10

Schedule Management

10.1 Introduction

The backbone of project management is the ability to accurately plan the project activities, resources and costs along with control over the schedule and costs. These are essential in meeting the specified time and cost goals. Schedule management includes the processes required to manage timely completion of a project. In this chapter, we will learn how the overall scope of a project is broken into well-planned tasks trackable till completion.

10.2 Project Schedule

Project schedule is the list of milestones, activities and deliverables put on the timeline and resource information for a particular project. From the schedule, overall project start and end date as well as activity level start and end dates are found. Also, it helps to know which resources would be working on which activities at which point of time. If there are dependencies between the activities, then that should also reflect in the project schedule. Based on the project schedule, various types of analyses become possible. Some examples are: (1) Finding out the critical path for effective risk analysis; (2) Analysis of the delay and possible fast-tracking of projects; and analysis of resource utilization and so on. In the subsequent sections, we will learn how an effective project schedule can be developed.

10.3 Steps to Develop a Project Schedule

The scope of a project should be documented at the beginning of the planning phase. From the planning phase, project manager and the project team needs to identify all the activities or tasks to be performed to get the necessary work done for delivering the scope to the customer. The following six broad steps are followed for creating and maintaining a proper project schedule.

1. Define activities and create Work Breakdown Structure (WBS): The process of defining the work (activities) that must be performed to meet the project objectives.
2. Sequence activities: The process of identifying and documenting the interaction and logical relationships between activities.
3. Estimate activity resources: The process of determining resources (e.g., equipment, materials, manpower, etc.) that are required, quantities of each resource that is planned to be used, and the availability of each resource to perform the project activities.
4. Estimate activity duration: The process of using information on project scope and resources, and developing durations for input to schedules.
5. Develop schedule: The process of determining the start, intermediate milestones, and end dates of project activities.
6. Control schedule: The process of monitoring the status of the project to update project progress and to manage changes to the accepted schedule.

Figure 10.1 explains the steps for developing a project schedule

Figure 10.1 Schedule Management Flow

10.3.1 Create Work Breakdown Structure and Define Activities

Every project has definite start and end dates, therefore, a project schedule becomes the basic building block for definition of the entire project. For finding out the start and end date of an entire project, it is necessary to define the start and end dates of all the tasks or activities involved in projects. So, the first step in the Define Activities process is breaking down the project deliverables into smaller and manageable chunks of work called ‘Work Breakdown Structure (WBS)’. The lowest tier of a project’s WBS is called ‘work package’.

Work Breakdown Structure

Work breakdown structure is a deliverable-oriented hierarchical decomposition of the work that needs to be completed by the project team to achieve the project deliverable. Each descending level of the hierarchy represents increasing level of details about the project work. So, a WBS contains all the project work as per the approved scope statement.

The steps involved in creating a WBS are as follows:

- Identify deliverables from the scope statement and related work.
- Structuring and organizing the higher level WBS.

- Decompose upper WBS levels into detailed components at the lower level.
- Assigning identification codes to the WBS components.
- Verify that the degree of decomposition of the work is in accordance to the project needs.

Figure 10.2 shows a sample WBS where the project is broken into phases and then deliverables of each phase are identified. After this, each deliverable is broken into smaller chunks of work called ‘work packages’. Work packages have sufficient amount of details and granularity that they can be estimated, planned and tracked in the project life cycle. The list of work packages are documented in the form of a WBS Dictionary comprising details like work package identification number, description of work and responsible organization, resource requirement, cost estimate, acceptance criteria, etc.

Figure 10.2 Work Breakdown Structure

Figure 10.3 Define Activities

Refer to Figure 10.3 for the steps involved in the Define Activities. Decomposition of work packages leads to activities. Activities provide a basis for estimating, scheduling, executing, monitoring, and controlling project work. Project assumptions and constraints, identified and documented in the project’s scope statement, also serve as inputs to the process of defining activities. Required quality levels—both stated and implied—serve as project constraints and have a substantial effect on activity definition. Rigorous quality standards would obviously entail more about project activities. At the end of Define Activities process, we generate an activity list which is a list of all activities to be performed as part of a project.

