Unit 4: Network Techniques

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4.1 PERT (Program evaluation and review technique) And CPM (Critical path method)

**Introduction:** network analysis plays an important role in project management. With the help of network analysis, the planning, scheduling and control of a project becomes easier. Network provide a comprehensive study of the entire project in terms of precedence and succession of various activities the resources available to perform the activities with an object to involve some better and quicker plan to complete the work.

A network is a graphic representation of a projects operations is composed of activities and events that must be completed to reach the objective of the project. Projects networks can be used to plan, record and document a schedule and to track actual results again the schedule.

PERT is a network technique of management activities like POSTDCORB. PERT (Program Evaluation and Review Technique) is used to assist in project scheduling similar to CPM. However, PERT assumes that activity durations are random variables (i.e., probabilistic).

• Project Network The first step in CPM/PERT is to construct a project network.

In the project network each activity is represented by an arc connected by two nodes. The first node represents the start of the activity and the second node represents the end of it. The network should reflect activities precedence relations.

This technique is used for large scale projects.
It is mainly used to analyze the project scheduling problems wherein the minimum time required for completing of each task.
A project is defined by a set of activities.
Each activity is defined by its duration (time to complete the activity) and its predecessors (activities that must be completed before the activity can start).

**Components of a network are:**

1. **Activity:** a task or item of work to be done, that consumes time, effort, money or other resources. It lies between two events called reading preceding and succeeding ones. Activity is represented by an arrow with its head indicating the sequence in which the events are to occur.
2. **Event**: an event represent the start or end of the activity. It has no time duration and does not consume any resources. It is also known as a node. An event is generally represented on the network by a circle, rectangle, hexagon or other geometric shape. Activities are identified by numbers of their starting event and ending event.

Predecessor activity: an activity which must be completed before one or more other activities known as producers activity.

Successor activity: activity which started immediately one or more of other activities known as success activity.

Dummy activity: an activity which does not consume either any resources or time is known as the main activity. It is shown by dotted in the network diagram.

3. **Remark**: a dummy activity in the network is added only to represent the given precedence relationships about activities of the project. When two or more parallel activities in a project have same head and tail events. When two or more activities have some of their immediate predecessor activity in common.

**Network techniques**: PERT and CPM are two network techniques

**PERT- program evaluation and review technique**: 
It uses three time estimates for an activity rather than a single estimation.1. Optimistic time(a) 2. Most likely time(m). 3. Pessimistic Time(b)

**Steps in PERT:**

1. **Drawing the pert network**: there are two common techniques for drawing pert network. AON- activity on node, the nodes represent the activity. AOA- activity on arc, the arcs are used to represent the activity. Activity on node technique is easier often used in commercial software

2. **activity time**:

   Pert technique used probability distribution based on three time estimates for each activity. Activity time estimation is not always an easy task. Without solid historical data managers are often uncertain.

   Optimistic time: this is the shortest time the activity can take to complete. There is more than one chance in a hundred of completing the activity in this amount of time. It represents an ideal estimate.

   Most likely time: this refers to the time that would be expected to occur most often if the activity where frequently repeated under exactly the same condition. It is the model time.

   Pessimistic time: this is the longest time the activity could take to finish. It is the worst time estimate represents the time the activity would take if bad luck was faced. It occurs with the probability of less than 1%.
Typically, completion of a given activity is assumed to follow beta distribution.

Average time: the three-time estimates are reduced into a single expected time with the weighted average formula:

\[ Tei = \frac{a+4m+b}{6} \]

Where, \( tei \) = expected time of the \( i \)th activity
\( A \) = optimistic time, \( m \) = most likely time, \( b \) = pessimistic time.

The standard deviation of and calculated activity of a time of an activity is calculated as follow,

\[ \sigma = \frac{b-a}{6} \]

Identifying critical path: once the expected completion time for each activity has been determined. Now the minimum time required for the completion of the whole project will be calculated, by analyzing network and determining critical. A path is a set of continuous series of activities through the network that lead from the initial node of the network to its terminal node.

Critical path is the longest path route through the network.

To find the critical path, we need to determine following quantities for each activity in the network.

**Earliest start time (ES):** the earliest time at which an activity can end

**Latest start time (LS):** the latest time an activity can begin without delaying the entire project

**Latest finish time (LF):** latest time an active can end without delaying the entire project

Probability of completing the project within given time:

After identifying the critical path and the occurrence times of all activities, now to find out what is the probability of a particular event on or before the scheduled date. This particular event may
be any event in the network which marks a significant state in the project and subsequent project activity.

