03. Project Planning and Scheduling:

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3.1 Work Breakdown structure (WBS) and linear responsibility chart,
3.2 Interface Co-ordination and concurrent engineering,
3.4 Project cost estimation and budgeting,
3.5 Top down and bottoms up budgeting,
3.6 Networking and Scheduling techniques. PERT, CPM, GANTT chart,
3.7 Introduction to Project Management Information System (PMIS).

3.1 Work Breakdown structure (WBS) and linear responsibility chart:

Work:- Sustained physical or mental effort to overcome obstacles and achieve an objective or result; a specific *activity*, duty, function, or assignment often being a part or phase of some larger undertaking; something produced or accomplished by effort, exertion, or exercise of skill.
Breakdown: - To divide into parts or categories; to separate into simpler substances; to undergo decomposition.
Structure: - Something arranged in a definite pattern of organization.
These definitions imply that a Work Breakdown Structure (WBS) has the following characteristics:

- It is representative of work as an activity, and this work has a tangible result.
- It is arranged in a hierarchical structure.
- It has an objective or tangible result, which is referred to as a deliverable.

The WBS:

- Decomposes (or disassembles) the overall project scope into deliverables and supports the definition of the work effort required for effective management.
- Clearly and comprehensively defines the scope of the project in terms of deliverables that the project participants and stakeholders can understand.
- Supports documenting the accountability and responsibility for the various deliverables by having a direct relationship between the WBS elements related to the *Organizational Breakdown Structure* (OBS) identified through the *Responsibility Assignment Matrix* (RAM).

The WBS provides a structure for organizing the scope and subsequent information of the project's progress, periodic status, and projected performance for which a project manager is responsible. The WBS also supports tracking problems to their root causes to assist the project manager in identifying and implementing changes necessary to assure desired performance.

3.1.1 How to Create a Work Breakdown Structure: -

1. PREPARING A WBS

The WBS evolves through an iterative consideration of the project's purpose and objectives, functional/performance design criteria, project scope, technical performance requirements, and other technical attributes. A high-level WBS can often be developed early in the conceptual stage of the project. Once the project is defined and specifications are prepared, a more detailed WBS can be developed. The WBS can assist the project manager and stakeholders in developing a clear vision of the end product(s) of the project and of the overall process by which it will be created. With this in mind, the following should stimulate thought when developing a WBS to manage the project:

- Think through the entire project. (Look at dividing high-level deliverables.)
- Think deliverables. (What is to be provided/what is required?)
- Think with the end in mind. (How will this component contribute to the finished deliverable?)
- Think through the production of the deliverables. (What methods? What special processes? What quality requirements? What inspections?)

Have you formulated a vision of the final product in your mind?

- What are its constituent parts?
- How do the pieces work together?
- What needs to be done?

These thoughts and questions are intended to help the project manager develop a clear statement of what the product of the project is—and to help answer the question, "How does one eat an elephant?" Answer: "One bite at a time!" The WBS is the technique for dividing "the elephant" into bite-sized pieces.

The following steps describe the general process for developing a WBS:

- Step 1: Identify the final product(s) of the project—what must be delivered to achieve project success. A thorough review of high-level project scope documents (inputs such as *statement of work* [SOW], technical requirements documents, and so on) is recommended to ensure consistency between the WBS and the project requirements.
- Step 2: Define the product's major deliverables, which are often predecessor deliverables necessary for the project, but that in themselves do not satisfy a business need (e.g., a design specification).
- Step 3: Decompose major deliverables to a level of detail appropriate for management and integrated control. These WBS elements normally tie to clear and discrete identification of stand-alone deliverable products.
- Step 4: Review and refine the WBS until project stakeholders agree that project planning can be successfully completed and that execution and control will successfully produce the desired outcomes.

2. FACTORS TO BE CONSIDERED

In developing a WBS, the following basic assumptions should be considered:

- ✓ Each WBS element should represent a single tangible deliverable.
- ✓ Each WBS element should represent an aggregation of all subordinate WBS elements listed immediately below it.
- ✓ Each subordinate WBS element must belong to only one single parent (or superior) WBS element.

- ✓ The deliverables should be logically decomposed to the level that represents how they will be produced (designed, purchased, subcontracted, and fabricated). The partitioning of deliverables from higher levels within the WBS to lower levels must be logically related.
- ✓ Deliverables must be unique and distinct from their peers, and should be decomposed to the level of detail needed to plan and manage the work to obtain or create them.
- ✓ Deliverables should be clearly defined to eliminate duplication of effort within WBS elements, across organizations, or between individuals responsible for completing the work.
- ✓ Deliverables should be limited in size and definition for effective control—but not so small as to make cost of control excessive and not so large as to make the item unmanageable or the risk unacceptable.
- ✓ The WBS development process should provide a vehicle for flexibility, particularly when the scope of the project effort may change. A well-managed project, however, will incorporate a rigorous change control process to document and manage *scope changes*. When work scope changes do take place, the WBS must be updated.
- ✓ Each entry in the WBS representing subcontracted or externally committed deliverables should directly correspond to matching entries in the subcontractor's WBS.
- ✓ All deliverables are explicitly included in the WBS.
- ✓ All significant reporting items (e.g., review meetings, monthly reports, test reports, and so on) are included and identified in the WBS.
- ✓ All WBS elements should be compatible with organizational and accounting structures.
- ✓ A coding scheme for WBS elements that clearly represents the hierarchical structure when viewed in text format should be used.
- ✓ Technical input should be obtained from knowledgeable technical subject matter experts (SMEs), and communicated to and validated by other key SMEs assigned to the project.

3. WBS MEASUREMENT CONSIDERATIONS

It is strongly recommended that project management activities foster measurement of work accomplishment, as opposed to goal achievement by providing an integrated view across project components. Proper linking between the WBS and associated cost and schedule is critical if integrated analysis of cost, schedule, and performance is to be accomplished. In doing so, the project manager should keep the following in mind:

- Cost and schedule impacts can be determined only if there is a clear link between performance parameters and budgeted work packages via the WBS. This link is accomplished in order to obtain a "performance budget baseline" or the budget associated at the work package level.
- All work in the WBS must be estimated, resourced, scheduled, budgeted, and controlled. The WBS has two parts: the structure and the component definition. It is the mechanism that divides and organizes the work scope into units of work so that each unit can be estimated, resourced, scheduled, budgeted, and controlled while progress is reported.
- Where there is a clear link between performance parameters and budgeted work packages via the WBS, the linkage should be made at a high level within the WBS. All work packages can then be associated with the performance parameters.

- Separate WBS elements should be included for integration *tasks* where several components are being brought together to create a higher-level WBS element. By identifying the integration work separately where ever the above occurs, performance measurement information will provide a timely indication that problems are emerging. Cost and schedule variances occurring in WBS elements that contain integration work can also indicate potential future rework in areas that have previously been completed. When these trends are projected, the result could be a far greater impact on revised estimates at completion than from projections of trends in other areas. Technical experts can provide guidance regarding potential integration problems, which can help the project manager decide whether or not to create these separate integration and assembly (I&A) WBS elements.
- Identification and tracking of performance metrics in a disciplined and systematic fashion helps provide significant early warning of potential problems and their nature.

4. CHALLENGES TO BE CONSIDERED

Challenges associated with developing the WBS include:

- Balancing the project definition aspects of the WBS with the data collecting and reporting requirements. (Remember that the primary purpose of the WBS is to define the project's scope through the decomposition of deliverables.) Each WBS is a tool designed to assist the project manager with decomposition of the project only to the levels necessary to meet the needs of the project, the nature of the work, and the confidence of the team. Excessive WBS levels may require unrealistic levels of maintenance and reporting.
- Developing a WBS that defines the logical relationships among all the components of the project. This is generally clarified through the use of a dependency network in the project schedule.
- Ensuring the development and utilization of the WBS. Omitting WBS development and proceeding directly to the network diagram (such as a Gantt chart, CPM Schedule, or Precedence Diagram) may lead to unforeseen and unexpected difficulty, including project delay.
- Avoiding the creation of WBS elements that are not deliverable-focused (for example, structuring the WBS strictly by process or organization). WBS elements that are not deliverable-focused may lead to project failure.
- Defining WBS elements representing opening and closing stages such as planning, assembly, and testing.
- Identifying and detailing all key project deliverables (e.g., regulatory permits, packaging, distribution, or marketing).
- Preventing the use of WBS elements that define overlapping responsibilities for the creation of a deliverable(s). Each WBS element must have one person who is clearly accountable for its completion.
- Identifying key project management work such as:
  - process management
  - services and provisioning
  - information/communication
- Administrative documentation, training, and software.

These should be defined as level-of-effort WBS elements in those cases where they may be interim deliverables, do not themselves generate discrete deliverables, and may not be included in the final project deliverables.

5. WBS LEVEL OF DETAIL

A. Overview

The WBS development process has been described as proceeding to successive levels of increasing detail until a level is reached that provides the needed insight for effective project management. This process can be summarized in the check-list in Section 4.6.2, which provides guidance for determining the need for further decomposition of the work. If the answers to most of the items in the checklist are positive, then further decomposition should be considered. The greater the number of positive answers to the questions in Section 4.6.2, the stronger the justification for further division of some or all of the WBS.

B. Determining Appropriate WBS Level of Detail

Should the WBS be decomposed further? Questions for consideration:

- Is there a need to improve the accuracy of the cost and duration estimates of the WBS element?
- Is more than one individual or group responsible for the WBS element? While there may be a variety of resources assigned to a WBS element, there should be one individual assigned overall responsibility for the deliverable created during the completion of the WBS element.
- Does the WBS element content include more than one type of work process or more than one deliverable?
- Is there a need to precisely know the timing of work processes internal to the WBS element?
- Is there a need to separately define the cost of work processes or deliverables internal to the WBS element?
- Are there dependencies between deliverables within a WBS element to another WBS element?
- Are there significant time gaps in the execution of the work processes internal to the WBS element?
- Do resource requirements change over time within a WBS element?
- Do prerequisites differ among internal deliverables within the WBS element?
- Are clear, objective criteria missing for measuring progress for the WBS element?
- Are there acceptance criteria applicable before the completion of the entire WBS element?
- Are there specific risks that require focused attention to a portion of the WBS element?
- Can a portion of the work to be performed within the WBS element be scheduled as a unit?
- Is the WBS element clearly and completely understood to the satisfaction of the project manager, project team members, and other stakeholders—including the customer?

- Is there a stakeholder interested in analyzing status and performance of only a portion of the work covered by the WBS element?

As identified earlier, the level of the detail in a WBS is a function of the size of the project and a balance between complexity, risk, and the project manager's need for control. The level of detail may also vary during the evolution of a project. A top-down and bottom-up analysis of the WBS can clarify whether the WBS is both complete and defined at the proper level of detail.

Short-duration projects may lend themselves to decomposition to appropriate levels of detail at the outset, while projects of longer duration and higher complexity may preclude decomposition of all deliverables until further in the future. Again, this may mean that on any given project, some portions of the WBS may have different levels of decomposition. This is especially true when doing *rolling wave planning*, where the plan is detailed for the immediately upcoming work only and work far in the future is defined at a high level until later in the project life cycle.