Environmental factors and organizational assets are also used as inputs to the Define Activities process. Organization assets generate the activities related to policies and procedures of a project; it also helps to define activities using historical information and lessons learnt. Environmental factors, such as infrastructure and project management software help to define the activities of the project.

Decomposition:

Decomposition is the first step in the Define Activities process, because the work packages of the WBS which lists only deliverable-oriented components, must be broken down into the actual tasks or activities required to realize the deliverables (Figures 10.4 and 10.5). The sub-division of work packages into smaller and manageable components of activities is often performed by the project team members responsible for that work package. The correct level of decomposition helps for accurate schedule estimation and timely completion of a project. Correct level of decomposition means decomposing a project to such a level that all efforts related to planning, executing, monitoring and controlling can be readily addressed and managed. Excessive decomposition leads to more work without addition of much value and also leads to inefficient use of resources with decrease in work efficiency.

Figure 10.4 Work Packages to Activities

Figure 10.5 Decomposition

Templates

Templates from other projects can be used to create activity lists and also to define activity attributes. Templates can be used to define typical milestones as well. Historical data is very useful not only to stop reinventing the wheel, but also to reduce the efforts involved in defining an activity. In a typical project, the Project Management Office provides the templates that can be used in the project. However, it is the project manager's responsibility to customize this template for its purpose.

At the end of the activity identification step, we get an activity list, where attributes and the milestone list are used for sequencing the activities according to project needs.

1. Activity List

At the end of the decomposition process, the activity list of the project gets generated. An activity list is a comprehensive list of all scheduled activities required for a project. It includes the activity identifier and scope of work description for each activity in sufficient detail. An activity identifier is a unique number that identifies a particular activity. It helps in distinguishing an activity from the others that are similar in nature or name. These activity identifiers are unique across the entire project schedule network diagram.

2. Activity Attributes

Activity attributes represent the inherent properties of a particular activity. A WBS identifier, an activity identifier, a predecessor activity, a successor activity, leads, lags, constraints and assumptions are the attributes associated with an activity. Some activities may require a disproportionately higher level of effort whereas some others may not. The duration of some activities may be controlled by the level of effort input whereas in some other activities, such types of control over duration may not be possible. These considerations need to be factored in determining activity duration estimations (see later in this chapter).

Figure 10.6 Milestone List

3. Milestone Lists

Generally, a milestone list is coupled with a milestone chart and it is used to provide a series of indicators regarding project progress till now and achievements or goals yet to be reached. In Figure 10.6, Tollgate 1 indicates that it will deliver Software Requirement Specification (SRS) document at the end of its phase. Assuming that a project consists of only these four milestones of equal efforts and duration, it can be said that 50% of the project is completed as after crossing Tollgate 2.

10.3.2 Sequencing the Activities

After defining all activities entailed by the project and generating the activity list, the project team needs to arrange these activities in a logical sequence from start to end. In other words, to identify all subsequent processes that require as inputs, the outputs of preceding processes need to be identified. The project team is required to identify the logical relationships, and preferred relationships between all activities. The project team accomplishes this task by identifying project dependencies. Therefore, the sequence activities process is for identifying and documenting such relationships among all project activities. Figure 10.7 shows the steps involved in sequencing the activities.

Figure 10.7 Sequence Activities

A project is a series of activities performed in a logical order. The ordering of the activities largely depends on the inter-dependencies between the activities. In the table (below), the different types of dependencies that can be present in a project are described.

Different Types of Activity Dependencies

Precedence Diagramming Method

Precedence Diagramming Method (PDM) is a widely used representation of activity sequencing and, is available in most of the project management scheduling software. Also, PDM employs a diagram that arranges all activities of a project with the relationships and dependencies among them as shown below. The PDM uses the notation of circle or boxes representing the activities called ‘nodes’. The arrows that connect these nodes represent the dependency or activity. This technique is also called ‘Activity-On-Node (AON)’. Here is an example of PDM:

Also, PDM is a technique used in the Critical Path Method (CPM), for constructing a Project Schedule Network Diagram (PSND) (see later in this chapter). PDM is not a diagram showing project schedule; rather, it is a technique used before the project schedule is defined. As mentioned earlier, PDM typically uses boxes to indicate project activities and arrows to connect them. A PDM usually has an activity number to identify each activity, a short description of the activity, and indications for early start, early finish, late start, late finish, and duration of the activities. An activity might have one, two or more predecessors and one, two or more successors.