**Advantages of PERT:**

1. Fan for production time event analysis is quite impossible without planning and seeing how the pieces together.
2. What encourages management control by exception? It concentrates attention on critical events that may need.
3. The network system with its subsystems creates a pressure for action at the right spot and level and at the right time.
4. It enables forward working control as a delay will affect the succeeding events and possibly the whole project. PERT can be effectively used for rescheduling the activity.
   5. It compels managers to plan their projects critically and analyse all factors affecting the progress of the plan. The process of the network analysis requires that the project planning be conducted on considerable detail from the start to the finish.
   6. It provides the management a tool for forecasting the impact of schedule changes and be prepared to correct such situations. The likely trouble spots are located early enough so as to apply some preventive measures or corrective actions.
   7. A lot of data can be presented in a highly ordered fashion. The task relationships are graphically represented for easier evaluation and individuals in different locations can easily determine their role in the total task requirements.
   8. The PERT time (Te) is based upon 3-way estimate and hence is the most objective time in the light of uncertainties and results in greater degree of accuracy in time forecasting.
   9. It results in improved communication; the network provides a common ground for various parties such as designers, contractors, project managers etc. and they must all understand each other’s role and contributions.
10. The network will highlight areas that require attention of higher priority so that concentration can be applied to the key jobs without ignoring the lower priority tasks. This gives the management an opportunity to shift attention to any critical task so that the entire project is completed in time.

**Disadvantages of PERT:**

1. It is time consuming and expensive technique
2. It is based on beta distribution and the assumption of Beta distribution may not always be true.
3. PERT is not suitable when program is nebula and a reasonable estimate of time schedule is not possible.
4. It is not useful for routine planning of recurring events such as mass production because once a repetitive sequence is clearly worked out, elaborate and continuous control is not required.
5. The expected time and the corresponding variances are only estimated values.
6. Uncertainty about the estimate of time and resources. These must be assumed and the results can only be as good as the assumptions.
7. The costs may be higher than the conventional methods of planning and control. Because of the nature of net working and net work analysis, it needs a high degree of planning skill and greater amount of details which would increase the cost in time and manpower resources,
8. It is not suitable for relatively simple and repetitive processes such as assembly line work which are fixed-sequence jobs.
9. Hence PERT is not very effective in manufacturing operations, since it deals in the time domain only and does not deal with the quality information which is necessary in manufacturing processes.

**CPM (Critical Path Method):**
Is used to assist the project manager in scheduling the activities (i.e., when should each activity start). The sequence of activities lying on longest duration is known as critical path, it would cause a delay in the whole project. To quicken the process, the activities lying on the critical path should be taken first.

**Objectives of CPM:**
1. To determine a route between two or more operations which optimizers some measures of performances.
2. To locate the obstacles and difficulties in a production process.
3. To assess the starting and finishing Times every operation
4. To determine the float associated with each non critical activity.

**Advantages of CPM:**
1. It identifies most critical element and pay more attention to these activities.
2. It assists avoiding waste of time, energy and money on unimportant activities.
3. It provides a standard method for communicating project plan, schedules and cost.
   CPM technique is very useful analysis in production planning of a large project.

**Scope of pert and CPM:**
Launching a spacecraft
Research and development program
Construction of plant
Building a river valley project
Training of Manpower
Starting a new venture

**The following steps are required for using CPM and PERT for planning and scheduling:**
Each project consists of several independent jobs or activities. All these jobs or activities must be separately listed. It is important to identify and distinguish the various activities required for the completion of the project and list them separately.

Once the list of various activities is ready the order of precedence for these jobs has to be determined. We must see which jobs have to be completed before others can be started. Obviously, certain jobs will have to be done first.

Many jobs may be done simultaneously and certain jobs will be dependent upon the successful completion of the earlier jobs. All these relationships between the various jobs have to be clearly laid down.

The next step is to draw a picture or a graph which portrays each of these jobs and shows the predecessor and successor relations among them. It shows which job comes first and which next.
It also shows the time required for completion of various jobs. This is known as the project graph or the arrow diagram.

The three steps given above can be understood with the help of an example. Suppose, we want to construct a project graph of the simple project of preparing a budget for a large manufacturing firm. The managing director of this company wants his operating budget for the next year prepared as soon as possible.

To accomplish this project, the company salesmen must provide sales estimates in units for the period to the sales manager. The sales manager would consolidate this data and give it to the production manager.

He would also estimate market prices of the sales and give the total value of sales schedules of the units to be produced and assign machines for their manufacture. He would also plan the requirements of labour and other inputs and give all these schedules together with the number of units to be produced to the accounts manager who would provide cost of production data to the budget officer.

Using the information provided by the sales, production and accounting departments, and the budget officer would make the necessary arrangements for internal financing and prepare the budget. We have seen that the project of preparing the budget involves a number of activities.