6. WBS LIFE-CYCLE CONSIDERATIONS

Decomposition of complex requirements into simpler components provides one of the primary methods for handling complex projects. WBS development is the technique for accomplishing this decomposition. In structuring the WBS, one must look to the future and determine how the work will be accomplished and managed. The WBS should reflect this structure. In addition to strict end-product identification, the WBS may also reflect level-of-effort functions such as project management activities and life-cycle timing (*project phases*). These other elements should only be used, however, to the required level of detail necessary to organize the work tasks. Remember that each of the lowest-level WBS elements should reflect work with specific, tangible deliverables.

7. PROJECT RISK AND THE WBS

A. **Overview-** For projects with highly related risk factors, a more detailed WBS is strongly suggested. The *risk events*—events that might have a detrimental impact on the project—are evaluated to identify and characterize specific risks.

Project risk is related to the likelihood of events positively or adversely affecting project objectives, including key elements such as technical design, quality, cost, and schedule. The WBS decomposition approach may assist in risk identification and mitigation. For instance, projects that require permits and approvals from regulatory authorities can be high risk. Since risk can impact several WBS elements, it would be prudent for the project manager to perform impact analyses against all WBS elements, thus isolating the risks, providing for individual treatment, and permitting more effective focus for risk management.

The first step in this technique is to review the WBS elements to the level being considered and segment them into risk events. This review should consider the critical areas (requirements analysis/development, design and engineering, technology, logistics, and so on) and other factors that may help to describe risk events. Using information from a variety of sources such as program plans, prior risk assessments, and expert interviews, the risk events are examined within critical areas to determine the probability of occurrence, severity of consequence (impact), and interdependency.

The risks associated with an effort may also define the level of detail necessary. Additional detail in high-risk areas provides for better assumption definition, as well as improved cost estimates and time assessment. This forced structuring provides an opportunity to define the assumptions and expectations at a controllable level.

Risk planning can be incorporated directly into the WBS by defining and including contingency activities as successors to the risk-impacted activities. The duration of the contingency activities are set to compensate for the degree of uncertainty and potential impact of the risk event. As an example, a permit-contingency activity could be created as a successor to the permit-application activity. The duration of the permit-application activity is set to the normal time period expected for a permit application, and the duration of the contingency activity is set to reflect the probability and impact of the risk of delay.

C. The Relationship between Project Risk and the WBS

The following questions should be addressed for each WBS element when considering project risk:

- Are the deliverables completely and clearly defined?
- Will the quality of the work be evaluated through efforts such as testing and inspection?
- What is the likelihood of change?
- Is the technology changing faster than the project can be accomplished?
- Have manpower, facilities capability, availability of internal resources, and potential suppliers been checked?
- Is extensive subcontracting expected?
- Is management committed to the project and will they provide the support needed?
- Are requirements defined and approved?
- Has a formal change process been defined and implemented?
- Have metrics been defined for how the deliverables will be measured?
- Have resource requirements been identified for development of the project deliverables?
- Have other risks been identified, including stakeholder buy-in, public relations, management approval, team understanding, and project opposition?
- Has a communication plan (internal and external) been defined and implemented?
- Are third-party dependencies understood and monitored for change?
- Have alternate suppliers of required products, supplies, or expertise been identified?

8. RESOURCE PLANNING, MANAGEMENT AND THE WBS

A. **Overview-** The WBS is decomposed to the level necessary to plan and manage the work. Normally this will be at least one level below the reporting requirements—one that allows for the effective planning, control, and performance measurement of discrete activities with uniquely identifiable resources.

Although full resource identification will come later in the planning process, it can be useful to understand in general how that will be done, and ensure that the level of detail in the WBS will support those efforts.

B. Resource Planning and Management

In order to prepare for adequate resource planning against the WBS, consider the following when examining the WBS level of detail:

- Is all the work planned to a degree of detail necessary to make and keep commitments?
- Is there an ability to establish and manage individual work assignments with the reporting structure indicated by this WBS?
- Can work assignments be established from a progressive expansion of the WBS?
- How will work generally be assigned and controlled?
- Will it be possible to reconcile individual work assignments to the formal scheduling system?
- How will budgets be established?
- Will it be possible to relate the budget to the proposed work assignments?
- Is the level of detail in the WBS appropriate for effective planning and control?
- Is the work defined by the WBS grouped in a logical manner?
- Is more than one organization involved (indicating the need to validate the WBS with others before doing detailed resource planning)?
- How will the status of work in progress be determined?

9. ADDITIONAL CONSIDERATIONS

The interrelationships between the specification of requirements, the WBS, the statement of work, resource plans, and the master and detailed schedules pro-vides specific information relative to the relationship among cost, schedule, and performance.

Once the WBS is developed, it is important that the project manager and other stakeholders involved in the management of the project know "how things are going" on a regular basis. In this regard:

- Think reporting and control mechanisms.
- How will WBS element completion be determined?

Work Breakdown structure (WBS) and linear responsibility chart

The Work Breakdown Structure (WBS) used in project management is a type of Gozinto chart and is constructed directly from the project's Action Plans. The WBS may also be perceived as an organization chart with tasks substituted for people as shown in Figure 4.3. It pictures a project subdivided into hierarchical units of tasks, work packages, and work units. The end result is a collection of work units each of which is relatively short in time span. Each has definite beginning and ending points along with specific criteria for evaluating performance. Each part of the project down to the smallest subtask elements is budgetable in terms of money, man hours, and other requisite resources. Each is a single, meaningful job for which individual responsibility can be assigned. Each can be scheduled as one of the many jobs that the organization must undertake and complete.

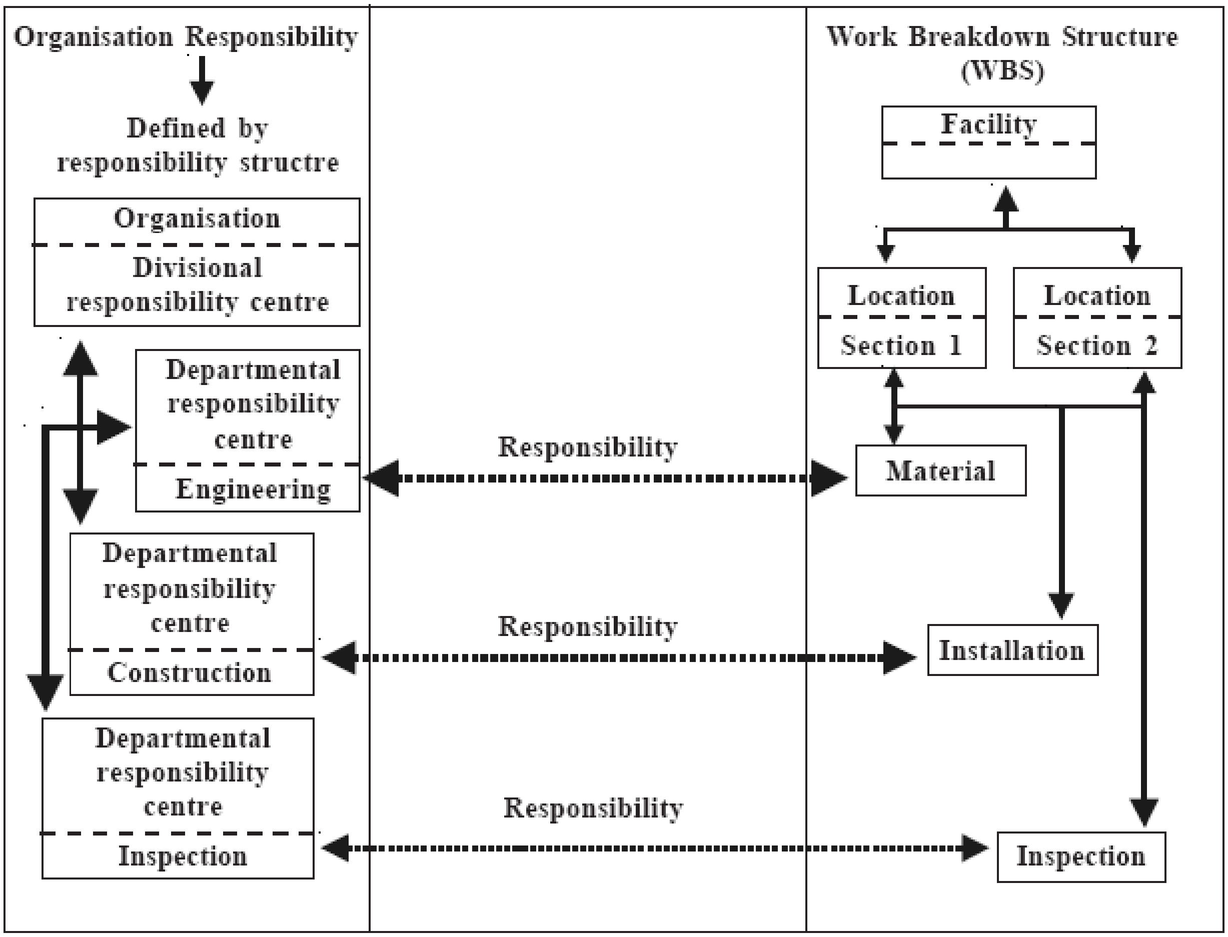


Fig. 3.1 Responsibility/WBS relationship

In constructing the WBS, it is wise to contact the managers and workers who will be directly responsible for each of the work packages. These people can develop a hierarchical plan for the package delegated to them. The WBS can be used to illustrate how each piece of the project is tied to the whole in terms of performance, responsibility, budgeting, and scheduling. The following general steps explain the procedure for designing and using the WBS as it would be used on a large project. For small or moderate-size projects, some of the steps might be skipped, combined, or handled less formally than our explanation indicates, particularly if the project is of a type familiar to the organization.

1) Using information obtained from the people who will perform the work, break project tasks down into successively finer levels of detail. Continue the decomposition of work until all meaningful tasks have been identified and each task can be individually planned, scheduled, budgeted, monitored, and controlled.

2) For each such work element:

Make up a work statement that includes the necessary inputs, the specification reference, particular contractual stipulations, and specific end results to be achieved. List any vendors, contract, and subcontractors who are or may be involved. Identify detailed end item specifications for each work element regardless of the nature of the end item, whether hardware, software, tests results, reports, etc.

Establish cost account numbers. Identify the resource needs, such as manpower, equipment facilities, support, funds, and materials. Cost estimators can assist the Project Manager in constructing a task budget composed of costs for materials, manufacturing operations, freight, engineering, contingency reserves, and other appropriate charges. List the personnel and organizations responsible for each task. It is helpful to construct a linear responsibility chart (sometimes called a responsibility matrix) to show who is responsible for what. This chart also shows critical interfaces between units that may require special managerial coordination. With it, the Project Manager can keep track of who must approve what and who must report to whom.

3) The WBS, budget, and time estimates are reviewed with the people or organizations who have responsibility for doing or supporting the work. The purpose of this review is to verify the WBS's accuracy, budget, schedule, and to check interdependency of tasks, resources, and personnel. The WBS may be revised as necessary, but the planner must be sure to check significant revisions with all individuals who have previously made inputs. When agreement is reached, individuals should sign off on their individual elements of the project plan.

4) Resource requirements, time schedules, and subtask relationships are now integrated to form the next higher level of the WBS; and so it continues at each succeeding level of the WBS hierarchy. Thus, each succeeding level of the WBS will contain the same kinds of information regarding resources, budgets, schedules, and responsibilities as the levels below it. The only difference is that the information is aggregated to one higher level.

