Project Management

Course Coordinator

Dr. Sricharan

Mechanical Engineering Department

S. R. K. R. Engineering College, Bhimavaram

IV/IV 1 Semester 2022-2023

UNIT 1: Overview of Project Management

- Introduction
- Characteristics of projects
- Project management: The Need, the Goal, and its key features
- Objectives of project management
- Evolution of project management and its different forms.
- The Project Life Cycle

Unit 1 – OVERVIEW OF PROJECT MANAGEMENT

INTRODUCTION

Statement: As long as the humankind does things, there will be projects.

This brings out three issues about the projects: 1. Not something new. 2. Project – an unique task. 3. It is applicable only to humans (purposeful, innovative, competitive and greedy minds).

Some of the projects from ancient days to the present day:

- Great religious structures and monuments like temples, churches, mosques, pyramids, etc.
- Extensive **municipal and government** works programs such as street paving, water supply, and sewers taken up by all ancient civilizations like, India, China, Romans, Greeks.
- To facilitate their military campaigns and commercial interests, the Romans **constructed the networks of highways** and roads throughout Europe, Palestine, and Northern Africa so that all roads would “lead to Rome”.
- River engineering, construction of canals, dams, port and harbour facilities.
- With the advent of *industrialization and electricity*, **the projects of humankind took on increasing complexity**. Projects for the construction of railroads, electrical and hydro electrical power facilities, subways, factories and so on became common place.

- Also, *research and installation* of **large systems** for communications, defense, transportation and IT have **spurred more complex** kinds of project activities.
- As the days pass the complexity of the projects **will only increase in terms of** increased scale of **effort** and the **advanced technology**. Examples of which include,

  English Channel Tunnel (Chunnel) and many other under water tunnels.

  Aerospace projects.

  Disaster clean-up projects.

  Energy projects.

  Spacecraft projects.

  Industrial cities.

  Sports and Cultural projects.

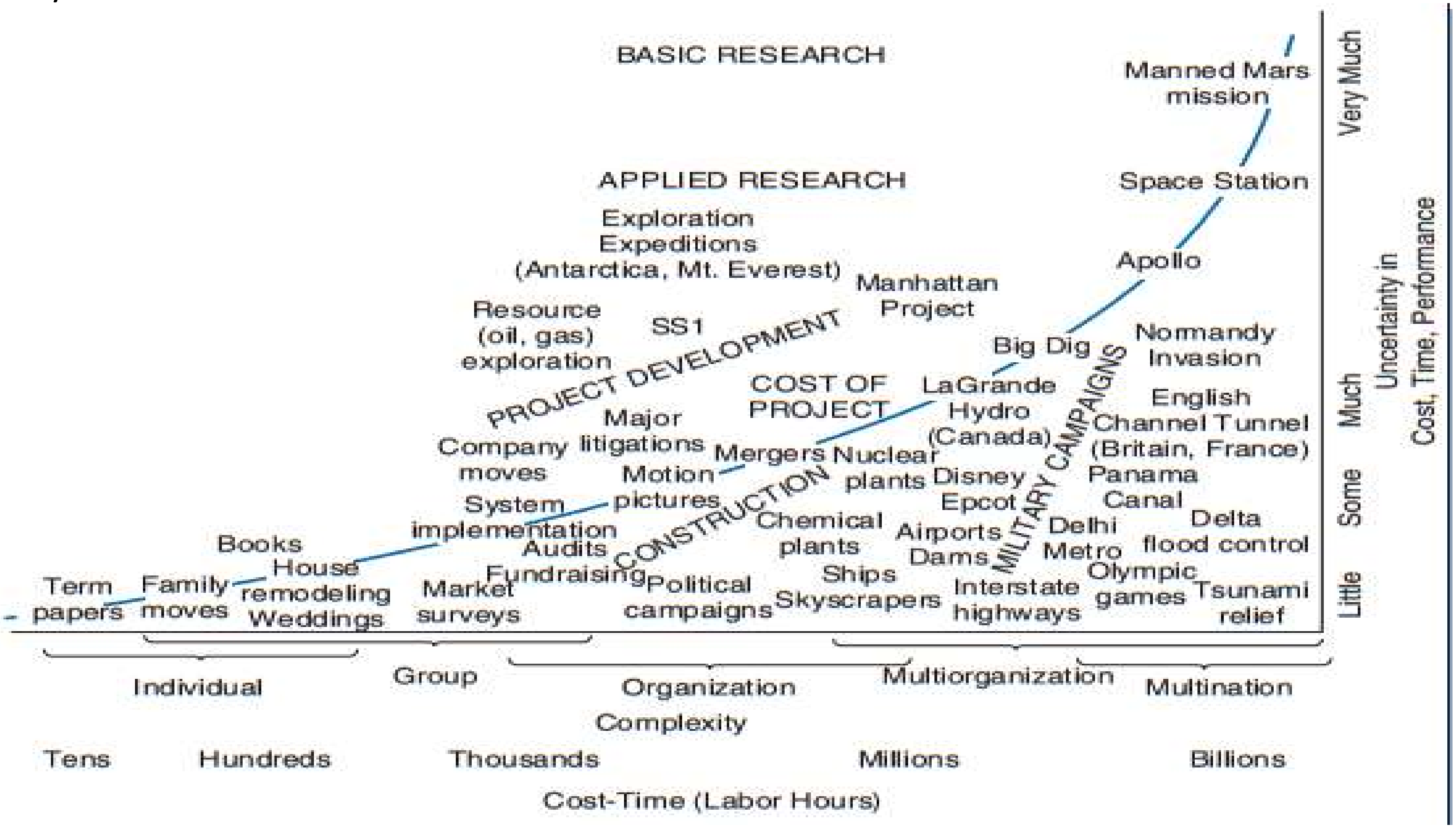
Note in Point

While some activities or works like these are considered projects, the other activities such as planting, harvesting a crop, stocking a warehouse, or manufacturing a product are not. **WHY?** Then what is a project? How to classify an activity as a project?

The unique features which classify an activity as a project/ The characteristics of a project

1. A project involves a single, definable **purpose**, end-item, or result, usually specified **in terms of** cost, schedule, and performance requirements.
2. Every project is **unique** in that it requires **doing something different** than was done previously. Even in **‘routine’ projects** such as home construction, variables such as geography, labour market, and public services make each project different. A project is a one time activity, **never to be exactly repeated again**.
3. Projects are **temporary** activities. An **ad hoc organization of** personnel, material and facilities is assembled to accomplish a goal, usually within a scheduled time frame. Once the goal is achieved, the organization is **disbanded or reconfigured** to begin work on a new goal.
4. Projects **cut across organizational lines** because they need the skills and talents from multiple functions, professions and organizations.
5. Involvement in **anything new or different** always carries some **uncertainty about the outcome**. It also involves **unfamiliarity and risk**.
6. The organization doing the project usually has **something at stake**. The work calls for **special scrutiny or effort**, because **failure would jeopardize** the organization or its goals.
7. A project is the **process of working** to achieve a goal. During the process the project passes through several distinct phases in the **project life cycle**. Often, the **tasks, people, organizations, and resources change** as the project moves from one phase to the next.

The following figure displays different projects depending upon where they fall w.r.t complexity and uncertainty.



Complexity is **measured by magnitude** of the effort, number of groups and organizations that need to be coordinated, and the diversity in the skills or expertise needed to accomplish the work. **Time and resource** commitments **tend to increase** with complexity.

Uncertainty is measured roughly by the **difficulty in predicting** the final outcome **in terms** of the dimensions of time, cost and technical performance. In most projects there is some uncertainty in **one or two** dimensions, **at least in the initial stages** of the planning. The **most complex projects** have uncertainty in **all three** dimensions (e.g. the international space station).

The **cost curve** indicates that the **expense of projects** increases roughly in proportion to both complexity and uncertainty.

When the uncertainty of the project drops to nearly zero, and when the project effort is repeated a large number of times, then the work is usually no longer considered a project.

Project Management: The Need

In comparison with repetitive tasks:

In all cases, projects are conducted by organizations that, after the project is completed**, go on to do something else** (construction companies) or **are disbanded** (Mars exploration team). In contrast, repetitive, high certainty activities (manufacturing the products in large quantities, tourist trips to different places) are performed by permanent organizations that do the same thing over and over, with few changes in operations other than scheduling.

It is because projects are not repetitive efforts, they must be managed differently.

In comparison with ancient projects:

- Project requirements in **ancient times**: more flexible in terms of time, funding, or other resources.
- In **modern times**: *Not flexible*; Involve great *technical complexity* and require a wide *diversity of skills*. Managers are placed with the problem of putting **together and directing** large temporary organizations while being **subjected to constrained** resources, limited time and environmental uncertainty. To **cope with this** complexity and uncertainty, **new forms** of project organization and management **have evolved**.

Imagine the project requirements of two modern projects:

Manhattan project to develop the first atomic bomb and the **Pathfinder Mission** to land and operate a rover vehicle on the surface of the Mars.

- Manhattan, undertaken during world war II, required developing the atomic bomb in the shortest time possible to end the war.
- For Pathfinder, the **mission team** was challenged with **developing and landing** a vehicle on Mars in less than 3 years time and on a 150 million dollar budget. This was less than half the time and one-twentieth the cost of the previous probe NASA had landed on Mars.

Both the projects involved **advanced R&D** and **explored new areas** of science and engineering. In neither case could technical performance requirements be **compromised to compensate** for limitations in time, funding, or other resources.

The constraints and uncertainty in project work are **not restricted to** large-scale government science programs. They are common in **every day business** and technology where **organizations continually strive** to **develop and implement** new products, processes, and systems, and **to adapt** to **changing requirements in a changing world**.

Examples:

1. **Product development project:** It is not sufficient to have innovative ideas. The company should be able to introduce the product well ahead in the market than its competitors. To move the idea from concept to product quickly with the involvement of engineers and technicians from several divisions of the company and the suppliers, the **project would need a new product development process *guided by project management*.**

2. **Change project** – projects initiated in response to changing needs and with the goal of transforming the organizations way of doing things: Imagine a concern trying to install a **new employee benefits plan** to better suit employee needs, add flexibility and value to the benefits package, and reduce costs. **This project would be big** – it would involve *developing new policies, training staff workers, familiarizing 10,000 employees (say), and installing a new computer network and database and require active participation from personnel in human resources, financial services, and information systems*, as well as experts from *two or three consulting firms*. This project would be different from anything the concern had done before.

Projects like these **defy traditional management approaches** for *planning, organization and control*. They are representatives of activities **that require modern methods of** project management to fulfil difficult technological or market related performance goals in spite of limitations on time and resources.

Hence, project management is a **distinct area** of management practice. It is still a **new idea and its methods are still unknown** to many experienced managers. Only 50 years ago, its **usage** was restricted largely to the defense, aerospace and construction industries. Today, however, PM is being applied in a wide variety of industries and organizations. Hence, we can say that PM has grown in **response to the need** of modern society.

Traditional organizational forms and management procedures **works** when there are **repetitive operations** where the market and the technology are tend to be **predictable**, anticipated outcomes are more certain and only one or a **few parties** of the organizations are involved, and where the decision making is **centralized and hierarchical** authority works.

Project Goal: Time, Cost, and Requirements

For virtually every project, the goal can be conceptualized in terms of **hitting a target** that **floats in the three dimensions** of *cost, time and requirements.* The **purpose of Project Management** is to hit the target.

- Cost is the specified or budgeted cost for the project.
- Time is scheduled period over which the work is to be done.
- Performance is what the project end-item, deliverables, or the final result must do; it includes whatever project customer or end-user considers necessary or important.

Obstacles to meet this goal:

- Technological complexity, changing markets, and an uncontrollable environment make it **easy to miss** the target.
- Time, cost, and technological performance are **interrelated**, and **exclusive emphasis** on anyone will likely undermine the others. In trying to meet schedules and performance requirements, costs increase; conversely, in trying to contain costs, work performance erodes and schedules slip. In the **earlier days**, most fixed could be met. But the **modern complexity** does not allow for this luxury. To an extent, **all the three dimensions must receive equal emphasis**.

PM offers a way to maintain **focus on all 3Ds** and to **control the trade-offs among them**. As a **systems approach**, it **integrates resources** and enables **simultaneous emphasis** on the whole project goal – time, cost, and performance requirements.

Project management: The Person, The Team, The Methodology

Three key features **distinguish PM from traditional forms** of management: the person, the team and the methodology.

The person:

The most important feature regarding PM is the **role of the project manager** – the individual who has overall responsibility to ***plan, direct and integrate*** *the efforts of all* ***project stakeholders*** to achieve the project goal. He ***coordinates*** *the efforts across all of the involved* ***functional areas and organizations***, and *oversees the* ***planning and control*** *of* ***costs, schedules, and work tasks***.

The team:

A project is a **team effort**, and the **Project management** is **bringing together** individuals and groups to form the team and to direct toward a common goal. Often, the team consists of people and groups **from different functional areas** and organizations. Depending on project requirements, the size and composition of the team may fluctuate, and the team may disband after the project is completed.

The methodology:

The project manager and the project team typically perform **work in phases according to** a “project management methodology”. As a project proceeds from one phase to the next, the *project management* ***methodology helps the project manager*** *to*

1. Identify the required project tasks
2. Identify the required resources and costs
3. Establish priorities
4. Plan and update schedules
5. Monitor and control end item quality and performance and
6. Measure project performance.

The objectives of Project Management

In brief, project management objectives are the successful **development of the project's procedures** for initiation, planning, execution, regulation and closure as well as the **guidance of the project team's** operations towards achieving all the agreed upon goals within the set scope, time, quality and budget standards. However, they can be explained in detail as follows:

1. The **successful development and implementation of all project's procedures** which includes Initiation, Planning and Design, Execution, Monitoring and Control, and Completion. **The smooth and uninterrupted** development and execution of all the above **procedures ensures the success** of a project.

2. **Productive guidance, efficient communication and apt supervision of the project's team**. The success or failure of a project is highly dependent on **teamwork**, thus, the key to success is always in **collaboration**. To this end, the establishment of **good communication** is of major importance.

3. The **achievement of the project's main goal within the given constraints**. The most important constraints are, Scope in that the main goal of the project is completed within the estimated Time, while being of the expected Quality and within the estimated Budget. **Staying within the agreed limitations** always feeds back into the **measurement of a project's performance** and success.

4. **Optimization of the allocated necessary inputs and their application** to meeting the project's pre-defined objectives, is a matter where is always **space for improvement**. **All processes and procedures can be reformed and upgraded** to enhance the sustainability of a project and to **lead the team** through the **strategic change process**.

5. **Production of a complete project which follows the customer's exclusive needs and objectives**. Meeting the customer's expectations and keeping them happy will lead to a successful collaboration which might help to eliminate surprises during project execution.

Evolution of PM

The idea of PM and the techniques of PM dates back to the ancient times (construction of monuments). Later these techniques were improved and modified for usage on other forms of construction projects such as shipbuilding.

Starting in the early twentieth century, industrial managers found that techniques used to manage construction could also be used for **large-scale non-construction projects**, such as designing and testing new products, and building and installing new machinery. Around the same time, during world war I, improved techniques for **planning non-standard, project type work** were being developed, and a new production **scheduling and tracking tool** called the ***Gantt Chart*** was introduced. About 30 years later, the first **network type display for describing industrial processes**, called a ***process flow diagram***, was developed. This would become the basis for ***project network diagrams.***

By the 1950s, the size and complexity of many projects had increased so much that existing management techniques proved **inadequate**. In particular, **large scale projects –** development of aircraft, missiles, communication systems, and naval vessels – were becoming so complex that they defied all existing methods to **plan and control them**. Repeatedly, these projects suffered **enormous cost and schedule overruns**. To grapple with the problem, two **network based planning and control methods** were developed.

One by the Navy in 1958, called PERT, and the other by the DuPont Corporation in 1957, called CPM. Both methods were created **exclusively for planning, scheduling and controlling** large projects with numerous interrelated work activities. A decade later, these methods were **combined with computer simulation methods to permit more realistic analysis of schedules**.

By the mid-1950s, wide scale usage of computers provided increased capability for handling the **immense amount of information** necessary to manage large-scale projects. **Network methods** were refined to **integrate project cost accounting with project scheduling**.

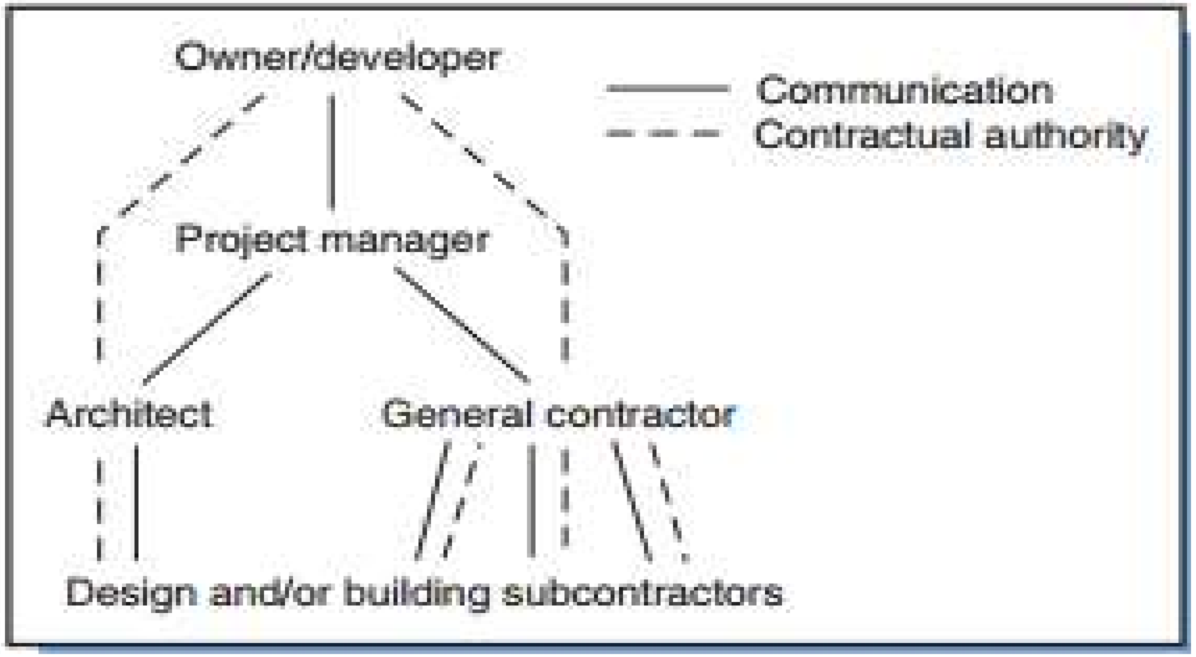
In the 1970s, a **project tracking concept called *earned value*** came into use. This concept led to **performance measurement systems** that track not only expenditures, but also the percentage of work completed. This led to more reliable **forecasting** of **final** project costs and completion dates.

The past 50 years have witnessed the **increased computerization** of project management. Initially, **project planning and tracking systems were available only for large mainframe computers**, and cost dollars 10,000 to 100,000. Today, relatively low cost software – between dollar 200 to 2000 – **makes it possible** to apply a variety of techniques for **scheduling, costing, resource planning, performance analysis, and forecasting to virtually any size project**.

Associated with the development of **methods or techniques** for project planning and control were the evolution of **forms of project organization and the role of project manager**. Not until world war II was the **project recognized as a distinct organizational form**. In 1961, IBM became one of the first companies in industry to ***formally* use the role of project/system manager** who were given broad responsibility **across functional lines** to oversee development and installation of mainframe computers.

In 1962, in **one of the first discussions** of the **evolution** of PM, Davis identified **four types of PM organization**, noting that **project organizations tend to evolve** from one type to the next as their problems become more complex and organizations become more sophisticated in dealing with them. Davis's **classification can be used to introduce** four types of **Project Managers**.

- *Project expeditors*, whose purpose is to try to **speed up the work**. They are the **communication link** between senior managers and the project. Their purpose is to achieve ***unity of communications***. They are **not really managers**, but are **go-betweens** who translates technical concepts into business concepts such as costs, schedules, and markets. The role is limited to funnelling information from technical workers to executives, and making decisions; thus, it tends to be restricted to **small projects** with low risk and little at stake.



- *Project coordinators,* whose purpose is to **achieve *unity of control* over project activities**. **They have authority to** control project matters and disburse funds from the budget, **but no** actual line authority over workers. Their **authority derives solely from their association** with upper-level managers. The project manager in **the above figure** would be in this position if he **coordinated** the work but **needed approval from the developer** for major decisions such as contracting or allocation of funds.
- *Matrix managers,* whose purpose is to achieve ***unity in direction***. Although they serve the **same purposes as the first two**, they additionally have **authority to plan, direct** and control project work. Matrix managers **direct people located administratively in different functional departments**, and the resulting **criss-cross pattern** of vertical-functional and horizontal-project **reporting relationships** create what is called a matrix organization.
- *Pure project managers,* whose purpose is to achieve ***unity of command*** **over the people** in ***pure project*** **organizations** that **report directly to them**. They are **primarily integrators and generalists** rather than technical specialists. They **must balance** technical factors of the project with schedules, costs, resources, and human factors. In the course of a project, **they deal with** top management, functional managers, vendors, customers and subcontractors. The manager of a large construction project who is hired by the developer and delegated the **authority to make major decisions (such as selecting and contracting with the architect and the contractor)** has such a role.

Generally, the **concept of PM** is being **referred** to the **latter two types**.

Different forms of PM

PM has different forms with different names, including *Systems management, Task force management, Team management, Ad hoc management, Matrix management, and Program management*. Regardless, all these forms share two features: (1) a **project team or project organization** created uniquely for the purpose of **achieving certain goal**, and (2) a **single person** – a project manager – assigned responsibility for seeing that the **goal is accomplished**.

Basic PM (the most commonly understood concept of PM)

1. The most common project approaches places the project manager and the functional managers on the **same organizational level** so that both report to the same senior level person.
2. The project manager is given **final authority** to plan, direct, organize, and control the project form start to finish.
3. The project manager may work directly with any level and functional area of the organization to accomplish project goals.
4. He reports to the GM or owner, and keeps him appraised of project status.
5. Some times the project manager has **authority to hire personnel and procure facilities although more often he negotiates** with functional managers to borrow them.

Basic PM is implemented in two widely used forms – **pure project** and **matrix**. In pure PM, a **complete self contained** organization is created, i.e. the needed resources belong to the project, and **do not have to be borrowed**. In matrix management, the project organization is created from resources allotted **(borrowed)** form the functional units. The project must **share** these resources with **other concurrent projects**, and with the **functional areas** from which they are borrowed.

Program management

The term "program management'" is often used interchangeably with project management due to the **similarities** of **programs and projects** in the sense that both

1. are defined in terms of goals (in terms of desired product or service) about what must be accomplished.

2. emphasize the time period over which goals are to be pursued, and

3. require plans, budgets, and schedules for accomplishing the goals.

However, they are **different**, with the main distinction being that,

- *A program extends over a longer time horizon* and consists of several **parallel and sequential** work efforts or projects that are **coordinated** to meet a **program goal**. The projects within a program share **common goals and resources** and often they **are interdependent**.

Examples of program management that contains many projects within them are an **Urban development program** (housing rehab, job and skill training, and small business consulting assistance), a **Mars exploration program** (unmanned probes to Mars and its Moons, manned mission to Mars, etc.).

Sometimes **individual projects** in a program **grow** to become so large that they themselves become full-fledged programs. The Manhattan Project was really a "program" unto itself.

- **Another distinction** is that projects are oriented to producing and delivering a product or service, after which the **project organization is dissolved**. Though the project organization develops and delivers the end item, **the operation and service of the end tem is someone else's responsibility**. In a program, however, once the end item is delivered (product or service), it is up to the program management **to ensure that it is integrated with other systems, and operational for as long as needed.**

For example, several contractors might **produce and deliver** a satellite and its booster rocket, but afterwards someone else is responsible for **launching** the rocket and the satellite, and after that someone else again deals with **monitoring and operating** the orbiting satellite. Program management would oversee everything – the development of the satellite and rocket, launch support, ongoing satellite monitoring, and so on – whatever is needed to achieve the overall satellite program goal.