These activities listed in the order of precedence are given below:

<table>
<thead>
<tr>
<th>Job identification</th>
<th>Alternate</th>
<th>Description</th>
<th>Deptt.</th>
<th>Time of performing the Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>(1,2)</td>
<td>Forecasting units of sale</td>
<td>Sales</td>
<td>14 days</td>
</tr>
<tr>
<td>b</td>
<td>(2,4)</td>
<td>Pricing sales</td>
<td>Sales</td>
<td>10 days</td>
</tr>
<tr>
<td>c</td>
<td>(2,3)</td>
<td>Preparing production schedules</td>
<td>Production</td>
<td>7 days</td>
</tr>
<tr>
<td>d</td>
<td>(3,4)</td>
<td>Costing the production</td>
<td>Accounting</td>
<td>4 days</td>
</tr>
<tr>
<td>e</td>
<td>(4,5)</td>
<td>Preparing the budget</td>
<td>Budget</td>
<td>10 days</td>
</tr>
</tbody>
</table>

In this graph jobs are shown as arrows leading from one circle on the graph to another. Thus, the arrow connecting the two circles represents a job. Circle one and two represent job a i.e. forecasting of units sale which would take 14 days.
Circles 2 and 4 represent job b which will take ten days and so on. It would be seen that job c is not dependent upon job b and therefore, the two jobs can be done simultaneously. Once we reduce the project to network of activities and events and we estimate activity durations, we are in a position to determine the minimum time required for completion of the whole project.

To do so, we must find the longest path or sequence connecting the activities through the network. This is called the ‘critical path’ of the project. The longest path is the critical path. In our example, there are two paths. One is connecting circle numbers 1, 2, 4 and 5. This path will take 14+10 + 10 = 34 days.

The other path, is connecting circles 1,2,3,4 and 5, this path will takes 14 + 7 + 4+ 10 = 35 days. Obviously the 2nd path is the critical path and the project of budget presentation will take this much of time. The students will however notice that this time is shorter than the total time listed under Table 1 which will be 45 days. This is because jobs b and c can be done simultaneously.

What we have basically described above is the very careful technique of CPM and PERT which consists of decomposing project into activities and then ordering activities according to their relationships to find out the shortest time required to carry on an activity.

This technique is very useful in case of projects which involve a large number of activities. It makes the project manager list out all the possible activities, their relationships, find out which activities can be performed first, which next and which can be performed simultaneously so as to find out the best possible manner of completing the project.

A good project network goes a long way in reducing costs. Many companies work out the cost estimate of each activity and show
<table>
<thead>
<tr>
<th>BASIS</th>
<th>PERT</th>
<th>CPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meaning</td>
<td>PERT is a project management technique, used to manage uncertain activities of a project.</td>
<td>CPM is a statistical technique of project management that manages well defined activities of a project.</td>
</tr>
<tr>
<td>What is it?</td>
<td>A technique of planning and control of time.</td>
<td>A method to control cost and time.</td>
</tr>
<tr>
<td>Orientation</td>
<td>Event-oriented</td>
<td>Activity-oriented</td>
</tr>
<tr>
<td>Evolution</td>
<td>Evolved as Research &amp; Development project</td>
<td>Evolved as Construction project</td>
</tr>
<tr>
<td>Model</td>
<td>Probabilistic Model</td>
<td>Deterministic Model</td>
</tr>
<tr>
<td>Focuses on Estimates</td>
<td>Time</td>
<td>Time-cost trade-off</td>
</tr>
<tr>
<td>Estimates</td>
<td>Three time estimates</td>
<td>One time estimate</td>
</tr>
<tr>
<td>Appropriate for</td>
<td>High precision time estimate</td>
<td>Reasonable time estimate</td>
</tr>
<tr>
<td>Management of</td>
<td>Unpredictable Activities</td>
<td>Predictable activities</td>
</tr>
<tr>
<td>Nature of jobs</td>
<td>Non-repetitive nature</td>
<td>Repetitive nature</td>
</tr>
<tr>
<td>Critical and Non-critical activities</td>
<td>No differentiation</td>
<td>Differentiated</td>
</tr>
<tr>
<td>Suitable for</td>
<td>Research and Development Project</td>
<td>Non-research projects like civil construction, ship building etc.</td>
</tr>
<tr>
<td>Crashing concept</td>
<td>Not Applicable</td>
<td>Applicable</td>
</tr>
</tbody>
</table>
4.2 Risk Analysis Using Simulation with Crystal Ball 2000:

**Introduction:** risk can be defined as the chance that the actual outcome from an investment differs from the expected outcomes. Risk analysis is a function of uniqueness of a project and the experience of the project team. Managers can anticipate the range of potential outcomes and manipulate aspects of the system design and project plan to achieve the outcomes desired. Therefore, risk analysis is one of the most complex and slippery aspects of capital budgeting. Many different techniques have been suggested and no single technique can be deemed as best in all situations. Spreadsheet risk analysis uses both a spreadsheet model and a simulation to analyze the effect of inputs and outputs of the model system. One type of spreadsheet simulation is Monte Carlo simulation. This randomly generated values for uncertain variables over and over to simulate a model.

