The cost graphs in the Project planner software can help a manager to get a update on project cost overflow. The cost variance (The difference between approved cost and the projected cost should be always in the minds of the project managers).

Project Planning Techniques

The three basic project planning techniques are Gantt chart, CPM and PERT. All monitor progress and costs against resource budgets.

Gantt Chart

Gantt charts are also called Bar charts. The use of Gantt charts started during the industrial revolution of the late 1800's. An early industrial engineer named Henry Gantt developed these charts to improve factory efficiency.

Gantt chart is now commonly used for scheduling the tasks and tracking the progress of energy management projects. Gantt charts are developed using bars to represent each task. The length of the bar shows how long the task is expected to take to complete. Duration is easily shown on Gantt charts. Sequence is not well shown on Gantt Charts (Refer Figure 7.2).

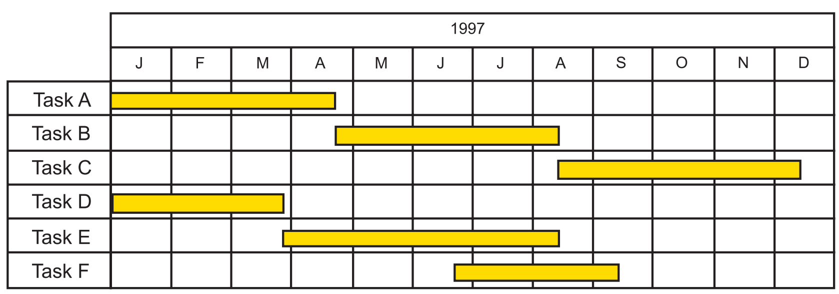

Figure 7.2 Gantt Chart

If, for example, the start of Task C depends on both Activity B and Activity E, then any delay to Task E will also delay Task C. We just don't have enough information on the Gantt chart to know this information.

CPM - Critical Path Method

DuPont developed a **Critical Path Method** (CPM) designed to address the challenge of shutting down chemical plants for maintenance and then restarting the plants once the maintenance had been completed.

Complex project, like the above example, require a series of activities, some of which must be performed sequentially and others that can be performed in parallel with other activities. This collection of series and parallel tasks can be modeled as a network.

CPM models the activities and events of a project as a network. Activities are shown as nodes on the network and events that signify the beginning or ending of activities are shown as arcs or lines between the nodes. The Figure 7.3 shows an example of a CPM network diagram:

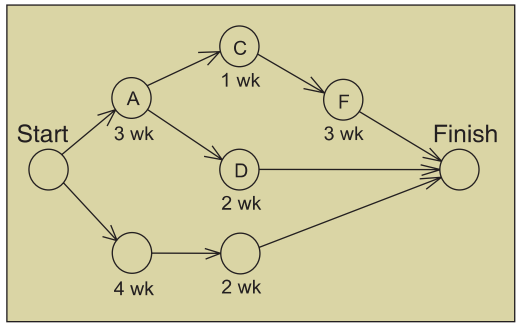

Figure 7.3 CPM Diagram

Steps in CPM Project Planning

1. Specify the individual activities.
2. Determine the sequence of those activities.
3. Draw a network diagram.
4. Estimate the completion time for each activity.
5. Identify the critical path (longest path through the network)
6. Update the CPM diagram as the project progresses.

1. Specify the individual activities

All the activities in the project are listed. This list can be used as the basis for adding sequence and duration information in later steps.

2. Determine the sequence of the activities

Some activities are dependent on the completion of other activities. A list of the immediate predecessors of each activity is useful for constructing the CPM network diagram.

3. Draw the Network Diagram

Once the activities and their sequences have been defined, the CPM diagram can be drawn. CPM originally was developed as an activity on node network.

4. Estimate activity completion time

The time required to complete each activity can be estimated using past experience. CPM does not take into account variation in the completion time.

5. Identify the Critical Path

The critical path is the longest-duration path through the network. The significance of the critical path is that the activities that lie on it cannot be delayed without delaying the project. Because of its impact on the entire project, critical path analysis is an important aspect of project planning.

The critical path can be identified by determining the following four parameters for each activity:

- ES - earliest start time: the earliest time at which the activity can start given that its precedent activities must be completed first.
- EF - earliest finish time, equal to the earliest start time for the activity plus the time

required to complete the activity.

- LF - latest finish time: the latest time at which the activity can be completed without delaying the project.
- LS - latest start time, equal to the latest finish time minus the time required to complete the activity.

The *slack time* for an activity is the time between its earliest and latest start time, or between its earliest and latest finish time. Slack is the amount of time that an activity can be delayed past its earliest start or earliest finish without delaying the project.