- Most **concepts in Project Management apply** also to the management of programs, though with **modification** to deal with the **larger scope and magnitude** of programs.
- A **program manager oversees and coordinates the projects within the program**, but because a program is composed of teams from various projects, a **program structure must be created to coordinate them**. This structure is similar to and overlays the project structure.
- Since many programs last too long for any one person to be in charge from start to finish, **different people might occupy the role of program manager** during a program's life.

New Venture Management (NVM)

Project Management resembles new venture management, a type of management **used in consumer-oriented firms** for generating **new products or markets**. In new venture management, **a team is created to find** new products or markets that fit an organization's specialized skills, capabilities and resources. Once it has defined the product, the team may go on to design and develop it, then determine the means to produce, market, and distribute it.

Similarities between the PM and NVM include:

- The focus on a single unifying goal
- Their multidisciplinary nature, with experts and managers from various functional areas working together under a single head.

- Being action oriented and dedicated to change
- Their temporary character - once a new venture team has completed its assignment, members go back to their original departments or another venture group, or to a new division or a **new company that splits off from the parent organization** with the purpose of producing the newly developed product.

Product management

The term product management refers to **a single person for overseeing all aspects of a products production, scheduling,** inventory, distribution and sales. The product manager **coordinates and expedites** the product's launch, manufacture, distribution and support. Like the project manager, the product manager **communicates directly with functions** inside and outside the organization, and coordinates efforts directed at **product goals**. The product manager **is active in managing conflicts and resolving problems** that would degrade manufacturing capability, forestall distribution, alter price, harm sales, or in any way affecting financing, production, and marketing of the product. For products **with long lifecycles**, the product manager role is **filled on a rotation basis**.

One of the earliest examples of product management has to that of the 1930s. A junior executive had to advertise a soap brand named ‘Camay’ by the company Proctor and Gamble. This soap had to compete with the ‘Ivory’ brand, the more dominant one. He came up with the idea of creating a designation called the Brand Man. The brand man would manage one product entirely, right from the production, to the marketing, and the sales.

Even the products of **Google** might involve product managers.

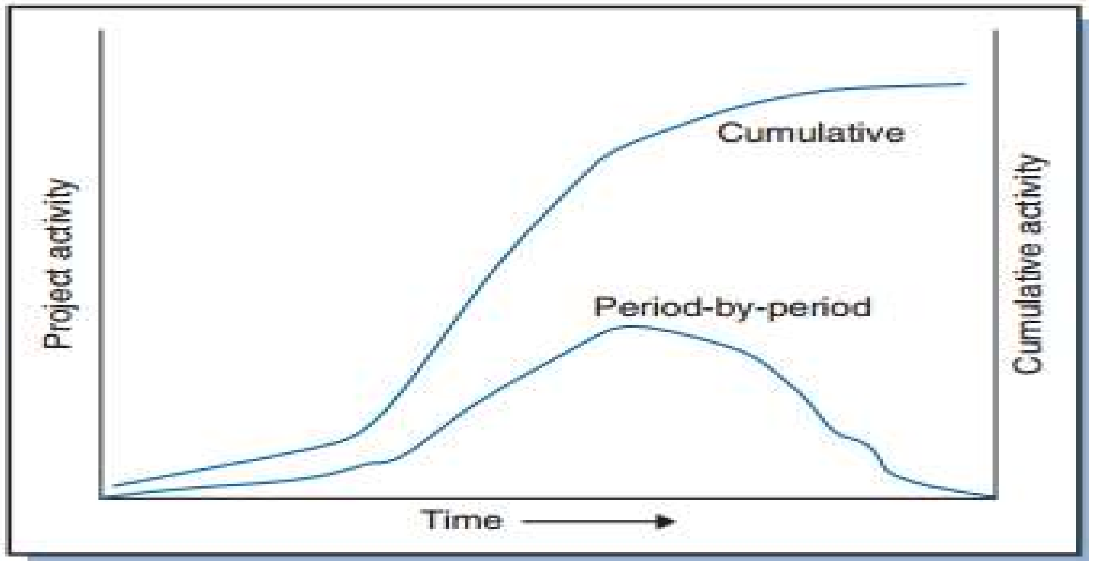
Product management examples also include the branding and customer communication required to launch a new product. Each product, in its nascent form, requires proper branding. This creates awareness about the product in the market. Branding, advertising, launching, and marketing a product requires proper planning. A product manager needs to handle all the responsibilities.

All the project forms described above are found in the **commercial environment**. However, the forms commonly found in government and military are basic PM and program management.

Project Life Cycle

Each project has a starting point and progresses toward a predetermined conclusion. **Starting with project conceptualization, projects experience a build up in "*effort*"** that eventually peaks and then declines. This activity can be measured in various ways, such as the amount of money spent on the project, the number of people working on it, or the amount of materials being used.

Besides changes in the level of effort, the **nature and emphasis** of the activity change too. For example, consider the **mix of project personnel**: customers and planners dominate the early stages of the project; designers, builders and implementers take charge in the middle stages: users and operators take over at the end.



No matter the **project phase or kind of work activity**, every project can be **measured** in three ways **at any point in its life cycle**: *time, cost,* and *performance.* **Time** refers to the temporal progress of the activities and the extent to which schedules and deadlines are being met. **Cost** refers to the rate of resource expenditure as compared to budgeted resources. **Performance** refers to outputs of the project as compared to objectives, specifications and requirements. Meeting all these performance requirements is a **measure of the quality** of the project output. The **project manager** attempts to achieve time, cost, and performance requirements as the project advances through the life cycle.

Managing the Project Life Cycle

Managing the project life cycle requires **special treatment**. Unlike non-project, repetitive operations, where everything tends to be somewhat familiar and stable, things in projects – *resources, schedules, work tasks, etc*. – are often unfamiliar and in a **constant state of change.** Hence, **work schedules, budgets, and tasks** must be **tailored to fit** each phase and stage of the project life cycle.

All projects contain an **element of uncertainty**. **Unforeseen obstacles can cause** missed deadlines, cost overruns, and poor project performance. Management must try to **anticipate the problems, plan for them, and *adjust activities and shift resources*** to mitigate or overcome them.

Organizations often undertake **several projects at once**. At a **given time** the projects are at different stages of their life cycles: some are just being started, others are underway and still others are being closed out. Management must be able to **continuously balance resources** so each project gets what it needs, yet all their needs **combined do not exceed** the resources available.

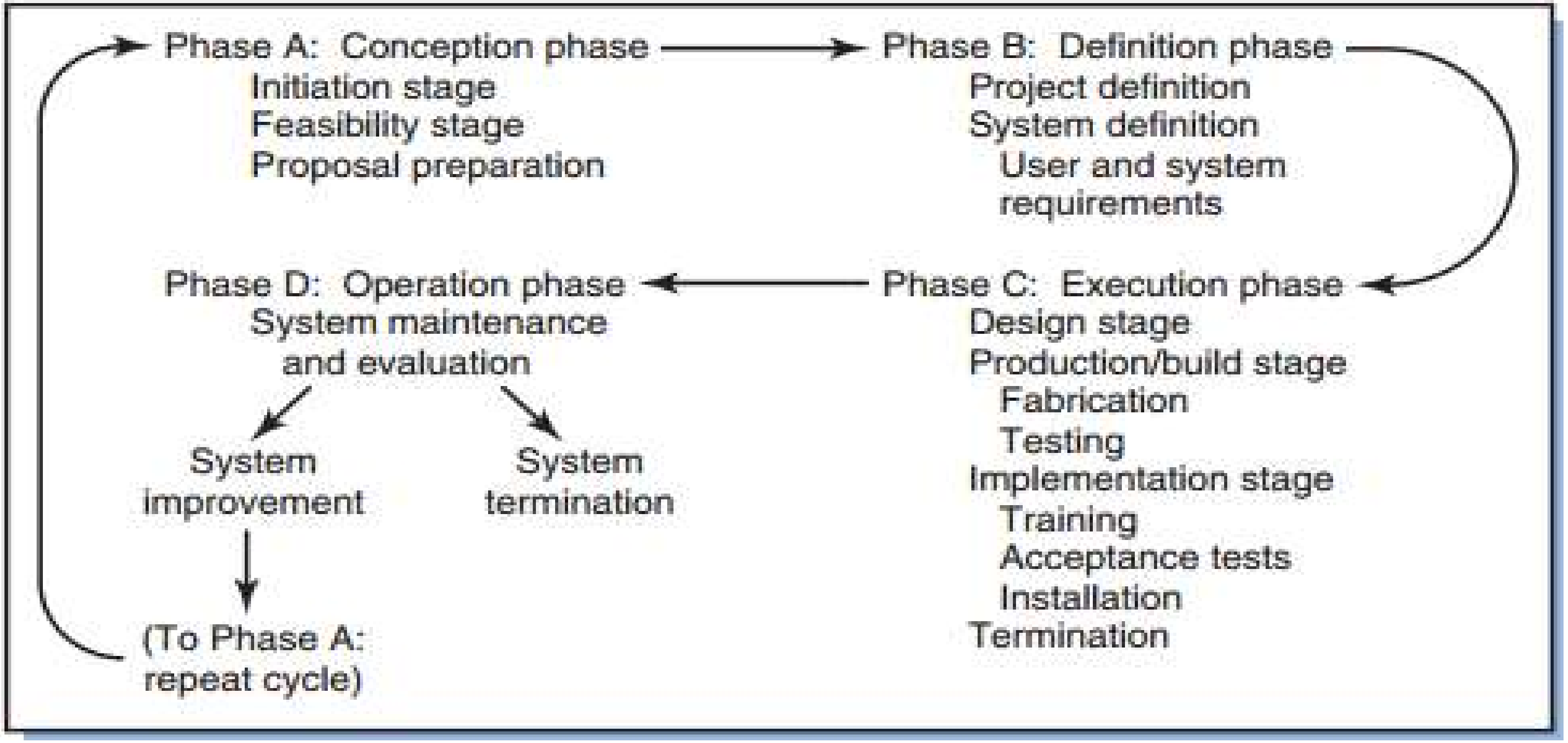
Systems Development Cycle

The life cycle of any **human made** system is divided into four phases and stages within them, collectively called the ***systems development cycle***:

1. Conception phase (Phase A)
2. Definition phase (Phase B)
3. Execution phase (Phase C)
4. Operation phase (Phase D)

The Phases

The four-phase cycle encompasses the total developmental and operational life cycle of all systems. The phases overlap and interact, yet are clearly differentiable. **They reflect the order of thought and action in the development and use of all systems**, whether *consumer products, space vehicles, information systems, or company relocations.*



For some systems, the development cycle **overlaps** identically with the project life cycle. A project **typically** spans phases A through C – the conception, definition, and execution phases of the cycle. Hence, the first three phases of the systems development cycle overlap with the project life cycle. When Phase C **ends upon implementation of the system, so does the project**. At that point, **the system transits from being the end-result of a project to being an operational entity**.

Virtually all projects progress through Phases A, B, and C, **though not necessarily through all the stages**. The actual stages in the life cycle depend on the system or the end item being developed. For some projects, some of the stages might receive little emphasis or be entirely skipped; most projects, however, ***do* pass** through all the stages, **even if informally**.

Sometimes, **between the phases** of the life cycle there are points at which decisions are made concerning the preceding phase and whether the project should be continued to the next phase or be terminated. Referred to as **"gating",** the project is assessed at the end of each phase and a go / no-go decision is made.

Phase A: Conception

Every project is an attempt to solve a problem. The **first step** in solving a problem is recognition and acceptance that the **problem exists**. After that, the individual facing the problem – the customer and users – seeks out someone **who can help**. The **steps** they **take include**, soliciting people who can do the work, evaluating their proposals, and reaching an agreement.

The conception **phase** nominally comprises **two separate stages**. The first stage, project **initiation**, establishes that a "need" or problem exists, and that it is worthy of investigation. The second, project **feasibility,** is a detailed investigation of the need or problem, a formulation of **possible alternative solutions**, and the selection of one. The **phase ends with an agreement** that a chosen contractor will provide a specified solution to the customer.

If the customer organization has an **internal group** capable of doing the work, it turns to this. If not, it will look to outside contractors, possibly by sending them a formal request for help called a ***request for proposal,*** or RFP. Each contractor examines the customers problem, objectives and requirements as stated in the RFP, and determines the technical and economic feasibility of undertaking the project. If the contractor decides to respond to the request, he presents the customer with a proposed solution in a ***proposal* or *letter of interest***. The customer then examines the proposal – or, when multiple contractors have responded, all the proposals – and makes a choice. The result is a **formal agreement** between the chosen contractor and the customer. **Most ideas or proposals never get beyond** phase A; the problems the proposals address are judged as insignificant, or the proposal as impractical, infeasible, or lacking benefits to justify funding and resources. The few that are approved and reach a contract move on to phase B.

The **result of Phase A** is a formalized systems concept. It includes:

(1) a clear problem formulation and list of user requirements;

(2) a rudimentary but well-conceptualized systems solution;

(3) an elemental plan for the project in the proposal; and

(4) an agreement between the customer and the contractor about all of these.

The project is now ready to move on to the “middle” and “later” phases of systems development and to bring the systems concept to fruition.

Phase B: Definition

In Phase A, most of the effort was devoted to investigating the *problem*—what is it, is it significant, should it be resolved, and can it be resolved in an acceptable fashion? The initial investigation and feasibility studies were largely **centred on the problem**. Now, in Phase B, definition, it is **the solution that receives scrutiny**. The **solution** is analysed and defined in **sufficient detail** such that **designers and builders w**ill be able to produce a system that meets the customer's needs. The definition phase has two main purposes: **determining the system requirements**, and **preparing the project plan**.

Having reached a commitment from the customer, the contractor begins a detailed analysis of the systems concept, during which he defines the **requirements** the system must fulfil to meet the customers needs, and the systems **functions and elements** necessary to meet those requirements. This definition results in a **preliminary design for the system**.

As the **process continues**, the major subsystems, components and support systems of the proposed system are **determined**, as are the resources, costs and schedules necessary to create the system. Meantime**, project management** assembles a comprehensive **project plan** that defines the activities, schedules, budgets, and resources to design, build and implement the system. **Contractor top management** reviews that plan for acceptability and then forwards it to the customer, who also reviews it for acceptability.

Phase C: Execution

The execution phase is when the work specified in the project plan is **put to action**. It often includes the stages of **design, production and implementation**, referring to the progression through which a system moves from being an idea to a finished, physical end-item. **All systems are comprised of elements arranged** in some pattern, configuration or structure, and it is in the *design* stage that the **elements and the pattern necessary** for the system to fulfil requirements are **defined**. Following design the system goes into *production,* where it is built as either a single item or a mass produced item. Near the end of the execution phase, the system is *implemented*; it is **installed in** and becomes a part of the users environment.

Phase D: Operation

In the operation phase the system is deployed; the customer takes over to operate the system and maintain it.

For systems such as products and equipment that people use and rely upon daily, phase D may last for years or decades, in which case the phase includes not only **operation ad maintenance** of the system, but also **improvement and enhancement** to keep the system viable and useful. All systems simply outlive their purpose or simply wear out. When that happens, there are two choices: to scrap the system, or to modify it so it remains useful. In the latter case the "modification" becomes a new system concept, the beginning of a new system development cycle, and the **start of a new project.**

For some systems phase D is short or non-existent: example are a political campaign, rock concert and any ceremony (the project ends on election day, or upon completion of the performance or ceremony).

Unit II – Project Planning and Scheduling

Project Planning

Because each project is **unique**, there is never an *a priori,* established way of how the project should be done. Each and every project poses **new questions** regarding *what, how, by whom, in what order, for how much* and by *when, and the **purpose of planning** is to answer them.*

Based on the **summary** presented in the proposal, a detailed **projects master plan** is developed with more abbreviated procedures. The **contents** of these master plans **vary** depending on the size, complexity and nature of the project. The **elements of a typical master plan** are outlined as follows:

I. Scope, Charter, or Statement of Work

Overview description of the project **oriented towards** management, customer, and stakeholders. Includes **a brief description** of the project, objectives, overall requirements, constraints, risks, problem areas and solutions, master schedule showing major events and milestones.

II. Management and Organization section

A. Project management and **organization**: key personnel and authority relationships.

B. Manpower: Workforce requirements and estimates: **skills, expertise** and **strategies** for locating and recruiting the qualified people.

C. Training and development: **executive** development and **personnel** training necessary to support the project.

III. Technical Section. Major project activities, timing, and cost.

A. High-level user requirements and system requirements.

B. The Work breakdown structure: work packages and **detailed description** of each, including resources, costs, schedules, and risks.

C. Responsibility assignments: list of key personnel and their **responsibilities** for work packages and other areas of the project.

D. Project schedules: **generalized** project and **task schedules** showing major events, milestones, and points of critical action or decision.

E. Budget: Control accounts and **sources** of financial support: **Budgets and timing** of all capital and developmental expenses.

F. Quality plan: **measures** for **monitoring** quality and **accepting** results for individual work tasks, components, and end item assemblies.

G. Areas of uncertainty and risk plan: risk **strategies**, contingency and mitigation plans for areas posing greatest risk.

H. Work review plan: **procedures** for periodic review of work, what is to be reviewed, by whom, when, and according to what standards.

I. Change control plan: **procedures for review and handling** of requests for changes to any aspect of the project.

J. Documentation policy/plan: **list of documents** to be produced, format, timing, and how they will be organized and maintained.

K. Procurement policy/plan: policy, budget, schedule, plan, and controls for all of the goods, work, and services to be **procured externally**.

Work Breakdown Structure

Once project objectives and deliverables have been set in the scope statement, the next step is to translate them into specific, well-defined work activities; that is, to specify the tasks and jobs that the **project team must do**. Particularly for large, unique projects, it is **easy to overlook or duplicate** activities. To insure that **every necessary activity** is identified and clearly **defined**, and that **no activities are missed**, a procedure called the "work breakdown structure" is used.

Complex projects consist of numerous smaller subprojects, interrelated tasks, and work elements. The **method for** subdividing the overall project into smaller elements is called the *work breakdown structure* or *WBS,* and **its purpose** is to divide the total project into "pieces of work" called *work packages.* Dividing the project into small work packages makes **it easier to** prepare schedules and budgets and to assign management and task responsibilities.

Creating a WBS begins with dividing the total project into major categories. These categories then are divided into subcategories that, in turn, are each subdivided. With this level-by-level breakdown, the **scope and complexity** of work elements at each level of the breakdown gets **smaller**. The **objective** is to reduce the project into many small work elements, each so **clearly defined** that it can **easily be planned, budgeted, scheduled, ad monitored**.

A typical WBS consists of the following four levels. However, the **actual number** of levels in the WBS **varies** by project, as do the **actual names** of the element descriptions at each level.

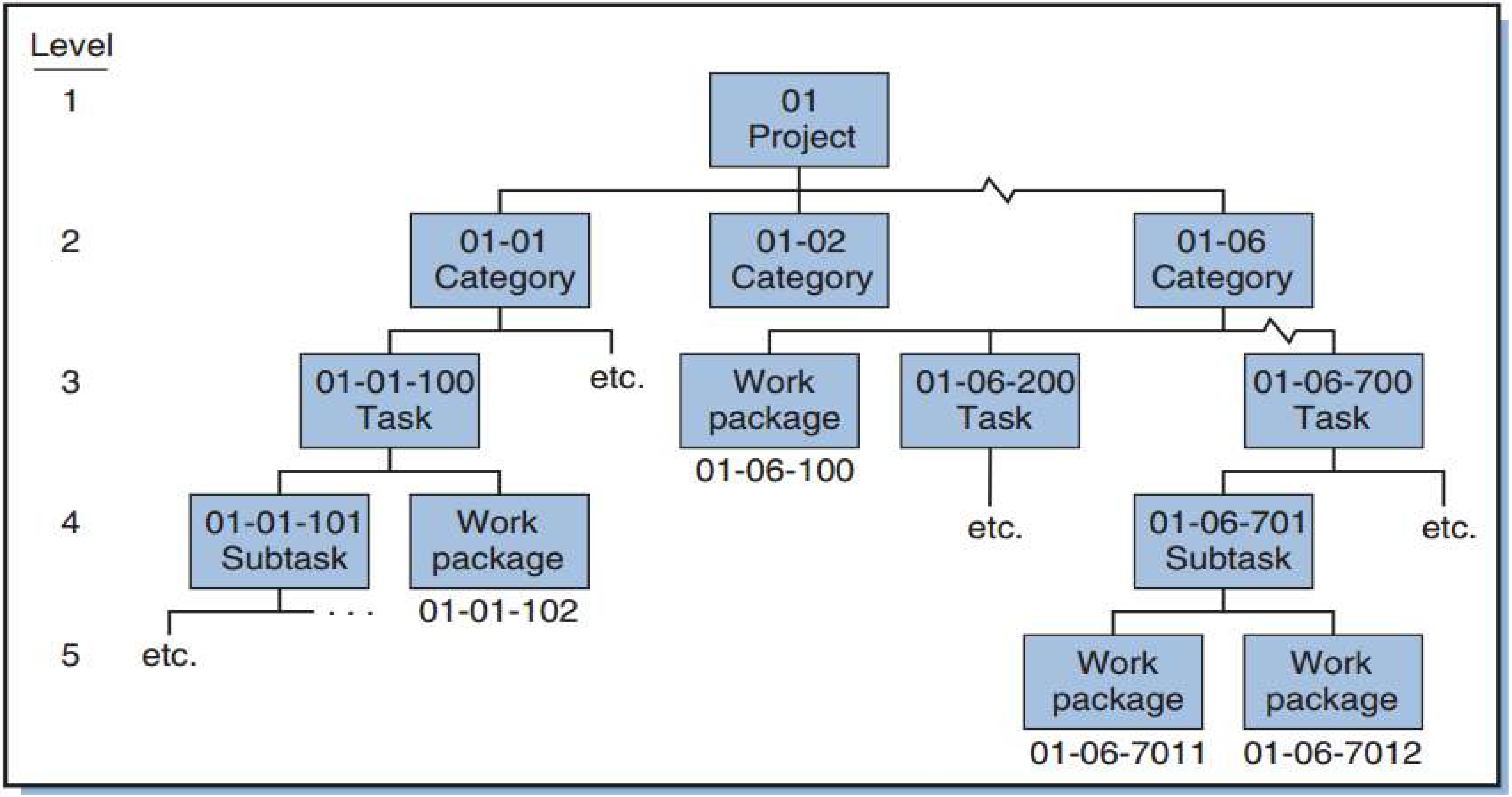
LEVEL	ELEMENT DESCRIPTION
1	Project
2	Sub-project
3	Activity
4	Work Package

When the entire process of WBS is completed, tasks at the **bottom levels**, whatever the levels might be, are called ***work packages.***

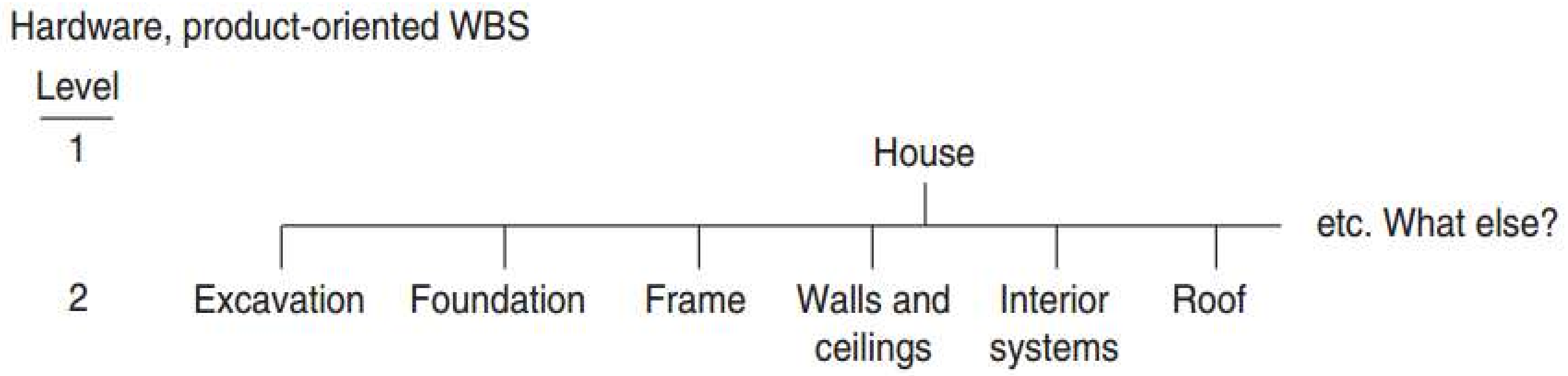
To **avoid unnecessary complexity**, the number of levels in the WBS should be **limited**. A five-level WBS might be appropriate for large projects, but for most small projects a three level WBS adequate.