**Crystal ball 2000:**
Crystal ball is an analytical tool that helps executives, analysts, and others make decisions by performing simulations on spreadsheet models. So decision makers can have information as possible to support wise decision.
Monte Carlo simulation was named for Monte, Carlo, Monaco, the primary attractions casinos containing games of chance, such as slot machines, dice etc....
Call is the spreadsheet based application suits for predictive modeling, forecasting, simulation and optimization. It gives unparalleled insight into the critical factors affecting risk. With crystal ball one can make correct tactical decisions to reach the objectives and gain a competitive edge under even the most uncertain market conditions. Crystal ball 2000 easy to use simulation program that helps to analyze the risks and uncertainty associated with the Excel spreadsheet model. Crystal ball is for anyone who uses spreadsheets and needs to forecast uncertain results. Geologist, Reservoir engineer, geophysicist and managers for upstream and downstream division all rely on crystal ball to improve quality of their decision making process. Crystal ball starts spreadsheets and by letting you Monte Carlo simulation.
Assumptions: in crystal ball, probability distributions are referred to an assumptions and are the basic inputs find the uncertainty in any model variable. Crystal ball offers 16 predefined distributions and one customizable distribution. The four most commonly used assumptions are the normal, triangular, uniform and lognormal. In this example, you define assumptions based on your own knowledge and intuition. Crystal ball improves the ability to analyze variables and save on the time paint building models. These professionals are ideal for portfolio analysis and project management.

**Steps for crystal ball:**
1. Create a spreadsheet model in Microsoft Excel format with data and formula sales.
2. Start crystal ball to load automatically with Microsoft Excel.
3. Load spreadsheet model
4. Using crystal ball define assumption sales and forecast sales
5. Set Run for simulation
6. Analyze the results
7. Consider using crystal ball predictor
8. Take advantages of the many resources to help to get most out of crystal ball

**Gantt chart**

Introduction: the Gantt chart was developed by Henry L Gantt about a century ago. Their purpose is to provide an immediate comparison between schedule and reality. A Gantt chart is a type of bar chart that illustrates a project schedule. Gantt charts illustrate the finish date of the terminal elements and summary elements of a project. Terminal elements and summary elements comprise the work breakdown structure of a project. Gantt charts can be used to show current schedule status using percent complete shading. The Gantt chart is actually a modified bar chart in which horizontal bars are drawn for each activity in proportion to the time required for completion. A cursor attached to the Gantt chart can be more across the chart to compare between the actual progress and plant work till any particular date.

**Advantages of Gantt chart:**
1. Simple to draw and read
2. Good for static environment
3. Useful for providing overview of project activity
4. Very widely used and calls for no special knowledge of mathematics

**Limitations of Gantt chart:**
1. Consists of too many activities, it becomes clumsy, to draw the chart. So difficult to Complex activities
2. Does not give any data about what exactly is completed and what is not
3. As the chart combines plan and schedule it is difficult to know whether the activities have optional starting dates.
4. The chart does not exhibit the dependencies or interrelationship between the activities and as such it is difficult to say what will be the effect of delay of one activity over the other.
5. Gantt chart is not at all useful in those projects where there are uncertainty is in determination or estimation of time required for the completion of various activities.
6. Gantt charts are useful for only small size projects specially construction and manufacturing projects, in which time estimates can be made with fair degree of uncertainty.

**Symbols used in Gantt chart:**
- Start of the activity----- [ 
- End of the activity------- ]
- Actual progress of the activity------- [ ]
- Point in time where the project is now------- V

**CRITICAL PATH METHOD – CRASHING A PROJECT**

Crashing is a schedule compression technique used to reduce or shorten the project schedule.

- **Adding additional resources to the critical path tasks**
  - this option has various constraints such as the securing of the budget to add the resources, and the availability of the resources.
- **Reduce the project requirements or scope**
  - This can be done only if the sponsor and major stakeholders agree to reduce the scope.
  - After applying the crashing, the critical path might have changed and result in creating a different critical path. Always revisit the project schedule to ensure the schedule has been crashed.

**STEPS IN CRASHING A PROJECT**

1. Schedule a project with all its activities at their normal duration. Identifying path and critical activities.
2. Calculate the cost for different activities and rank the activities in the ascending order of cost slope.
3. Crash the activities based on their rankings.
4. As the critical path duration is reduced by the crashing, other paths may also become critical.
5. After crashing one reaches a point when further crashing is either not possible or does not result in the reduction of crashing of project duration.
6. Compute the total project cost by adding corresponding fixed cost to the direct cost, which is obtained by adding the crashing cost cumulatively to the normal cost.