5) At the uppermost level of the WBS, we have a summary of the project budget. For the purpose of pricing a proposal, or determining profit and loss, the total project budget should consist of four elements: direct budgets from each task as described above; an indirect cost budget for the project, which includes general and administrative overhead costs (G&A), marketing costs, potential penalty charges and other expenses not attributable to particular tasks; a project "contingency" reserve for unexpected emergencies; and any residual, which includes the profit derived from the project, which may, on occasion, be intentionally negative.

6) Similarly, schedule information and milestone events can be aggregated into a project master schedule. The master schedule integrates the many different schedules relevant to the various parts of the project. It is comprehensive and must include contractual commitments, key interfaces and sequencing, milestone events, and progress reports. In addition, a time contingency reserve for unforeseeable delays should be included.

This series of steps complete the use of the WBS as a project planning document. The WBS is also a key document for implementing, monitoring, and controlling the project. The remaining steps concern its use for these purposes.

7) One can now compare required task performance and outputs specified in the WBS with those specified in the basic project plan in order to identify potential misunderstandings, problem, and schedule slippages, and then design corrective actions.

8) As the project is carried out, step by step, the Project Manager can continually examine actual resource use, by work element, work package, task, and so on up to the full project level. By comparing actual against planned resource usage to a given point in time, the Project Manager can identify problems, harden the estimates of final cost, and make sure that relevant corrective actions have been designed and are ready to implement if needed. It is necessary to examine resource usage in relation to results achieved because, while the project may be over budget; the results may be further along than expected. Similarly, the expenses may be exactly as planned, or even lower, but actual progress may be much less than planned.

9) Finally, the project schedule must be subjected to the same comparisons as the project budget. Actual progress is compared to scheduled progress, by work element, package, task, and complete project, to identify problems and take corrective action. Additional resources may be brought to those tasks behind schedule so as to expedite them. These added funds may come out of the budget reserve or from other tasks that are ahead of schedule.

3.2 Interface Co-ordination and concurrent engineering: -

Interface management: -

A system is an assemblage of people, things, information, or other attributes, grouped together according to a particular system "objective." A system may be logically broken down into a number of subsystems, that is, assemblage of people, things, information, or organizations required to achieve a defined system objectives, like the switching, outside plant, building, transmission, and subscriber subsystems in a telephone system.

The systems perspective has contributed substantially to the development of project management. Firstly, the system emphasis on viewing the system as a whole in project management. Secondly, system thinking has shown how projects should work as successfully regulated organizations. A third important contribution is that the dynamic control needs of projects are' now better understood the importance of feedback, the progressive development of information and multilevel projects control. And a fourth contribution is the widespread use of systems techniques systems analysis, systems engineering, work breakdown structures, and simulation models.

Interface Management, as is used in project management today, is an Outgrowth of the first two of these influences of systems thinking on project management. Interface Management identifies the following:

- The subsystems to be managed on a project,
- The principal subsystem interfaces requiring management attention.
- The ways in which these interactions should be managed successfully.

Interface management is essentially the project manager’s job: planning, coordinating, and controlling the work of others at project interfaces.

None of the subsystems functions independently. All rely on the outputs of other functions and, in turn, provide inputs to still others; in a word, they *interface*. Part of the preliminary design process is to identify all interfaces in the system and establish requirements for the interfaces.

Identifying the interfaces is necessary for setting requirements on the inputs and outputs of every subsystem and element. For example, since the fuselage of the spacecraft contains the motor and also supports the wings, neither wings nor motor can be designed without also considering the design of the fuselage, and *vice versa*. The requirements for each interface are set by a design team that includes representatives from the subsystems at both sides of the interface.

STATIC AND DYNAMIC INTERFACES

The likely existence of these subsystems in a project, no matter how it unfolds, enables us to categorize certain interfaces as on-going or "static” they are not a function of the way the project develops but represent relationships between on-going subsystems (like engineering and procurement, or Level I and Level II). There is another group of interfaces, however, which arise

only as a function of the pattern of activity interdependencies generated by the way the project develops. These we may identify as life-cycle or "dynamic" interfaces. Dynamic interfaces between life-cycle (or activity) subsystems are of the utmost importance in project management, first because of the continuous importance of the clock in all projects, and second because early subsystems (like *Design)* have a managerially dominant role on subsequent ones (like *Manufacturing).* Dynamic interrelationships require careful handling if minor mistakes in early systems are not to pass unnoticed and snowball into larger ones later in the project.
Boundaries should be positioned where there are major discontinuities in technology, territory, time, or organization. Major breakpoints in 'the project life cycle-as, for instance, between each of the four major phases, and also between activity subsystems within each phase (for example between manufacture, inspection, delivery, warehousing, installation, and testing)-provide important dynamic interfaces. These serve as "natural" check points at which management can monitor performance.

A systems approach is fundamental to thinking about project organizations. Systems management is a key systems concept. It focuses on two major activities:

- Goal achievement — getting the required results from the system
- Boundary management, which covers monitoring transactions at the system's boundary and ensuring that the boundary is properly maintained and developed.

A major part of a project manager's job involves boundary interactions. His task consists largely of monitoring the interrelationships between functional groups to achieve the overall project scope, cost, and schedule goals. Such monitoring is both technical (boundary monitoring) and managerial (maintenance and development).

Interface management principles:-

- Tight control of dynamic interfaces is essential to achieving project cost, schedule and scope targets.
- Static project interfaces should be kept clearly defined through the life of the project.
- Organizational factors should not be allowed to inhibit required project integration.
- Project organization structures generally need to change as the project develops.
- Early, firm control of design is essential for effective project control.
- The design/production interface is the most critical project interface; it is also the most difficult to manage.
- The required amount of project management effort is a function of project size, speed, and complexity.

The three levels of project managements are: the technical/tactical level (III) manufactures the product; middle management (II) coordinates the manufacturing effort; at the institutional level-(I) top management connects the enterprise to the wider social system.

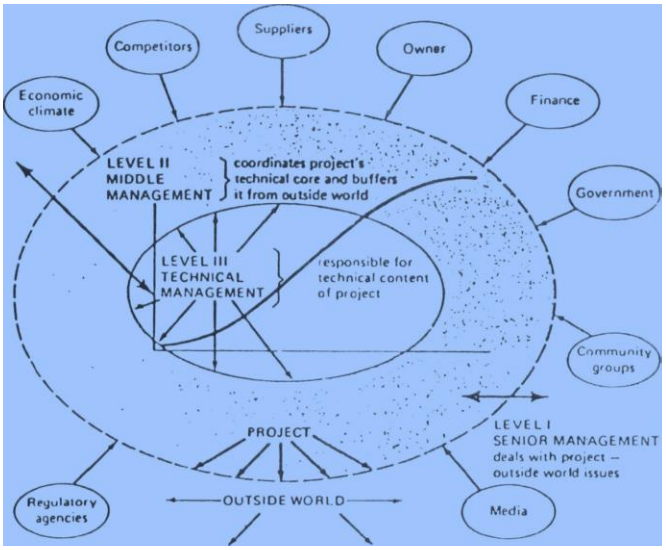


Fig.3.2 The three levels of project management

The important dynamic interfaces are relatively sharply, defined for Level II and III management, at Level I they are less distinct. Level I management is certainly partly driven by the anatomy of the project's internal development, but it also has its own dynamic interfaces for each of its own principal subsystems. Operation, Sales, many of the Outside Groups, Manpower, and Finance and Commercial issues each have their own often distinct life cycles. At Level I, dynamic interfaces do not become less important; rather they become more varied and less clearly defined. They are still crucial to the project's success.

Static interfaces too are less clearly defined at Level I than at Levels II and III, partly due to the wider scope of concern of Level I (which gives rise to much multifaceted subsystem interaction, as, for example, between Operations, Sales, Manpower, and Finance) and partly due to the disruptive effect of the outside environment.

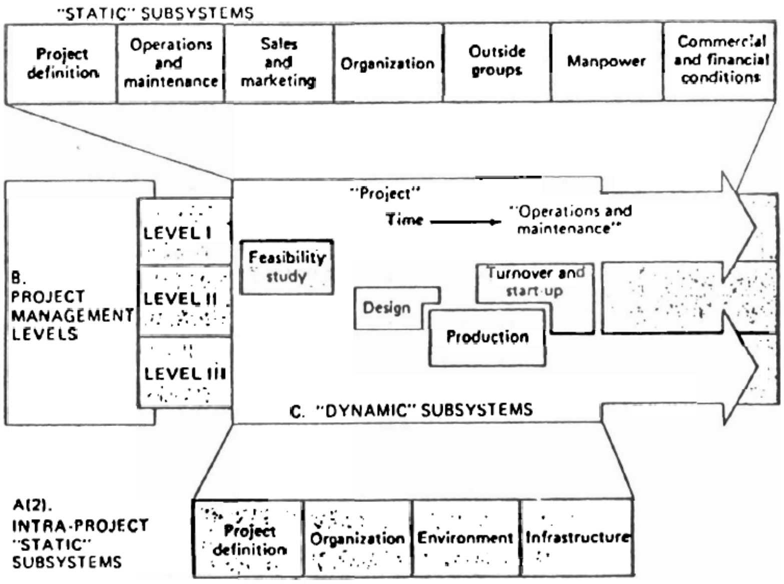


Fig. 3.3 The three sets of project subsystems.

INTERFACES WITH THE PROJECT'S (WIDER) EXTERNAL ENVIRONMENT

Government♣ Economic climate♣ Finance♣ Community groups♣ Media♣ Regulatory agencies♣ Competitors♣ Suppliers (subcontractors,♣ consultants) Other disciplines♣ Owner (customer, client)♣ Cultural interfaces♣ Other external stakeholders♣

INTERFACES WITH THE REST OF THE (MATRIX) ORGANIZATION

Organizational interfaces o Other projects o Top management o Line management o Line personnel o Social contacts o Personnel and training o Financial system o Technical support o Computer programmers o Customer or client o Sales and marketing o Operations and maintenance o

INTERNAL PROJECT INTERFACES Major breakpoints in the Project Life Cycle• Major breakpoints between activity subsystems within phases • Change of responsibility interfaces• Information interfaces• Material interfaces• Time interfaces• Geographic interfaces• Technical interfaces• Social interfaces• Personal interfaces• Review points•

Concurrent Engineering-

Concurrent Engineering is a systematic approach to integrated product development, that emphasizes response to customer expectations and embodies team values of cooperation, trust and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life cycle perspectives, synchronized by comparatively brief exchanges to produce consensus.

CE is an approach that can be used to cooperative work and team work effectively. There are seven "T"s of CE as shown in Figure 3.4. They are tasks, teamwork, techniques, technology, time, tools and talents.

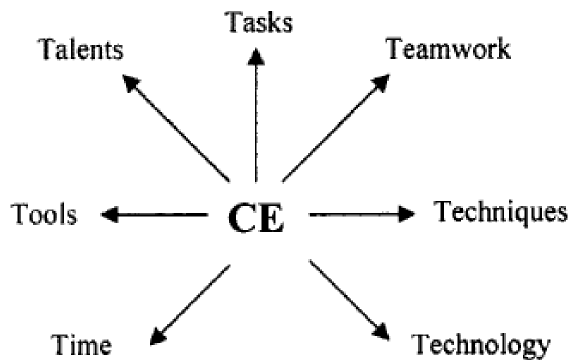


Fig. 3.4 The seven "T"s of CE

The techniques of work flow and process modeling can prove to be powerful aids during project execution. The techniques allow project identification and subdivision thereby allowing parts of a project to be modeled accordingly.

