work packages, it should be ensured that all activities in the network under an End Item Subdivision fall within a work package, and that all work packages must be capable of summarisation to an End Item Subdivision. There are two criteria in setting up the work packages:

(i) There should be time duration, and
(ii) They should not exceed certain monetary limit in cost.

4.5.1. However, in fixing the monetary limit of work packages, the following factors are taken into account:

(i) Nature of industry.
(ii) Stage of programme. Early stages of programme require a high am0!1nt because of higher material content, as against later stages of programme.
(Hi) Size of programme the smaller programmes require less money as against large programmes.
(iv) The depth and shape of the work breakdown structure. If the work breakdown structure goes to a low level, work packages are likely to be smaller in size.

4.6. It is necessary to establish the starting and terminating events for each work package, in order to derive the benefit of correlating the time and cost performance. This requires that work packages should be built around continuous paths, Another problem is whether work package is functional or represents another level of task breakdown involving various organisation elements and/or resource skills. All these limitations and factors have to be considered in setting up work packages, involving judgment and depth of knowledge on the content of network. It is also desirable to indicate a single individual or party as having unit responsibility, for anyone work package.

5. Programme Evaluation Through Reporting

5.1 Work Package Cost estimating data are then developed showing man hour requirements by resource skills converted into money value together with material requirements- and other resources needed, expressed in monetary terms, for input into the PERT/Cost system. Time data are, of course, based on scheduled elapsed times for network activities It is necessary to make estimates on a periodic basis to develop cost data to complete each work package that has been commenced., The time schedule of each activity in a work package is examined, and all the schedule slippages are analysed to determine the need for revising the original time and cost estimates. Schedule slippages, however, call for revised estimates, and a reallocation of resources.

5.2 The updating of cost estimates is facilitated by setting up specific review dates. Estimates can be easily prepared and revised by assigning responsibility to individuals in the programme performance. The cost and resources updating worksheet can be used as a detailed record of current costs and resource estimates an1i as a guide for the preparation of the latest revised estimates.

5.3 With the help of the data processing equipment, a number of output reports are prepared analysing the problems and identifying the areas or sources of those problems. These reports, therefore, lead naturally to executive decision and early action. The following are the main reports:

(i) Management summary report.
(ii) Manpower loading and. display report.
(iii) Milestone report.
(iv) Cost of work report.
(v) Cost outlook and schedule outlook Report.

6. Modification of PERT Cost Techniques.

6.1. One of the more commonly known modifications of PERT/Cost technique is the 'time-cost optimisation or augmentation' technique originally developed in connexion with the Critical Path Method. Under this metalloid, there will be two sets of time, and cost data, viz., normal and crash. In the 'normal' estimate, the stress is on cost with time being associated with minimum cost. The 'crash’ estimate, on the other hand, involves the absolute minimum time required for the programme, and the cost necessary to achieve that time.

6.2 Compression of time involves cost; in other words, time can be bought only with money and resources. It is, therefore, necessary to estimate the cost

to expedite the programme. From a graphical representation of time and cost, it is possible to show the cost to expedite.

6.3. An analysis of the cost to expedite each activity in the critical path provides way to crash or compress an activity by which minimum increase in cost per unit of time saved is obtained. A new schedule with a higher cost level will then emerge.

6.4. When activities along the critical path are expedited, the direct cost is likely to increase, whereas the indirect cost or overhead cost is likely to reduce with reduction in project time. It is, therefore, necessary to have the following cost data for expediting:

(i) Normal time and normal cost for each activity.

(ii) Crash time and crash cost for each activity, i.e. the minimum possible time completion of an activity and corresponding direct cost to be incurred.

(iii) Indirect cost in relation to time.

6.5. While expediting the activities along the critical path, the activities which cost less should be expedited first in order to keep the overall expediting cost to a minimum

6.6. Keeping these broad principles in mind, the steps required for expediting are given below:

(i) List all the activities in a Data Analysis sheet.

(ii) Calculate expediting cost per unit of time for all the activities

$$\frac{\text{which is Crash Cost*... Normal Cost*}}{\text{Normal Time-Crash time}}$$

(*These are direct costs which increase with expediting).