**NETWORK COST MODELS:**

**Direct costs**

Direct costs are expenses that a company can easily connect to a specific "cost object," which may be a product, department or project. This includes items such as software, equipment and
raw materials. It can also include labor, assuming the labor is specific to the product, department or project.

For example, if an employee is hired to work on a project, either exclusively or for an assigned number of hours, their labor on that project is a direct cost. If your company develops software and needs specific regenerated assets, such as purchased frameworks or development applications, those are direct costs.

Labor and direct materials, which are used in creating a specific product, constitute the majority of direct costs. For example, to create its product, an appliance maker requires steel, electronic components and other raw materials. Two popular ways of tracking these costs, determining whether and when your company actually uses materials in production, include last in, first out (LIFO) or first in, first out (FIFO). This can be helpful when the costs of materials fluctuate in the course of production.

The majority of direct costs are variable. When direct costs vary, it's because they increase as additional units of a product or service are created. For example, smart phone hardware is a direct, variable cost because its production depends on the number of units ordered. A notable exception is direct labor costs, which are usually fixed, and remain constant throughout the year. Typically, an employee's wages do not increase or decrease in direct relation to the quantity of a product.

**Indirect costs**

Indirect costs go beyond the expenses associated with creating a particular product to include the price of maintaining the entire company. These overhead costs are the ones left over after direct costs have been computed, and are sometimes referred to as the "real" costs of doing business.

The materials and supplies needed for the company's day-to-day operations are examples of indirect costs. These include items such as cleaning supplies, utilities, office equipment rental, desktop computers and cell phones. While these items contribute to the company as a whole, they are not assigned to the creation of any one service.

Indirect labor costs make the production of cost objects possible but aren't assigned to a specific product. For example, clerical assistants who maintain the office support the company as a whole instead of just one product line. Thus, their labor can be counted as an indirect cost.

Other common indirect costs include advertising and marketing, communication, "fringe benefits," such as an employee gym, and accounting and payroll services.

Much like direct costs, indirect costs can be both fixed and variable. Fixed indirect costs include things like the rent paid for the building in which a company operates. Variable costs include the ever-changing costs of electricity and gas.

**RESOURCE ALLOCATION:**
Resource allocation is very important function for identification of main problems with the help of various network techniques for identification of critical activities. The project must be finished by a certain time, using few resources but every project has a time constraints.

Resource allocation helps you to choose the best available resources for your projects and manage them throughout the work, so you can avoid under or overutilization of your employees. Sadly, not all project managers use it to their advantage.

How do we know that?

Only 26% of companies always use resource management to estimate and allocate resources, and 36% of them do it often, according to last year’s PMI’s survey. At the same time, less than 60% of projects meet the original budget and barely 50% of them are being completed on time, the same study says.

If this is the case with you or your company, you should definitely learn more about resource allocation and resource planning. Especially, as the very same study says that resource dependencies, inadequate resource forecasting and limited resources account for many projects’ failures.

From this article you will learn:
- what is resource allocation,
- how to implement it at your organization,
- How it helps project managers in their work.

**Resource allocation definition**

Resource allocation—part art, part science as some call it—is recognizing the best available resources for the project, assigning them to your team and monitoring their workload throughout the work, and re-assigning resources if needed.
“In project management, resource allocation or resource management is the scheduling of activities and the resources required by those activities while taking into consideration both the resource availability and the project time.” –Wikipedia

Proper allocation of resources increases the effective use of resources available across the company to maximize their utility.

**RESOURCE CONSTRAINTS METHODS OR HEURISTIC METHODS:**
This rule is based on decision rules called priority rules or dispatching rules like as soon as possible, as late as possible, shortest task time, least slack, first come first served, earliest due date etc.

**Common challenges of resource allocation**
Resource management is prone to several challenges that you need to be aware of to properly allocate resources and manage them throughout the project.

1. **Client changes**
   As a project manager you might have already experienced how changes to the scope, timeline or budget can affect project delivery. With resource allocation it’s actually the same – having an up-to-date resource calendar will help you to smoothly adjust resources once the changes appear.

2. **Availability of resources**
   **Starting off a new project,** ideally you could use any resources you need that are available at your company. But what if your agency is running multiple projects and you have to negotiate over the same resources with another PMs? Or what if a given team member is out on their sick leave? Availability changes and you have to monitor it all the time to spot threats to your project’s delivery.

3. **Project dependencies**
   Allocating resources, you need to include project dependencies, which are a form of a relationship between the tasks or activities in the project. For example, in IT projects there are tasks that can only be done after some other ones are completed, so there’s no point to hog resources early on.

4. **Project uncertainties**
   Even if you’ve checked all the boxes when starting off a project, agreed on the timeline, the budget and the scope, there’re always things you can’t predict. Resource management requires you to be able to respond to project uncertainties, e.g. by shifting resources from other projects or re-assigning them.
5. Priorities across the company

If your company runs multiple projects simultaneously, you and your peers may have to share limited resources, very often in a similar timeframe. But even if you manage to negotiate over resources you both need, there may be a change in priorities regarding one of the projects.