Figure 10.8 Types of Relationship Between Tasks

Relationships between activities shown in a PDM can be of four types. These four types may be referred as the logical relationships in a PDM.

Logical Relationships

A total of four logical relationships or dependencies are possible between any two activities, because an activity can have start or finish relationship with another (Figure 10.8).

Finish–Start Relationship: Here, the initiation of a successor activity depends on the completion of a predecessor activity. Many project activities bear this relationship with others. For example, the User Acceptance Test (UAT) cannot be started until final deployment into the testing environment is completed. Deployment needs to be completed for UAT to start.

Start–Start Relationship: Here, the initiation of a successor activity depends on the initiation of a predecessor activity (Figure 10.9). Therefore, a subsequent task may start even before a preceding task has been completed; only the latter should have started and—as would be the case—partially completed. In other words, two tasks related by a start–start relationship may be performed in tandem. For example, code review can be started only after writing the codes starts.

Figure 10.9 Precedence Diagram

Finish–Finish Relationship: Here, the completion of a successor activity depends on the completion of a predecessor activity. For example, a project manager cannot close a project until customer's sign-off has been completed.

Start–Finish Relationship: Here, the completion of a successor activity requires the start of a predecessor activity. Such a relationship is unusual, but is often found in activities involved in just-in-time management processes. When people work in shifts, the beginning of one shift indicates the end of another shift. The project manager of such a project may use this type of relationship.

Leads and Lags

Applying leads and lags is the next step in the activity sequencing process. Leads and lags refer to buffers introduced between tasks for better control of activities.

A lag directs a delay in a successor activity. If a delay of x days is required between the finish of a task and the start of another, then a finish–start dependency may be established with a specification lag time of x days. For example, a technical-writing team can begin editing the draft of a document 10 days after it begins writing. The two tasks, writing and editing—bear a start–start relationship with a 10-day lag.

Lead accelerates the start of the successor activity prior to the completion of the predecessor. For example, the coding team may not wait for the whole design to complete before starting the design in case there is time constraint in the project. In this case, the finish to start relationship between design and coding is established with a lead of x days, which means that coding starts x days prior to the scheduled completion of design. Lead creates parallel activities.

Points to Remember

A lead time tends to accelerate a successor activity. A lag time directs a delay in a successor activity.

Project Schedule Network Diagram

The PSND is a schematic display of project's activities and dependencies, showing the flow of project work, which is then used to develop the project schedule. A sub-network is simply a section of the overall PSND. The PSNDs are created within the Sequence Activities process and it becomes an input to the develop schedule process. PSNDs are generally Activities On the Node (AON) and use all four types of dependencies between activities (i.e., finish–start, finish–finish, start–start, and start–finish) as mentioned above. Following are the advantages of generating PSNDs:

- PSNDs show interdependencies of all activities (a decomposition of WBS).
- They depict project work-flow clearly showing activities that need to be performed in the required sequence.
- They compress the schedule in planning and throughout the life of a project.
- If used for schedule control and reporting, they show project progress.
- They help in justifying the project manager's estimate for the duration of a project.

Figure 10.9 shows an example of a precedence diagram that uses different type of dependencies.

10.3.3 Estimating the Activity Resources

This is the process for determining:

1. The resources (including human resource, equipment and materials) that are required.
2. The quantities of each resource that will be used.
3. The point in time (in the future) when each identified resource will be available to perform assigned project activities.

Figure 10.10 shows the steps involved in this.

Resource Calendars

An important input required for determining the resource requirement and resource availability for a project is the resource calendar. In the context of project management, calendars are of two types: project calendars and resource calendars. Project calendars are related to all the resources involved in a project whereas resource calendars refer to particular resources or groups of resources and their availability. Resource calendars are used to ensure that work is scheduled only when resources are available for work. The working time settings in the resource calendar need to match those in the project calendar. Moreover, there source calendar can be customized to show individual schedule information, such as vacations and leaves of absence. If work time settings of resources involve part-time or the night shift, a separate base calendar for each shift may be set up and applied. Also, project managers can use resource calendars to accommodate exceptions in the work timing of individual resources.