The critical path is the path through the project network in which none of the activities have slack, that is, the path for which ES=LS and EF=LF for all activities in the path. A delay in the critical path delays the project. Similarly, to accelerate the project it is necessary to reduce the total time required for the activities in the critical path.

6. Update CPM diagram

As the project progresses, the actual task completion times will be known and the network diagram can be updated to include this information. A new critical path may emerge, and structural changes may be made in the network if project requirements change.

CPM Benefits

- Provides a graphical view of the project.
- Predicts the time required to complete the project.
- Shows which activities are critical to maintaining the schedule and which are not.

CPM Limitations

While CPM is easy to understand and use, it does not consider the time variations that can have a great impact on the completion time of a complex project. CPM was developed for complex but fairly routine projects with minimum uncertainty in the project completion times. For less routine projects there is more uncertainty in the completion times, and this uncertainty limits its usefulness.

PERT

The *Program Evaluation and Review Technique* (PERT) is a network model that allows for randomness in activity completion times. PERT was developed in the late 1950's for the U.S. Navy's Polaris project having thousands of contractors. It has the potential to reduce both the time and cost required to complete a project.

The Network Diagram

In a project, an activity is a task that must be performed and an event is a milestone marking the completion of one or more activities. Before an activity can begin, all of its predecessor activities must be completed. Project network models represent activities and milestones by arcs and nodes.

PERT is typically represented as an activity on arc network, in which the activities are represented on the lines and milestones on the nodes. The Figure 7.4 shows a simple example of a PERT diagram.

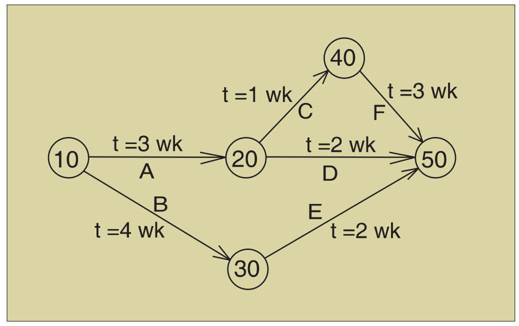

Figure 7.4 PERT Diagram

The milestones generally are numbered so that the ending node of an activity has a higher number than the beginning node. Incrementing the numbers by 10 allows for new ones to be inserted without modifying the numbering of the entire diagram. The activities in the above diagram are labeled with letters along with the expected time required to complete the activity.

Steps in the PERT Planning Process

PERT planning involves the following steps:

1. Identify the specific activities and milestones.
2. Determine the proper sequence of the activities.
3. Construct a network diagram.
4. Estimate the time required for each activity.
5. Determine the critical path.
6. Update the PERT chart as the project progresses.

1. Identify activities and milestones

The activities are the tasks required to complete the project. The milestones are the events marking the beginning and end of one or more activities.

2. Determine activity sequence

This step may be combined with the activity identification step since the activity sequence is known for some tasks. Other tasks may require more analysis to determine the exact order in which they must be performed.

3. Construct the Network Diagram

Using the activity sequence information, a network diagram can be drawn showing the sequence of the serial and parallel activities.

4. Estimate activity times

Weeks are a commonly used unit of time for activity completion, but any consistent unit of time can be used.

A distinguishing feature of PERT is its ability to deal with uncertainty in activity completion times. For each activity, the model usually includes three time estimates:

- *Optimistic time (OT)* - generally the shortest time in which the activity can be completed. (This is what an inexperienced manager believes!)
- *Most likely time (MT)* - the completion time having the highest probability. This is different from expected time. Seasoned managers have an amazing way of estimating very close to actual data from prior estimation errors.
- *Pessimistic time (PT)* - the longest time that an activity might require.

The expected time for each activity can be approximated using the following weighted average:

Expected time = (OT + 4 x MT+ PT) / 6

This expected time might be displayed on the network diagram.

Variance for each activity is given by:

$$[(PT - OT) / 6]^2$$

5. Determine the Critical Path

The critical path is determined by adding the times for the activities in each sequence and determining the longest path in the project. The critical path determines the total time required for the project.

If activities outside the critical path speed up or slow down (within limits), the total project time does not change. The amount of time that a non-critical path activity can be delayed without delaying the project is referred to as slack time.

If the critical path is not immediately obvious, it may be helpful to determine the following four quantities for each activity:

- ES - Earliest Start time
- EF - Earliest Finish time
- LS - Latest Start time
- LF - Latest Finish time

These times are calculated using the expected time for the relevant activities. The ES and EF of each activity are determined by working forward through the network and determining the earliest time at which an activity can start and finish considering its predecessor activities.

The latest start and finish times are the latest times that an activity can start and finish without delaying the project. LS and LF are found by working backward through the network. The difference in the latest and earliest finish of each activity is that activity's slack. The critical path then is the path through the network in which none of the activities have slack.