Resource allocation in project management: how to allocate resources

Let’s take a look at how to effectively use resources at your disposal.

1. Know the project and the team

Only knowing the scope and resources available at your company, you can properly assign team members to your project. Start by creating a high level plan of the project, consisting of its requirements and deliverables. Then, as you know exactly whom you will need to complete the project, you can use a skills matrix to discover which employees at your company to involve. Or, if you’re a Team deck user, you can simply filter your employees by their skills, spotting relevant employees and their existing bookings in no-time:

At this point, the rule of thumb is to not get carried away and over-allocate resources for the project. Actually, resource hogging is considered a mistake projects managers make to protect themselves from uncertainties. But, in turn, it makes project estimates and long-term plans inaccurate, affecting the company’s bottom line.

Always think of the big picture while allocating resources. Check the bookings already made by other PMs to spot resources you may both need, in case you should adjust your schedule to that.

Knowing when your team members have their days off helps, too. See the yellow entries below? You need to include them in your estimate, as that’s exactly when these employees will be unavailable. Similarly, you can spot national holidays taking place during your project.

Keep track of the project

Remember how resource allocation is about improving the effectiveness of your team’s utility? Now is the time to check how you’re team is doing. You can do it by measuring resource utilization.

Start with tracking the time and workload. In Team deck, you can easily spot employees with too much or too little (which can also be an issue) to do. Remember the availability bar? Overtime is marked with red color, while the unutilized time is white.
Measuring resource utilization, you can also use a simple formula:

**Resource utilization = Busy time / Available time**

During the project it’s also recommended to compare estimates with actual once in a while, and re-allocate resources if you need to. Chances are that because of some changes you need to adjust bookings to avoid under or overutilization of your resources, and to meet project’s requirements.

Setting up regular check-ins with your team will help you to spot these threats, too.

As a project manager, you may also be responsible for tracking your project’s budget. You can do it based on your team’s timesheets, multiplying the number of hours they’ve spent on the project by the rate you charge your client per hour. Again, by comparing estimates with actual, you can see if you’re on the budget, or not.

**4. Analyze the project**

Using the data you’d gathered during past projects will give you a huge advantage. Based on that data, you will be able to better plan and manage your future projects. Having a tool with custom reports helps a lot, as you can then organize that data to calculate different metrics, like employee payroll or sales KPIs.

**Benefits of resource allocation**

As you can see, following the right processes and using a complete resource management tool, you can make resource allocation easier and benefit from it in many ways:

- It improves visibility of all resources across the company
- You can avoid under and over-utilization easier
- It helps to keep bookings more accurate
- It’s easier to negotiate bookings with other PMs

**4.4 PROJECT PLANNING, MONITORING AND CONTROLLING**

Project monitoring and control are two stages of the project management process aimed at creating high quality software and delivering it in time. The third stage is called project planning. It usually takes place at the beginning of each software development project. Its main goal is to create a good and realistic plan of a certain project. The plan is required to define all actions of the team during the period of project realization and forecast the terms of product delivery. After the plan is created, the team begins the next stage of project management process – project monitoring.

This stage lasts during the entire period of project realization. Its main goal is to detect problems with plan implementation. Such problems should be neutralized because they can impact the
quality of the final software product and terms of its delivery. The third and the last stage of project management process is called project control. At this stage the problems with plan implementation are eliminated. After that the developers should test the final product to make sure that problems with project realization didn’t impact it negatively.

Now let’s return to the main topic of our article and discuss project monitoring and control tools.

The first thing we should know about them is that there are no special applications for project monitoring and control in modern software development industry. That is because of the fact that these two activities are parts of the project management process. Hence, software developers use project management tools to handle them.

These applications are capable of performing all functions necessary for project monitoring and control. Most of them are focused on visualizing the workflow of software development teams in various forms, including charts, diagrams, and tables. This function helps the developers monitor their projects and detect problems in them. If some problem appears, it is depicted at the chart or diagram immediately. Additionally, most modern project management tools can be used as issue tracking systems. It means that they can test software products and report on defects in them automatically. This function is just what developers need at the stage of project control.

**Reporting process:**

Everyone concerned with the project should be appropriately tied into the project reporting system. Personnel have a need for detailed information about individual tasks affecting such task. Report frequency is usually high. The structure of the reports should reflect the work breakdown structure (WBS). With each managerial level receiving reports that allow the control at the relevant level.

Report should be scheduled in the project plan. They should be issued on time. The nature of the monitoring report should be consistent with the logic of the Planning, budgeting and scheduling system.

**Benefits of report system:**

Mutual understanding of the goals of the project

Awareness of progress of parallel activities and problems associated with coordination among activities.