There are different estimation techniques used for estimating the activity resources. These are:

1. Bottom-up Estimating

The bottom-up estimating technique is just the opposite of the top-down estimating. The technique is used to estimate every activity or work item individually and sum that estimate to determine a final estimate. Although, bottom-up estimations are accurate, these are time consuming and are used only when definitive, detailed estimates are required.

2. Published Estimating Data

Production rate and unit cost of the resources can be obtained from published data based on historical information gathered from different companies. This data is useful for determining the resources of an activity. It can be used as the base data to arrive at accurate estimation of resources.

3. Activity Resource Requirements

The activity resource requirement technique is used to identify the type and quantity of resources required for each activity in a work package. These requirements then can be aggregated to determine the estimated resources for each work package. The level of detail varies by application area.

Figure 10.10 Estimate Activity Resources

Figure 10.11 Resource Breakdown Structure

At the end of the activity resource estimation stage, a project manager identifies the RBS which depicts the resource requirement to complete the project activities.

Resource Breakdown Structure

A Resource Breakdown Structure (RBS) is a hierarchal structure of human resources, organized by function. For example, the top level of an RBS could be the business unit to which a resource belongs; the second-to-lowest level would be a team manager to whom the resource reports and the final level is the resource itself. In the following table, the resource at Level 3, i.e., the assistant vice president of operations could be provided access to all resources through Level 4 to Level 7 (Figure 10.11).

10.3.4 Estimating the Activity Duration

This process analyses information on project scope and resources and then develops activity durations from input to schedules. Activity duration refers to the number of work periods needed to complete the activities listed in the activity list. The accuracy of estimates can be improved by considering the amount of risk in the original estimate. More the realistic risks are identified, more estimates become accurate and realistic (Figure 10.12).

Figure 10.12 Estimate Activity Duration

The estimate activity duration process requires the following:

- Amount of work effort required to complete the schedule activity is estimated.
- Assumed quantity of resource to complete the schedule activity is estimated.
- Work periods required to complete a scheduled activity is calculated.
- Resource calendar is considered to cross-check resources with required skills are available at right point of time.

A related concept addresses the efforts required to complete an activity. There are three types of effort, namely, Level of Effort (LOE), Apportioned Effort (AE), and Discrete Effort (DE).

Level of Effort

Level of Effort (LOE) refers to work of a supportive nature that does not directly add to execution of activities and does not require a definite product outcome. However, it is mandatory, as support for other work activities or the entire project effort, and consists of short amounts of work that must be repeated periodically.

Examples of such an activity are project budget accounting or oiling of machinery in manufacturing.

Apportioned Effort

Apportioned Effort (AE) is the effort that is directly related to some other measured effort and is related and proportional to the measured effort in other work packages. For example, we may consider (apportioned) efforts of the quality assurance division depending on performance of the project team as a whole.

Discrete Effort

These kinds of efforts can be directly traced against each deliverables. It is easily measurable. This is just opposite to AE.

Estimating activity duration accurately is very important for the success of a project. Inaccurate estimation leads to cost and schedule overruns. Moreover, activity duration should allow for leakage time or hidden time and intervening breaks. For example, if an activity takes 1½ days to complete and starts on a Friday morning, Saturday and Sunday being holidays, the activity duration should be calculated considering the two intervening holidays. The activity should be scheduled as complete only on the following Monday afternoon and the elapsed time being 3½ days. In activity duration calculation, the duration of a work package is equal to the amount of time required to do the work, divided by the number of people working. It is given as:

Duration = Work/Unit

Discussed below are the techniques followed during estimation of activity duration.

1. Analogous Estimating

This technique uses the actual duration information of similar previous projects to get a gross estimation value. The project complexity is also considered to achieve more accuracy. Analogous estimation is naturally less accurate and used at the early stage of the project. This is technique is less costly and time consuming. The accuracy of this estimate increases if the previous project that is considered is very similar to the current project and the experts involved in this estimation are very knowledgeable.

2. Parametric Estimating

This estimation technique uses the statistical relationship between historical data and other variables in the project to estimate the duration, cost, budget, etc. By multiplying the quantity of work by the labour hour per unit of work, the duration estimation can be calculated. For example, if one person can complete 20 test cases per day, then to write 200 test cases 10 days will be required.