In concurrent engineering aspect, the project management not only concerns with activities information during project development but also the resource information and product information concurrently. The activity, resource, and status report information are used to represent the constraints, which are used to start or end an activity and to identify when the activity is enabled. In other words, modeling of the activity flow and related constraints are focused. The main requirements are identified towards the models and the solution methods of an integrated Planning and Scheduling (PS) system which are as follows:

1. Representation methods at both levels should be able to capture relevant temporal as well as resource constraints of project.
2. The results should be optimal or close-to optimal according to various objectives, and robust to cope with unexpected disorders,
3. Project plans should be un-foldable into executable schedules. Therefore, planning must also handle precedence relations that ensue from complex project structures and technological routings,
4. However, resource allocation problems and precedence constraints are in general extremely hard to solve. Planning must apply aggregation so that typical instances of planning problems could be solved in a tractable way and
5. The solution methods applied at both levels have to be efficient enough to support interactive decision making.

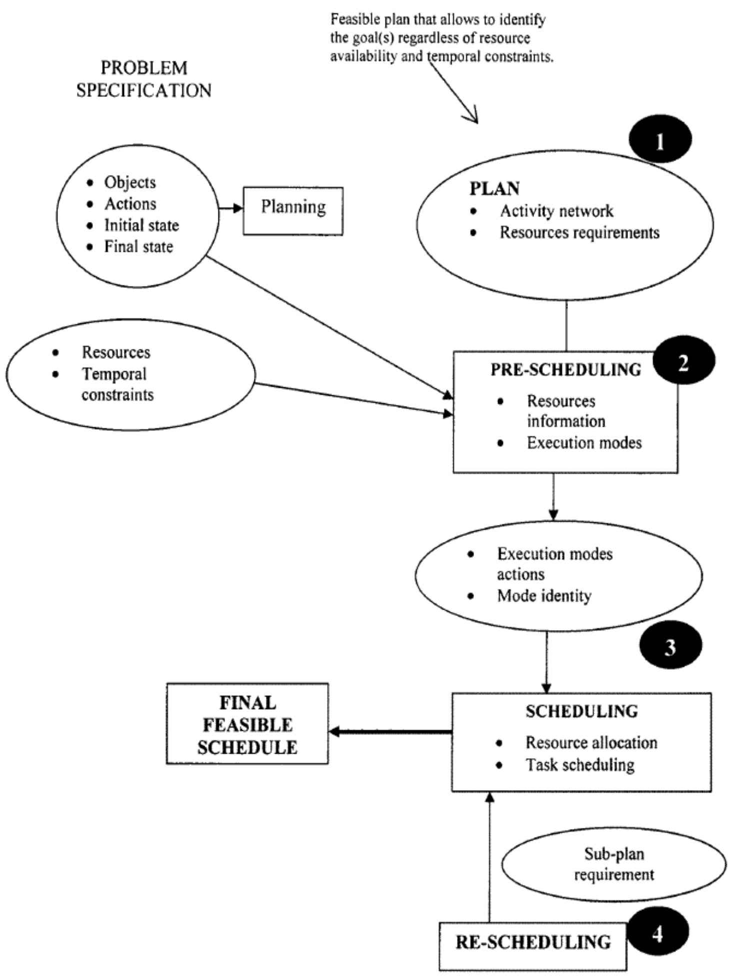


Fig. 3.5 Planning and scheduling integration model

The model proposed for integrating planning and scheduling is a stepwise model (Figure 3.5). The process starts with the problem specification that implies the specification of actions and objects as well as the initial and the final (or desired) state. Stage 1 is the planning process that obtains an

abstract plan without considering the resources needed for temporal constraints to perform the activities. Stage 2 is a pre-scheduling process that characterizes the abstract plan of stage 1 by adding types of resources that is to be assigned to each activity (modes to perform an action), usage cost by using each resource types, set of activities related by the same mode identity and precedence constraints to be satisfied. As output of this stage a set of activities precedence related and the set of resources needed to perform them are determined. The resulting project will be considered for scheduling in stage 3.
According to the specifications of the previous stage, scheduling times and execution mode are assigned to each activity taking into account both precedence relations and the limited capacity of resources. This scheduling process can be repeated in order to obtain a near optimal schedule considering the goal(s) to reach. Resources required to perform activities are not available in different problems during the third scheduling stage and hence, re-scheduling can be done during stage 4.
The systems to support management of collaborative projects into three categories: Process management, communication and knowledge management. Table 3.1 presents the four major components of collaborative project management approach.

Table 3.1 Four major components of collaborative PM approach

Components	**Descriptions**	**Functions**
Basic PM Support	Scheduling, Time Management Resource Management Cost Management Task Analysis Task Allocation Status Tracking Reporting	Collaborative Calendaring / Gantt Chart Resource Management Cost Management Work Breakdown Structure Task Dependency Management Pert Chart
Knowledge Management	Develops High Level of Project Awareness Project Dictionary Business Rules & Policies Project Context Info	Electronic Doc Repository With Functions of Uploading/Downloading Updating Searching (Key Word and Full Text Search) Browsing
Process Management	Conducts Project Training and Increase Project Process Visibility	Work Flow Management Integration Management Change & Risk Management Issues Management
Communication and Collaboration Support	Facilitates Communication in Synchronous & Asynchronous Mode, Group Decision Making, Problem Solving	Session Management Desktop Sharing Idea Generation, Organization Group Writing and Modeling Shared Whiteboard

Both PM and CE can be viewed as approaches to achieve better products. This can be achieved by integrating concurrent engineering principles into the project planning and scheduling as shown in

Figure 3.6. Therefore, the attempts are to propose a concurrent engineering project management method to realize the CE philosophy. In order to sustain changes in the project management, there arises the need for an integrated project planning and project scheduling, and to facilitate the integrated project management.

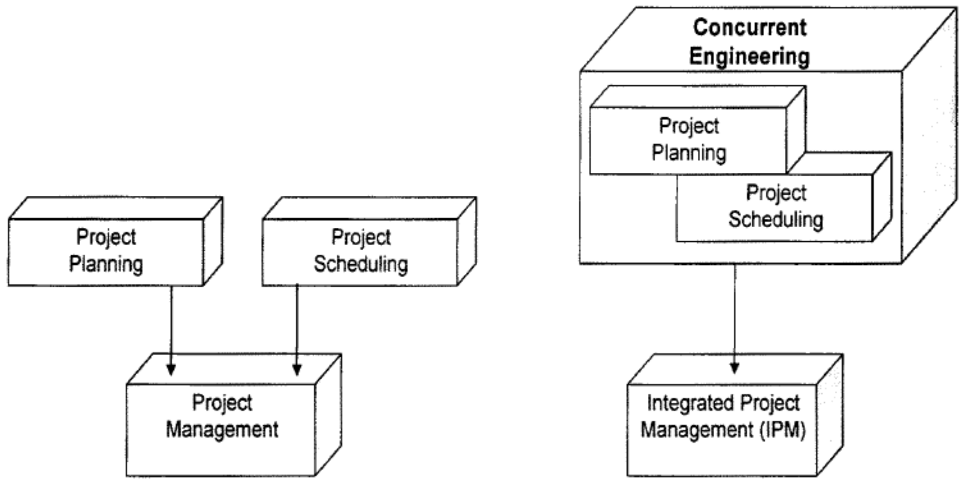


Fig. 3.6 Integrated project management

The philosophy of CE has been introduced into software project management and a concurrent project modelling method proposed and this method consists of two components: concurrent information sharing framework that facilitates concurrent cross-functional sharing of information among product, activity and resource pools and concurrent project modelling diagram.

3.4 Project cost estimation and budgeting: -

Terms commonly used in project cost accounting

Absorption costing – a method that attempts to recover indirect costs (overheads) by apportioning them over all the company's direct costs.

Below-the-line costs – a collective name for the various allowances that are added once a total basic cost estimate has been made. Below-the-line costs typically include allowances for cost escalation, exchange rate fluctuations, contingencies and provisional cost items.

Cost escalation – increases in all costs above their original estimates owing to national cost inflation and increases in wages and salaries. It is usually expressed as a rate per cent and only significant in times of high inflation, or for projects planned to last for several years.

Direct costs – costs that can be directly attributed to project work. These are also 'variable costs', because their rate of expenditure depends on the intensity of project activity. When no work is being done on the project, there are no direct costs.

Cost of sales – equivalent to the sum of all the above-the-line costs. .

General and administrative costs – a general cost burden, added as a proportion per cent of the above-the-line costs by some companies to recover selling and other expenses (for instance head office costs) that are not included in the overhead costs.

Indirect costs – costs that must be incurred by the organization to provide heat, light, accommodation, insurances, maintenance, accountants, secretaries, welfare, management salaries, and other general running costs of the business that cannot be attributed as costs to be charged to a specific project. Because these costs do not vary from day to day they are also ‘fixed costs’. It is also known as ‘overhead costs’. However, the administration and accommodation costs of a construction site are a special exception because they *can* be directly attributed to the particular construction project and can therefore be treated as direct costs.

Labour burden – an amount, usually a percentage of wages or salaries, that is added to the basic hourly or weekly rate for employees to allow for non-working time and various additional expenses such as the cost of paid holidays and per capita amounts payable by the employer as employee benefits, either voluntarily or as a requirement of the national legislation. In the UK, for example, these would include employers’ National Insurance contributions. For project estimating and control, it is best if this burden is included in standard labour cost rates.

Materials burden – an amount added by some contractors to the actual cost of bought out materials to recover their purchasing administration costs. This might be charged at 10 per cent or less for very high-cost but at (say) 25 per cent on small low-cost items that have relatively high handling and administration costs. A common all-round rate used for the materials burden is 15 per cent.

Overhead rate – more properly called the overhead absorption rate, this is a rate calculated by accountants that expresses the company’s total expected overhead costs for a given period (usually a year) as a proportion of the expected direct costs over the same period. It is used to calculate the overhead recovery amount included in prices. There are differences between companies in the treatment of overhead costs, but a common method in projects is to apportion the overhead costs as a percentage of direct labour costs. Overhead rates vary considerably from one company to another, perhaps from as low as 50 to as high as 200 per cent or even more. In a few cases contractors will even apply different overhead rates to different projects. The rate used will depend on many factors that include, for example, the ratio of direct to indirect staff, the amount of internally funded research and development being done, local authority and public utility charges, and so on. High overhead rates increase prices and reduce competitive advantage.

Prime cost – the sum of all the direct costs needed to fulfill a particular job or project (direct labour plus direct materials plus direct expenses).

Standard costing – an important and common accounting system in which cost estimates and actual project expenditure are calculated using average or ‘standard costs’ for direct labour and materials.

These standards are calculated by cost accountants as expected averages for each grade of labour and for materials that are commonly held in stores and issued from general stock. Standard costs for materials are particularly relevant to manufacturing projects. Standard labour costs are important for most projects and they greatly simplify cost estimating. From time to time the accountants check the current standard labour cost rates against actual expenditure and they will issue revised standard rates whenever the variances become significant (usually as a result of cost inflation).

Variance – a term commonly used by accountants to describe the difference between actual costs and standard costs in a standard costing system. More widely, it is the amount by which any actual cost differs from its corresponding estimate or budget. Also used less commonly for the difference in time between an actual event and its planned time. Variances concentrate management attention on departures from budget or plan and are a good example of ‘management by exception’.

CLASSIFICATION OF ESTIMATES ACCORDING TO CONFIDENCE

Some companies find it convenient to classify project cost estimates according to the degree of confidence that their estimators can express in their ultimate accuracy. These classifications depend on the quality of information available to the estimators, the time allowed for preparing the estimates and the stage reached in the project life history. Different organizations have their own ideas, but here is one example of a classification set.