1. More realistic planning for the needs of all groups of people working on the project.
2. Understanding the relationship of individual tasks to one another.
3. Early warning signal of potential problems and delays in the project.
4. Minimizing the confusion associated with the change.
5. Higher visibility to top management.
6. The client and other interested outside parties up to date on project status.

7. Senior management levels overview reports describe progress in more aggregate terms with less individual task.

**Types of reports:**

**Routine:** on a regular basis, varies depending on what level.

**Exception:** directly oriented to project management decision making and should be distributed to the team members who have prime responsibility for decision. They may be issued when a decision is made on a exception basis.

Spatial analysis: to disseminate the results of special studies conducted as part of the project or as a response to special problems that arise during the project.

**Tools of monitoring a project**

There are two main tools used for monitoring a project.

1. **Earned value analysis**

   Is an integrated planning and control tool which integrates is cost and time. Earned value technique was set up initially to track the progress of cost and time, in practice it is often more appreciated to track progress measured as on man hours and time.

   Earned value is an approach where you monitor the project plan, actual work, and work completed value to see if a project is on track. Earned value shows how much of the budget and time should have been spent, with regard to the amount of work done so far.

   It is a method for measuring project performance. It compares the amount of work that was planned with what was actually accomplished to determine if cost and schedule performance is as planned.

   Earned value is also known as performance measurement, management by objectives, budgeted cost of work performed and cost schedule control system.

   Full implementation of earned value principles can result in:

   Better visibility into program performance
   Reduce the cycle time to deliver a product.
   Increased accountability
   Reduce the risk

   Earned value method shows a direct relationship between project on value and the percentage degree of accomplishment. It is simple and consistent measure to evaluate project progress. On value method allows to analyse project activities constantly. Comparing cost between project
activities. In the earn value analysis when evaluating the recency of accomplished work monetary and time units are used. By earned value method budget is formed, so called planned budget work which directly determines the amount of companies used financial resources related to planned activity.

**Steps in EV**

1. Set up an on value table
2. Calculate BCWS for the project, draw the curve BCWS against time
3. Track project two time now record the following data for each activity: percentage complete and A CWP
4. Calculate BCWP= BAC* PC, draw BCWP to time now
5. Draw a CWP to time now, and extrapolate the line to the new completion date. This will forecast the EAC
6. Calculate the variances
7. Plot varieties
8. Apply control

2. **Abandonment Analysis:**

Also known as termination of project, when future cash flow of the project becomes negative considers termination of project.

**Project control:**

Comparing actual performance with planned performance & taking appropriate corrective action.

**Introduction:**

The purpose of the project control process is to guarantee that design requirements, budget and schedule are met by project team. The plan involves checkpoints throughout the project cycle. As the project advances, the actual work is compared to the original plan

**4.5 The fundamental purpose of project control**

- The purpose of the project control process is to guarantee that design requirements, budget and schedule are met by project team.
- Project control begins with a plan composed of design documents, an estimate, and schedule
- The plan involves checkpoints throughout the project cycle.
• As the project advances, the actual work is compared to the original plan. Actions maybe taken based on this comparison.
• The expected cost and duration to complete the work must be continually updated and reported. Why?

**Types of project control process:**

1. **Cybernetic Control:**
   1. **First-order control system**
      
      Standard is set and there is no provision made for altering it except by intervention from outside.
   2. **Second order control system**
      
      This system can alter the system standards according to some predetermined set of rules or program.
   3. **Third order control system**
      
      Can change its goal without specific predetermines set of rules. It can work by its own way.

2. **Go/No go Control:**

   Used to know whether output meet its predetermined standard or not. These systems are flexible and can apply for all aspects of project management.

3. **Post controls:**

   Apply after the completion of project.

**Tools for project control**

1. **Variance Analysis**

   Must be tracked and reported schedule, technical performance or cost deviation from a specific plan,

   \[
   TV = STWP - ATWP
   \]

   Where, \( TV \) = Time variances

   \( STWP \) = SCHEDULE FOR WORK THAT HAS BEEN PERFORMED

   \( ATWP \) = ACTUAL TIME USED TO PERFORM IT
2. Cost Variances:
   
   It indicates how much over and under budget the project is.

   \[ CV = BCWP - ACWP \]  
   (Budget for work that has been performed - Actual cost of that work)

3. Scheduled Variances:
   
   It is a quantitative measure used to determine schedule performance during or after the completion of project.

   \[ SV = BCWP - BCWS \]  
   (Budgeted cost of the work performed - date and cost of the work to be performed)

4. **Trend Analysis**
   
   To predict future events, to measure uncertain events in the past, it is a project management quality control tool used for tracking variances in cost and schedule performance.

5. **Earned Value Analysis**
   
   It is an integrated planning and control tool which integrates cost and time.