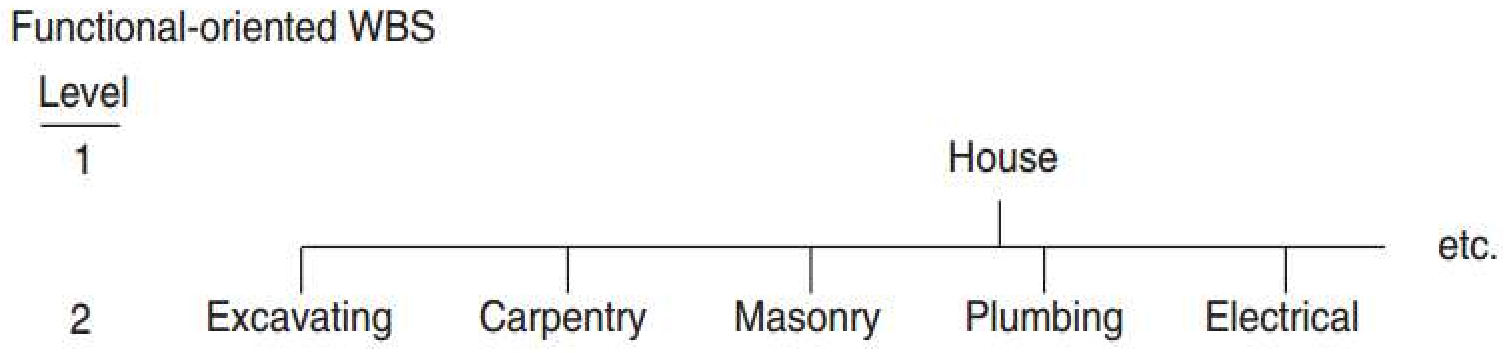
To help **organize and track** project activities, **each work element is coded with a unique identifier or number**. Usually the number at level is based on the number at the higher level. The project manager establishes the numbering scheme.

Elements of a WBS.



The WBS can be **product oriented**, or **functional/task** oriented. It is a matter of preference. Whatever, it may be, during the WBS process, the **questions** "what else is needed?" and "what's next?" are constantly being asked. Supplementary or **missed elements** are identified and added to the WBS at appropriate levels.





Work packages

How far down does the breakdown go? Simply, for as far as needed to completely define all work necessary for the project. The work in each box or element of the WBS must be “well defined; if it is not, then the box must be subdivided into smaller boxes. **For a box to be well-defined it should include** the following.

1. Clear, comprehensive Statement of Work (SOW): Work task or activity to be done.
2. Resource requirements: Labour, equipment, facilities, and materials needed for the task.
3. Time: Estimated time to perform the task.
4. Costs: Estimated resource, management, and related expenses for the task.
5. Responsibility: Parties, individuals, or job titles responsible for doing and / or approving the task.
6. Outcomes: Requirements, specifications, and associated deliverables, end-items or results of the task.
7. Inputs: Preconditions and predecessors necessary to begin the task.
8. Quality assurance: Entry, process, and exit **conditions** to which the task **must conform**; as specified in the quality plan.
9. Risk: Uncertainty about time, cost, and resources with the task.
10. Other: Additional information as necessary.

The level of work breakdown must not however result in an unnecessarily large number of work packages. During the project each work package becomes the **focal point** for planning and control and, as such, **involves paperwork, schedules, budgets, and so on**. Thus, the larger the number of work packages, the greater the **time and cost to manage them**.

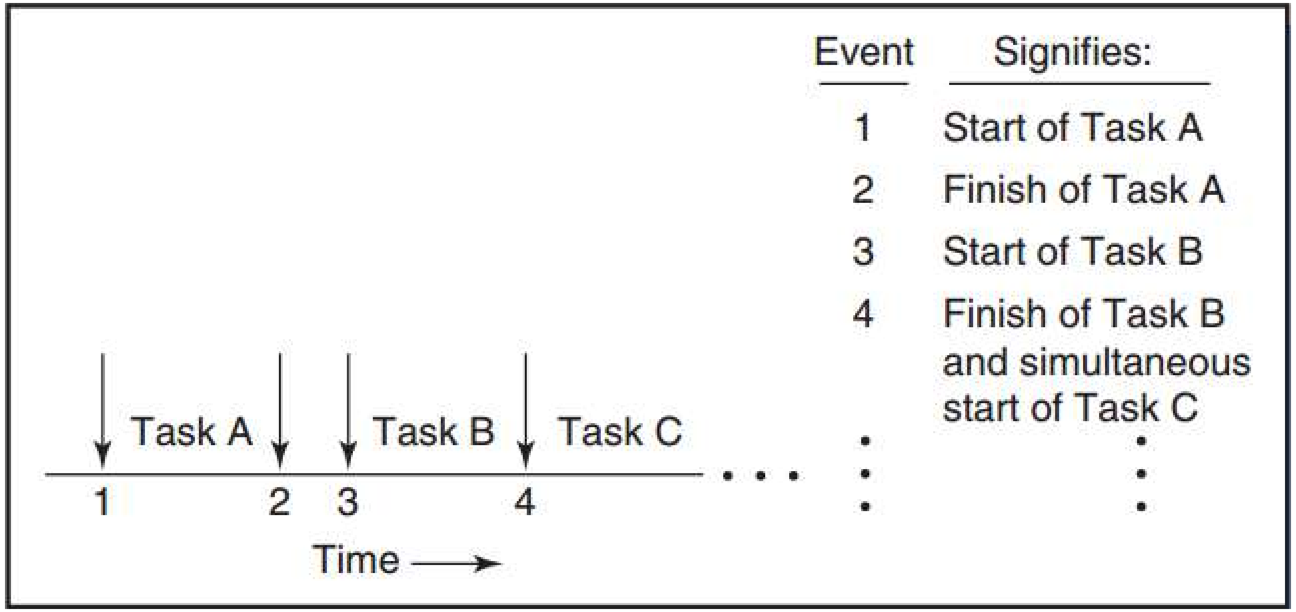
SCHEDULING

The next logical step after **requirements** definition and **work** definition is to ***schedule*** the project work tasks. A schedule shows the **timing for work tasks** and when **specific events** and **project milestones** should take place.

- A **task or work package** is the actual work planned or being done, and represents the ***process*** of doing something; **it consumes** resources and time.
- In contrast, an ***event*** signifies *a* ***moment in time*** – the instant when something happens. In a project events represent the ***start* or *finish*** of something. In most project schedules, each task is depicted as a line segment, the two ends of the line segment represents the events of starting and completing the task. In project schedules, each event is attached to a specific calendar date (day, month, and year).

There are two special kinds of events in projects: interface and milestone.

1. An *interface event* denotes the completion of one task and **simultaneous** start of one or more subsequent tasks. It often represents a **change in responsibility**: one individual or group completes a task and another individual or group starts the next task.



2. A *milestone event* represents a **major project occurrence**, such as completion of a phase or several critical or difficult tasks, **approval** of something important, or availability of **crucial resources**. Milestone events signify **progress**, and as such they are **important measures**. Often, approvals for system requirements, preliminary design, detailed design, or completion of major tests are considered milestones; they signify the project is **ready to proceed** to the next stage of the project life cycle. Failure to pass a milestone is usually a **bad omen**, followed by **changes to the budget and schedule**.

There are **two kinds of schedules**: *Project schedule* and *Task schedule*.

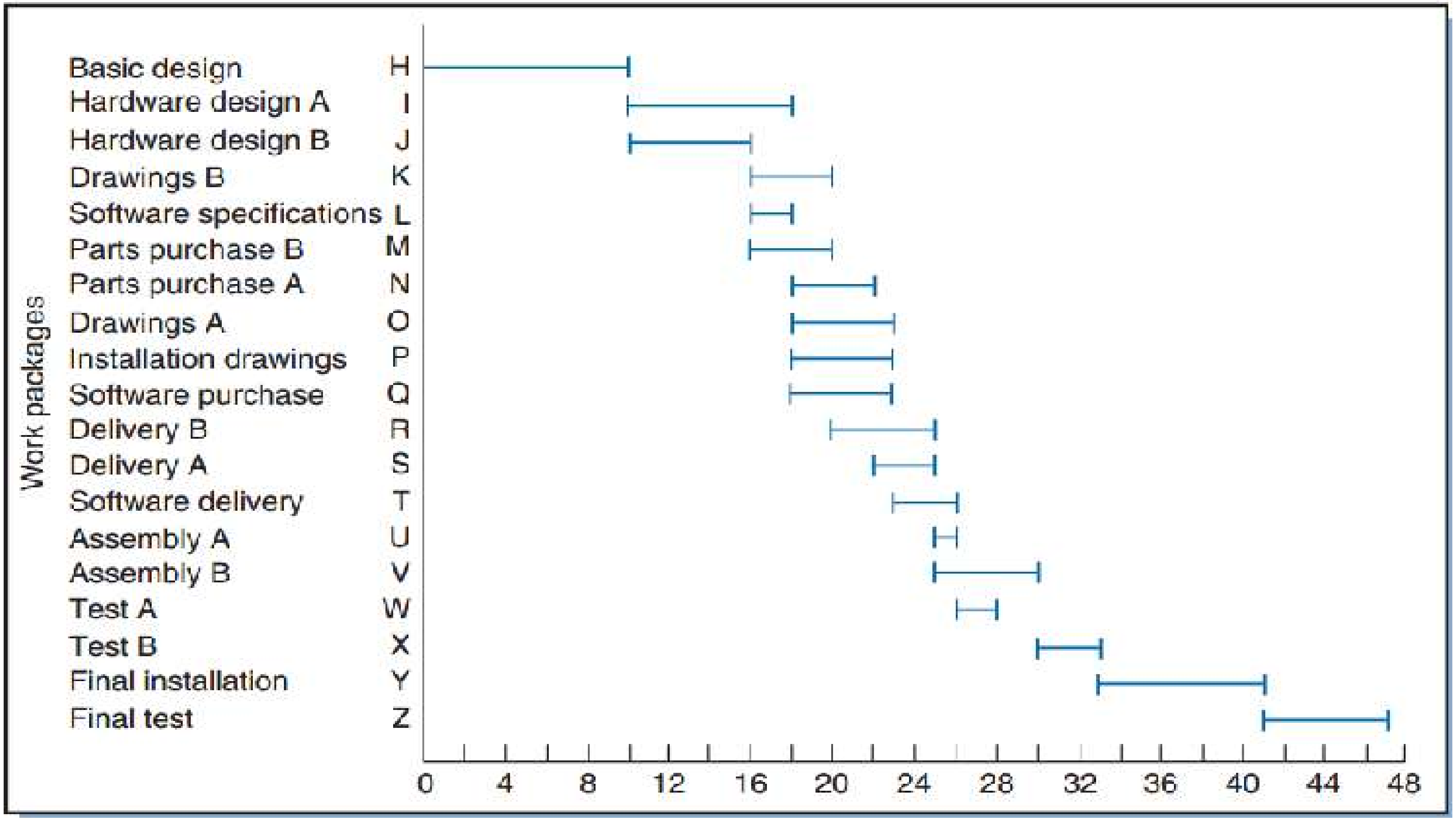
Project managers and upper management use the ***project schedule*** (or project master schedule) to plan and review the entire project. This schedule shows all the **major project activities**, **but not** much detail about each. A ***task schedule*** shows the **specific activities** necessary to complete a **work package**. It is created for the people working on a specific task and enables lower level managers and supervisors to focus on the task and not be distracted by other tasks with which they have no interaction. However, both the project schedule and task schedule are **prepared and displayed in many ways**, including with Gantt Charts.

Gantt charts

The simplest and most commonly used technique is the Gantt chart (or **Bar chart**), named after the management consultant Henry L. Gantt (1861-1919). 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**.

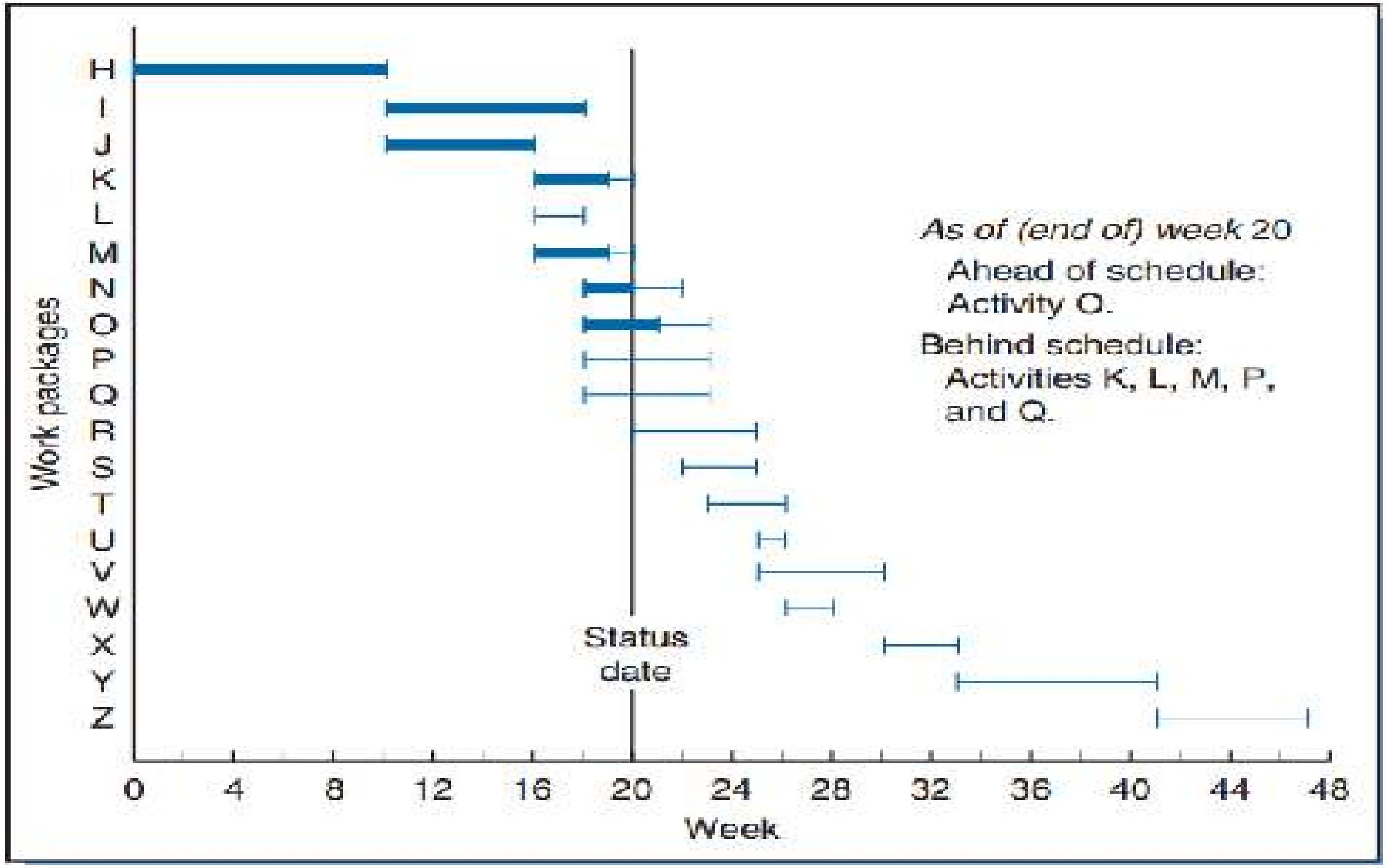
The chart consists of a horizontal scale divided into time units – days, weeks, or months – and a vertical scale showing project work elements – tasks, activities, or work packages.

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**.



Work packages
Basic design H
Hardware design A I
Hardware design B J
Drawings B K
Software specifications L
Parts purchase B M
Parts purchase A N
Drawings A O
Installation drawings P
Software purchase Q
Delivery B R
Delivery A S
Software delivery T
Assembly A U
Assembly B V
Test A W
Test B X
Final installation Y
Final test Z
0
4
8
12
16
20
24
28
32
36
40
44
48

Once the project is **underway,** the Gantt chart becomes a **tool for assessing the status** of the individual work elements and the project as a whole. The following figure shows progress as of the "status date," week 20. The heavy portions of the bar indicates the amount of work that has been completed. The thinner part of the bar represents the 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***.



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**.

Disadvantages of the Gantt chart

In all the projects, certain work elements depend upon others before they can begin; **if these are delayed** then so will others and possibly, the entire project.

A disadvantage of the Gantt chart is that it does not necessarily show the **effects** of one work element **falling behind schedule** on other work elements. Also, Gantt charts alone provide no way of distinguishing **which elements can be delayed** from those that cannot.

Network based approaches

Project scheduling involves much more than just displaying tasks on a Gantt chart. It is an **integral part** of project planning, an **often trial and error process** of adjusting work tasks to satisfy resource constraints while trying to meet project deadlines. Gantt charts are **good for communicating** project schedules, but they are **limited as a planning tool** because they do not explicitly show **how activities are related** or **how delaying activities or shifting resources affects the overall project**. However, the network methods do not have these limitations; they clearly show interdependencies and what happens to the project when resources are altered or activities delayed. Let us now discuss **the most widely used** network based approaches to project scheduling and planning.

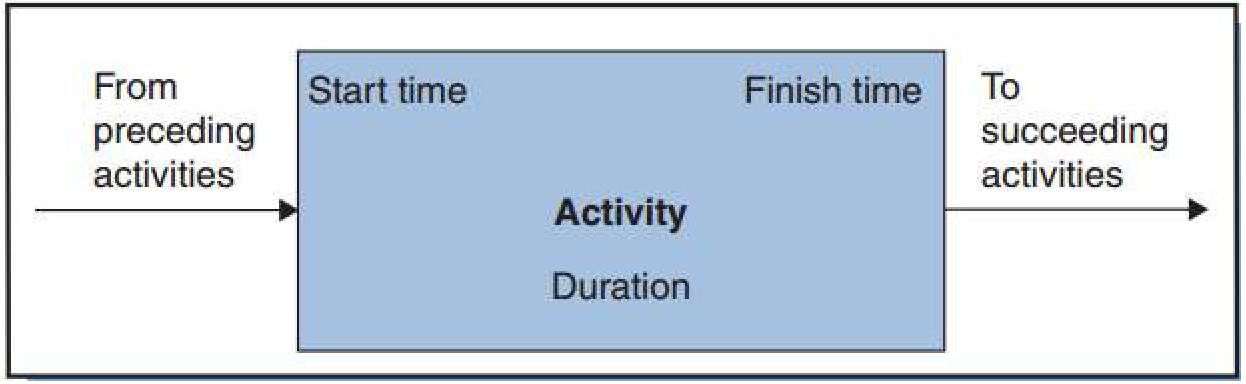
Network Diagrams

A network diagram shows a group of activities or tasks and their logical relationships, i.e. the precedence relationships or dependencies among the tasks.

There are two methods for constructing the network diagrams: *activity-on-node (AON),* also called *precedence diagram method (PDM),* and *activity-on-arrow (AOA). Both* were developed independently during the late 1950s. Let us first discuss the most commonly used AON method.

AON Diagrams

- The *node* (the box in the figure) is the activity; inside the node is the information about the activity, such as its duration, start time, and finish time. The arrows connecting the nodes show **the order in which they should occur**.



- To construct an AON network, start by drawing the first activity in the project. From this activity, draw lines to the activities that happen next. Then the remaining activities are added **in sequence or parallel**, until the last activity is included.

But before you can actually start a network, you must first know each activity's relationship to the other activities – for example:

- What activities are its predecessors?
- What activities are its successors?
- What activities are to be done at the same time as it?

- In a network, every activity except the first one has predecessors, which are activities that must be completed ahead of it. Similarly, every activity except the last one has successors, which are activities that cannot begin until the current activity is completed.

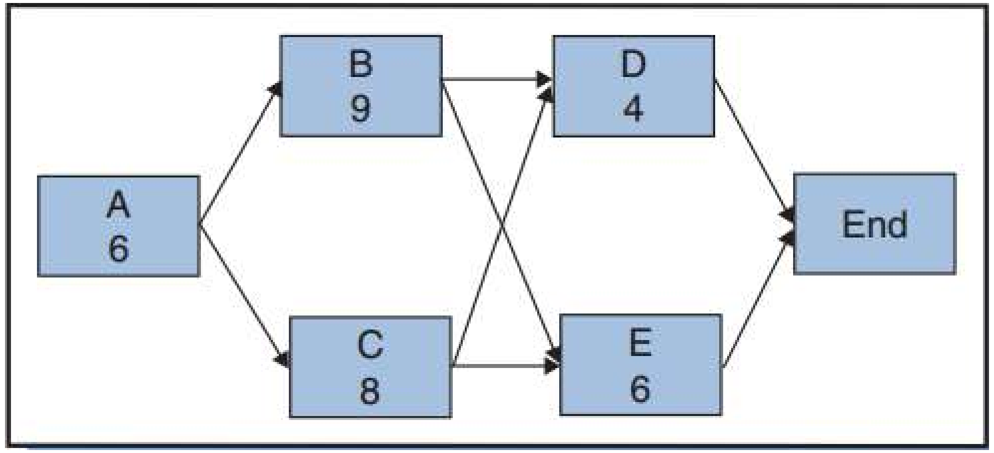
- **Mandatory and discretionary predecessor/successor dependency relationships:**

Mandatory: the sequence of two activities cannot be reversed.

Discretionary: the sequence is a choice.

In another kind of dependency called **external dependency**, an **activity must follow** some event or activity, that is **not in the network**. External dependencies can be either mandatory or discretionary.

- In general, good practice dictates that a network should always have only **one start and one end** node. Whenever a project has **multiple nodes** at the start or end of the network, then a single node should **be inserted before or after** them, respectively. For example, a single **end** node (with implied zero duration) has been inserted after activities D and E. without this node, a mistaken understanding might be that the project ends upon completion of **either activity D or activity E**. the "end" node means that the project ends when **both D and E are completed**.

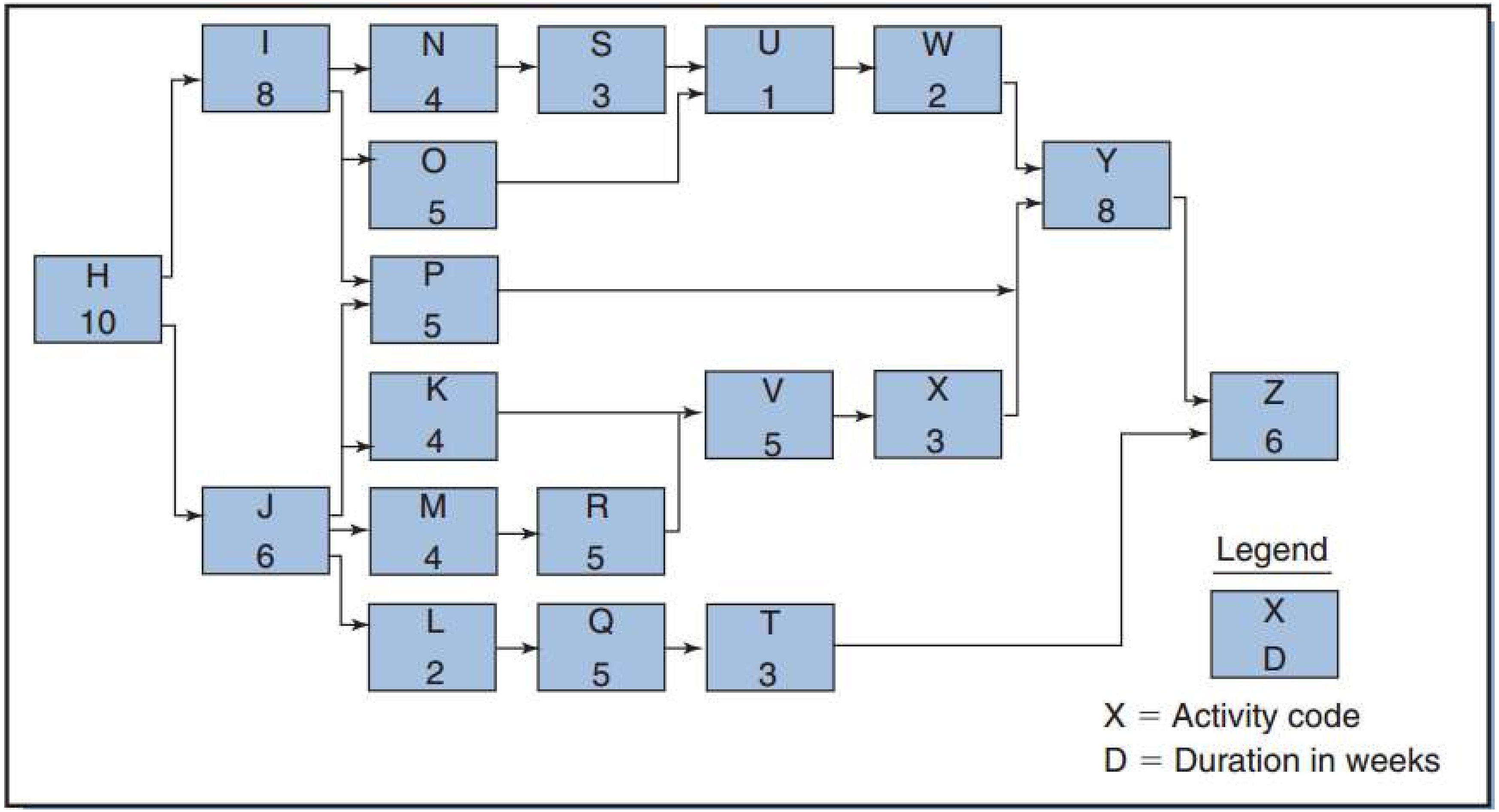


- **Only immediate predecessors** for each activity need to be known to construct a network. While it would have been okay to show all the predecessors for each activity, much of that would have been unnecessary.