Above-the-line items	*Direct (variable) costs*	Direct labour	The wages and salaries of people employed on the project, for time that can be wholly and specifically attributed to the project. These times should be costed at the standard cost rates applicable to each grade of staff.
		Direct materials	Equipment, materials and bought-out services used specifically on the project.
		Direct expenses	Travel, accommodation and other costs chargeable specifically to the project. Can include the hiring of external consultants.
	Indirect (fixed) costs	Overhead costs	A portion of the costs of running the business, such as general management and accommodation. Usually calculated as a proportion of total direct costs. Not applicable if the project is itself charged as an overhead.
Below-the-line items		Contingency sum	An addition, usually calculated as a small percentage of the above-the-line costs, in an attempt to compensate for estimating errors and omissions, unfunded project changes and other unexpected costs.
		Escalation	An addition to allow for costs that increase with time as a result of annual cost inflation. Particularly important for long-duration projects in times when national cost inflation rates are high.
		Mark-up for profit Selling price	These two items apply only to projects sold to external clients. There are various ways in which they can be calculated and their levels are often judged according to the strength of the competition and what the market will stand. These are management decisions, not part of the cost estimating process. Such decisions are always more easy to make when there is confidence in the cost estimating accuracy.
		Provisional sums	The estimated costs of items that are not included in the quoted price which might have to be charged extra if the need for them is revealed as project work proceeds.

Figure 3.7 Typical summary layout of a project cost estimate

Ballpark estimates are those made when only vague outline information exists and when practically all details of the work have yet to be decided. Ballpark estimates are also made in emergencies, when all the detailed information necessary for a more detailed estimate is available but there is insufficient time allowed for its proper consideration. An example of such a ballpark estimate is seen when a manager is presented with a set of manufacturing drawings and, when asked to answer the question ‘What will this lot cost to make?’, weighs the pile of drawings thoughtfully in his/her hands and declares ‘About fifty thousand pounds’. Ballpark estimates are widely used in many industries. They are particularly valuable for carrying out preliminary checks on possible resource requirements, for screening enquiries for tenders and for other early decisions. Ballpark estimates are unlikely to provide sufficient accuracy for other purposes and should clearly not be used as a basis for fixed price-tendering. A well-reasoned ballpark estimate might achieve an accuracy of ±25 per cent, given a very generous amount of luck and good judgment but far wider divergence can be expected.

Comparative estimates, as their name implies, are made by comparing work to be done on the new project or one of its tasks with similar work done on previous projects. They can be attempted before detailed design work takes place, when there are no reliable materials lists or work schedules. They depend on a good outline project definition, which must enable the estimator to identify all the principal elements and assess their degree of size and complexity. The other main requirement is access to cost and technical archives of past projects which contain comparable (they need not be identical) elements. Apart from commercial risks outside the estimator’s control (foreign exchange rate fluctuations, for example), accuracy will depend very much on the degree of confidence that can be placed in the proposed design solutions, on the working methods eventually chosen and on the closeness with which the new project elements can be matched with those of previous projects. It might not be possible to achieve better than ±15 per cent accuracy.

Comparative estimates are commonly used as the basis for tenders in manufacturing and other engineering projects. When the time available for tendering is very short, contractors for construction projects may also be obliged to rely on comparative estimates, but they should then build in as many allowances for contingencies as competitive pricing will permit.

Feasibility estimates can be derived only after a significant amount of preliminary project design has been carried out. In construction projects, for example, the building specification, site data, provisional layouts and outline drawings for services are all necessary. Quotations must be obtained from potential suppliers of expensive project equipment or subcontracts, and material take-offs or other schedules should be available to assist with estimating the costs of materials. The accuracy ‘confidence factor’ for feasibility estimates should be better than ±10 per cent. This class of estimate is often used for construction tenders.

Definitive estimates cannot be made until most design work has been finished, all significant purchase orders have been placed at known prices and work on the project is well advanced or nearing completion. Definitive estimates can be produced from scratch, but the best practice is to arrive at them by updating the original comparative or feasibility estimates routinely as part of the project cost reporting and control procedure. Barring shocks or disasters during project execution, the accuracy of the total project estimate should improve as work proceeds and the estimated costs are, one by one, replaced by their corresponding actual costs. Estimates can be labeled as ‘definitive’ when the time is reached where their accuracy is regarded as ±5 per cent or better. Unless the accounting and cost control systems are flawed the figures for actual project costs and the definitive project estimate should converge when all work on the project is finished.

The degrees of accuracy quoted in these examples are about as good as could ever be expected. It is very likely that many organizations will assign wider limits. It is also common to find asymmetric limits, slewed about zero. A company might, for example, work on the assumption that its ballpark estimates are accurate to within +50 or –10 per cent.
All those, using estimates for pricing decisions, setting budgets, financial planning or any other purpose need to be aware of how much confidence can be placed in the figures put before them. If the organization's estimating procedures recognize and define different categories, such as ballpark, comparative, feasibility, definitive or whatever, then managers can make their decisions accordingly, and to better effect.

3.5 Top down and bottoms up budgeting: -

TOP-DOWN OR BOTTOM-UP

There are two fundamentally opposite ways of approaching cost estimating for a large project. The approach taken depends upon the time available, the degree of accuracy expected and, above all, the level of project definition.

Top-down

Very early in the project life history, there will be outline proposals for the nature and scope of the project, but certainly no detailed task list or comprehensive work breakdown. Thus cost estimates can be made only on a global comparative basis. That means trying to assess the cost of the whole project by comparing it with similar projects that have been completed in the recent past and for which their actual cost records can be accessed.
If the project can be divided into a few major parts at this early stage, it should be possible to distribute the total estimate over those parts, remembering to leave something in reserve in the form of a separate contingency item. Thus all estimates originate from the whole, or top of the project, which is why this approach is called top-down.
It is apparent that top-down estimates must usually be ballpark. They have the disadvantage of not being based on a detailed project specification. They cannot take into account many factors that will not become known until much later in the project life history and their inherent accuracy will not be high. However, because top-down estimates are often based on comparisons with completed projects, there is less risk (when compared to bottom-up estimating) of forgetting to include items and thus arriving at dangerously low estimates.

Bottom-up estimating

The opposite extreme to the top-down approach is bottom-up estimating. This method can only take place when a good project specification exists and a fairly complete task list has been compiled. Bottom-up estimating begins at the lowest level of detail, and is gradually extended up through the hierarchical structure of the project until the total estimated project cost is reached at the top of the tree. Because bottom-up estimates are made later in the project life history, when more is known about the project, they should be more accurate than top-down estimates. However, bottom-up estimates can be more prone to errors of omission than top-down estimates. The methods that follow in this chapter are all based on bottom up estimating.

DISTINCTION BETWEEN PLANNING AND SCHEDULING

In project management terminology, the words 'plan' and 'schedule' can have different meanings.

A plan can be considered as the listing or visual display that results when all project activities have been subjected to estimating, logical sequencing, target timing and the determination of priorities. For projects of any significant size, some form of network analysis is usually the preferred method for preparing a plan. However, some charting methods provide better visual aids, can be more effective for communicating plans to project personnel and are often quite adequate for small projects.

A schedule is obtained by doing additional work on the initial plan, so that resources needed to carry out all the project activities are taken into account. In other words, a schedule is the practicable working document that results by matching the organization's available resources to the initial plan.

When a suitable computer application is used to process planning and scheduling, and to filter and sort all the resulting data, all the project planning and scheduling requirements can be satisfied

3.6 Networking and Scheduling techniques. PERT, CPM, GANTT chart: -

Originally, PERT was strictly oriented to the time element of projects and used probabilistic activity time estimates to aid in determining the probability that a project could be completed by some given date. CPM, on the other hand, used deterministic activity time estimates and was designed to control both the time and cost aspects of a project, in particular, time/cost trade-offs. In CPM, activities can be "crashed" (expedited) at extra cost to speed up the completion time. Both techniques identified a project critical path with activities that could not be delayed and also indicated activities with slack (or float) that could be somewhat delayed without lengthening the project completion time. Some writers insist on a strict differentiation between PERT and CPM. This strikes us as unnecessary.

One can estimate probabilistic CPM times and can "crash" PERT networks.

Terminologies used in Network diagram:

Network: A network is the graphical representation of the project activities arranged in a logical sequence and depicting all the interrelationships among them. The arrangement of all activities (and, in some cases, events) in a project arrayed in their logical sequence and represented by arcs and nodes. This arrangement (network) defines the project and the activity precedence relationships. Networks are usually drawn starting on the left and proceeding to the right. Arrowheads placed on the arcs are used to indicate the direction of flow—that is, to show the proper precedence. Before an event can be realized—that is, achieved—all activities that immediately precede it must be completed. These are called its predecessors. Thus, an event represents an instant in time when each and every predecessor activity has been finished.

Activity: A specific task or set of tasks that are required by the project, use up resources, and take time to complete. An activity means work/job. It is a time consuming process. It is represented by an arrow in the network diagram (AOA system).

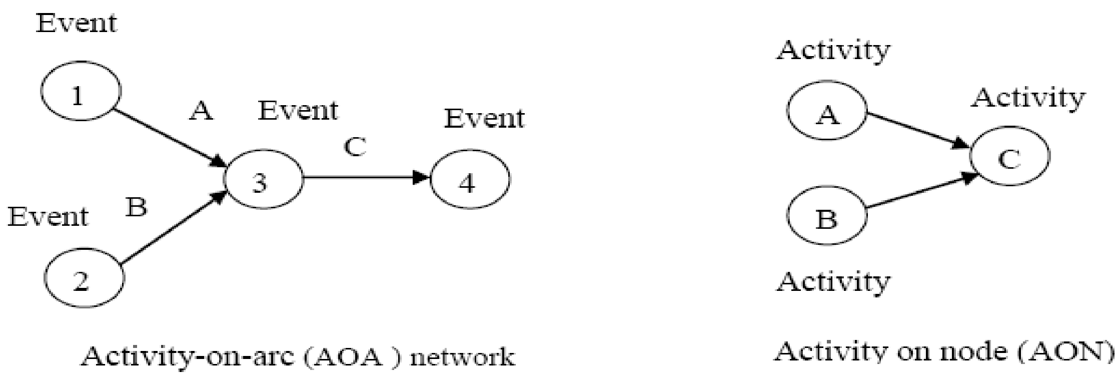


Fig. 3.8 AOA and AON Network

Event: The result of completing one or more activities. An identifiable end state that occurs at a particular time is event. Events use no resources. An event is a specific instant of time marks the start and end of an activity.

Network: Path: The series of connected activities (or intermediate events) between any two events in a network.

Critical: Activities, events, or paths that, if delayed, will delay the completion of the project. A project's critical path is understood to mean that sequence of critical activities (and critical events) that connects the project's start event to its finish event and which cannot be delayed without delaying the project. Critical path is the sequence of activities which decides the total project duration.

Duration (d): Duration is the estimated or actual time required to complete a task or an activity.

Total project time: Time to complete the project. In other words, it is the duration of critical path.

Earliest start time (E): It is the earliest possible time at which an activity can start. It is calculated by moving from 1st to last event in the network diagram.

Latest start time (Li): It is the latest possible time by which an activity can start.

Earliest finish time (Ej): It is the last event time of the head event. It is calculated by moving backward in the network diagram.