(iii) Rank least expediting cost first in respect of all the activities.

(iv) Calculate the total time (normal time-crash time) available for reduction in respect of various activities.

(v) For expediting purposes, select the activity along the critical path first which ranks least in expediting cost. Mark this activity as reduction on No. 1.

(vi) For reduction No.1, determine the time reduction permissible looking carefully into the float periods available on other paths.

(vii) Calculate the cost involved in the above time reduction (time reduction X expediting cost per unit of time).

(viii) Subtract this time from the total elapsed time which now shows the revised total elapsed time after crashing first activity, ranking least in expediting cost.

(ix) Adding the expediting costs arrived at step (vii) to the total cost involved after crashing the first activity.

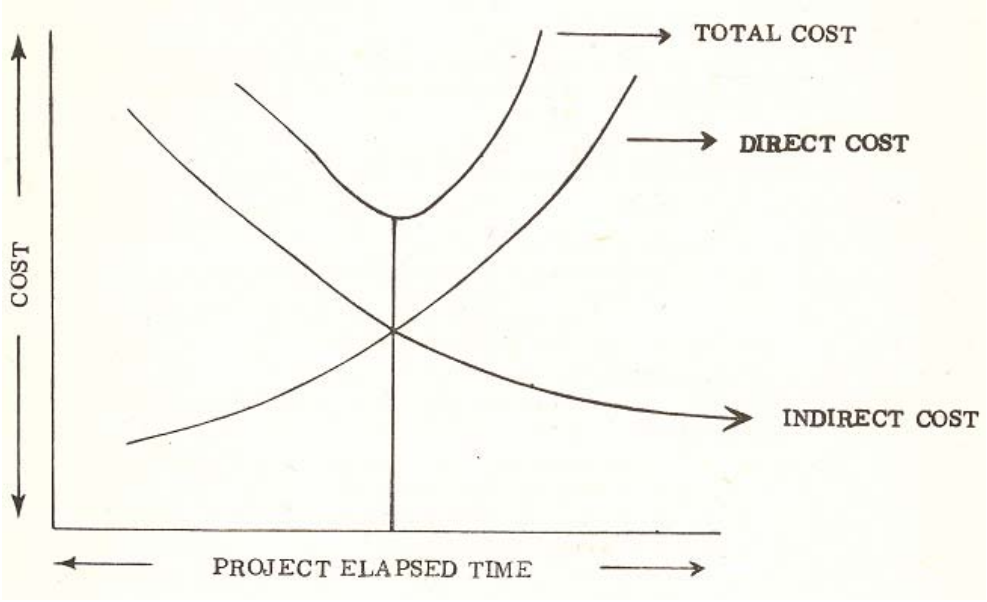
(x) Repeat steps (v) to (ix) for all the remaining activities on the critical path, working out at each stage the revised cumulative total elapsed time and the total cumulative cost of crashing.

(xi) It is likely that in the process of crashing activities on the critical path, other paths, may also become critical. In such cases a given activity on the original critical path must be studied simultaneously with other activities on the paths having assumed criticality, ranking least in expediting cost.

6.7 Expediting of activities on critical path(s) will give a set of value of total elapsed time of a project under step (viii), and corresponding total expediting (direct) costs under step (ix.) This data can be tabulated as follows:

Project elapsed	Direct cost	Indirect cost	Total cost

6.8 The direct, indirect and total costs can now be plotted against the time-scale known as the least cost curve:

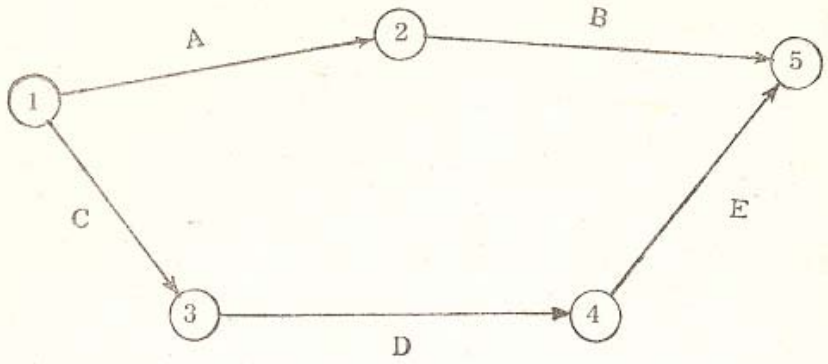


The point X, on the horizontal time-scale, is the optimum project elapsed time, leading to minimum project cost.