Let us take the example of following Work packages from a WBS.

ACTIVITY	DESCRIPTION	IMMEDIATE PREDECESSORS	DURATION (WEEKS)
H	Basic design	—	10
I	Hardware design for A	H	8
J	Hardware design for B	H	6
K	Drawings for B	J	4
L	Software specifications	J	2
M	Parts purchase for B	J	4
N	Parts purchase for A	I	4
O	Drawings for A	I	5
P	Installation drawings	I, J	5
Q	Software purchases	L	5
R	Delivery of parts for B	M	5
S	Delivery of parts for A	N	3
T	Software delivery	Q	3
U	Assembly of A	O, S	1
V	Assembly of B	K, R	5
W	Test A	U	2
X	Test B	V	3
Y	Final installation	P, W, X	8
Z	Final system test	Y, T	6

Network diagram for the above project is



Project networks are important tools for project planning an control. They are useful for determining ***how long*** the project will take (the *expected project duration*), ***when*** **each activity** should be scheduled to start and finish. And the ***likelihood*** of completing a project on time.

Critical path

In general, the **expected project duration, *Te,*** is determined by finding the ***longest path*** through the network. A "path" is any route comprised of one or more activities connected in sequence. The longest path from the project start node to the end node is called the ***critical path*** and its length is the expected project duration. Should any activity that forms part of the critical path (**critical activity**) **take longer than planned** (because of delays, interruptions, lack of resources, etc.), the entire project will take longer than planned. Thus, the critical path shows the project manager **which activities are most critical** to completing the project on time. In order to **prevent delays**, the project manager should focus on the critical activities.

However, the non critical activities **can be delayed somewhat** without delaying the project. **But when** the non critical activity is delayed, if the length of the non critical path grows to **exceed the critical path**, the formal non critical path becomes critical and the former critical path becomes non critical. Hence, the project manager **should not give exclusive focus** on critical paths only and neglect the non critical activities. Expected time for different paths are laid out as follows:

H-I-N-S-U-W-Y-Z = 42;

H-I-O-U-W-Y-Z = 40;

H-I-P-Y-Z = 37;

H-J-P-Y-Z = 35;

H-J-L-Q-T-Z = 32;

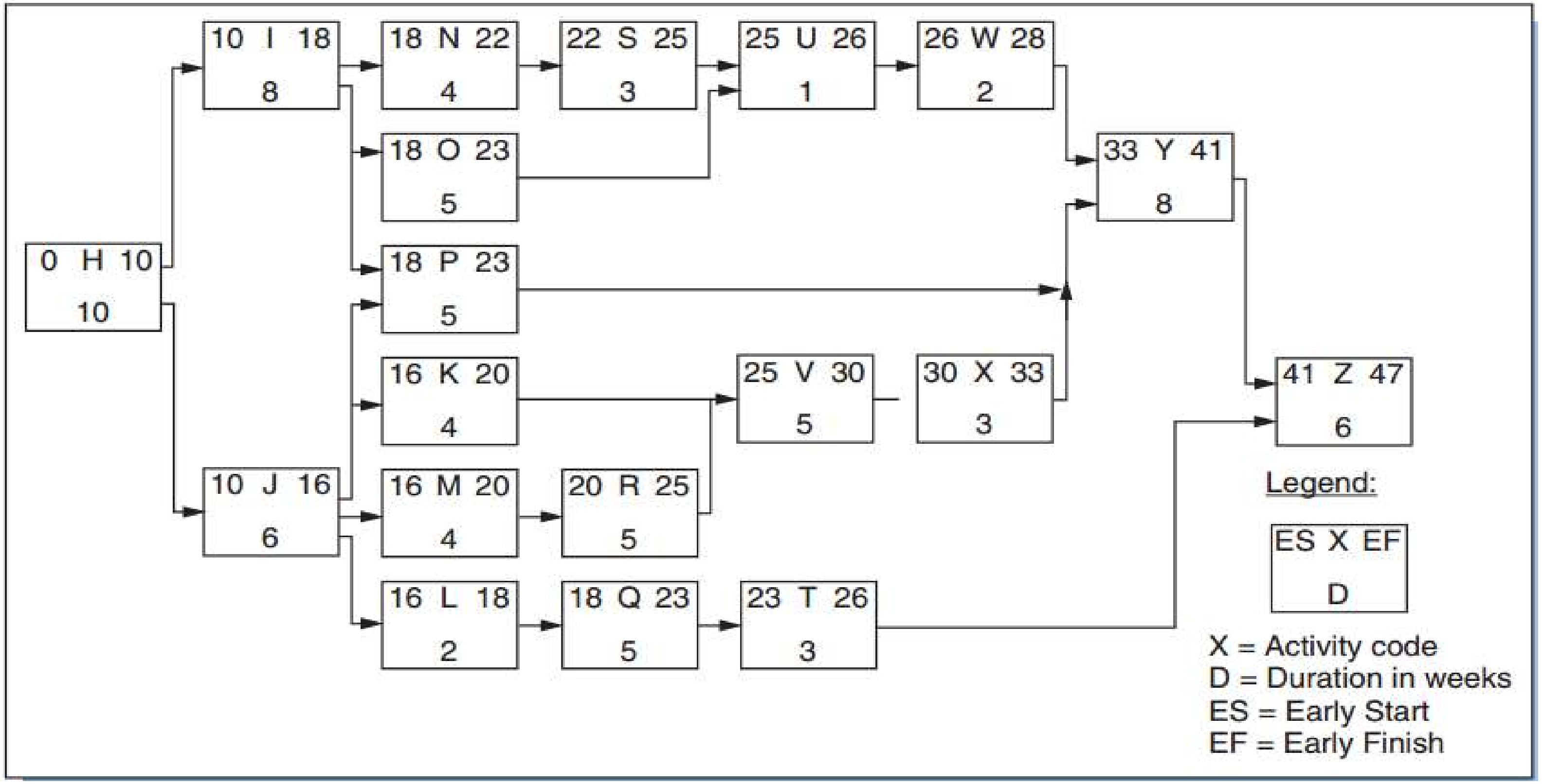
H-J-K-V-X-Y-Z = 42; and H-J-M-R-V-X-Y-Z = 47

The critical path for the above project is H-J-M-R-V-X-Y-Z and thus the expected project duration Te is 47 weeks.

Early times: the **earliest possible times** that the activity can be started or finished are called as *early start time (ES)* and *early finish time (EF).*

$$EF = ES + Duration$$

The network showing ESs and EFs is as follows:



The above ESs and EFs are computed by taking **"forward pass"** through the network. When an activity has only one immediate predecessor, its ES is simply the period following the EF of the predecessor. If its has several immediate predecessors, its ES is based on the latest EF of all its immediate predecessors.

Late Times:

As a **non critical activity can be delayed** without delaying the project, the question is: **How much can it be delayed**? To answer that we must determine not only the early times but also the "late times" – that is, the **latest allowable times** that the activity can be started and finished **without delaying the project completion**. Just like the ES and EF, every activity has a late start time, LS, and a late finish time, LF.

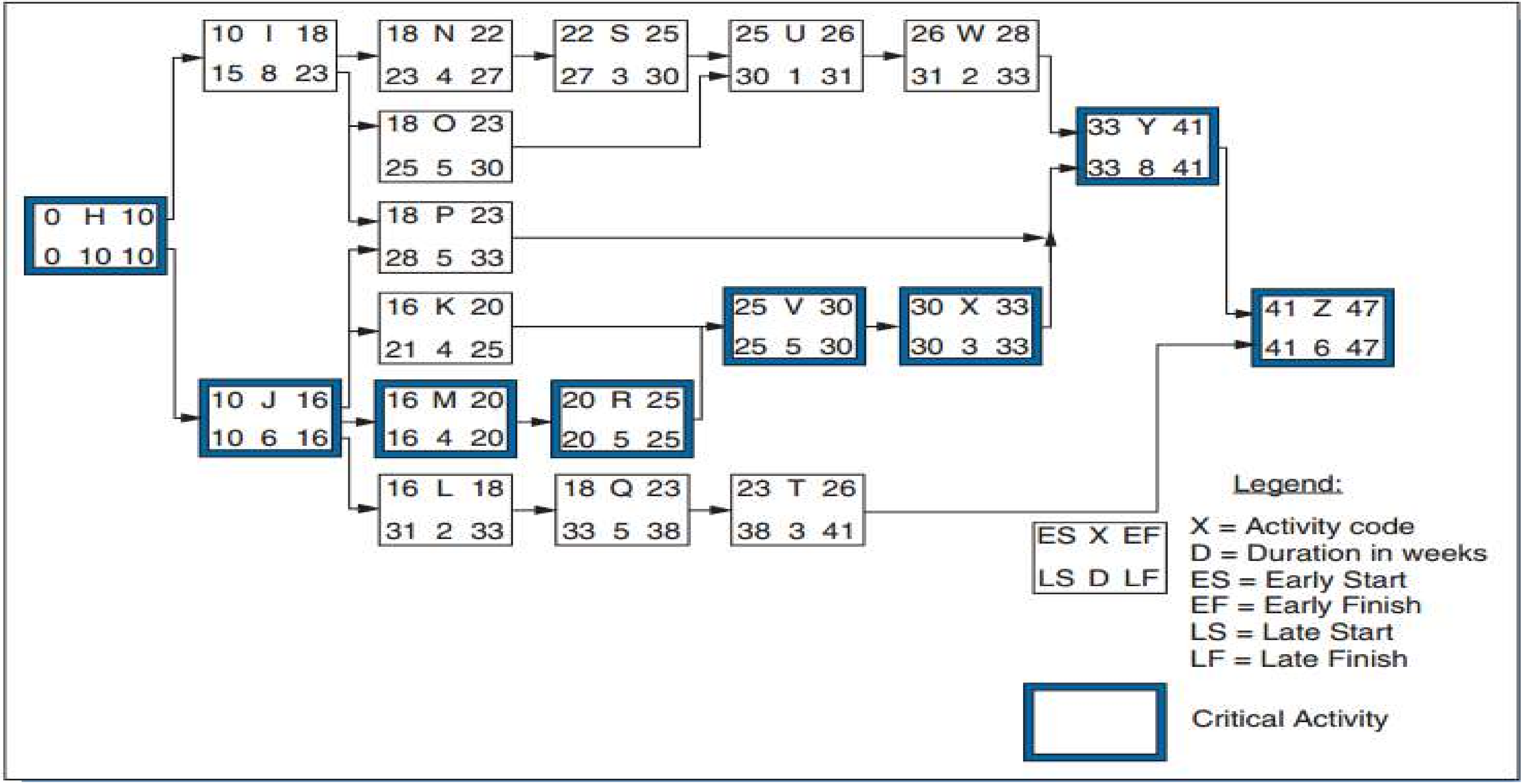
To determine the late times, **begin by assigning a target completion** date, Ts, to the last node of the network. For projects that have to be **completed as soon as possible**, the date for Ts is the same as the Te calculated in the forward pass; this is the EF of the last activity. For projects with a **due date set by the customer or the sponsor**, Ts is the due date, not the calculated Te value.

To determine the late times, start at the last activity in the network and make a **"backward"** pass through the network using the formula:

$$LS = LF – Duration$$

Whenever we encounter an activity that has multiple paths leading back to it (i.e. it has multiple successors), it is the *longest backward path* that determines the activity's LF. The successor with the longest path leading back to it also has the *smallest* LS. Thus, the smallest LS of all immediate successors determines an activity's LF.

Network showing LSs and LFs



Total Slack

The difference between LS and ES (or LF and EF) is referred to as *total slack (total float)* or simply slack (float) of an activity. Slack is the **maximum amount of allowable deviation** between when an activity must take place at the latest and when it can take place at the earliest; it is the **amount of time an activity can be delayed without delaying the project**.

$$\text{Total Slack} = LS - ES$$
$$= LF - EF$$

In the above figure, notice that the activities on the critical path have zero slack. Hence, these activities cannot be delayed by any amount without delaying the project. The activities that do have slack (which, as it turns out, are the non critical activities) can be delayed by their slack time without delaying project completion.

When activities lie in **sequence in a path**, a **delay in earlier activities will result in a delay to later ones**; this is the equivalent of **reducing slack** for the remaining activities. For example, the activities, L, Q, and T all lie on the same path and all have the same slack of 15 weeks. But if the activity L is delayed 5 weeks, then activities Q and T will also be delayed 5 weeks and thus will have only 10 weeks of remaining slack, not 15. If, in addition activity Q is delayed 10 weeks, then activity T will have no remaining slack and must be started immediately upon completion of Q. Having used up all their slack, activities L, Q, and T would then all become critical activities.

The **practical implication of the slack** is that it gives the project manager **flexibility** regarding exactly **when non critical activities can be scheduled**: any schedule is feasible as long as it lies somewhere within the available slack. Knowing the amount of flexibility is important for **managing resource workload**. By starting some activities as early as possible and delaying others, the **workload can be smoothed**. In general, when sufficient resources are available, non critical activities are usually scheduled to happen as early as possible; this preserves the slack and **minimizes the risk of non critical activities delaying the project**.

Notice that decisions about when exactly to schedule an activity require knowing **both the late and early times** for the activity. The implication is that a **network analysis should be done before the Gantt chart is created.**

Free Slack

While *total slack* refers to the amount of time an activity can be delayed without delaying the project, the term *free slack* refers to the time an **activity can be delayed without delaying the start of any successor activity**. Free slack of an activity is determined by the formula:

Free slack for the activity = ES (earliest successor) – EF (activity)

Knowing the free slack, managers can readily identify activities where slippages immediately impact other activities. When an activity has zero free slack, any slippage will cause at least one other activity to also slip. For example, if activity L slips, then so will Q and T.

Activity	Duration (weeks)	Start Node		Finish Node		Slack		Note
		ES (Start of week)	lS (Start of week)	EF (Start of week)	lF (Start of week)	Total*	Free**	
H	10	0	0	10	10	0	0	CP
I	8	10	15	18	23	5	0	
J	6	10	10	16	16	0	0	CP
K	4	16	21	20	25	5	5	
L	2	16	31	18	33	15	0	
M	4	16	16	20	20	0	0	CP
N	4	18	23	22	27	5	0	
O	5	18	25	23	30	7	2	
P	5	18	28	23	33	10	10	
Q	5	18	33	23	38	15	0	
R	5	20	20	25	25	0	0	CP
S	3	22	27	25	30	5	0	
T	3	23	38	26	41	15	15	
U	1	25	30	26	31	5	0	
V	5	25	25	30	30	0	0	CP
W	2	26	31	28	33	5	5	
X	3	30	30	33	33	0	0	CP
Y	8	33	33	41	41	0	0	CP
Z	6	41	41	47	47	0	0	CP
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	

Total slack, (7) = (4) − (3) = (6) − (5)
Free slack, (8) = [(3) of earliest successor] − (5)

**Total slack* is the spare time on an activity that, if used up and the activity is delayed any further, delays successors and affects the end date of the project as a whole.

***Free slack* is the spare time on an activity that, if used up, does not affect the early start time of any succeeding activities (i.e., will not affect the total slack or delay any successor).

The effect of project Due Date

In discussing the total slack we assumed that the target completion date, Ts, was the same as the earliest expected completion date Te. But in fact the target completion date can be set to make it either late or earlier than Te to reflect the wishes of the customer.

Setting the target date to later than Te has the effect of increasing total slack for every activity in the project by the amount Ts – Te. Although no longer zero, the slack on the critical path will still be the **smallest any where** in the network. If Ts is set earlier than Te, then the total slack times everywhere in the project will be reduced by the amount Ts – Te and the activities along the critical path will have **negative slack times**. However altering Ts has **no influence on free slack times** (as these depend on early start and early finish times, both of which are affected by the same amount when changing Ts).

For projects that have to be completed as soon as possible, the project manager does a forward-pass calculation through the network, then commits to the resultant Te. For projects that must meet a predetermined due date, the project manager substitutes Ts at the last event, then works backwards through the network.

PERT and CPM

In the previously discussed scheduling problems, the activity times are assumed to be known and fixed. But in reality they are **estimated** and are **variable**. Now, let us discuss the ***implications of*** *variable activity times on project schedules* by means of CPM and PERT techniques. To be more specific, how to **reduce the project duration** using CPM and how to **handle the uncertainty** in project completion dates using PERT.

CPM and Time-Cost Trade-Off

The critical path method (CPM) is a **systematic approach** for **allocating resources** among activities to **reduce project duration** for the **least cost**. It is a mathematical procedure for estimating the **trade-off** between project duration and project cost.

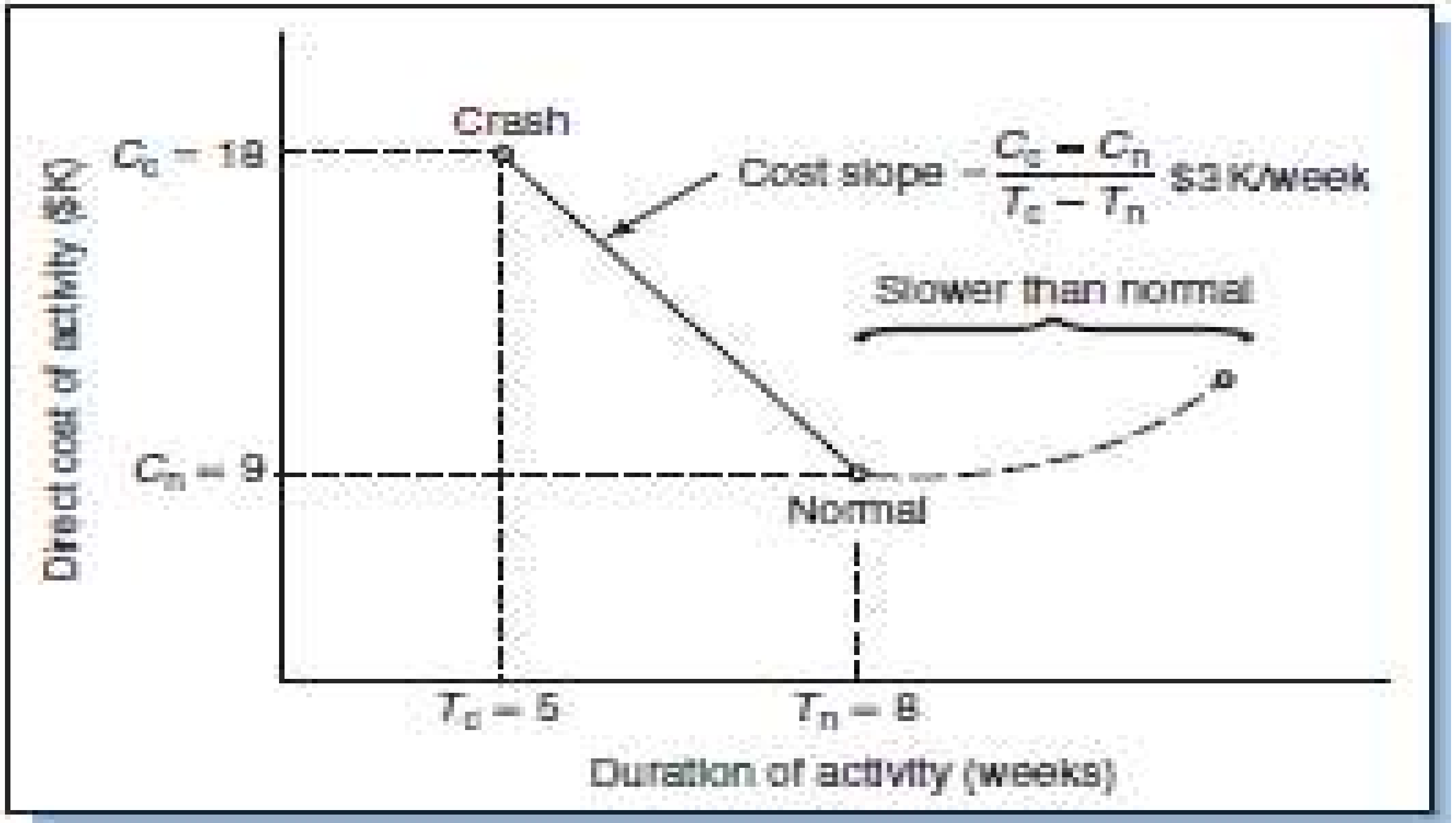
Example: House built in less than four hours and Flyover laid overnight.

Time-Cost Relationship

CPM assumes that the time to perform a project activity varies depending on the amount of effort or resources applied; project duration can be shortened by applying more resources (labour, equipment, etc.) to particular activities. Projects can be sped up by adding resources, but doing so increases the cost.

Ordinarily, work on any activity in a project is performed at a normal (usual and customary) work pace. This is the normal point shown in the following figure. Associated with this pace is the *normal time,* T_n – i.e., how long the activity will take under normal working conditions, and the *normal cost,* C_n, which is the cost of doing the activity in the normal time. (The normal time is assumed to be the most efficient and thus *least costly* pace. Extending the time beyond the normal pace will not produce additional savings and might increase the cost.)

Time–cost relationship for an activity.



To reduce the time to complete the activity, more resources are applied in the form of additional personnel or overtime. As more resources are applied, the duration shortens but the cost increases. When the maximum effort is applied so that the activity can be completed in the shortest possible time, the activity is said to be **crashed**. The crash condition represents not only the *shortest duration*, but the *most costly* as well. For some activities, however, there is no time-cost trade-off; an activity that is **process limited** requires a specific time that cannot be changed regardless of resources. An example is the time needed to cure concrete.