Latest finish time (Lj): It is the last event time of the head event. It is calculated by moving backward in the network diagram.

Float/Slack: Slack is with reference to an event and Float is with reference to an activity.

Free float: (Latest Finish Time – Earliest Start Time) – Activity duration.
Rules for Network Construction:

The following are the primary needs for constructing Activity on Arc (AOA) network diagram.

1. The starting event and ending event of an activity are called tail and head event respectively.

2. The network should have a unique starting node. (tail event)

3. The network should have a unique completion node. (head event)

4. No activity should be represented by more than one are ( ) in the network.

5. No two activities should have the same starting node and same ending node.

6. Dummy activity is an imaginary activity indicating precedence relationship only. Duration of dummy activity is zero.

7. The length of the arrow bears no relationship to the activity time.

8. The arrow in a network identifies the logical condition of dependence.

9. The direction of arrow indicates the direction of workflow.

10. All networks are constructed logically or based on the principle of dependency.

11. No event can be reached in a project before the completion of precedence activity.

12. Every activity in the network should be completed to reach the objective.

13. No set of activities should form a circular loop.

Network scheduling

The biggest advance in project scheduling since the development of the Gantt chart in 1917 was made between1956-58. During this period, two new scheduling techniques were developed. These techniques are

(i) Critical path method (CPM)
(ii) Program evaluation and review technique (PERT)

Both are based on the use of a network/graphical model to depict the work tasks being scheduled. The popularity of network based scheduling can be attributed to its many benefits, especially its ease use. Other benefits include the following.

1. It provides a visual display of needed task and their temporal ordering, which makes it easy to see how tasks should be sequenced as shown below. This assists communication and co-operation among task teams because each team can see how its work affects other team.
2. It provides a relatively accurate estimate of the time required to complete the project at the proposed resource level.

3. It identified and highlights the tasks that are critical to keep the project on schedule.
4. It provides a method for evaluating the time-cost tradeoffs resulting from reallocating resources among tasks.
5. It provides a method for monitoring the project throughout its life cycle. As the project progresses, PERT/CPM easily identifies change in which tasks are critical and how the expected completion date is affected.
6. It provides a convenient method for incorporating uncertainty regarding task times into the schedule and it helps to evaluate the effect of this uncertainty on project completion time.

Table 3.2 Difference between PERT and CPM

SR	PERT	CPM
1	PERT is a probabilistic model with uncertainty in activity duration. Activity duration is calculated from to, tp and tm.	CPM is a deterministic model with well known activity duration.
2	It is an event oriented approach.	It is an activity oriented approach.
3	PERT terminology uses word like network diagram, event and slack.	CPM terminology employs word like arrow diagram, nodes and float.
4	The use of dummy activity is required for representing the proper sequencing	No dummy activity required
5	PERT basically does not demarcate between critical and non-critical activities.	CPM marks the critical activities.
6	PERT is applied in projects where resources are always made available.	CPM is applied to projects where minimum overall cost is the prime importance.
7	PERT is suitable in Defence project and R&D where activity time can’t be readily predicted.	Suitable for plant maintenance, civil construction projects etc. where activity duration is known.

Steps in using network techniques

1. Plan of project

(a) The project is analyzed by determining all the individual activities (sometimes called tasks/jobs/operation) that must be performed to complete it.
(b) A planned sequence of these activities are shown on a network (a graph where arrow and circles represent the relationship among project activities)

2. Schedule of project

(a) How long it will take to perform each activity is estimated.

(b) In order to locate the critical path, calculation is performed (the longest time chain of sequential activities which determines the duration of project). This step also provides other information that is useful in scheduling.
(c) The above information are used to develop a more economical and efficient schedule.

3. Project monitoring

(a) The plan and schedule started above are used to monitor the progress.
(b) Throughout the execution of project, the schedule is revised and updated so that the schedule represents the current plan and status of progress.
(c) PERT, Critical path, Most likely time estimates.
The above points can be explained with the following examples.

CPM (Critical Path Method)

The critical path method (CPM) aims at the determination of the time to complete a project and the important activities on which a manager shall focus attention.

Assumption For Cpm
In CPM, it is assumed that precise time estimate is available for each activity.

Project Completion Time
From the start event to the end event, the time required to complete all the activities of the project in the specified sequence is known as the project completion time.

Path In A Project
A continuous sequence, consisting of nodes and activities alternatively, beginning with the start event and stopping at the end event of a network is called a path in the network.

Critical Path And Critical Activities
Consider all the paths in a project, beginning with the start event and stopping at the end event. For each path, calculate the time of execution, by adding the time for the individual activities in that path. The path with the largest time is called the critical path and the activities along this path are called the critical activities or bottleneck activities. The activities are called critical because they cannot be delayed. However, a non-critical activity may be delayed to a certain extent. Any delay in a critical activity will delay the completion of the whole project. However, a certain permissible delay in a non –critical activity will not delay the completion of the whole project. It shall be noted that delay in a non-critical activity beyond a limit would certainly delay the completion the whole project. Sometimes, there may be several critical paths for a project. A project manager shall pay special attention to critical activities.

Problem 1
Find out the completion time and the critical activities for the following project:

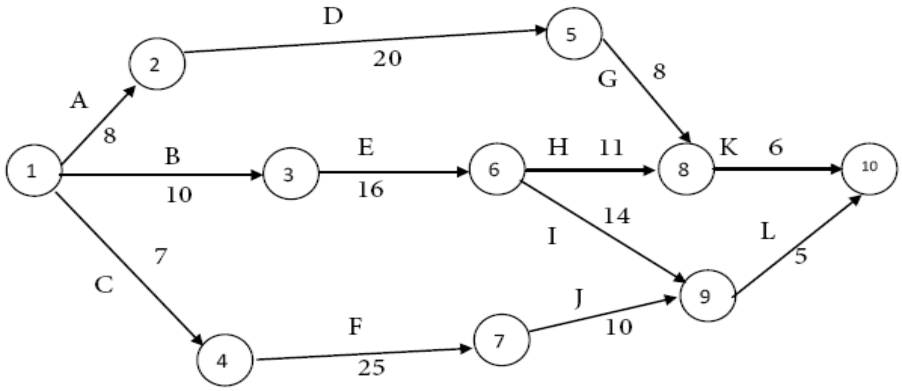
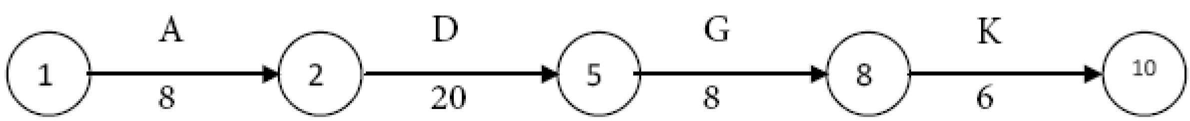


Fig. 3.9 Network Diagram for Problem 1

Solution

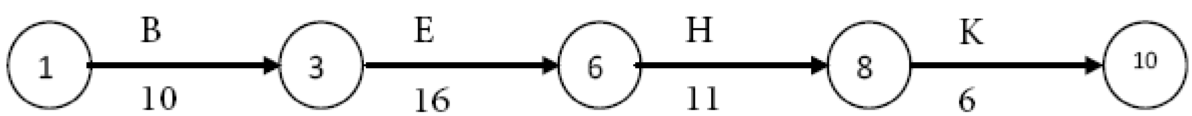
In all, we identify 4 paths, beginning with the start node of 1 and terminating at the end node of 10. They are as follows:

Path I



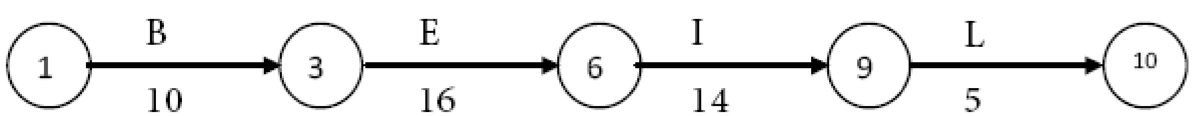
Time for the path = 8 + 20 + 8 + 6 = 42 units of time.

Path II



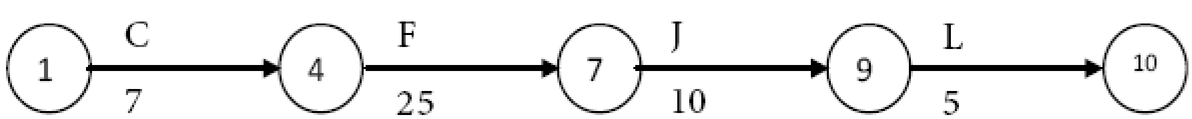
Time for the path = 10 + 16 + 11 + 6 = 43 units of time.

Path III



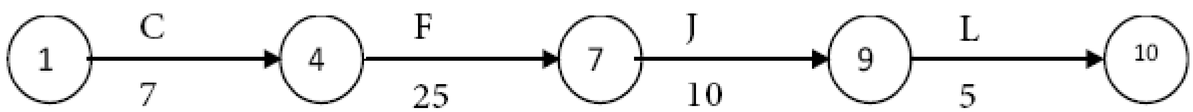
Time for the path = 10 + 16 + 14 + 5 = 45 units of time.

Path IV



Time for the path = 7 + 25 + 10 + 5 = 47 units of time.

Compare the times for the four paths. Maximum of {42, 43, 45, 47} = 47. We see that the following path has the maximum time and so it is the critical path:



The critical activities are C, F, J and L. The non-critical activities are A, B, D, E, G, H, I and K. The project completion time is 47 units of time.

Problem 2

Draw the network diagram and determine the critical path for the following project:

Activity	Time Estimate (week)
1-2	5
1-3	6
1-4	3
2-5	5
3-6	7
3-7	10
4-7	4
5-8	2
6-8	5
7-9	6
8-9	4

Solution

We have the following network diagram for the project:

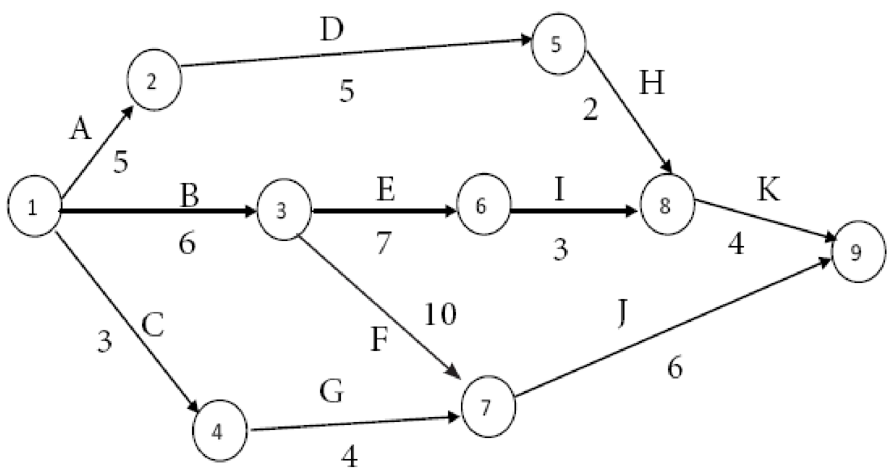
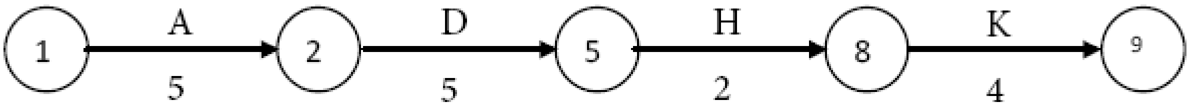


Fig. 3.10 Network Diagram for Problem 2

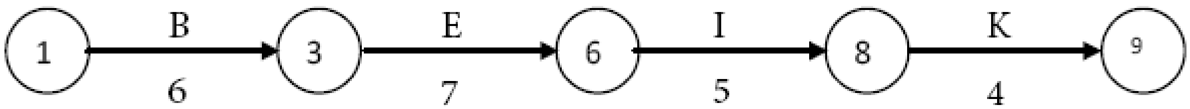
We assert that there are 4 paths, beginning with the start node of 1 and terminating at the end node of 9. They are as follows:

Path I



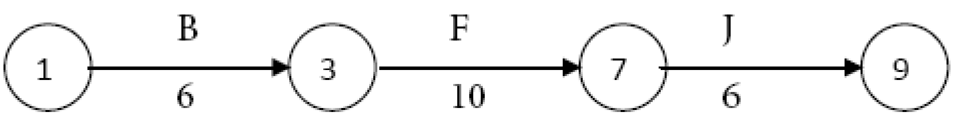
Time for the path = 5 + 5 + 2 + 4 = 16 weeks.