Parametric estimation can be accurate if the model is sophisticated and the underlying data is accurate.

3. Regression Analysis and Learning Curve Method

When accurate information on an activity is not available, project managers use regression analysis and learning curve methods, for duration estimation. In regression analysis, two variables are plotted on a graph and their relationship is derived using mathematical modeling. The regression equation deals with the following variables:

$$Y = f(X, \beta)$$

Where,

β is a constant, a scalar or a vector of length k.

X is the independent variable.

Y is the dependent variable.

The Learning Curve Method assumes that a resource consumes progressively less time in carrying out a task, that is, all other work factors being the same, a resource always consumes less time compared to the duration consumed previously to complete a similar activity.

4. Heuristics

Heuristics refers to the 'rule of thumb' estimate, based on knowledge of duration actually consumed after working on large number of similar activities.

5. Three Point Estimation

The Three Point Estimation technique, better known as PERT (program, evaluation, and review technique) improves the accuracy of the estimate manifold by considering the risks in the project. This technique assumes that there is very small probability that a project will be completed on a given date estimated at the beginning of the project. The project manager makes three types of estimations, namely, best, worse, and most likely, for completing an activity. The Expected duration is the weighted average of best case, most likely and worst case estimates.

$$\text{Expected value} = (P + 4M + O)/6$$

$$SD = (P – O)/6$$

Where

O is the best-case estimate, considering the resource availability, their productivity, dependency of activities, and the interruptions.

M is the most likely estimate made with realistic expectations about the above parameters.

P is the worst-case estimate considering the pessimistic situation for the above parameters.

SD is standard deviation.

This estimate is more accurate as the three points clarify the range of uncertainty of the duration of estimation.

6. Graphical Evaluation and Review Technique

The Graphical Evaluation and Review Technique (GERT) is a combination of network logic and activity duration estimates. Usually, it allows looping. Consider an activity 'A' which is executed five times, continuously. We cannot represent it using the normal diagramming technique. We need to use GERT to represent it. Any graphical method can be used to represent the looping.

7. Reserve Analysis

Reserve analysis addresses buffer in the calculation of duration estimation. Contingency reserve or buffer is generally factored in as a percentage of the overall activity duration estimation. The buffer, often set at 10% of the estimated overall activity duration, is used to manage unknown future project risks.

If we are ready to take more risks in the activity, then reserve can be zero. In order to reduce risks, we add more reserve. However, it is better for the reserve to be always at an optimum level (neither too high nor too low). There can be some minor setbacks for the activity duration since it depends on various factors, such as:

- Resource attrition
- Resource at activity taking leave
- External factors like strike, etc.

We may accommodate the above factors by doing reserve analysis.

The Role of a Project Manager in Estimation

Many of the estimates discussed so far are created not by the project managers, but by the team members or resources are assigned to actually carry out the activities. A project manager, however, provides team members with sufficient information to accurately estimate the duration of activities, after communicating to them the criticality of the accuracy of their estimates. The project manager also performs a sanity check of the estimates received, in addition to formulating a contingency management plan. As in all other processes, the project manager documents the assumptions made during estimating for later review.

At the end of this process, the duration of the project activities are arrived at which gives an indication how big or small the project duration is. It may also include some indication of the range within which the duration can vary in cases of uncertainties in the project.

10.3.5 Developing the Schedule

As we have now identified all the tasks in the project, their dependencies and resource requirements and as we have also estimated the duration that each activity will be taking, now our task is to put all these information together and create the project schedule. So, the next task is to determine the start and end dates of the project activities. Once we put the activities with their start and end dates, connect the activities through their dependencies, put the resource calendar and also analyse the possible options to shorten the schedule, we finally get the project start and end dates. Figure 10.13 shows the steps involved in this process.

Figure 10.13 Develop Schedule

All the artefacts that we created till the last step are considered while creating the schedule like, activity list, activity attributes, PSDN, resource calendar and activity duration estimates.

Definition of Float/Slack

The concept of float and slack is important for understanding how the project activities are scheduled with sufficient flexibility.

Total Float/Slack: This is the time for which completion of an activity can be delayed without delaying the project end date or an intermediary milestone.

Free Float/Slack: This is the time for which completion of an activity can be delayed without delaying the early start date of its successor activities.