The variance in the project completion time can be calculated by summing the variances in the completion times of the activities in the critical path. Given this variance, one can calculate the probability that the project will be completed by a certain date.

Since the critical path determines the completion date of the project, the project can be accelerated by adding the resources required to decrease the time for the activities in the critical path. Such a shortening of the project sometimes is referred to as *project crashing.*

6. Update as project progresses

Make adjustments in the PERT chart as the project progresses. As the project unfolds, the estimated times can be replaced with actual times. In cases where there are delays, additional resources may be needed to stay on schedule and the PERT chart may be modified to reflect the new situation.

Benefits of PERT

PERT is useful because it provides the following information:

- Expected project completion time.
- Probability of completion before a specified date.
- The critical path activities that directly impact the completion time.
- The activities that have slack time and that can lend resources to critical path activities.
- Activities start and end dates.

Limitations of PERT

The following are some of PERT's limitations:

- The activity time estimates are somewhat subjective and depend on judgment. In cases where there is little experience in performing an activity, the numbers may be only a guess. In other cases, if the person or group performing the activity estimates the time there may be bias in the estimate.
- The underestimation of the project completion time due to alternate paths becoming critical is perhaps the most serious.

7.2.6 Performance Monitoring

Once the project is completed, performance review should be done periodically to compare actual performance with projected performance. Feedback on project is useful in several ways:

a) It helps us to know how realistic were the assumptions underlying the project
b) It provides a documented log of experience that is highly valuable in decision making in future projects
c) It suggests corrective action to be taken in the light of actual performance
d) It helps in uncovering judgmental biases
e) It includes a desired caution among project sponsors.

Performance Indicators (PIs) are an effective way of communicating a project's benefits, usually as part of a performance measuring and reporting process. Performance Indicators are available for a wide range of industries and allow a measure of energy performance to be assigned to a process against which others can be judged.

Depending on the nature of the project, savings are determined using engineering calculations, or through metering and monitoring, utility meter billing analysis, or computer simulations.

Implementation Plan for Top Management

As a result of energy audit, many energy saving opportunities would emerge. These could be classified broadly as measures with and without investment. House keeping measures and moderate cost measures need no intervention from top management. However, top management need to be appraised of these measures.

In case of projects where considerable investment are required, project manager has to rank the list of projects based on the technical feasibility and financial analysis indicated in the previous chapter (Simple payback, IRR, ROI etc.) and submit the same to the top management for appraisal and approval. This will help top management in allocating resources and other facilities.

Planning Budget

Budget requirement varies depending upon the duration and size of the project. For projects involving long duration with multiple tasks and procurements, resources have to be allocated judiciously as and when required. Top management should ensure that this is done to ensure successful completion of project.

Procurement Procedures

Having identified the material and equipment required for the project, the next step is to identify the various vendors, provide specifications, invite quotations, and carryout discussions with select vendors. For medium to high value items, tendering process can be adopted. Tenders have to be evaluated for technical and financial aspects. It would be desirable to have purchase manager as part of energy efficiency team to facilitate smooth procurement process.

Construction

During the construction phase, plant may need to be shutdown. Careful planning is required, so that the task is carried out without affecting the production. Project manager has to be aware of the annual maintenance schedule, holidays, annual maintenance or any major breakdown period during which anyway plant will be shutdown. Construction activity should be carefully supervised by energy and project manager so as to ensure quality and safety.

Measurement & Verification (M&V)

Facility energy savings are determined by comparing the energy use before and after the installation of energy conservation measures. The "before" case is called the baseline; the "after" case is referred to as the post-installation or performance period. Proper determination of savings includes adjusting for changes that affect energy use but that are not caused by the conservation measures. Such adjustments may account for differences in capacity utilization, raw material quality, product mix and other parameters, between the baseline and performance periods.
In general,

$$\text{Savings} = (\text{Baseline Energy Use})_{\text{adjusted}} - \text{Post-Installation Energy Use}$$

For example in a paper mill a variety of products depending on thickness (Grams per Square meter) are made. If energy consumption is evaluated as kCals or kWh per tonne of paper the figures could be misleading. Under these circumstances the measurement and verification system is to be designed accounting for these variations.

Case Example

Replacing an existing boiler with an energy efficient boiler.

Activity Code	Activity	Duration in days	Depends on
A	Prepare technical specifications	10	-
B	Tender Processing	25	A
C	Release of work orders	3	B
D	Supply of Boiler equipment	60	C
E	Supply of Auxiliaries	20	C
F	Supply of Pipes & Pipe fittings	10	C
G	Civil Work	15	C
H	Installation of Auxiliary equipment & piping	5	E, F&G
I	Installation of Boiler	10	D & H
J	Testing and Commissioning	2	I

A. Gantt Chart

The Figure 7.5 shows a Gantt chart for a simple energy management project, i.e. Replacing an existing boiler with an energy efficient boiler.