Path II



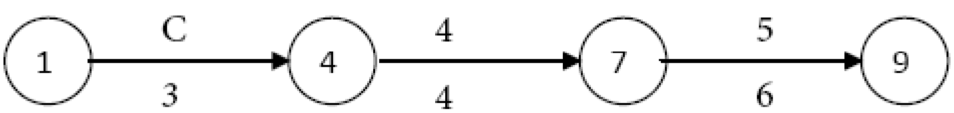
Time for the path = 6 + 7 + 5 + 4 = 22 weeks.

Path III



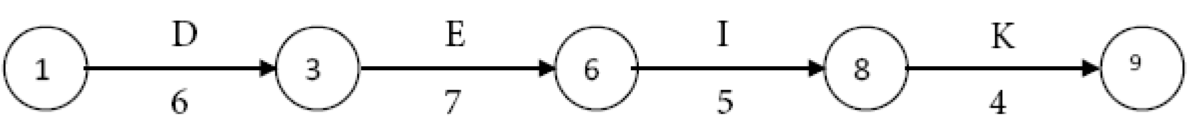
Time for the path = 6 + 10 + 6 = 16 weeks.

Path IV



Time for the path = 3 + 4 + 6 = 13 weeks.

Compare the times for the four paths. Maximum of {16, 22, 16, 13} = 22. We see that the following path has the maximum time and so it is the critical path:



The critical activities are B, E, I and K. The non-critical activities are A, C, D, F, G, H and J. The project completion time is 22 weeks.

Programme Evaluation and Review Technique (PERT)

Programme Evaluation and Review Technique (PERT) is a tool that would help a project manager in project planning and control. It would enable him in continuously monitoring a project and taking corrective measures wherever necessary. This technique involves statistical methods.

Assumptions for Pert

Note that in CPM, the assumption is that precise time estimate is available for each activity in a project. However, one finds most of the times that this is not practically possible.

In PERT, we assume that it is not possible to have precise time estimate for each activity and instead, probabilistic estimates of time alone are possible. A multiple time estimate approach is followed here. In probabilistic time estimate, the following 3 types of estimate are possible:
Pessimistic time estimate (*tp*)
Optimistic time estimate (*to*)
Most likely time estimate (*tm*)
The optimistic estimate of time is based on the assumption that an activity will not involve any difficulty during execution and it can be completed within a short period. On the other hand, a pessimistic estimate is made on the assumption that there would be unexpected problems during the execution of an activity and hence it would consume more time. The most likely time estimate is made in between the optimistic and the pessimistic estimates of time. Thus the three estimates of time have the relationship $to \leq tm \leq tp$
Practically speaking, neither the pessimistic nor the optimistic estimate may hold in reality and it is the most likely time estimate that is expected to prevail in almost all cases. Therefore, it is preferable to give more weight to the most likely time estimate.
We give a weight of 4 to most likely time estimate and a weight of 1 each to the pessimistic and optimistic time estimates. We arrive at a time estimate (*te*) as the weighted average of these estimates as follows:

$$(te) = (to+ 4tm+ tp)/6$$

Since we have taken 6 units (1 for *p t* , 4 for *m t* and 1 for *o t*), we divide the sum by 6. With this time estimate, we can determine the project completion time as applicable for CPM.
Since PERT involves the average of three estimates of time for each activity, this method is very practical and the results from PERT will be have a reasonable amount of reliability.

Measure Of Certainty

The 3 estimates of time are such that $to \leq tm \leq tp$
Therefore the range for the time estimate is $tp - to$.
The time taken by an activity in a project network follows
a distribution with a standard deviation of one sixth of the range, approximately.
i.e., The standard deviation =

$$\sigma e = \left[\frac{tp - to}{6}\right]$$

and the variance =

$$\sigma^2 e = \left[\frac{tp - to}{6}\right]^2$$

The certainty of the time estimate of an activity can be analyzed with the help of the variance. The greater the variance, the more uncertainty in the time estimate of an activity.

Problem 3

A project consists of the following activities and time estimates.

Activity	Least time (t0) in days	Greatest time (tp) in days	Most likely time (tm) in days
1-2	3	15	6
1-3	2	14	5
1-4	6	30	12
2-5	2	8	5
2-6	5	17	11
3-6	3	15	6
4-7	3	27	9
5-7	1	7	4
6-7	2	8	5

Construct the network. Determine the expected task time and the critical path.

Solution: The network diagram is shown below:
Expected task time (te) = (t0+ 4tm+ tp)/6
Using this formula, te for different activities are shown below.

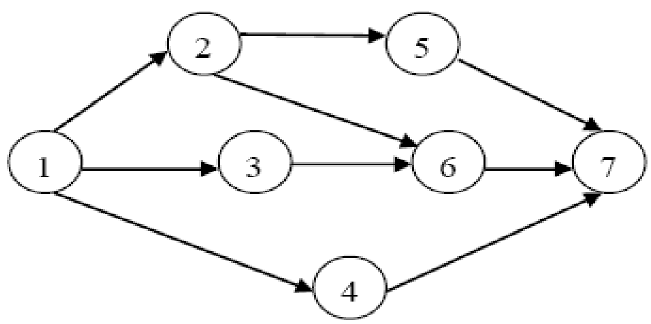


Fig. 3.11 Network Diagram for problem 3

Activity	te value
1-2	6
1-3	7
1-4	14
2-5	5
2-6	11
3-6	7
4-7	11
5-7	4
6-7	5

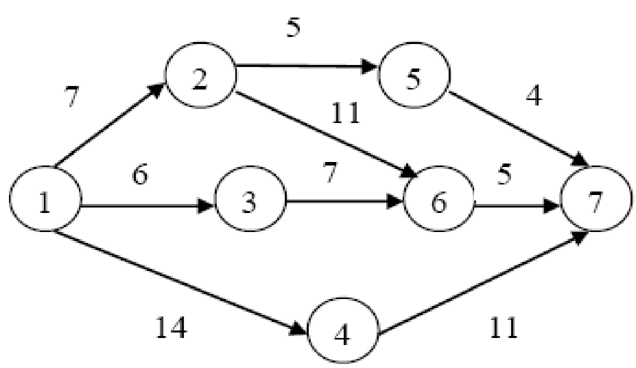


Fig. 3.12 te calculation and depiction on network diagram

From the above figure, 1-4-7 is the critical path. The project duration is 14+11 = 25 days.

Problem 4

A project consists of seven activities with the following time estimates. Find the probability that the project will be completed in 30 weeks or less.

Activity	Predecessor Activity	Optimistic time estimate (to days)	Most likely time estimate (tm days)	Pessimistic time estimate (tp days)
A	-	2	5	8
B	A	2	3	4
C	A	6	8	10
D	A	2	4	6
E	B	2	6	10
F	C	6	7	8
G	D, E, F	6	8	10

From the three time estimates, and, calculate for each activity. The results are furnished in the following table:

Activity	Optimistic time Estimate (to)	4 x Most likely time estimate	Pessimistic time estimate (tp)	to+ 4tm + tp	Time estimate Te= (to+ 4tm + tp)/6
A	2	20	8	30	5
B	2	12	4	18	3
C	6	32	10	48	8
D	2	16	6	24	4
E	2	24	10	36	6
F	6	28	8	42	7
G	6	32	10	48	8

With the single time estimates of the activities, the following network diagram is constructed for the project.

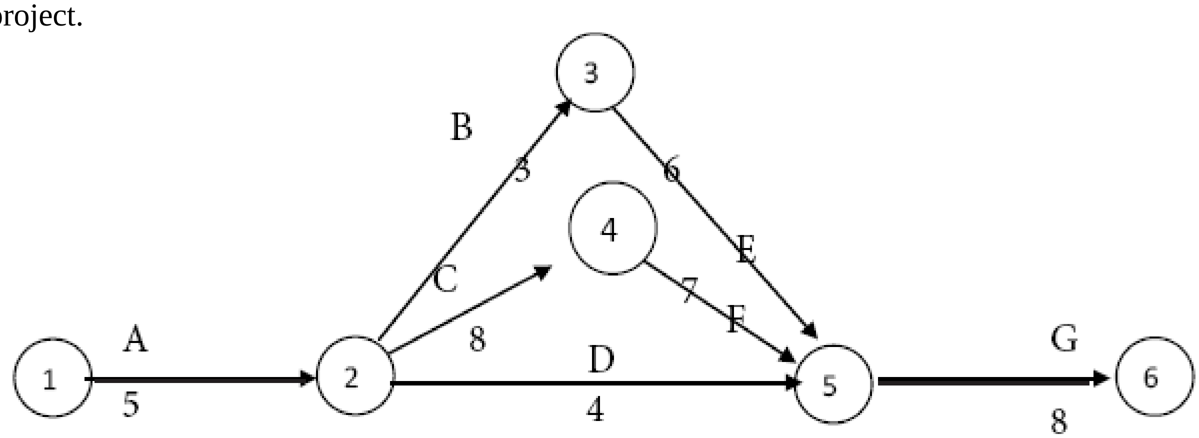
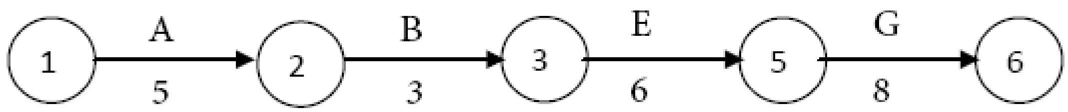


Fig. 3.13 Network Diagram for problem 4

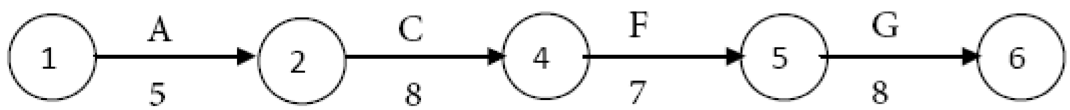
Consider the paths, beginning with the start node and stopping with the end node. There are three such paths for the given project. They are as follows:

Path I



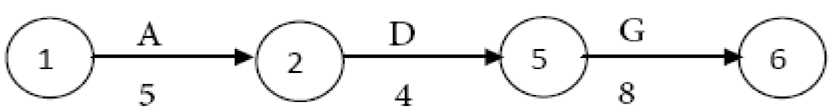
Time for the path: 5+3+6+8 = 22 weeks.