Project Float/Slack: This is the time for which completion of a project work can be delayed without delaying the externally imposed project completion date (imposed by the customer).

Schedule Creation Techniques

Some of the well-known techniques for schedule development are as follows:

1. Schedule Network Analysis

Schedule network analysis is a technique that generates the project schedule using the PSND. It employs various techniques, such as Critical Path Method (CPM), schedule compression techniques, what-if analysis, critical chain analysis, etc. as elaborated here. It also uses resource levelling techniques to compress the schedule by identifying path convergence and path divergence.

2. Critical Path Method (CPM)

In this technique, the theoretical early start and end dates, and late start and end dates for all activities are calculated without considering any resource constraint through forward and backward pass. CPM is a method of using network analysis techniques to identify those tasks that are on the critical path, that is, where any delay in the completion of these tasks will lengthen the project timescale, unless action is taken. Critical path is the longest path which is the minimum duration of a completion of a project. There can be more than one critical path and those increases the risks in the project because all these paths need to be monitored closely to avoid any possible delay. A critical path can change during the project life cycle as the duration, dependency and resource requirement, etc., of the tasks may change over time. These are discussed here:

- The network diagram does not change when the end date changes. The project manager should investigate the options, such as fast-tracking and crashing the schedule to meet the new date and then change the network diagram following the approved changes.
- When a project has a negative float, the project manager should consider compressing the schedule. For all activities in critical path, the float will be zero. Figure 10.14 shows calculation of critical path for a process.
- In the diagram (Figure 10.4) the project has 8 nodes and the activities that need to be performed to move from one node to the next are shown as the arrows (Refer to PSDN for more explanations). The estimated duration of each task is mentioned above the arrow. There are parallel activities that are taking place in this project, but the minimum duration of the project is the length of the critical path as calculated here.

Figure 10.14 Critical Path Calculations

Path Convergence

The merging of different network paths into the same node in a project schedule network diagram is called 'path convergence'. It is usually characterized by a schedule activity with more than one predecessor activity. The merging of different network diagrams into a single node is also called 'path convergence'.

Path Divergence

This is the opposite of path convergence. Branching of different paths from a single path or node is called 'path divergence'. For example, when we are handling a software project, design for different modules can be progressed in parallel after requirement analysis is done.

Figure 10.15 shows an example on path convergence and path divergence.

3. What-If Scenario Analysis

What-If Scenario Analysis (WISA) is a powerful tool that can analyse various 'What-If' scenarios to determine the schedule of a project.

The schedule of a project depends on various parameters including, but not limited to:

1. Resource utilization
2. Cost factors
3. Dependencies of activities
4. Risk parameters
5. Unknown external factors like, strike, storming, etc.

Figure 10.15 Path Convergence and Path Divergence

The WISA estimates the effect that each potential event may have on the project schedule. This allows the project team to plan for contingency and mitigation plans in case any adverse scenarios may take place during the project execution. There are several simulation techniques which help in calculating the effect of different combination of scenarios on the project schedule. Monte Carlo simulation is such a powerful simulation technique.

4. Schedule Optimization

Schedule optimization is mandated when execution of a project as per schedule has been affected because of internal or external factors, upon which a project manager is required to optimize schedule. Here is a list of the tools which a project manager commonly uses to optimize a project schedule.

Crashing

Here, total project duration is decreased with minimal compromises on original objectives. We, usually add extra resources to decrease the project duration. Consequently, the cost of the project increases due to the crashing technique.

Fast Tracking

Here, instead of processing in sequence as per the project schedule, the activities are processed parallelly. The risks associated with projects increase by doing things in parallel. Activities in critical path that are to be done in parallel are first identified to reduce the overall project duration. In this technique, either the duration of critical activities is shortened or working hours increased.

5. Resource Levelling

Resource levelling is the reapportioning of available resources to avoid over-allocation or under-allocation and to ensure that activities are performed with maximum efficiency.

Here, peak overloads are reduced by redistributing allocations to activities with float (discussed later in this section). This optimization technique can increase the activity duration.