As already mentioned, Gantt chart is the simplest and quickest method for formal planning. Gantt charts can be very useful in planning projects with a limited number of tasks and with few inter-relationships. This chart typically depicts activities as horizontal lines whose length depends on the time needed to complete the activities. These lines can be progressively over-printed to show how much of activity has been completed.

Drawing a Gantt chart requires information on:

- The logic of the tasks;
- The duration of the tasks;
- The resources available to complete the tasks.

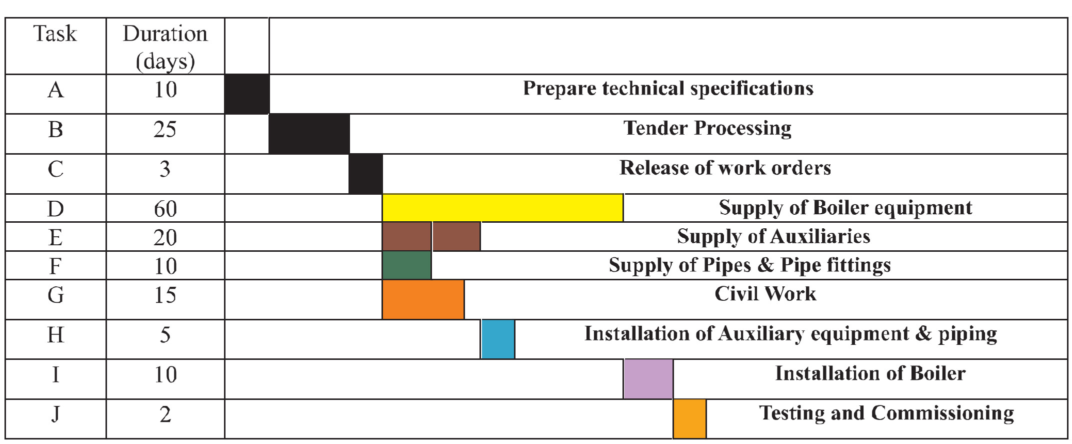

Figure 7.5 A Simple Gantt Chart for Boiler Replacement

B. PERT / CPM Technique:

A PERT/CPM network for Boiler Replacement (Refer Figure 7.6)

Activity on Arrow: Activity and duration of the activity are shown in arrow.

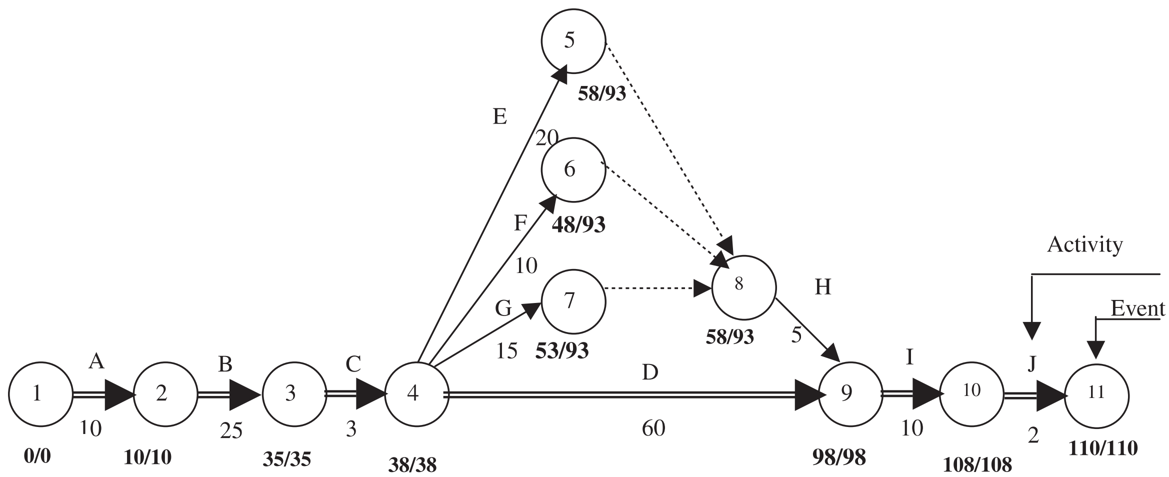

Figure 7.6

- ✓ 10/10: In this Numerator denotes the Earliest Event Occurrence Time and Denominator is the Latest Event Occurrence Time.
- ✓ The Critical Path for this network is: ⟹ **A-B-C-D-I-J.**
- ✓ The events on the critical path have zero slack.
- ✓ Dummy activity has no duration ---------->
- ✓ The total duration for the completion of the project is 110 days based on the critical path.