Path II



Time for the path: 5+8+7+ 8 = 28 weeks.

Path III



Time for the path: 5+4+8 = 17 weeks.

Compare the times for the three paths.
Maximum of {22, 28, 17} = 28.
It is noticed that Path II has the maximum time.
Therefore the critical path is Path II. i.e., 1 →2→ 4 →5 →6.
The critical activities are A, C, F and G.
The non-critical activities are B, D and E.
Project time = 28 weeks.

Calculation of Standard Deviation and Variance for the Critical Activities:

Activity	Optimistic time Estimate (to)	Most likely Time Estimate (tm)	Pessimistic time estimate (tp)	Range (tp -to)	Standard Deviation σ=(tp-to)/6	Variance $\sigma^2=\{(tp-to)/6\}^2$
A: 1-2	2	5	8	6	5	1/9
C: 2-4	6	8	10	4	3	4/9
F: 4-5	6	7	8	2	8	1/9
G: 5-6	6	8	10	4	4	4/9

Standard deviation of the critical path = √2 = 1.414. The standard normal variate is given by the formula

$$Z = \frac{Given\ value\ of\ t - Expected\ value\ of\ t\ \text{in}\ the\ critical\ path}{SD\ for\ the\ critical\ path}$$

So we get

$$Z = \frac{30-28}{1.414} = 1.414$$

We refer to the Normal Probability Distribution Table.
Corresponding to Z = 1.414, we obtain the value of 0.4207. We get 0.5 + 0.4207 = 0. 9207
Therefore the required probability is 0.92 i.e., There is 92% chance that the project will be completed before 30 weeks. In other words, the chance that it will be delayed beyond 30 weeks is 8%

Gantt Chart: -

The simplest and most commonly used scheduling technique is the *Gantt chart* (or bar chart), named after the management consultant Henry L. Gantt (1861–1919). During World War I Gantt worked with the US Army to find a way to portray visually the status of the munitions program. He realized that time was a common denominator to most elements of a program plan, and that it would be easy to assess progress by viewing each element's status with respect to time. His approach, which came to bear his name, became widely adopted in industry, and is used today in a variety of ways.
The chart consists of a horizontal scale divided into time units—days, weeks, or months—and a vertical scale showing project work elements—tasks, activities, or work packages. Figure 5.10 shows the Gantt chart for work packages in the SPHIL project. Listed on the left-hand side are work packages, and along the bottom are work weeks. The starting and completion times of packages are indicated by the beginning and ending of each bar. Preparation of the Gantt chart comes after a WBS analysis and identification of work packages or other tasks. During WBS analysis, the functional manager, contractor, or others responsible for a work package estimate its time and any prerequisites.
The work elements are then listed in sequence of time, taking into account which elements must be completed before others can be started. As an example, consider how the first nine work elements in Figure 5.10 (work packages H through P) are scheduled. In every project there is a precedence relationship between the tasks (some tasks must be completed before others can begin), and this relationship must be determined before the tasks can be scheduled. These are the "predecessor" inputs mentioned earlier in the discussion of work package definition. Suppose that during the WBS analysis for SPHIL it was determined that before work elements I and J could be started, element H had to be completed; that before elements K, L, and M could be started, element J had to be completed; and that before elements N, O, and P could begin, element I had to be completed. That is:

Before these can be started . . .	this must be completed
I ,J	H
N,O,P	I
K,L,M	J

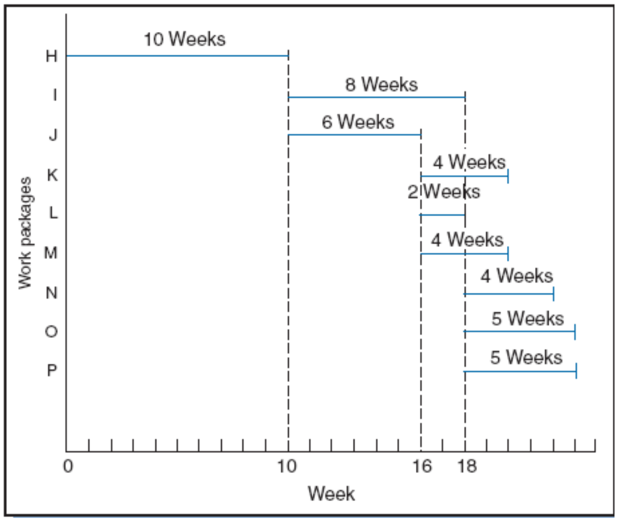


Figure 3.16 Setting up a Gantt chart.

This sequencing logic is used to create the Gantt chart. Thus, as shown in Figure 5.11 (and given the times shown for the work packages), only after element H has been completed—i.e., after week 10—can elements I and J be started; only after element J has been completed—after week 16—can elements K, L, and M be started; and only after element I has been completed—after week 18—can elements N, O, and P be started. As each new work element is added to the chart, care is taken to locate it following completion of all of its predecessor work elements. This example uses work packages as the elements being scheduled, but in fact any unit of work can be scheduled depending on the detail level desired.

Once the project is underway, the Gantt chart becomes a tool for assessing the status of individual work elements and the project as a whole. Figure 3.16 shows progress as of the "status date," week 20. The heavy portion of the bars indicates the amount of work that has been completed. The thinner part of the bars represents work unfinished or yet to be started. This method is somewhat effective for showing which of the work elements are behind or ahead of schedule. For example, as of week 20, work element N is on schedule, element O is ahead of schedule, and elements K, L, M, P, and Q are behind schedule; L is the furthest behind, because it should have be completed but has yet to be started.

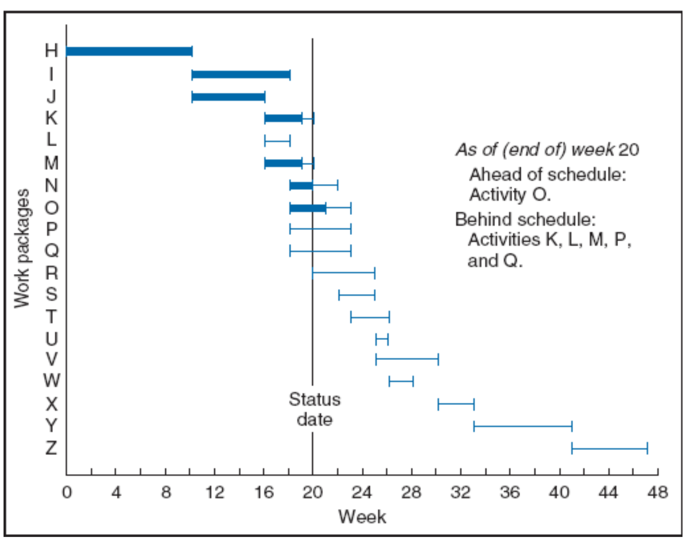


Figure 3.17 Gantt chart for SPHIL project showing work progress as of week 20.

When the Gantt chart is used like this to monitor progress, the information it reflects must be the most current possible, and the chart must be updated on a daily or at least weekly basis. Tracking progress is important for identifying and rectifying problems, and posting progress like this is a good way to keep the team motivated.

GANTT CHARTS: THEIR ADVANTAGES AND THEIR LIMITATIONS

Gantt charts need little explanation and no training because anyone who can understand a holiday walls chart or even a calendar should be able to understand a project Gantt chart. Gantt charts are named after the American industrial engineer Henry Gantt (1861– 1919). They are also known widely as bar charts.
Gantt charts are always drawn to a linear timescale. They are excellent visual aids and their effectiveness can be enhanced by the use of different colors. Gantt charts are useful for very simple resource scheduling because the amount of any particular kind of resource needed in a given time period can be calculated by adding the number of times that tasks needing that resource appear in each period column. Before the advent of computers this was the only resource scheduling method possible, and we used to plan using Gantt charts set up on wall-mounted pegboards that allowed the tasks to be represented by colored plastic strips. These strips could be plugged in and moved around to achieve the best possible resource usage pattern. Another version of these charts used Lego bricks, and yet another idea was based on magnetic strips stuck to a steel back plate, rather in the manner of fridge magnets.
Senior executives and others unskilled in the project management arts often prefer to be given Gantt charts in reports because the more powerful network planning diagrams need some training before they can be interpreted. However, Gantt charts are not able clearly to show all the complex interdependencies that exist between the different tasks in most projects.
All competent project management computer programs can convert critical path network diagrams into Gantt charts, optionally showing all the complex inter-task dependencies. However, except in the very simplest cases, a project Gantt chart can become very cluttered and difficult to follow when the inter-task links are added and it is usually best to hide them. Critical path network diagrams provide the notational methods needed to overcome these difficulties.

3.7 Introduction to Project Management Information System (PMIS): -

The PMIS provides access to information technology (IT) software tools, such as scheduling software tools, work authorization systems, configuration management systems, information collection and distribution systems, as well as interfaces to other online automated systems such as corporate knowledge base repositories. Automated gathering and reporting on key performance indicators (KPI) can be part of this system.
Almost all project management information systems allow you to perform the scheduling functions. Specifically, activity estimated durations can be in hours, days, weeks, months, or years, and with a click of the mouse, time scales can easily be converted from days to weeks, weeks to days, and so on. The estimated durations can easily be updated and revised. In addition, calendaring systems provide the project manager with the ability to handle weekends, company holidays, and vacation days.

Project start and finish times can be entered as specific calendar dates (for example, June 1, 2018, or December 31, 2018), or an overall number of days (or weeks or months), without specific calendar dates assigned, can be entered (for example, the project needs to finish by week 50). Given the project required completion date and the list of activities with their estimated durations, the software will calculate the date by which a project needs to start. Similarly, it will calculate the earliest project completion date, based on the actual start date and the list of activities with their estimated durations. The software will also calculate ES, EF, LS, and LF times, TS and FS, and the critical path, all with a click of the mouse. It is important, however, for the project manager to understand what these terms are and what the calculations mean.

Most project management information systems have the ability to provide Gantt or bar charts that display the dependencies among tasks by connecting tasks and their predecessors with lines and arrowheads. The user can click back and forth between the Gantt or bar charts and the network diagrams.

Virtually all project management information systems allow you to perform the control functions identified in this chapter. Specifically, while an activity is in progress or once an activity has been completed, current information can be entered into the system and the software will automatically revise the project schedule. Likewise, if the estimated durations for any future activities change, these changes can be entered into the system and the information system will automatically update the schedule. All network diagrams, tables, and reports produced by the software will be updated to reflect the most recent information.

Also, Project management information systems make it fairly easy to handle the cost considerations of a project. All costs associated with each resource in a project can be stored, and the system will calculate the budget for each work package and for the entire project. It will calculate the actual costs as the project proceeds and will forecast the final costs as well. Because various resources have different rate structures and charge their rates at various points in the project, project management information systems usually allow the user to define different rate structures for each resource and determine when charges for those resources will actually be accrued. At any time during a project, cost estimates, actual cost, committed costs, and a cost forecast can be calculated for each task, each work package, or the entire project, with a click of the mouse. Cost tables and graphs are often available to help analyze cost performance.

Module-3 Project Planning & Scheduling **(Question Bank)**

1. Why communication is most important part of project manager's job?
2. Differentiate between the Functional, Pure Project and Matrix organizations.
3. How virtual projects can be handled more effectively?
4. Explain work breakdown structure.
5. What is concurrent engineering?
6. Compare the top down budgeting and bottoms up budgeting.