Figures 10.16 and 10.17 illustrates this tool. Application of resource levelling can result in the same tasks (say Tasks A, B, and C) being completed in five days with only six resources, whereas without resource levelling tool applied, the tasks may have used eight resources to complete the tasks. The resource leveling tools are as follows:

Figure 10.16 Before Resource Levelling

Figure 10.17 After Resource Levelling

- *Rule of Thumb*: Allocate scarce resources to critical path activities first.
- *Increased Project Duration*: Often results in a project duration that is longer than the preliminary schedule.
- *Reallocation*: Resource reallocation and adjustments are used to bring the schedule back or as close as possible to the originally intended duration.
- *Reverse Resource Allocation*: Resource is scheduled in reverse from the project end date.
- *Critical Chain*: A technique that modifies the project schedule to account for, and accommodate limited resources.

6. Critical Chain Method

This technique modifies the project schedule to account for limited resources, mixes deterministic and probabilistic approaches, and puts more emphasis on the resources. When resources are always available in unlimited quantities, then a project's critical chain is identical to its critical path. This technique involves adding duration buffers which are not actual activities. In this technique, the following steps used to calculate earliest and latest times:

Earliest Time (TE):

1. For the start node, TE = 0.
2. Begin from the start node and move toward end node in all paths. Add duration with previous node's TE to arrive the TE for the new node.
3. If more than one value comes for a particular node, insert the maximum value in that node.

Latest Time (TL):

1. For the end node TL = TE.
2. Begin from the end node and move backward toward start node in all paths. Subtract duration with previous node's TL to arrive the TL for the new node.
3. If more than one value comes for a particular node, insert the minimum value in that node.

Figure 10.18 Gantt Chart

The schedule created using these tools and techniques which acts as the basis of all the plannings in the project. There are several representations possible for a project schedule, but the most common one is the Gantt chart.

Gantt Chart

The most common representation of the project schedule is through a Gantt chart. The types of Gantt charts mostly used are:

Bar Chart: It displays activity start and end dates as well as expected duration.

Milestone Chart: It displays scheduled start or completion of the major deliverables.

Combination Chart: It displays events and activities as a function of time.

Figure 10.18 represents a bar type Gantt chart.

10.3.6 Controlling the Schedule

During the life cycle of a project, one of the key activities that the project manager needs to perform is to monitor, track and update the project schedule called 'controlling the schedule'. The main steps under this process are:

- Measuring the current status of the project schedule.
- Influencing the factors that cause schedule changes, ensuring that these are agreed upon.
- Determining the reason for the deviation, if any.

- Managing the changes when they occur.

The schedule control process is used to monitor the status of project execution, to update on project progress, and to manage changes in the schedule for its baseline, if required. Following are the important metric and tools concerning schedule control (See Figure 10.19).

Project Schedule: The approved project schedule is called 'schedule baseline'. It provides the basis for measuring and reporting schedule performance.

Work Performance Information: This information updates the project manager on schedule performance, such as which planned dates have been met and which have not.

Performance Reviews (Earned Value): This process involves in the assessment of schedule variations to determine whether they require corrective actions.

Figure 10.19 Control Schedule

Progress Reporting: The progress reporting and current schedule status include information, such as actual start and end dates as well as the remaining durations for incomplete schedule activities.

PM Software: This schedule-control tool is used for tracking planned dates against actual dates and forecasting.

Variance Analysis: This tool compares the target dates with the actual forecasted start and end dates to analyse variance.

Work Performance Measurements: This tool is used to calculate Schedule Variance (SV) and Schedule Performance Index **(SPI)** values for **WBS** components, in particular, the work packages and control accounts, and also document and communicate the same to the stakeholders.

Points to Remember

The following steps are adhered for effective project schedule management:

- Estimation based on a WBS will improve accuracy.
- Activity duration should be estimated by the resource actually performing the activity.
- Use of historical information improves accuracy of estimates.
- A schedule baseline should be maintained and not changed except for approved project changes.

- Estimates are more accurate if smaller-sized work components are estimated. Bottom-up estimation is the most accurate type of estimation.
- Corrective and preventive actions should be recommended when schedule problems occur.
- Continuous monitoring of schedules helps in anticipating deviations.
- Plans should be revised during completion of the work.