As illustrated in the figure, the points for completing an activity under normal conditions and crash conditions define two theoretical extremes. The line connecting the points, called the **cost slope,** represents the time-cost relationship or marginal trade-off of cost-to-time for the activity. The time-cost relationship for every activity is **unique**, and can be linear, curvilinear (concave or convex), or a step function. Because the shape of the actual time-cost relationship is unknown, it is often **assumed to be linear**. Given this assumption, the formula for the cost slope is:

$$\text{cost slope} = \frac{C_c - C_n}{T_c - T_n}$$

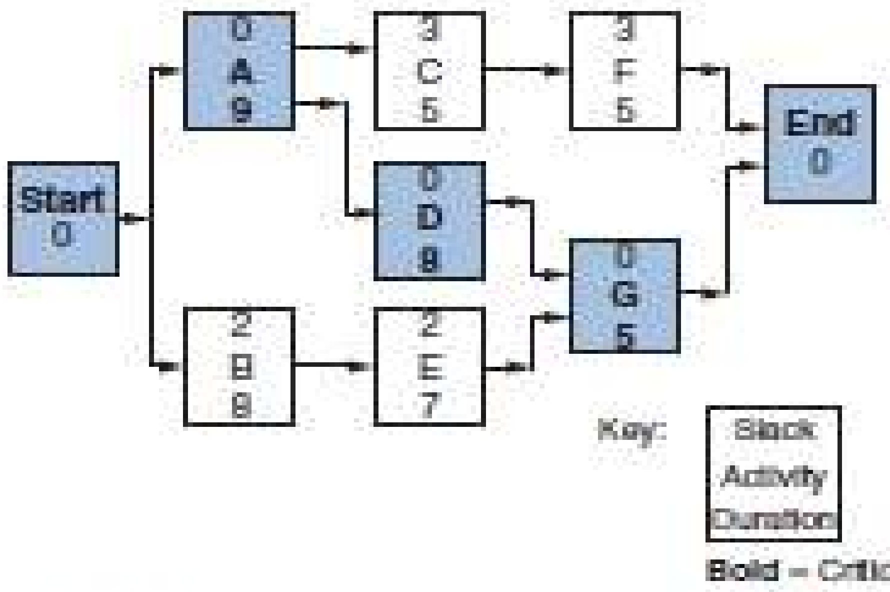
where C_c and C_n are the crash and normal costs, respectively, and T_c and T_n are the crash and normal times for the activity. The cost slope indicates **how much it would cost to speed up or slow down the activity.**

Using this formula, the cost slope for the activity in the above figure is $3K per week. Thus, for each week the activity duration is reduced from the normal time of 8 weeks, the cost will increase by $3K.

Reducing Project Duration: Shorten the Critical Path

The cost-slope concept can be used to determine the **least costly way to shorten a project**. To illustrate this let us begin with the preliminary project schedule by assuming a normal pace for all activities; therefore the project in the below figure can be completed in 22 weeks at an expense of $55K.

Time–cost trade-off for example network.

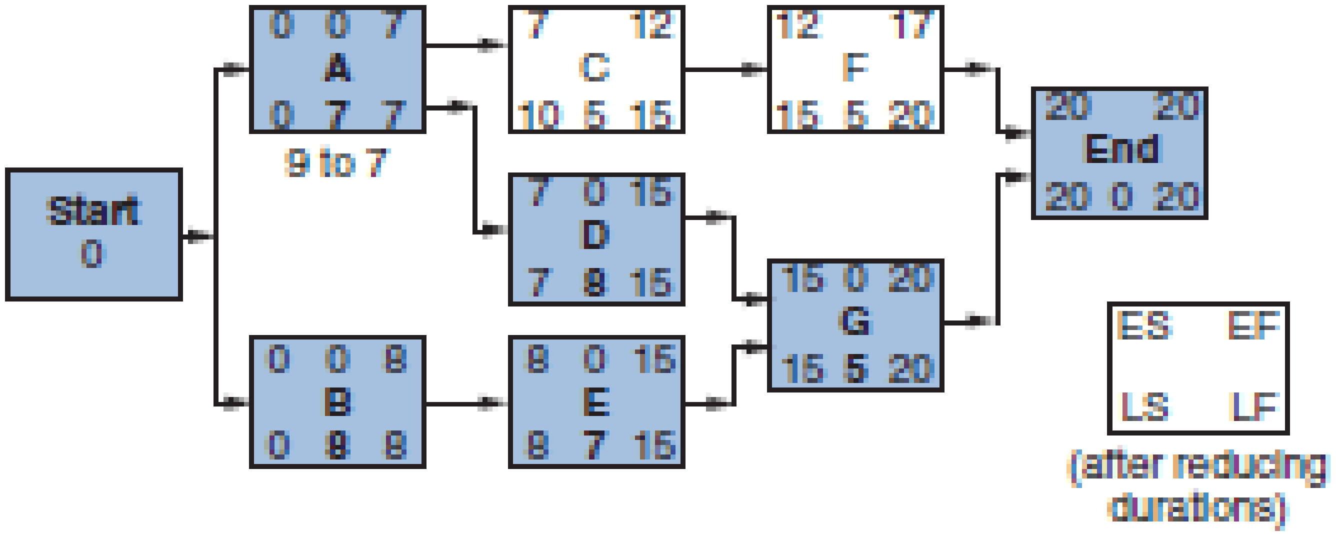


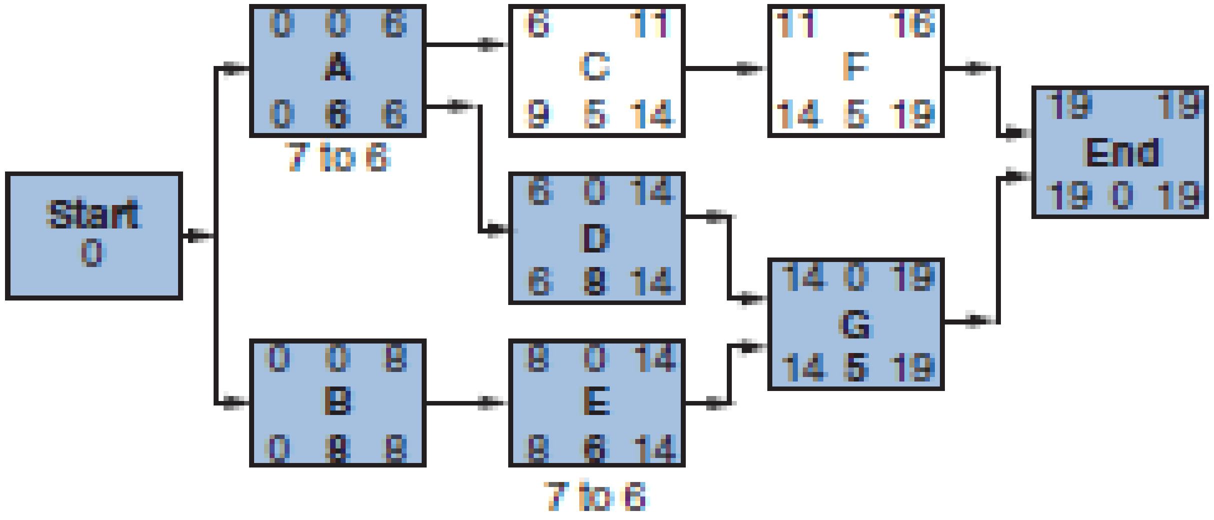
Activity	Normal T_n	Normal C_n	Crash T_c	Crash C_c	Cost slope
A	9	10	6	16	2
B	8	9	5	18	3
C	5	7	4	8	1
D	8	9	6	19	5
E	7	7	3	15	2
F	5	5	5	5	
G	5	8	2	23	5
		$55K		$104K	

Assume start occurs immediately upon finish of all immediate predecessors

Suppose we want to shorten the project duration, which is actually the **length of the critical path**. Because the critical path A-D-G is the longest path (22 weeks), to shorten the project it is necessary to shorten a critical activity – A, D, or G. Reducing an activity increases its cost, but because the reduction can be made anywhere on the critical path, the increase in cost is minimized by selecting the activity with the smallest cost slope, which is activity A. Reducing A by 1 week shortens the project duration to 21 weeks and adds $2K (the cost slope of A) to the project cost, bringing it to $57K. This step does not change the critical path, so, if need be, an additional week can be cut from A to reduce the project duration to 20 weeks for a cost of $59K.

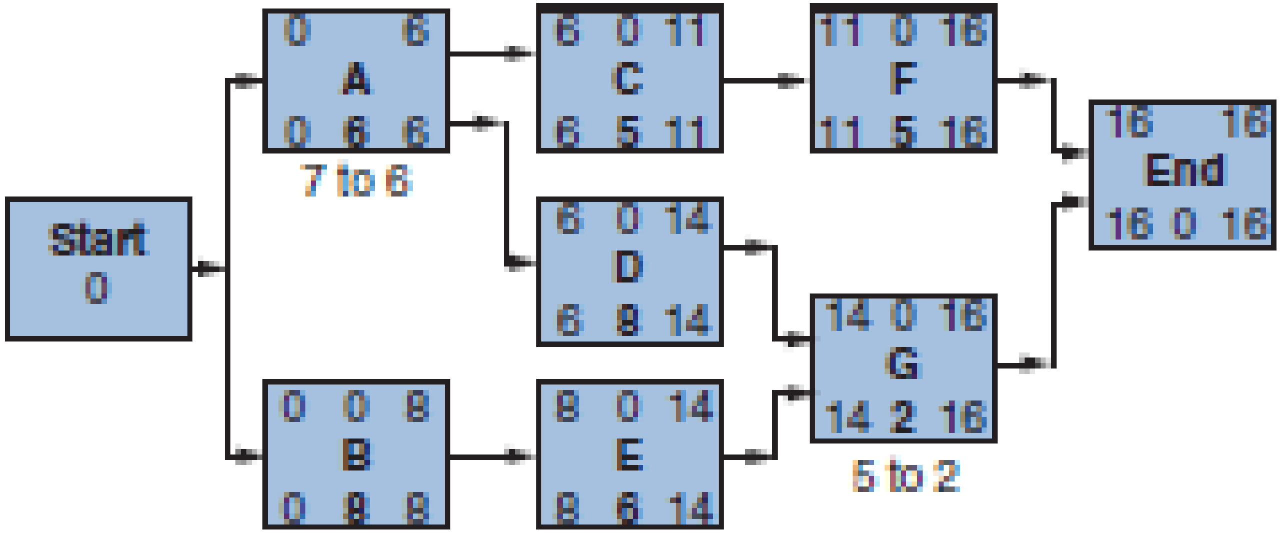
With this second step, the **nature of the problem changes**. That is, the network now has two critical paths, A-D-G and B-E-G as shown in the next following figure. Any further reduction in project duration must be made by shortening *both* paths, because shortening just one would leave the other at 20 weeks. The least costly way to reduce the project to 19 weeks is to reduce both A and E by 1 week, as shown in the next consequent figure. The additional cost is $2K for A and $2K for E, so the resulting project cost would increase to $63K. This last step, reduces A to 6 weeks, its crash time, so no further reductions can be made to A.


Start
0
0 0 7
A
0 7 7
9 to 7
7 12
C
10 5 15
12 17
F
15 5 20
7 0 15
D
7 8 15
0 0 8
B
0 8 8
8 0 15
E
8 7 15
15 0 20
G
15 5 20
20 20
End
20 0 20
ES EF
LS LF
(after reducing durations)


Start
0
0 0 6
A
0 6 6
7 to 6
6 11
C
9 5 14
11 16
F
14 5 19
6 0 14
D
6 8 14
0 0 8
B
0 8 8
8 0 14
E
8 6 14
7 to 6
14 0 19
G
14 5 19
19 19
End
19 0 19

If a further reduction in project duration is desired, the least costly way to shorten both paths is to reduce G. In fact, because the slack on the non critical path C-F is 3 weeks, and because the crash duration for G is 2 weeks (which means, if desired, 3 weeks can be taken out of G), the project can be reduced to 16 weeks by shortening G by 3 weeks, as indicated in the next figure. This adds $5K per week, or $15K for 3 weeks, to the project cost. Now the project cost has increased to $78K. With this step, all the paths in the network (A-C-F, A-D-G, and B-E-G) become critical.

Any further reductions desired in the project must shorten all three critical paths. Now, the most economical way to reduce the project to 15 weeks is to cut 1 week from each E, D, and C, bringing the project cost up to $86K. This step **reduces the time of C to its crash time**, the shortest possible project duration.

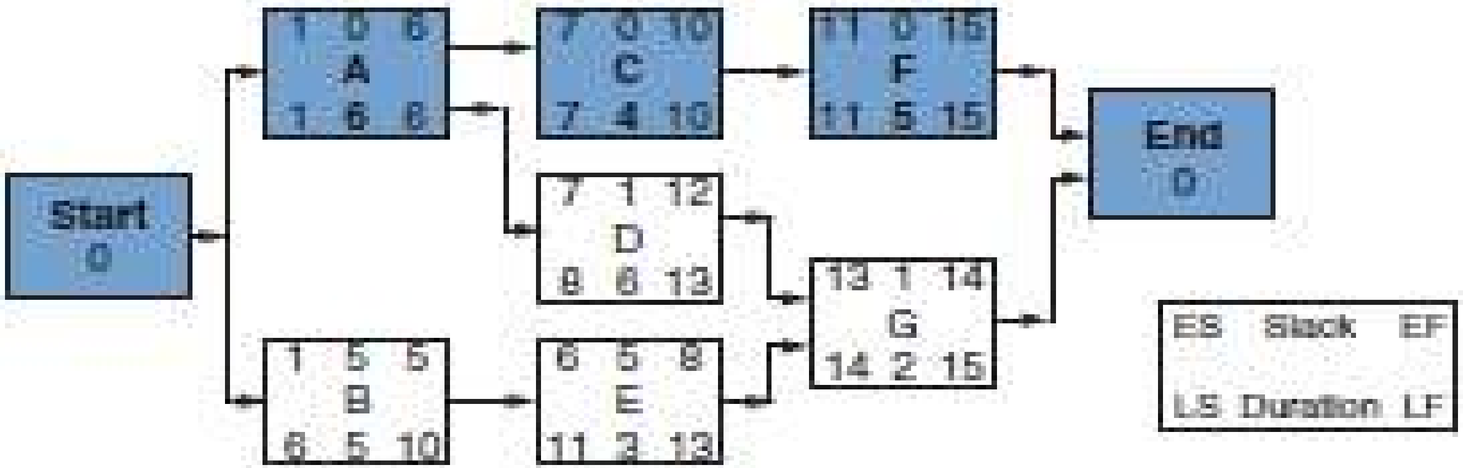


Shortest Project Duration

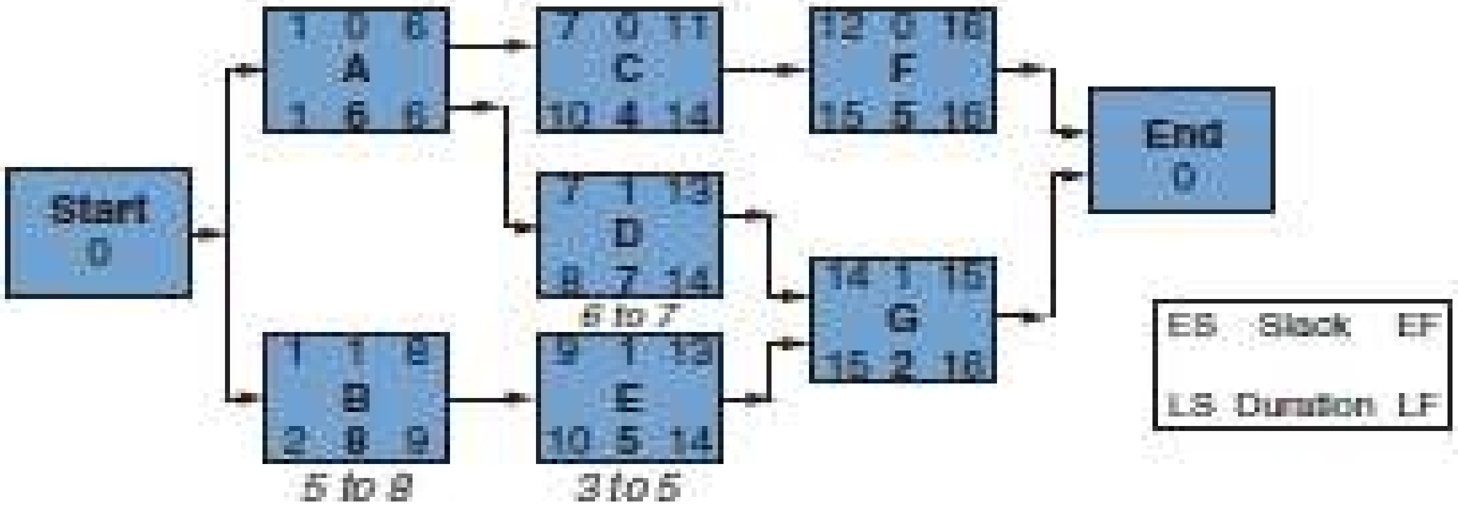
The time-cost procedure described above determines which activities to speed up**, step-by-step**, so as to reduce the project duration. This stepwise reduction of the project duration eventually leads to the shortest possible project duration and its associated cost. However, if we want to **directly find** the shortest possible project duration and **avoid the intermediate steps**, a simpler procedure is to **simultaneously crash all activities** at once. This, as shown in the following figure also yields the project duration of 15 weeks. However, the expense of crashing all activities, $104K is artificially high because, **not all activities need to be crashed** to finish the project in the shortest time.

The project duration of 15 weeks is the time along the critical path A-C-F. Because the critical path is the longest path, other (non-critical) paths are of shorter duration and, consequently, have **no influence** on project duration. Thus, it is possible to **stretch or increase** any non critical activity by a certain amount without lengthening the project.

Just as reducing activities time from the normal time increases its cost, so extending its time from the crash time **reduces its c**ost. As a result, by extending non critical jobs the project cost of $104K can be reduced. To do so, start with those non critical activities that will **yield the greatest savings** – those with the greatest cost slope.



Crash everything



After extending durations

In this figure because path B-E-G has a slack of 5 weeks, activities along this path can be stretched by up to 5 weeks without extending the project. 3 weeks can be added to activity B, 2 weeks to E, and 1 week to D, without changing the project duration. The final project cost is computed by subtracting the resulting savings from the initial crash cost.

$$\$104K – 3(\$3K) – 2(\$2K) – 1(\$5K) = \$86K$$

In general, to obtain the shortest project duration, start by crashing all activities, and then extend the non-critical activities with the greatest cost slopes to use up available slack and obtain the greatest cost savings. An activity can be extended up to its normal duration, which is assumed to be its least-costly time.

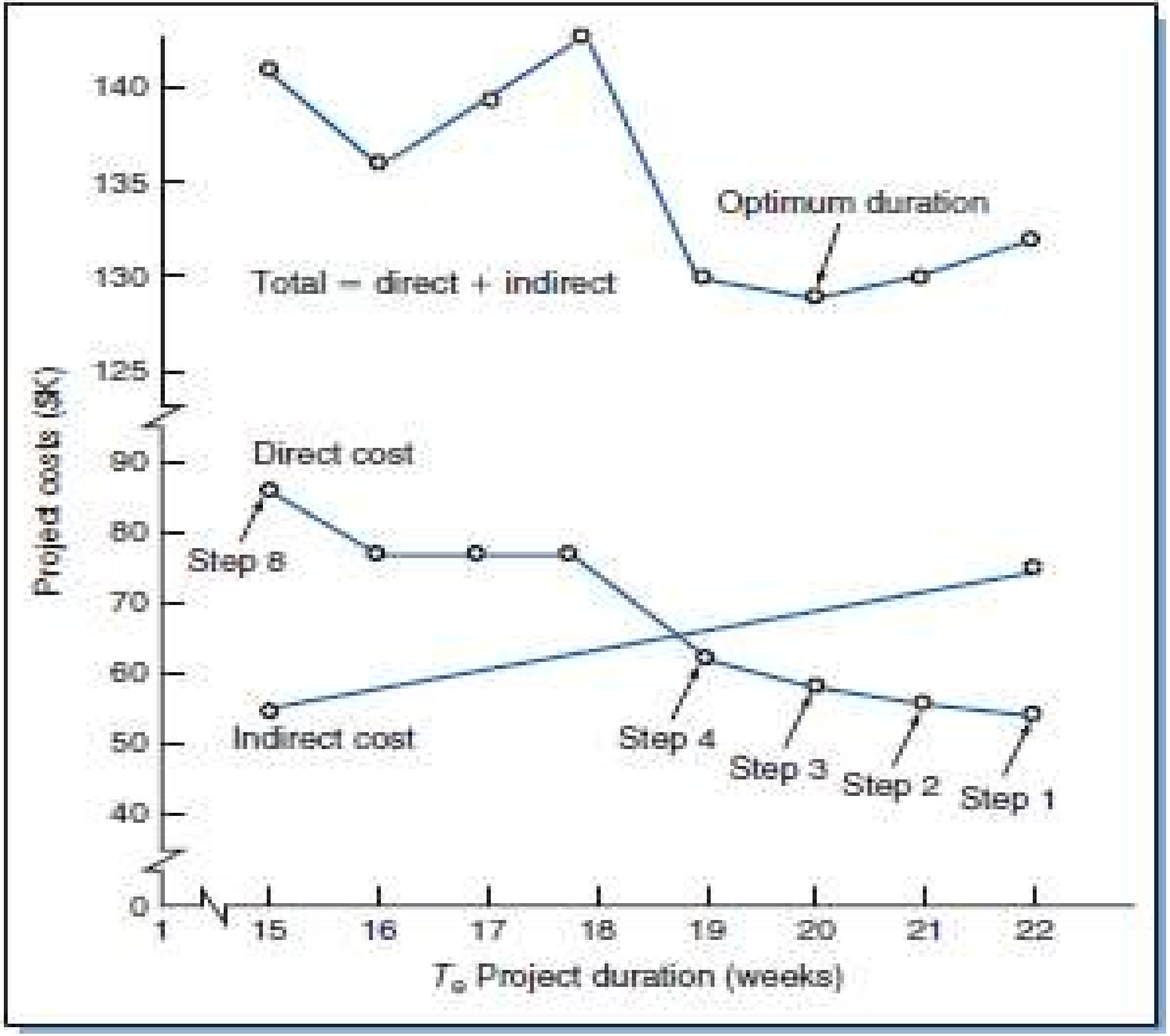
Total Project Cost

The previous analysis dealt only with direct costs – costs immediately associated with individual activities that increase directly as resources are added to them. But the cost of conducting a project includes more than direct activity costs; it also includes indirect costs such as administrative and overhead charges. Usually, indirect costs are a function of, and increase proportionately to, the duration of the project.

The mathematical function for indirect costs can be derived by estimation. As an illustration, suppose indirect costs in the previous example are approximated by the formula

$$\text{Indirect cost} = \$10\text{K} + \$3\text{K}\ (T_e)$$

where T_e is the expected project duration in weeks. This is represented by the indirect cost line in the following figure. Also, shown is the total project cost, which is computed by summing indirect and direct costs. Notice from the figure that by combining indirect costs and direct costs it is possible to determine the project duration that gives the lowest total project cost. This figure shows that, from a cost standpoint, 20 weeks is the "optimum" project duration.