6. **Critical Ratio**
   
   Is an index used by project managers as a tool to determine the status of a task.

7. **Benchmarking**
   
   If a company is to be successful, it needs to evaluate its performance in a consistent manner.

   In order to do so, businesses need to set standards for themselves and measure their processes and performance against recognized industry leaders or against best practices from other industries, which operate in a similar environment.

   This is commonly referred to as *benchmarking* in management parlance.

   The benchmarking process is relatively uncomplicated. Some knowledge and a practical dent is all that is needed to make such a process a success.

   Therefore, for the benefit of corporate executives, students and the interested general populace, the key steps in the benchmarking process are highlighted below.

   **A Step-by-Step Approach to Benchmarking**

   Following are the steps involved in benchmarking process:
(1) **Planning**

Prior to engaging in benchmarking, it is imperative that corporate stakeholders identify the activities that need to be benchmarked.

For instance, the processes that merit such consideration would generally be core activities that have the potential to give the business in question a competitive edge.

Such processes would generally command a high cost, volume or value. For the optimal results of benchmarking to be reaped, the inputs and outputs need to be redefined; the activities chosen should be measurable and thereby easily comparable, and thus the benchmarking metrics needs to be arrived at.

Prior to engaging in the benchmarking process, the total process flow needs to be given due consideration. For instance, improving one core competency at the detriment to another proves to be of little use.

Therefore, many choose to document such processes in detail (a process flow chart is deemed to be ideal for this purpose), so that omissions and errors are minimized; thus enabling the company to obtain a clearer idea of its strategic goals, its primary business processes, customer expectations and critical success factors.

An honest appraisal of the company's strengths, weaknesses and problem areas would prove to be of immense use when fine-tuning such a process.

The next step in the planning process would be for the company to choose an appropriate benchmark against which their performance can be measured.

The benchmark can be a single entity or a collective group of companies, which operate at optimal efficiency.

As stated before, if such a company operates in a similar environment or if it adopts a comparable strategic approach to reach their goals, its relevance would, indeed, be greater.
Measures and practices used in such companies should be identified, so that business process alternatives can be examined.

Also, it is always prudent for a company to ascertain its objectives, prior to commencement of the benchmarking process.

The methodology adopted and the way in which output is documented should be given due consideration too. On such instances, a capable team should be found in order to carry out the benchmarking process, with a leader or leaders being duly appointed, so as to ensure the smooth, timely implementation of the project.

(2) Collection of Information
Information can be broadly classified under the sub texts of primary data and secondary data.

To clarify further, here, primary data refers to collection of data directly from the benchmarked company/companies itself, while secondary data refers to information garnered from the press, publications or websites.

Exploratory research, market research, quantitative research, informal conversations, interviews and questionnaires, are still, some of the most popular methods of collecting information.

When engaging in primary research, the company that is due to undertake the benchmarking process needs to redefine its data collection methodology.

Drafting a questionnaire or a standardized interview format, carrying out primary research via the telephone, e-mail or in face-to-face interviews, making on-site observations, and documenting such data in a systematic manner is vital, if the benchmarking process is to be a success.

(3) Analysis of Data
Once sufficient data is collected, the proper analysis of such information is of foremost importance.

Data analysis, data presentation (preferably in graphical format, for easy reference), results projection, classifying the performance gaps in processes, and identifying the root cause that leads to the creation of such gaps (commonly referred to as enablers), need to be then carried out.

(4) Implementation
This is the stage in the benchmarking process where it becomes mandatory to walk the talk. This generally means that far-reaching changes need to be made, so that the performance gap between the ideal and the actual is narrowed and eliminated wherever possible.

A formal action plan that promotes change should ideally be formulated keeping the organization's culture in mind, so that the resistance that usually accompanies change is minimized.
Ensuring that the management and staff are fully committed to the process and that sufficient resources are in place to meet facilitate the necessary improvements would be critical in making the benchmarking process a success.

(5) Monitoring
As with most projects, in order to reap the maximum benefits of the benchmarking process, a systematic evaluation should be carried out on a regular basis.

Assimilating the required information, evaluating the progress made, re-iterating the impact of the changes and making any necessary adjustments, are all part of the monitoring process.

Conclusion
As is clearly apparent, benchmarking can add value to the organization's workflow and structure by identifying areas for improvement and rectification.

It is indeed invaluable in an organization's quest for continuous improvement.

Importance of Control:
1. Reduce risk
2. Basis for future action
3. Size of the business
4. Indicator for managerial weakness
5. Facility of coordination
6. Simplifies the task
7. Decentralization

Question Bank (Assignment IV)
1. WRITE SHORT NOTES:
   - PERT & CPM
   - GANTT CHART
   - CONSTRAINED RESOURCE ALLOCATION
   - RESOURCE LEVELLING
   - RESOURCE LOADING
   - BENCHMARKING