10.4 Project Scheduling Tools

Most of the common project management tools provide the facility to create and manage project schedules. The basic capabilities of the scheduling tools are, facility to sequence project activities, mark the activity dependencies and assign dates and resources to them. More sophisticated scheduling tools provide advanced facilities like resource levelling, critical path analysis and tracking. Scheduling tools may provide support for:

- Defining dependency relationship (single or multiple) types between activities.
- Resource assignment and resource leveling.
- Critical path analysis.
- Estimating activity duration and probability-based simulation.
- Activity cost accounting.

It is expected that the scheduling software should provide information related to the activities, duration, resource availability and planning costs, monitoring and tracking the projects. Scheduling software is expected to provide the following information to different stakeholders:

- Overview of how long the tasks will take to complete.
- Early warning of any risks of schedule failure in the project.
- Information on workload or holiday plans.
- Tracking of actual and planned performance.
- Utilization of available resources.
- Cost of projects.
- Status tracking of projects.

Microsoft Project, ZOHO Projects, FastTrack Schedule 9, Primavera P6 and @task are some of the popular project schedule management tools.

SUMMARY

Time management of a project produces the schedule baseline. From WBS, in particular from the workpackages, individual activities to be scheduled and activity durations for the schedule are determined.The activities are sequenced in a logical order called a network diagram using the PDM method. ‘Fast-tracking’ and ‘crashing’ are two techniques for optimizing schedules. Buffering is a technique for adjusting the schedules for accommodating future risks. All activities on critical paths are called ‘critical activities’. Slack or float is the time for which a task can be delayed without delaying successor activities.

- **Activity:** Work performed during the course of a project (Normally it has duration, cost, and resource requirements).
- **Critical Path:** Longest path, float less than or equal to specified value, mostly zero. This series of activities determines the earliest completion of the project and, is usually defined as those activities with float less than or equal to a specified value (usually zero).
- **Float:** The overall amount of time that an activity may be delayed from its early start without delaying the project finish date (It is also called ‘slack, total float and path float’).
- **Lag:** Modification of a logical relationship which directs a delay in the successor task and they are basically inserted waiting times in between tasks.

- **Lead:** A modification of a logical relationship where the successor task can be started earlier than planned. For example, in a Finish to Start relationship with a six day lead, the successor can start six days prior to the completion of the predecessor.
- **Milestone:** A significant event in the project, usually completion of a major deliverable, which determines the signal to go ahead to the next phase or project.
- **Precedence Diagram Method (PDM):** It is the network diagramming technique where activities are represented by nodes. Activities are linked by precedence relationships to show the logical sequence in which the activities are to be performed.
- **Resource Leveling:** Form of network analysis in which start and finish dates are driven by resource management concerns. Resource leveling refers to keeping the resources same across the duration of the project, thereby, avoid resource overloading.

EXERCISES

PART A (Objective-type Questions)

1. Fast-tracking is also known as
    1. Overtime
    2. Resource leveling
    3. Crashing
    4. Concurrent engineering
2. Which of the following relationship represents concurrency between two activities?
    1. Start-to-start
    2. Finish-to-start
    3. Start-to-finish
    4. Finish-to-finish
3. Fast-tracking usually adds more
    1. Cost
    2. Risk
    3. Time
    4. Scope
4. This kind of dependency is difficult to change
    1. Mandatory dependencies
    2. Discretionary dependencies
    3. External dependencies
    4. Nothing is difficult to change
5. This kind of dependency is inherent in the nature of the work
    1. Mandatory dependencies
    2. Discretionary dependencies
    3. External dependencies
    4. Team dependencies
6. Between any two activities how many logical relationships are possible?
    1. 2
    2. 4
    3. 3
    4. 6
7. Which structure is a hierarchal structure of human resources, organized by function?
    1. RBS
    2. WBS
    3. OBS
    4. EBS
8. Lag allows the following type of relationship
    1. Finish–Start
    2. Start–Start
    3. Finish–Finish

4. Start–Finish

PART B (Write the answer in one or two lines)

1. What is milestone list?
2. Define lead and lag. Give an example.
3. What is resource breakdown structure? Give example.
4. What is GERT?
5. What are path convergence and path divergence?
6. What are fast-tracking and crashing?
7. Discuss various project time management processes in detail.
8. Discuss three different types of project dependencies in detail with examples.
9. Discuss four different types of relationships possible between any two activities with examples for each.
10. Discuss crashing, fast-tracking, resource leveling with examples.