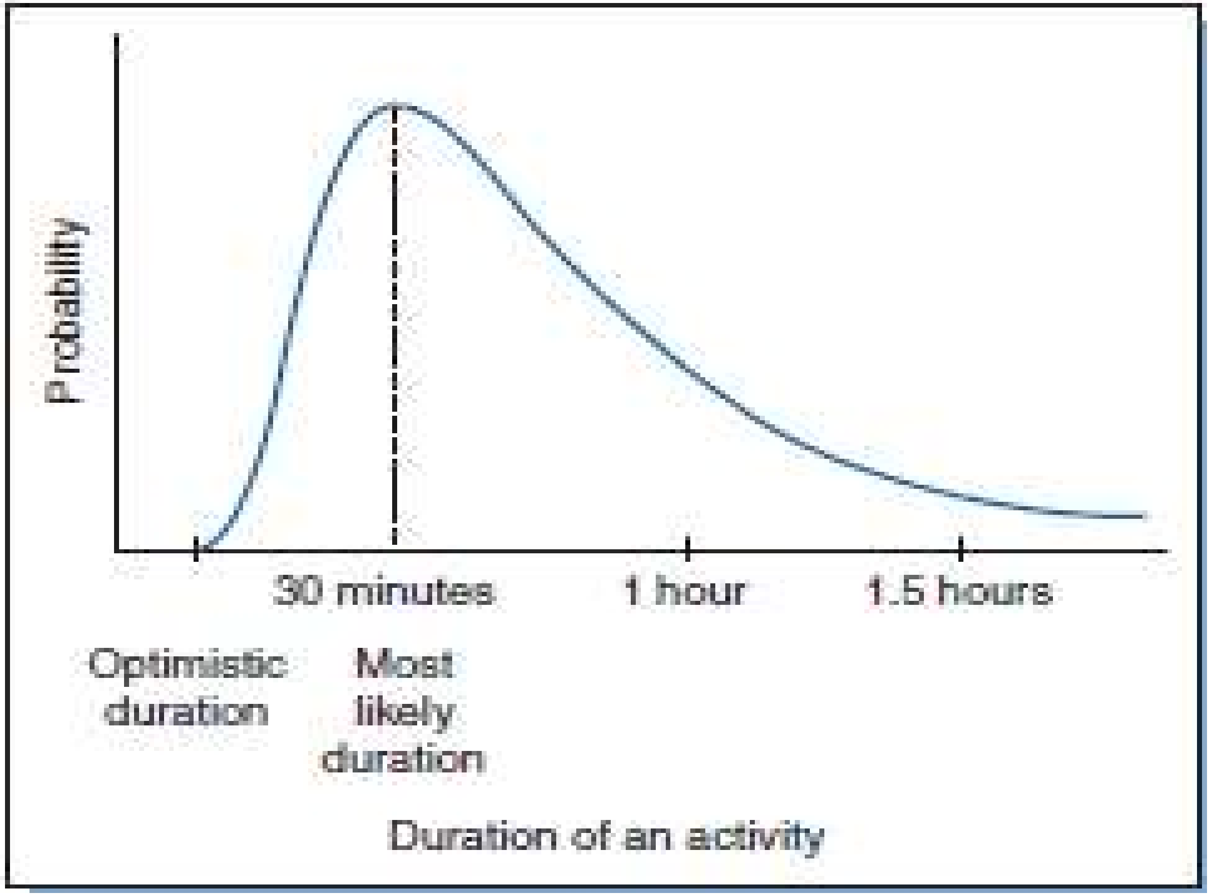


140
135
130
125
90
80
70
60
50
40
0
Project costs ($K)
Total = direct + indirect
Optimum duration
Direct cost
Step 8
Indirect cost
Step 4
Step 3
Step 2
Step 1
1
15
16
17
18
19
20
21
22
T_e Project duration (weeks)

In addition to direct and indirect costs, another cost that influences total project cost (and hence the optimum T_e) is any contractual incentive, such as penalty charge or a bonus payment. A penalty charge is a late fee imposed on the contractor for not completing a deliverable on time. A bonus payment is a reward – a cash inducement – for completing work early. Hence, based on all these costs, the decision is made on what is the optimum project duration that results in lowest possible project costs.

Variability of Activity Duration

Suppose you are driving to somewhere; the following figure shows the estimated time it will take you to get there and the variability in that time.



If everything goes well you will get there very quickly. This is “optimistic duration.” Most likely, however, it will **take you longer** than that. This is shown by the most likely duration time of 30 minutes. Of course it could take longer than this – say, when traffic is congested or worse, you are involved in an accident. Note in the figure that the **area** below the curve to the left of the most likely duration is **much less** than to the right of it. This indicates that the **chances of you arriving** later than the most likely time are greater than the chances of you arriving earlier.

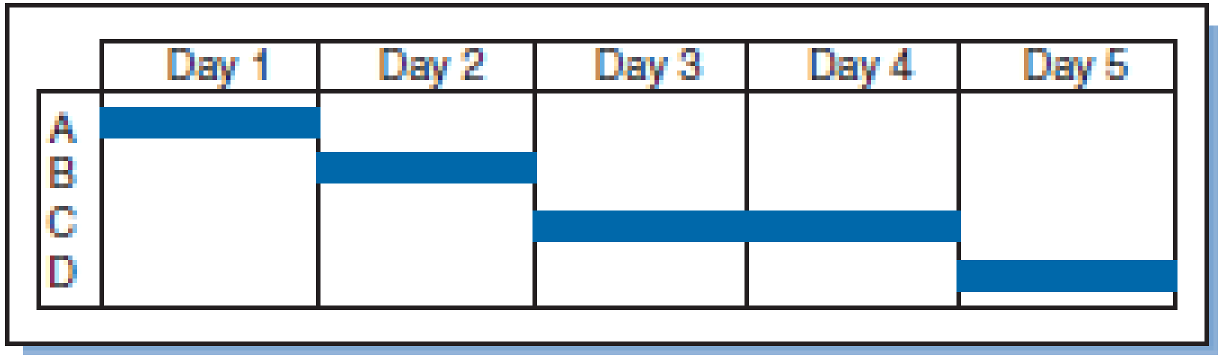
Like your travel time, the **activity durations** in a project are variable. The **question** is: Given that you cannot say for sure when each activity will be completed, how can you possibly say when the project will be completed?

When the activity durations are assumed to be constant, this is called **deterministic approach**. However, when the variability in the activity durations is considered, this is called **stochastic approach**, which we are going to study now.

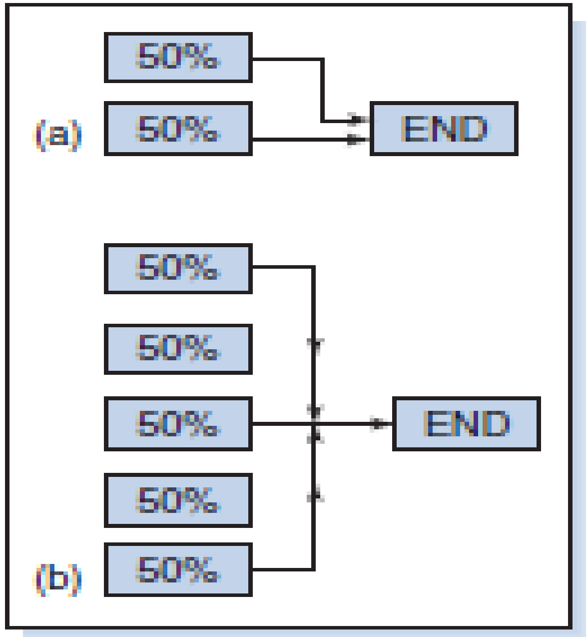
Variability Effects on a Project Network

The above figure relates to a single activity. In a project some activities will be completed earlier than expected, others later. When activities are combined in a network, however, the early activities and late activities **do not average out**: in general, it is **only the late activities** that impact the project completion. This is one reason why **projects tend to take longer** than expected.

Consider, for example, activity A in the following figure. **If activity A takes longer than** planned, it will delay activity B, which in turn will delay activities C and D and, thus, the completion of the project. Suppose, however, that activity A were finished earlier than planned. In that case would activity B start earlier? Not necessarily. Resources needed for activity B, such as people and equipment, would likely have **other commitments**, which would likely preclude activity B starting before the scheduled start date.



Consider **second example**. Most project networks consist of several paths that merge together into a **critical path**. The following first figure illustrates a project with two critical paths, each with a 50 percent chance of finishing on time. The probability that the project will finish on time is the probability that both paths will finish on time, or 0.5×0.5 = 0.25 or 25 percent. The second figure shows five paths merging, each with a 50 percent probability of finishing on time. The probability of finishing the project on time is only about 3 percent. This effect is called merge-bias or merge-point bias.



PERT is **one of several methods** developed to help grapple with the **uncertainty about** when a project will be completed.

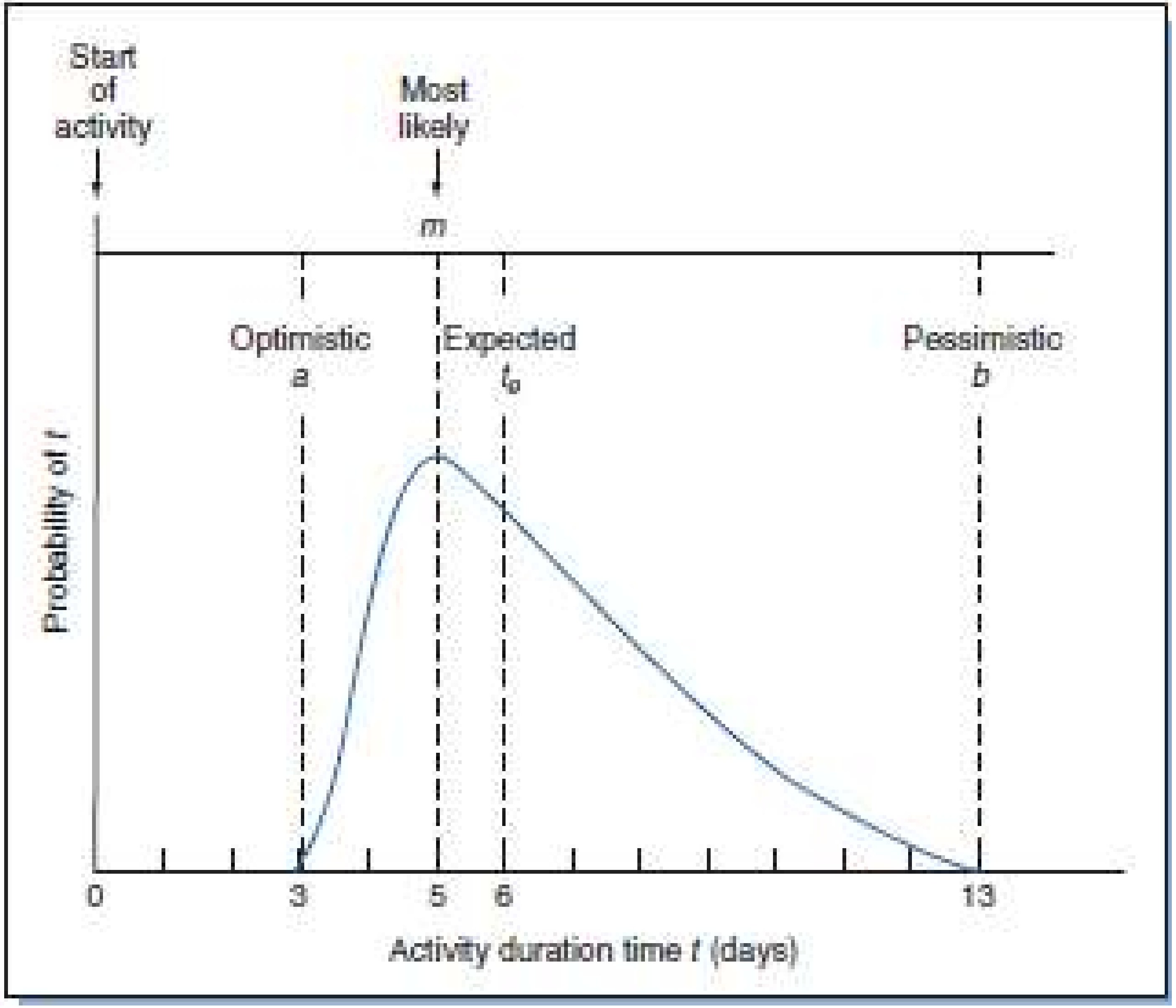
Program Evaluation and Review Technique (PERT)

The PERT method was **developed explicitly** for application in projects where the activity durations are uncertain. It is a technique to **estimate the likelihood/probability** of a project finishing on time. The purpose of PERT is to **analyse** the project network, **not to create a schedule**. The method provides insight into the likelihood of finishing a project by a certain time, though it says **nothing about how to increase that likelihood or reduce the duration of a project**.

Three time estimates

PERT addresses uncertainty in the durations by using three time estimates – *optimistic, most likely, and pessimistic.* These estimates are obtained from the project experts.

As seen in the next figure, the optimistic time is the minimum time for an activity, the situation where everything goes well and there is little hope of finishing earlier. The most likely time is the time that would occur most often if the **activity were repeated**. The pessimistic time is the maximum time for an activity – the situation where bad luck is encountered at every step. The pessimistic time includes likely problems in work, **but not highly unlikely** events such as natural disasters.



Start
of
activity
Most
likely
m
Optimistic
a
Expected
t_e
Pessimistic
b
Probability of t
0
3
5
6
13
Activity duration time t (days)

The three estimates in the figure are related in the form of Beta probability distribution with parameters a and b as the end-points and m, the **most frequent value**. The Beta distribution is used because it is unimodal (has a single peak value) and not necessarily symmetrical – properties that seems desirable for a distribution of activity durations.

Based on this distribution and the three estimates, the mean or expected time t_e, and the variance, *V,* of each activity are computed with the following formulas:

$$t_e = \frac{a + 4m + b}{6}$$

$$V = \left(\frac{b-a}{6}\right)^2$$

Since $V = \sigma^2$,

$$\sigma = (b - a)/6$$

The expected time, t_e, represents the point on the distribution with a **50-50 chance** that the activity will be completed earlier or later than it.

In the figure,

$$t_e = \frac{3 + 4(5) + 13}{6} = 6 \text{ days}$$

The variance, V, is a measure of variability in the activity duration:

$$V = \left(\frac{13 - 3}{6}\right)^2 = (1.67)^2 = 2.78$$

The larger V, the less reliable t_e, and the higher the likelihood the activity will be completed much earlier or much later than t_e. This simply reflects that the farther apart a and b, the more dispersed the distribution and the greater the chance that the actual time will significantly differ from the expected time. In a routine (repetitive) job, estimates of a and b are close to each other, V is small, and t_e is more likely.

Probability of finishing by a target completion date

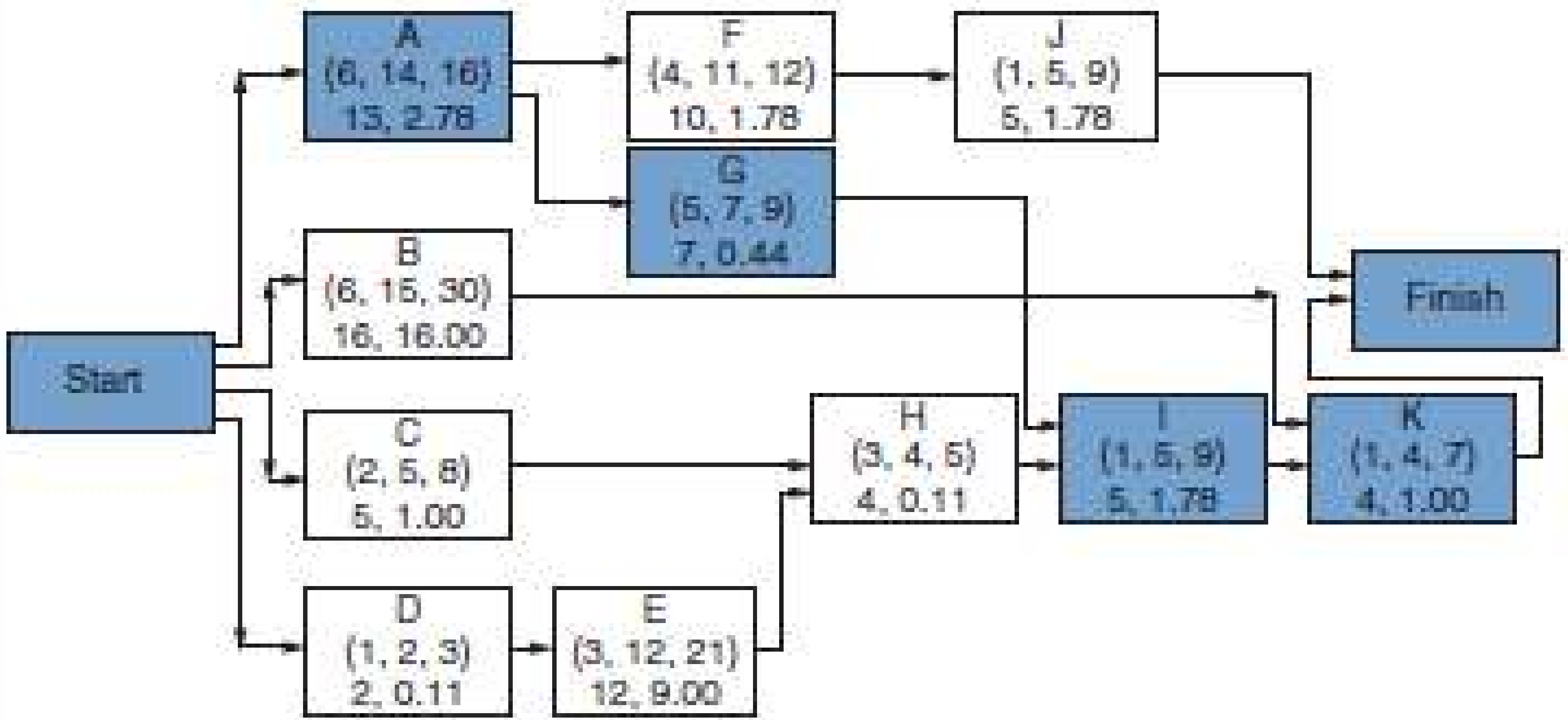
The expected time t_e, is used in the same way as the estimated activity duration was used in the deterministic networks. Because statistically the expected time of a sequence of independent activities is the sum of their individual expected times, the expected duration of the project, T_e, is the sum of the expected activity durations along the critical path (CP):

$$T_e = \sum_{CP} t_e$$

Similarly, the variation in the project duration distribution is computed as the sum of the variances of the activity durations along the critical path:

$$V_P = \sum_{CP} V$$

These concepts are illustrated in the following network.



	Path	$T_e = \Sigma t_e$	$V_p = \Sigma V$
(a)	A-F-J	28**	6.34
(b)	B-K	20	17.00
(c)	**A-G-I-K**	**29***	**6.00**
(d)	C-H-I-K	18	3.89
(e)	D-E-H-I-K	27**	12.00

* **Critical path**
** "Near-critical" paths

Key
Activity
(a, m, b)
t_e, V

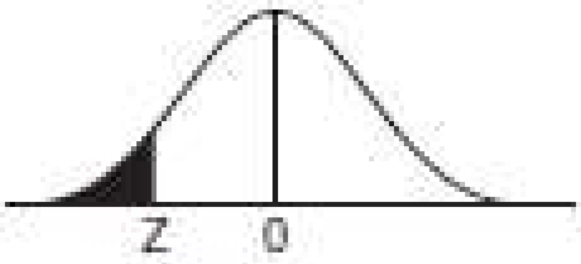
The distributions of project durations is assumed to be normal, no matter the shape of the distributions for the individual activity durations. Given this assumption, it is easy to determine the probability of meeting any specified project target completion time, T_S.

As examples, consider two questions about the project shown in the above figure.

1. What is the probability of completing the project in 27 days?
2. If we want to make a commitment on project duration and to be 95 percent sure, what duration should we quote?

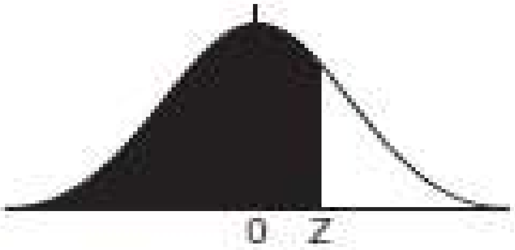
The formula used for the calculation is: $$z = \frac{T_s - T_e}{\sqrt{V_P}}$$

In answering the first question, z = -0.82. The probability of completing the project within 27 days is equal to the area under the normal curve to the left of z = -0.82. Referring the table below, the probability is about 21 percent.



z value	Probalility	z value	Probalility
0	.50	–1.2	.12
–0.1	.46	–1.3	.10
–0.2	.42	–1.4	.08
–0.3	.38	–1.5	.07
–0.4	.34	–1.6	.05
–0.5	.31	–1.7	.04
–0.6	.27	–1.8	.04
–0.7	.24	–1.9	.03
–0.8	.21	–2.0	.02
–0.9	.18	–2.1	.02
–1.0	.16	–2.2	.01
–1.1	.14	–2.3	.01

To answer the second question (duration with a 95 percent certainty): using the following table, for a probability of 0.95 the z value is 1.6.



Z VALUE	PROBALILITY	Z VALUE	PROBALILITY
0.0	.50	1.2	.88
0.1	.54	1.3	.90
0.2	.58	1.4	.92
0.3	.61	1.5	.93
0.4	.66	1.6	.95
0.5	.69	1.7	.96
0.6	.72	1.8	.96
0.7	.76	1.9	.97
0.8	.79	2.0	.98
0.9	.82	2.1	.98
1.0	.83	2.2	.99
1.1	.86	2.3	.99

As before, we calculate $1.6 = \frac{T_s - 29}{\sqrt{6}}$, so $T_s = 33$ days

In other words, it is highly likely (95 percent probable) that the project will be completed within 33 days. Note that since we are working with values that are merely estimates, it does not make sense to compute figures of great precision.

Criticisms of PERT

This method is criticized because it is based on the following assumptions that sometimes yield problematic results.

1. It ignores human behaviour and assumes that whenever an activity is completed earlier than scheduled that succeeding activities will start straight away – ignoring the fact that resources might not be available or that people procrastinate.
2. It assumes that activity **durations are independent**. But whenever resources are transferred from one activity to another, the durations of both activities are changed. Activity durations are usually not independent.
3. It assumed three activity estimates are better than one. Unless based upon good historical data, the three estimates are still guesses, which might not improve over a single “best” guess.
4. Accuracy of estimates often depends on experience. In fact, reliance good historical data (which is framed based on the experience from previous similar projects) for estimating times makes the PERT method appropriate for projects that are **somewhat repeatable**. Hence, PERT is generally used in **construction and standardized** engineering projects, but seldom elsewhere.

Risk Management in Projects and Project Control – Unit III

Risk Concepts

Risk in a project depends on the **uniqueness of the project and the experience** of the project team. When activities are routine or have been performed many times before, managers can **anticipate the range of potential outcomes and manipulate** the system design and project plan to achieve the desired outcomes. However, when the work is unique or the team is inexperienced, making it difficult to anticipate the problems, the **potential outcomes are less certain**. **Even routine projects have risks**, because outcomes may be influenced by the factors that are **new and emerging**, or beyond anyone's control.

The notion of risk involves two concepts:

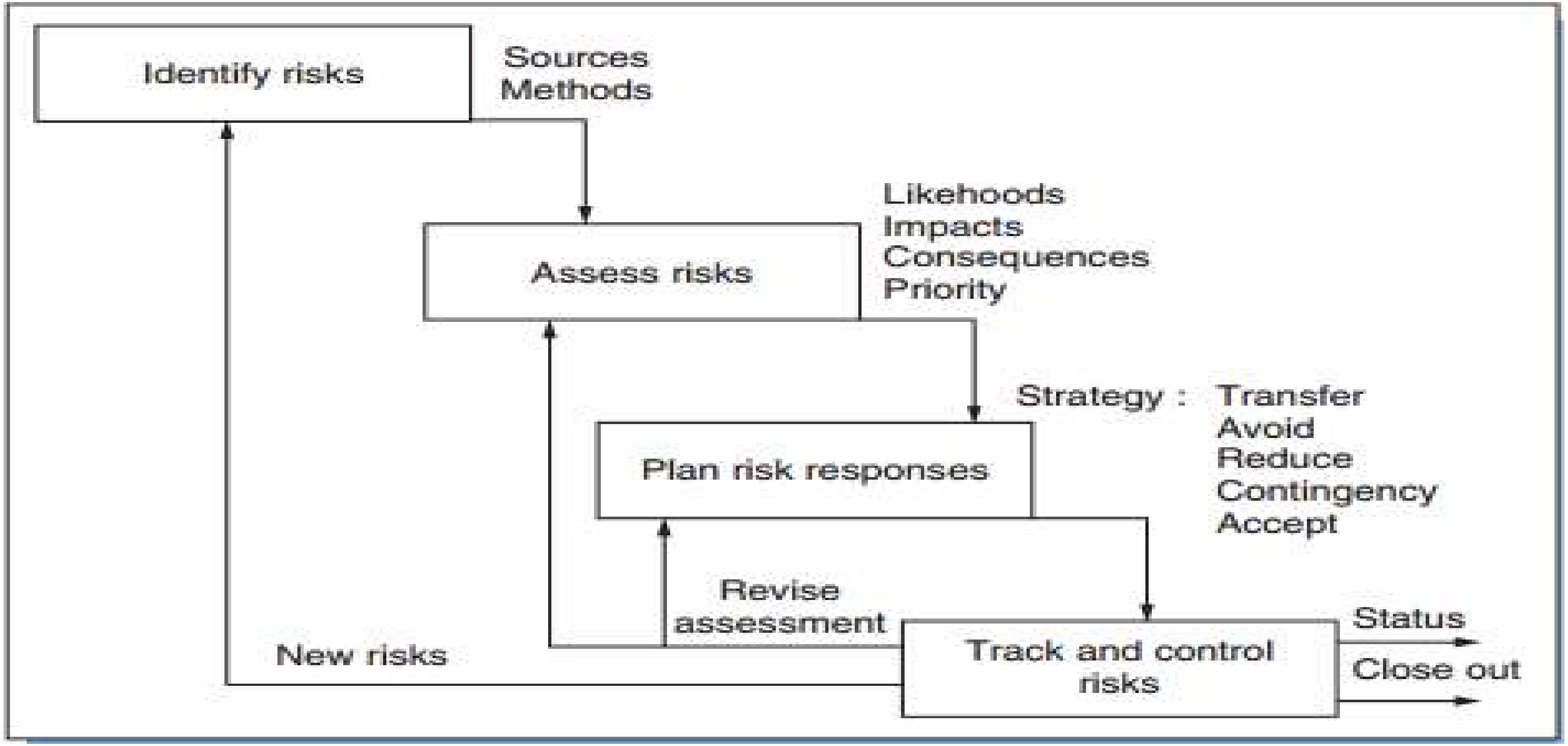
1. The *likelihood* that some problematic event will occur.
2. The *impact* of the event if it does occur.