6.9. Sometimes penalty cost is also taken into account in addition to the direct and indirect costs. This cost may represent loss in production resulting, from the shut-down time of the plant or in the value of a product not marketed at the earliest possible time relative to competing products.

7. Example of Time-Cost Optimisation

7.1. Let us take a simple network.



7.1.1. The time and cost data pertaining to each activity are given as under:

Activity	Normal		Crash	
	Time	Cost	Time	Cost
A	5	40	3	46
B	7	50	4	62
C	4	20	3	33
D	6	50	4	54
E	7	60	4	66
Normal project duration/cost.	26	220		

7.1.2. From the expediting cost analysis (See Page 69), the least cost results can be tabulated as follows:

Project elapsed time	Direct Cost	Indirect Cost	Total Cost
17	220	400	620
14	226	375	601
12	238	360	598
11	254	355	609

EXPEDITING COST ANALYSIS

Activity	Expediting Cost Per Unit	Ranking	Normal Time *Less* Crash Time	Reduction No.	Time Reduction	Balance	Crash Cost	Cumulative	
								Elapsed Time	Cost
1	2	3	4	5	6	7	8	9	10
A	3	II	2	III	1	1	3	—	—
B	4	III	3	—	—	—	—	—	—
C	13	IV	1	III	1	0	13	11	254
D	2	I	2	II	2	0	4	12	238
E	2	I	3	I	3	0	6	14	226

Notes for explanation

Col. 2 : Expediting cost per unit $= \frac{\text{Crash Cost—Normal Cost}}{\text{Normal time—Crash time}}$

Col. 7 = Col. 4—Col. 6, and Col. 8 = Cols. 2×6

Cumulative elapsed time = Project normal time—time reduction = 17—3 = 14 (1st reduction)

Cumulative Cost = Total Normal Cost+Crash Cost = 220+6 = 226 (1st reduction)

After reduction number II, both parts in the network are critical. Hence activities C and A have to be expedited simultaneously under reduction number III.

7.1.3. Thus the project duration of 12 units of time wili yield the minimum project cost.

7.1.4. The optimum project duration can also be read from the least cost curve, as discussed earlier.

8. Conclusion

8.1. To sum up, PERT/Cost information aids management in identifying trouble spots and problem areas sufficiently in advance, so that the management can make timely decision and take such corrective action as diversion of resources to critical areas to ensure accomplishment of programme to schedule, and to prevent costs from over-running. The timely summarising of PERT/Cost information and its presentation in a decision-making form enables the evaluation of programme status by the Management without reviewing the entire mass of information. The integrated nature of the PERT/Cost reporting system can provide any additional information needed by management for a more detailed analysis when it is confronted with specific Problems. Managements of industrial enterprises thus stand to gain by the application of PERT in the planning, execution, and control of their programmes. In fact, the scope of PERT and its application have increased enormously during the last two years, as to cover such fields as Systems Engineering, Configuration Management, and Profit Control.

8.2. A few of the successful applications of PERT resulting in Cost Reduction may be cited here:

(i) In a refinery, the turn around time was cut by 25% with less than half the total work force.

(ii) In a design-cum-construction project of a building, a total of five months was saved by eliminating bottlenecks in the delivery of machines and design drawings.

(iii) The maintenance time on a spindle unit in a chemical fib replant was cut by almost 50%.

(iv) In another plant, the shut-down time was reduced by 37%.

(v) The maintenance time of a mine hoist requiring complete shut down of a mine was cut down by 27%.

(iv) In one of the building construction projects, the time for completing the project was reduced by 22%.

(vii) Expansion of a plant to meeting the growing seasonal demand was accomplished in less than 25% of the original estimate.

(viii) A company generally requiring 30 weeks for closing the annual accounts, could do the job in less than 13 weeks-more than 50% reduction in time.