Hence, risk is a joint function of the two:

$$\text{Risk} = f\,(\text{likelihood, impact})$$

A project may be considered **risky** whenever **at least one** – either the likelihood or the impact – is **large**. For example, a project will be considered risky when the potential impact is human fatality or massive financial loss even when the likelihood is small.

Although the risk cannot be eliminated altogether, it **can be reduced** and plans readied in case things go wrong; this is the **purpose of risk management**. The **process and elements** of risk management are shown in the following figure.



Risk Identification

You can only manage things you are aware of. Thus, **risk management begins** with identifying the risks and predicting their consequences. Risks in projects is generally referred to as the **risk of failure**, which implies that a project might fall short of **schedule, budget, or technical performance** goals by a significant margin. The **Sources** or **Causes** of high risk must be studied and well understood before the project can be **approved and funds committed**.

Different types of Risks and their Causes

Any factor that can influence the outcome of a project is a ***risk cause* or *risk hazard*.** Risk in projects can be classified as internal risks and external risks.

Internal risks

Internal risks originate **inside** the project, and project managers and stake holders usually have **some measure of control** over them. Three main categories of the internal risks are as follows:

Market risk is the risk of not fulfilling the market needs or the requirements of particular customers. **Sources** of market risk include:

- Failure to adequately define market or customer needs and requirements.
- Failure to identify changing needs and requirements.
- Failure to identify newly introduced products by competitors.

Market risk stems from the **developer misreading the market environment**, it can be reduced by working closely with the customer; thoroughly defining needs and requirements early in the project; closely monitoring trends and developments among markets, and competitors; and updating requirements as needed throughout the project.

Assumption risk is risk associated with the numerous implicit or explicit assumptions made in **feasibility studies and project plans** during project conception and definition. The risk of meeting cost, time, and performance requirements depends on the **accuracy of many assumptions**.

Technical risk is the risk of **encountering technical problems** with the end-item or project activities (sometimes these risks are listed in **special categories** – *schedule risks* being those that would cause delays*, cost risks* those that would lead to overruns, and so on). Technical risk is high in projects that involve new and untried technical applications, but is low in projects that involve familiar activities done in customary ways.

One approach to **expressing technical risk** is to rate the project **end-item** or primary process as being high, medium, or low according to the following features.

- *Maturity*: how experienced or knowledgeable the project team is in the project technology. An end-item or process that takes advantage of existing experience and knowledge is less risky than one that is innovative, somewhat untried, or cutting edge.

- *Complexity*: how many steps, elements, or components are in the **product or process**, and how tightly **interrelated** they are. An end item or process with numerous, interrelated steps or components is riskier than one with few steps and simple interrelationships.
- *Quality*: how producible, reliable, and testable the end-item or process is. In general, an end-item or process that has been produced and is reliable and/ or testable is less risky than one that has yet to be produced or has unknown reliability or testability.
- *Concurrency or Dependency*: the extent to which multiple activities in the project overlap or are dependent. **Sequential activities** with no overlap are less risky than activities with much overlap.

External Risks

These originate from outside the project, and project managers often have limited or no control over them. External risk causes include:

- Market conditions
- Customer needs and behaviour
- Competitor’s actions
- Supplier relations and business failures
- Government regulations

- Physical environment, i.e. whether conditions
- Interest rates and exchange rates
- Labour availability (strikes and walkouts)
- Decisions by senior management or the customer regarding project priorities, staffing, or budgets
- Material or labour resources (shortages)
- Subcontractor failure

Any of these can affect the success of a project.

Identification Techniques

The Project risks and their sources are identified in many ways. The principle methods are explained as follows.

Project Analogy

The project analogy method involves scrutinizing records, post-completion summary reports, and project team member's recollection from earlier **analogous projects** to identify risks in new, upcoming projects. The **better the documentation** (the more complete, accurate, and well-catalogued) of past projects and the better people's memories, the more useful these are as means for identifying risks.

Checklist

Documentation from prior projects is also used to create checklists – lists of risks and their causes in projects. A checklist is originally created from the experiences from past projects, and is **updated as new experience** is gained from recent projects. Risk checklists can **pertain** to the project as a whole, or to specific phases, work packages, or tasks within the project.

The more experience a company or managers gain with projects, the more they learn about the risks, and the more comprehensive they can make the checklists. As experience grows with completed projects, the checklist are expanded and updated. When a checklist **cannot guarantee** that all significant risk sources or causes in a project will be identified, it does help ensure that the **important known one's won't be overlooked**.

A **disadvantage** of risk checklist is that people might only consider the risks listed and not consider any not in the list.

Work Breakdown Structure (WBS)

Risks can be identified through analysis of the WBS. **Every package is scrutinized** for potential **technical hurdles** or **problems with** management, customers, suppliers, equipment, or resource availability. Processes or end-items within each work package are assessed for **internal risks** in terms of, for example, complexity, maturity, quality, and concurrency. The work package is also assessed for **external risks** – for example, relying on a subcontractor to manage the work package.

Process Flowchart

Project risks can also be identified from process flowcharts. A **flow chart illustrates** the **steps, procedures and flows** between tasks and activities in a process. Examination of a flowchart can pinpoint potential trouble spots and areas of risks.

Project Networks** and **Convergence Points

The risks can also be identified through scrutiny of the **precedence relationships and concurrent or sequential scheduling of activities** in project networks. For example, **risk sometimes increases at merge points** in the project network. At these points, work performed by different teams comes together and must be integrated; sometimes only do then errors become evident, such as subsystems produced by two teams **not matching up or functioning correctly**. The result is that the project may get delayed.

Cause-and-Effect Diagram and Brainstorming

Risks can be identified from the **collective experiences of project team members** who participate in a brainstorming session to share opinions about possible risk sources in the project, and **record them on a cause-and-effect diagram**. This can be worked out in two ways: 1. Given an identified, potential outcome (effect), to identify the potential causes (sources); 2. Given a risk source (cause), to identify the outcomes that might ensue (effects).

Delphi Technique

The term “Delphi” refers to a **group survey technique** for **combining the opinions of several people to develop a single judgement**. This technique comprises a series of structured questions and feedback reports. Each respondent is given series of questions (e.g., what are the **five most** significant risks in this project?). For which he writes his opinions and reasons. The responses of everyone surveyed are summarized **in one report that is given to everyone**. Seeing others opinions, respondents **have the opportunity to modify** their own opinions. Because the written responses are **anonymous**, no one feels pressurized to conform to their opinions. If people change their opinions, they must explain the reason why; if they don’t, they must also explain why. The process **continues until the group reaches** a collective opinion. Studies have proven this technique to be an **effective way** of reaching consensus.

Risk Symptoms and Triggers

As the sources and outcomes of each risk are **identified**, **so are its symptoms**, which are visible indicators or warning signs that the risk is materializing; these serve as a **trigger** to initiate counteractions or contingencies to mitigate or combat the risk. For example, for the risk “failure to meet technical requirements”, a symptom might be “failure of component X during test”; should that symptom be observed, it would trigger the action “move to design plan B”.

Risk Assessment

Risks are ubiquitous, but it is only the notable or significant ones that require attention. If a risk and its consequences are **significant**, ways must be found to avoid or reduce the risk to an **acceptable level**. What is considered "acceptable" depends on the *risk tolerance* of project stakeholders. Similarly, what is considered significant depends on the risk likelihood, the risk impact, and the risk consequence.

Risk Likelihood

Risk likelihood is the **probability that** a risk factor will actually materialize. It can be **expressed as a** numerical value between 1.0 (certain to happen) and 0 (impossible), or as a qualitative rating such as high, medium, or low. The following table shows an example of qualitative ratings and the **equivalen**t percent values for each. When, for example, someone says the **likelihood** of this or that risk is low, **the probability of its** happening, according to the table, is 20 percent or less.

QUALITATIVE	NUMERICAL
Low	0–0.20
Medium	0.21–0.50
High	0.51–1.00

The **association** between qualitative ratings and particular numerical values is **subjective**, and depends on the **experience of the project team and the risk tolerance of stakeholders**. For example, the above table **might be** for a project with high **economic stakes**, and therefore a numerical likelihood greater than 50 percent equates to “high risk”.

When the project has multiple, independent risk sources (as is common), they can be combined into a **single *composite likelihood factor*,** or CLF, which can be computed as a weighted (W) average.

CLF = W1*Likelihood of risk source 1 + W2*Likelihood of risk source 2 + W3*Likelihood of risk source 3 + -------

Where W1, W2, W3, and so on each have values 0 through 1.0 and together total 1.0.

For example, if there are five risk sources with their likelihood of happening as 0.1, 0.3, 0.5, 0.3, and 0.5 and all of them are rated equally at 0.2, then

$$CLF = (0.2)0.1 + (0.2)0.3 + (0.2)0.5 + (0.2)0.3 + (0.2)0.5 = 0.34$$

However, when the risk sources are not independent, then the individual likelihoods cannot be summed up. In such a situation the sources would be **subjectively combined into one source and a single likelihood value based on judgement is assigned**.

Risk Impact

What would happen if a risk source or hazard materialized? The result would be a *risk impact.* A **poorly marked highway** intersection is a risk hazard; it poses the risk impact of a collision and injury or death. Risk impacts in projects **can be specified** in terms of time, cost, performance, publicity, and so on. For example, the impact of **insufficient resources** might be **failure to meet schedule** or user requirements.

Similar to risk likelihood, risk impact can be expressed as a qualitative rating (such as high, medium, or low) or as a numerical measure between 0 and 1.0 (where 0 is not serious and 1.0 is catastrophic), based upon a manager’s or expert’s judgement about the impact.

Just as the likelihoods for multiple risks in a project can be combined, so can the impacts from multiple risk sources. Accordingly, the ***composite impact factor*** **(CIF)** can be computed using weighted average. However, if the risk impacts are not independent, they should be treated jointly.

Risk Consequence

Earlier, the notion of risk was defined as being a function of risk likelihood and risk impact; the combined consideration of both is referred to as the ***risk consequence*** **or risk exposure**, which can be expressed as follows

$$\text{Risk consequence} = \text{Impact} \times \text{Likelihood}$$

Example: Suppose the likelihood associated with a risk is 0.40. Also, should this risk materialize, it would set the project back 4 months and increase the cost by an estimated 3,00,000/-. The expected risk consequences for time and cost are thus:

Risk consequence time (RT) = 4 months × 0.40 = 1.6 months = 6.4 weeks

Risk consequence cost (RC) = 3,00,000 × 0.40 = 1,20,000/-

Risk Response Planning

Risk response planning addresses the mater of how to *deal* with risk. The following are the ways of dealing with a risk.

Transfer the Risk

Risk can be transferred between customers, contractors, and other parties using contractual incentives, warranties, or penalties.

Insurance

The customer or contractor **purchases insurance** to protect against a wide range of risks, including those associated with

- Property damage or personal injury suffered as a consequence of the project.
- Damage to materials while in transit or in storage.
- Breakdown or damage of the equipment.
- Theft of equipment or materials.
- Sickness or injury of workers, managers, and staff.
- Fluctuations in exchange rates.

Subcontract work

Risks arise from uncertainty about how to approach a problem or situation. One way to avoid such risk is to hire contractors that specialize in handling those problems or situations. For example, to minimize the **financial risk** associated with the capital cost of tooling and equipment for production of a large, complex system, a manufacturer might subcontract the production of the **system's major components** to suppliers familiarize with those components. This relieves the manufacturer of the financial risk associated with the tooling and equipment to produce these components. But, as mentioned, **transfer of one kind of risk often means inheriting another kind**. For example, subcontractor work for the components means that the manufacturer must rely on outsiders, which increases the risks associated with **quality control and scheduling**. However, such risks often can reduce through careful management of the subcontractors.

Risk Responsibility

The individual or group responsible for each particular risk in a project should be specified. Risks may be transferred, but they can never be completely “offloaded”. A warranty or guarantee specifies the time or place at which the risk is transferred from one party to another. For instance, when an item is procured and shipped from abroad, the risk of damage usually remains with the seller as long as the item is on the ship; as soon as it is hoisted over the rail of the ship the risk is transferred to the buyer. Generally a party willing to **accept responsibility for high risk** in a project will usually **demand a high level of authority** over the project.

Avoid risk

Risk can avoided by **such measures** as increasing supervision, eliminating risky activities, minimizing system complexity, altering end-item quality requirements, changing contractors, etc. But attempts to avoid risk can entail the addition of **innumerable management controls and monitoring systems**, which tend to increase system complexity and, perversely, **introduce new sources of risk**. Risk avoidance attempts can also **diminish payoff opportunities**. Many risk factors can be avoided, but not all, especially in complex or leading edge projects. Projects for **research and new product development are inherently risky**, but offer potential for huge benefits later on. Because the size of the risk is often proportional to the potential payoff, rather than avoiding risk it is **better to try to reduce risk** to an acceptable level.

Reduce Risk

Among the ways to reduce the technical risk (**its likelihood, impact, or both**) are the following.

- Employ the best technical team
- Use mature, computer-aided system engineering tools
- Provide the technical team with incentives for success
- Hire outside specialists for critical review and assessment of work
- Perform extensive tests and evaluations
- Minimize system complexity
- Use design margins.

The latter two points deserve further explanation. In general, system risk and uncertainty increase with system complexity: the **more elements** in a system and the more they are **interconnected**, the more likely it is that an element or **interconnection will go wrong**. Thus, minimizing complexity through reorganizing and modifying elements in product design and project tasks reduces the project risk. For example, by **decoupling** activities and subsystems – i.e., making them independent of one another – a **failure** of one activity or subsystem **will not spread to others**.

Incorporating design margins into design goals is another way to reduce risk associated with meeting technical requirements. A design margin is a quantified value that serves as a safety buffer held in reserve and allocated by management. In general, a design margin is incorporated into a requirement by setting the **target design value to be stiffer or more rigorous than the design requirement**. By striving to meet a target vales that is stiffer than the requirement, the risk of not meeting the requirement is reduced.

Accept Risk (Do Nothing)

Not all the risks are severe. If the cost of avoiding, reducing, or transferring the risk is estimated to **exceed the benefits**, then “do nothing” might be the best alternative. This accept risk strategy would be chosen for risks falling in the **low consequence category**.

Risk Tracking and Control (or) Risk Monitoring

Identified risks are documented, added to a list called a ***risk log* or *risk register***, and rank ordered with greatest risk consequence first. For risks with the most serious consequences, **mitigation plans are prepared and strategies** adopted (transfer, reduce, avoid, or contingency); for those of little or no consequence, nothing is done (accept).

The project should be ***continuously tracked* for symptoms** of previously identified risks as well as newly emerging risks (not previously identified). Should a **symptom reach the trigger point**, a decision is made as to the course of action, which might be to institute a **prepared plan** or to **organize a meeting** to pick a solution. Sometimes the response is to do nothing.

All risks deemed critical or **important are tracked throughout** the project or the phases to which they apply; to guarantee this, **someone is assigned responsibility** to track and monitor the **symptoms of every important risk**.

Altogether, the risk log (risk register), mitigation strategies, monitoring methods, people responsible, contingency plans, and schedule and budget reserves constitute the ***project risk management plan***. The plan is continuously **updated** to account the **changes in risk status**. The project manager (and sometimes other managers and the customer) is **alerted about emerging problems** and people readily **notify the project manager** whenever they detect a known risk materializing or new one emerging.

Risk Profile and Management Plan

Risk Number	Last Update	Originator	Risk Category
Project	Phase	Department	WBS Number
Likelihood	Impact	Consequence	Priority

Risk Assessment

Risk description

____
____
____
____
____

Risk sources

____
____
____
____
____

Risk assessment

____
____
____
____
____

Strategy:	Risk Plan
☐ Accept ☐ Avoid ☐ Contingency ☐ Reduce ☐ Reserves ☐ Transfer	1. ______ 2. ______ 3. ______ 4. ______ 5. ______ 6. ______ 7. ______

Risk Tracking

Member Responsible	Risk Officer
Measures/Symptoms	Comments
Trigger Event	Comments

Signoffs

Cost Engineer	System Engineer	Quality Manager	Project Manager
Date:	Date:	Date:	Date:

Tools to manage a risk

- **Risk register:** A risk register is a chart that contains all the risks associated with a project, as well as their priority levels, mitigation plans, and other important details. A risk register might also be called a **risk matrix**. You can find project **management software** that can help you compile risk registers, or else create your **own in a spreadsheet**.
- **Risk management plan:** A risk management plan is generally a living document that contains all information related to risk in your project. This can contain an executive summary, your risk, mitigation plans, risk owners, and any other information pertaining to risk. Project managers may update the document as the project progresses and needs fluctuate.

Benefits of project risk management

- **Evaluating Problem Areas: -** A **detailed** project risk management **plan** will give you a **clear picture** of your project and the potential problematic areas in it. That way, you will be able to direct your (& your Stakeholders) attention towards the weak links of the project, perform periodic status checks, peer reviews and audits to keep up the project performance.
- **Fewer Surprises: -** Who doesn't like surprises, correct? But in a Project, none of us would like a surprise!. So, risk management plans give you an **early warning of potential risks** or issues. This enables the team to gear up and take the necessary steps to mitigate problems before they escalate to severe issues and cause any irreversible harm.

- **Better Decision Making: -** With information on risks in advance, the upper management is able to make better and efficient decisions. They will be having real-time information on risk through a dashboard which will be continuously providing them with the latest data.
- **Enhanced Communication: - Effective** risk management **enhances the flow of** communication. With the risks detected beforehand, it opens up the discussion point between the team involved. All the teams to bring their minds together and to talk about the problem areas and handle the causes of it rather than blaming each other after the harm has been done.
- **Accurate Budget Estimations: -** With project risk management **mapped** into your schedule and cost planning, you will be able to predict the potential problems. This will help you in **setting aside a buffer budget** (also called as **contingency**) for each of the domain like cost, time, resource etc. resulting in less wastage and better quality.
- **Elevated Project Success Rate: -** With an effective risk management plan incorporated in your project management, it boosts up the mindset of the entire team as they know the risks are being actively managed and there is very less probability of failure.
- **Focused Approach: -** Knowing the fact that the risks are being actively tracked and managed, the teams can focus more on **their assigned tasks**. Not only this, risk management highlights the problem areas of a project so that the teams can swiftly deal with them ensuring the project success.

- **Better Escalation Management: -** A systematic risk management plan will give you a proper idea of **when a risk needs to be escalated to the senior level for advice and action**. This will help in alerting the right people at the right time to analyze and fix the risk.

Challenges of project risk management

- **Identifying risk:** The act of determining risks can be **a challenge**. There is no way **for one person** to be aware of all the financial and time limit risks. Hence this task is incredibly time consuming and require compliance from other individuals.
- **A lack of buy-in:** From co-workers to upper management and others **may not understand** the importance of developing a risk management plan. Project managers have to get the team and top management **buy-in** (acceptance of and willingness to actively support and participate) for most components of a project. If others don't see the value in doing this, then project managers might not be allowed the time to do it, and co-workers might not adhere to guidance from it.
- **Cannot precisely predict the future:** Regardless of how much planning a project manager does, there is no way to predict the issues that will occur correctly. Managers can only include information concerning past events that deterred a project. If a company has never had anyone develop a risk management plan, then managers have to piece together the past to the best of their ability. Regarding the future, the best anyone can do is guess, and sometimes this is not always good enough.

Aligning risk management with business strategy: Project managers have the sometimes daunting task of making sure that risk management plans have to align with company goals and strategy. The **contingency** (Contingency reserves are used to manage identified risks (known unknowns) and are calculated/estimated and linked to specific risks) of a risk management plan **may scale back on the budget or alter the schedule** which may not line up with the policies of upper management. This means project managers will have to work alongside senior management to iron out synergies and take care of any differences which may **not always be the easiest of processes**.

Principles of risk management

The following are general principles for managing risks.

- Create a *risk management plan* that specifies **ways to identify major** project risks. The plan should specify the person(s) **responsible** for managing risks, as well as **methods** for allocating time and funds from the **risk reserve**.
- Create a *risk profile* for each risk that includes risk likelihood, cost and schedule impact, and contingencies to be invoked. It should also specify the earliest visible symptoms (trigger events) that would indicate when the risk is materializing. In general high-risk areas should have lots of eyes watching closely.

- Appoint a *risk officer* to a project; a person whose principal responsibility is the project's risk management. The risk officer should **not be the same person** as the project manager; he should not be a can-do person, but instead, to some extent, a devil's advocate identifying and tracking all the reasons why something might not work – even when everyone else believes it will.
- Include in the budget and schedule a calculated *risk reserve* – a buffer of money, time, and other resources to deal with risks should they materialize. The reserve is used at the project manager's **discretion** to cover risks **not specified** in the risk profile. The project manager keeps the amounts held in the reserves strictly confidential (else the project will tend to consume whatever amount is available).
- Establish *communication channels* (perhaps anonymous) with the project team to ensure that **bad news** gets to the project manager **quickly.** Ensure that risks are continually monitored, current risk status is assessed and communicated, and the risk management plan is **updated**.
- Specify **procedures** to ensure accurate and comprehensive documentation of proposals, detailed project plans, change requests, progress reports, and the post completion summary report. In general, the **better the documentation** of past projects, **the more information** is available for planning future, similar projects and identifying possible risks.
- **Document the profile and management plan** for every identified risk. It provides places to **summarize** everything known about the risk. Such a document should be retained in a binder or library, to be updated as necessary and until the risk is believed to no longer exist and is "closed out".

Unit IV

Project Evaluation, Communication and Termination

Project Evaluation

The **purpose of project evaluation** is to assess performance, reveal areas where the project deviates from goals, and uncover extant or potential problems so that they can be corrected. Evaluation for the **purpose of guiding** the project is called *formative evaluation;* it addresses the questions ”what is happening?” and “how is the project proceeding?” Evaluation for the purpose of **appraising the project after it is completed and assessing the end results** is called *summary evaluation;* it addresses the questions “what happened?” and “what were the results?”

Project Formative Evaluation

A wide variety of methods, measures, and sources should be used to provide **evaluative information**, and these methods and measures should be specified in the project plan. Using a variety of measures and sources increases the **validity of the evaluation**, particularly when they **all lead to the same conclusion**. The **primary ways evaluative information** is obtained and/or conveyed are written reports, oral reports, observation, and review meetings.

Written reports are the most common and expeditious way to review cost, schedule, and work performance information; however, they can hide or obscure information.

Oral reports provide a quick way to gain information, although their accuracy depends on the interpretative and verbal skills and honesty of the presenter.

Report accuracy, both oral and written, also **depends on the number of channels** through which the information has passed to get to the writer or presenter; in general, the more channels the less accurate the information. Project managers knows this, as a consequence, they also try to **walk around the project, talk to people, and make their own first hand observations**.

The manager of a **geographically dispersed project** cannot be at every sit. In such cases he has to rely on technology – video and audio conferencing, websites, email, and telephone. The **more sensitive** the issue, the **lower the technology** to communicate it. For highly sensitive issues, it is worth travelling the distance to visit the site and meet face to face; for relatively sensitive issues, use telephone; for non-sensitive issues, email or fax is okay.

Project Summary Evaluation

Among the final activities of the **project team after project closeout** is to perform a formal evaluation. This final *summary evaluation* gives project and company management the **opportunity to learn from its success and mistakes in the project.** It also reviews and assesses the **performance of the project team and the end-item system**. Two forms of summary evaluation are the post-completion project review and the post-installation system review.

Post-Completion Project Review

The post-completion project review (also called a post mortem) is a summary review and assessment of the project conducted by the contractor immediately after project closeout – **early enough** that project team members are **still around**, available to participate, and remember what happened. It is an important task **funds and time should be included** in the projects budget and schedule. Post completion reviews are one way companies try to **continuously improve future projects** through lessons learned from past projects.

The post-completion project review should review:

1. Initial project **objectives** in terms of technical performance, schedule, and cost; and the **soundness of objectives** in view of the problem the system should have resolved.
2. Changes in objectives and **reasons for changes**, noting which changes were avoidable and which not.
3. The **activities and relationships of the project team** throughout the project life cycle, including the effectiveness of the project management; **relationships** among top management, the project team, the functional organization, and the customer; customer reactions and satisfaction.
4. Involvement and **performance** of all stakeholders, including subcontractors and vendors, the client, and outside support groups.
5. Expenditures, sources of costs, and profitability.
6. Organizational benefits and marketable innovations.
7. Areas of the project where performance was **particularly good**, noting reasons for success and identifying processes that worked well.
8. Problems, mistakes, and oversights, and areas of **poor performance**, and the causes.
9. A list of **lessons learned** form the project, and recommendations for incorporating them into future projects.

The review happens in a half- or day-long meeting with representatives from all functional areas that substantially contributed to the project. To encourage openness, the **managers of these areas should not be at the meeting**. An **outside facilitator** might be selected to guide the process to ensure the review is **comprehensive and unbiased**. At the meeting, participants independently list things that went right and wrong with the project; they then **share their notes** and **create lists of lessons learned and recommendations for future projects**. The completed lists are then **formally presented** to stakeholders, to others on the project team, and to project, functional, and senior managers.

The review seeks **not to place blame**, but to determine **lessons** that may be applied to future projects. Its results are documented in a ***project summary report,*** which becomes the **authoritative document** on the project. The report **describes** the project, its evolution, and the outcome. It describes the project plan, where it worked, and where it failed.

The project summary report becomes the **reference** for **project-related questions** that might arise **later**. **Thoroughness and clarity** are essential, since people who worked on the project usually will **not be available later** to answer questions. The report is retained in a **project library**. In essence, post-completion reviews and summaries are **ways to capture and reapply knowledge to future projects – tools for project knowledge management**.

Post Installation System Review

Some months after its delivery, the *operational end-item* or *system* should be evaluated to **assess its performance** in the user environment and under ongoing operational conditions. This post installation system review focuses on **the end-item system** and serves a **variety of purposes**, such as providing **operation and maintenance information** for the system designers, and revealing possible **needed enhancements** for the system's users. Based upon the original user requirements, the post installation system review **attempts to answer the questions**: Now that the system is fully operational, is it doing what it was intended to do? Is the user getting expected benefits from the system? What changes, if any, are necessary for the system to better fulfil user needs.

During the course of review, the evaluation team might discover elements of the system in need of repair or modification. Design flaws, operating problems, or necessary enhancements that **could not have been foreseen earlier** sometimes become obvious **only after the system** has been in routine operation.

Results of the review are summarized in a **report** that describes the system's **performance compared** to its objectives, any **maintenance problems**, and suggested **possible enhancements**. The post-installation system review and the project summary review are **filed together** and retained as **references for planning future** projects.

Project Communication Management

The project master plan should **include a communication plan**. The communication plan addresses **all forms** of project communication – formal and informal, verbal and written. It includes a **tentative schedule** for all formal reviews and milestone meetings, and **describes the** meetings formats, expected itineraries, advance preparations, presentation time limits, attendance policy, and who will lead. The communication plan should be **distributed to everyone** on the project team, and **discussed before** the project begins. So that **everyone understands** the required documentation and the content and format of each, the plan should **include examples of good and bad** documentation from previous projects. Many of these documents can be posted online.

Project Review Meetings

Review meetings are the most common and important way to **communicate and assess project evaluation information**. The main function of these meetings is to **identify deviations** from the project plan and **quickly correct them**. Participants at meetings discuss project progress, current and anticipated problems, and opportunities.

Review meetings can be **informal** and convened as needed, or **formal** and scheduled at key project milestones. Most large projects require both.

Informal Reviews

Informal reviews are **held frequently and regularly**. Called "**peer reviews**," because they are attended by a group of peers, the meetings focus on ***project status, special problems, and emerging issues***. Participation depends on the phase of the project and issues at hand; **only those** team members, customer representatives, functional or line managers **who need to be involved** participate. **Before** the meetings, **status reports** and estimated time and cost-to-complete are updated. Attendees with assignments are expected to give **presentations**.

Because the reviews are intended to uncover problems and issues, **bad news and problems** are expected and openly confronted. The project manager acts as facilitator, and encourages **honesty and candor** (frankness). **Finger pointing** or passing blame should be avoided; these behaviours waste time, discourage attendance, and negate the purpose of the meetings – **to identify issues and agree on the course of action**.

Stand-Up Meetings

A form of the informal review is the "daily stand-up meetings." intended primarily to update status, identify problems, and expedite solutions, the meeting is short (15 minutes) and to the point. Usually held at the **start of every day**, the team gives a quick run-through of **yesterday's progress and today's next steps**. (The occasional surprise attendance of a prominent person – e.g., a senior manager from the contractor or customer – adds zip and keep everyone on their toes.) problems that require **more than a minute's reflection** are deferred for a **scheduled meeting**.

Formal Reviews

Formal reviews are scheduled at **milestones or critical project stages**. Sometimes these reviews serve as a precondition for continuing the project; the **decision to continue or terminate the project** at the end of a phase depends on the results of the review.

In every project, regardless of contractual obligations, the customer should **assume some responsibility as watchdog**. The **project audit**, is a **special formal review initiated** by the **customer** to independently **assess** project progress. It **can be conducted** early in the project, during design or construction, or upon any significant change to the budget, schedule or project goals. The audit scrutinizes the plans, schedules, budgets, constraints, communications, and overall management of the project. Its **purpose is similar to that of the critical review**: to verify project progress, identify constraints to progress, assess the effectiveness of the organization in doing its job, and advise possible solutions to problems.

Action Plan

Any problem surfaced **in a review** is noted on an **action plan**, and if the problem requires further investigation, someone is named responsible and **another meeting is scheduled** to address it. The **action plan includes** a statement of the problem, **objectives** for resolving the problem, the **course of action**, a target date, and person responsible. One of the **first orders of the business** at each review meeting is to assess the **status** of items on the action plan. Always, the **project manager** should lead the action plan review, take notes and, afterwards, summarize and distribute them. This **reinforces the perception** (and reality) that the leader is committed, involved, and in charge.

NASA, for instance, uses such an action plan, called as **problem failure report** for tracking problems and keeping focused on the most important ones. On the Mars Pathfinder project, over 800 of such mission threatening problems were generated and subsequently evaluated.

Project Meeting Room

Project meetings and conferences are often **convened in a central meeting place** or project office. The meeting room serves as a **physical reminder** of the project, and provides space for preparing, storing, and displaying project information. Gantt charts, networks, and cost charts showing planned and actual performance are **displayed on the walls** for easy reference. The room has a conference table, chairs, cabinets for project files, computers, a projector, and sometimes, teleconferencing equipment.

Formal Reports and Documents

Company management must be kept apprised of the status, progress, and performance of ongoing and upcoming projects. **Problems affecting** profits, schedules, or budgets, as well as recommended actions, need to be reported promptly. Stakeholders should also be kept up to date. Frequent, honest communication with stakeholders **builds trust and avoids surprises**.

Reports to Top Management and the PMO

The project manager and staff send reports to top management and the project management office (PMO) using **information generated** by the Project Cost Accounting System (PCAS) or Project Management Information System (PMIS). The reports include:

1. A summary of project status
2. Red flag items where corrective action has been or should be taken
3. Accomplishments to date, schedule changes, and estimates for schedule and cost at completion
4. Current cost situation and cost performance
5. Manpower plan and limitations.

When several projects are simultaneously underway, the PMO **compiles** and provides the management monthly summaries showing **their relative status**. The summaries enable to assess the relative performance of the projects and their **combined influence** on the company.

Reports to Project, Program, and Functional Managers

On large projects, work package leaders send project and program managers monthly reports about the value of work completed, current and forecast costs, and updated schedules for completion. **Each month** the project manager sends the company **financial manager** a report showing costs incurred, and the functional managers reports showing **labour-hours and costs expended for work packages in their areas**.

Reports to Customer / Users

Each month the project manager should send the customer a report about work **progress** and the **impacts of any changes** on work scope, schedule, or cost. He should be available to answer customer **questions and satisfy requests** for project information.

Project Termination and Closeout

By the time the end item has been delivered and installed, many members of the project team will be **eager to move onto something new**. Managers eagerly shift emphasis to upcoming projects, and, as a result, might give the termination ***little attention***. However, terminating a project is no less important than any other project activity. In fact, the **method of termination can ultimately determine the project's success or failure**. Not only does a **project as a whole** has to be **closed out**; **each phase of a project** must also be **formally** closed.

At closeout, the product or deliverable is **handed over** to the customer. Sometimes **contracts** provide for a ***first handover*** at completion as well as a ***second handover*** after a *defects liability period* (also known as retention period, guarantee period, or maintenance period). At first handover the customer should ensure that all ***patent defects*** (defects that can readily be detected by a qualified person) are identified and reported. After first handover the contractor is only liable for rectifying ***latent defects***, which are those that could not be detected though a reasonable inspection at first handover. If, **for instance**, it wasn't raining at the time of the first handover, a roof that leaks later *when it does rain* would be considered a latent defect. The purpose of second handover is to **afford the customer more time** to identify deviations from specifications, or substandard workmanship. After second handover the contractor is **no longer liable for defects**; any ***retention fees*** **withheld** by the customer to ensure compliance are paid to the contractor.

The **best possible** way termination should occur is by **formally planning in systematic manner**. Unless the project is **officially terminated**, work orders remain open and labour charges **continue to accrue.**

Kinds of Termination

Even when the project is terminated because all work has been completed and contractual objectives met, it takes a **skilled project manager to orchestrate** termination and ensure that no activities or obligations left uncompleted and unfulfilled. The **seeds of successful termination** are sown early in the project. Because **termination requires customer acceptance** of the project results, the **criteria for acceptance** should have been clearly defined, agreed upon, and documented early in the project; any **changes made after that** should have been approved by the contractor and customer.

The reasons why some projects never reach successful completion are many. The project may be aborted when the financial or other losses from early termination are considered less than the losses expected form completing the project. The customer may **simply change his mind** and no longer want the project end-item.

Projects are also halted because of changing market conditions or technology, unsatisfactory technical performance, poor quality of materials or workmanship, violation of contract, or customer dissatisfaction with the contractor. Many of these reasons are **the fault of the contractor**, and could have been avoided had project management exercised better planning and control, respected the customer more, or acted in a more ethical manner.

Termination and Closeout responsibilities

As with earlier stages of the project work, the **project manager is responsible for planning, scheduling, monitoring, and controlling termination and closeout activities**. The corresponding ***responsibilities of project manager with respect to*** closeout activities are listed as follows.

A. Planning, scheduling, and monitoring closeout activities:

- Obtain and approve termination plans from involved functional managers
- Prepare and coordinate termination plans and schedules
- Plan for transfer of project team members and resources to other projects
- Monitor completion of all contractual agreements
- Monitor the disposition of any surplus materials and project equipment.

B. Final closeout activities:

- Close out all work orders and contracts with subcontractors and completed work
- Notify all departments of project completion
- Close the project office and all facilities occupied by the project organization
- Close project books
- Ensure delivery of project files and records to the responsible managers.

C. Customer acceptance, obligation, and payment activities:

- Ensure delivery of end-items, side-items, and customer acceptance of items
- Notify the customer when all contractual obligations have been fulfilled
- Ensure that all documentation related to customer acceptance as required by contract has been completed
- Expedite any customer activities needed to complete the project
- Transmit formal payment and collection of payments
- Obtain from customer formal acknowledgment of completion of contractual obligations that release the contractor from further obligation (except warranties and guarantees).

Unit V – Roles, Authority, and Teams in Project Management

When an organization undertakes a project, if it forms any type of project organization **other than pure project**, most people on the team are **borrowed**. Project management **gets work done through outsiders** – people from various technical, functional, and professional groups scattered throughout the parent company and outside subcontractors. Hence, part of being a project manager is the ability to ***influence people without giving orders or making decisions in the same way as other managers***. Most project managers have a **great deal of responsibility but not so much formal authority**, so they need a **different skill set and leadership style** than traditional managers.

The Project Manager

Project Manager's Role

Without project manager there would be no such thing as project management. To be a project manager, a person must wear **different hats**, often at the **same time**; they include the hats of integrator, communicator, decision maker, motivator, evangelist, and entrepreneur.

As the **central figure** in the project, the project manager's prime role is to ***integrate everything and everybody*** to accomplish **project goals**. He is the ***communication hub,*** for he accepts inputs from more sources and directs information to more receivers than anyone else in the project. Between sources and receivers, he refines, summarizes and translates information to make sure that all significant stakeholders are well-informed about policies, objectives, requirements, plans, progress, and changes.

Being the communication hub, the project manager is also the central ***decision maker*** for allocating resources, setting project scope and direction, and balancing schedule, cost, and performance criteria. **Even when lacking authority** to make high level decisions, he is often **well-situated to influence** the decisions and actions of others who do have authority.

The prime **motivational factor** in any diverse group is strong commitment to a central goal. In a project organization, it is the project manager who provides ***direction*** and build **commitment** to the goal. The successful project manager is able to foster enthusiasm, team spirit, confidence, and drive the team towards excellence, **even when the work becomes stressful** and frustrating.

You could say the project manager is a sort of ***evangelist*** who builds faith in the project, its value, and workability. During the conceptual phase, he is often the only person who sees the big picture. Whether or not it gets funded often depends on his ability to gain the endorsement of influential stakeholders.

The project manager is like an ***entrepreneur*** too, driven to procure the funds, facilities, and people needed to get the project off the ground and keep it flying. He must *win over reluctant stakeholders* who question supporting or assigning resources to the project. After the work is underway, he must *continue to champion* the project and might find himself *fighting for its very existence*. In the end, whether the project succeeds or fails, the project manager is ultimately held *accountable*.

Job Responsibilities

The project manager's **principal responsibility** is to deliver the project end-item within budget and on time, in accordance with technical specifications, and, when specified, in fulfilment of profit objectives. **Other, specific responsibilities** vary depending on the project manager's capabilities, the stage of the project, the size and nature of the project, and the responsibilities delegated by upper management. Delegated responsibilities **ranges** at the low end from the rather limited influence of a project expeditor up to the highly centralized, almost autocratic control of a pure project manager. Though responsibilities vary, they usually include:

- Planning project activities, tasks, and end results, which includes creating the WBS, schedule, and budget, and coordinating tasks and allocating resources.
- Selecting and organizing the project team.
- Interfacing with and influencing stakeholders

- Negotiating with and integrating functional managers, contractors, users, and top management.
- Maintaining contact with the customer.
- Monitoring project status.
- Communicating project status to stakeholders
- Identifying technical and functional problems.
- Solving problems directly or knowing where to find help.
- Dealing with crises and resolving conflicts.
- Recommending termination or redirection of efforts when objectives cannot be achieved.

Authority

Authority refers to a managers power to **command others** to act or not to act. There are different kinds of authority; the most familiar is that conferred by the organization and written in the manager's job description, called ***legal authority.*** Given legal authority, people in higher organizational positions are viewed as having the **"right" to control the actions** of people below them. Associated with legal authority is ***reward power***, the power to evaluate and reward subordinates.

Another kind of authority, ***charismatic authority***, stems from the power one gains by personal characteristics such as charm, personality, and appearance. People both in and outside the formal organization can increase their authority by being charismatic.

Traditional Authority

Management theory says that **authority is always greater at higher levels** in the organization, and is delegated downward from one level to the next. This is presumed to be how it ought to be, because managers at higher levels are assumed to know more and, therefore, to be able to make decisions, delegate responsibility, and command workers at lower levels. This point has been **challenged** on the grounds that managers, particularly **in technology-based** organizations, cannot possibly know everything needed to make complex decisions. They often **lack technical expertise** and so, increasingly, must rely upon subordinate specialists for advice. Even managers who are technically skilled **cannot always manage alone**; they rely upon staff groups for personnel and budgetary assistance. Especially in projects, this aspect of **"participatory management"** has become common place.

Influence

It is important to distinguish between legal authority and the ***ability to influence***. Managers with legal authority influence subordinates by giving orders and controlling salaries and promotions. Generally, however, the most effective managers are able to influence others ***without ordering*** them or making **issue of their superior-subordinate relationship**. In fact, managers who rely solely on legal authority are often relatively ineffective. Effective managers tend to rely instead on **two other sources** of influence: ***knowledge*** and ***personality***. The first source, called ***expert power***, refers to a special level of knowledge or competency. Others believe that the person possesses knowledge and information that is important and that they themselves do not have, and so readily defer to his requests.

The other, called ***referent power***, derives from rapport, personal attraction, friendship, alliances, and reciprocal favours. The subordinate in someway identifies with the power holder and defers to his requests.

Authority in projects in comparison with traditional management

Functional managers tend to rely on different forms of influence – knowledge, expertise, persuasion, and personal relationships; when these fail, however, they are able to fall back on their legal authority. But project managers are not able to do this. Except in this case of pure project manager, the typical project manager ***lacks any form of legal authority.***

Unlike traditional organizations where influence and authority **flow vertically**, in projects influence and authority flow **horizontally and diagonally**. The project manager exists **outside** the traditional hierarchy. The role is **temporary, superimposed** on the existing structure, and so is **not afforded the leverage** inherent to a hierarchical position. Project managers work across functional and organizational lines, and, except for members of the project office, have **no subordinates** reporting to them in a direct line capacity.

Thus, despite the considerable degree of responsibility they carry, most project mangers lack a comparable level of formal authority. Instead they have ***project authority***, meaning they **can make decisions** about project objectives, policies, schedules, and budgets, **but cannot give orders to back up those decisions**.

The disparity between high formal responsibility and low formal authority has been referred to as the **authority gap**. The gap implies that project managers must **strive to develop other forms of influence** in the absence of legal authority.

Project Manager's Authority

Most project managers **handle the authority gap** in similar ways: having no legal authority, their own recourse is to rely on influence derived from expert power and referent power. They have to do this also because, usually, no matter the project, they **depend on others** to get the job done. Numerous decisions must be made, many of which they have **neither the time nor the expertise for**.

Project managers also **gain influence through networks of alliances and informal connections** they build with their managers. The strength and breadth of these networks **increase** with the project manager’s perceived competency, reputation from prior project accomplishments, and charisma. The final feature, charisma, refers to the project manager’s personal appeal – something about the project manager’s demeanour, behaviour, or personality that people *like*. If the project gets into **trouble**, a project manager that people like will have many friends to call upon for help.

In summary, project managers tend to rely upon knowledge, experience, personal relationships, and personality to influence others. To build **expert-based power**, they must be perceived as technically and administratively competent. To build **referent-based power**, they must develop effective interpersonal, persuasion, and negotiation skills.

Teams in Project Management

The term ***project team*** refers to any particular group or different groups of people working together in the project towards a common goal. Thus, virtually all **work accomplished** in a project, whether mental or physical labour, is the **product of teams**. To be successful, a project needs ***teamwork***.

The trouble with teams

Failures in projects often can be traced to the **inability** of a team to make the **right decisions or perform the right tasks**. These failures often stem from the **maladies that teams suffer**: internal conflict; time wasted on irrelevant issues; and decisions made haphazardly. Team members often are more concerned with getting the task *done* than with doing it *right*.

In projects with multiple teams, each might have a **different orientation** and goals. The team might be physically isolated and maintain **separate offices**, creating and reinforcing separating boundaries that lead to "us versus them" attitudes. These make for a portentous project environment and bode ill for project success.

High-performing teams

In contrast, successful projects are the result of the **efforts of** *effective* teams – those that succeed in **achieving** whatever that have **set out to do**. In an effective team, individuals and groups work together as a **single cohesive unit**.

What makes a team effective? The prominent feature of all highly effective teams is that they **know** and are **committed** to team goals. Members are **never confused** about why the team exists or what their individual roles are. Leaders **inculcate belief** in the team's purpose, eliminate doubts, and embody a team spirit. It is also found that:

- Motivation and commitment to the purpose is always high.
- Teamwork is focused on the **task**. Members **develop behaviours** that enable them to do what they must.
- **Leadership** is strong, clear, and never ambivalent. Leaders are **reliable and predictable**, regardless of style.
- The team views itself as clearly distinct from others; members feel "**we are different**".

There are three characteristics that are always present in high performing teams, called as *time, feeling,* and *focus.* First, leaders and members fully commit themselves to the project, and they devote extraordinary amounts of time to it. They work at home, in the office, in taxicabs – anywhere. Second, they **feel very strongly** about attainment of the **goal**. They **care deeply** about the teams purpose, history, future, and the people in it. And third, they focus on **key issues**; they have a **clear list of priorities** in mind. Time, feeling, and focus are always found together.

Effective project teams

Project work requires **close collaboration**, and people in project teams must **rely on** and **accept one another's judgement**. Managers must **share information** and **consult with each other** to make decisions, and team members must support each other. Every person and group must be **committed** to the project objectives, not just their own.

One way to increase collaboration and common commitment is to locate everyone in the project team in the **same office quarters**. Presumably, frequent **daily contact** will make individuals more likely **identify** with the team and its goals.

However, even if co-locating team members were possible, close proximity alone will **not guarantee** an effective, cohesive team. Effective teams must be clear about their purpose, committed to it, know their individual roles, and understand how to work together as a team. In many projects, especially where people have not previously worked together, team member's don't know the team's goal and their own responsibilities, and they never learn to work together. The **purpose** of **team-building** is to ensure that doesn't happen.

The Team-building approach

In a study of two NASA research centres, 36 project managers were asked to rank the **most important functions** of their job. The function of collecting, organizing, directing, and motivating the ***project team*** and ***supporting groups*** was ranked as either first or second in importance by all the managers. In another study involving 32 research and product development projects, ***group* cohesiveness** was identified as the single most important factor in achieving project goals.

Effective groups do **not just happen**. Like any other purposeful system, every team and organization **must be developed**. This is the purpose of ***team-building***, a **procedure** whereby a team **formally ponders** how it should work or has been working, with the purpose of improving its functioning. Team-building considers **issues** such as decision-making, problem-solving, team objectives, internal conflict, and communication. These are called ***group process issues,*** referring to **processes or methods** by which the team gets things done. Ordinarily these are **responsibilities** of the team leader, though many leaders ignore them. Effective groups **recognize** and monitor these issues, **regardless** of the leader.

When It Is Needed

The need of team-building **depends** on the team members and the nature of the task. Generally, **the more varied** the backgrounds and responsibilities of team members, the **greater the need**. For example, members of **multidisciplinary teams** have different **work backgrounds** and different **outlooks** on planning and doing work; some members take a **wider perspective**, others are **detail people**. Team-building can help both types **accept their differences and define common goals**.

Projects involving innovation, new technology, high risks, and tight schedules typically place teams under **high stress**. Some stress will motivate a team, but after a point it becomes detrimental. **Team-building can help** the team to deal with the stress, to disclose and resolve problems as they occur, **before** they escalate and interfere with team performance.

Aspects of Team-building Efforts

The purpose of team-building is to improve **group problem-solving** and **group work efforts**. To this end, the approach strives to achieve norms such as:

1. Effective communication among members
2. Effective resolution of group process problems
3. Techniques for constructively using conflict
4. Greater collaboration and creativity among team members
5. A more trusting, supporting atmosphere within the group
6. Clarification of the team's purpose and the role of each member

Three **features common** to any team-building effort are that:

- It is carefully planned and facilitated, often by a consultant or professional staff person from human relations or the PMO

- A consultant collects **data about the team's process functioning** in advance, then helps the team **"work through"** the data during a diagnostic/problem-solving **workshop**
- The team makes provision for later self-evaluation and follow-up.

Emotional Stress

There are numerous **downsides** to working in projects. Long hours, tight schedules, high risks, and high stakes take a toll on social and family **relationships**, and on individual mental and physical **health**. Projects achieve great things, but they also institute ulcers, divorce, mental breakdowns and heart attacks. One of the **major problems** associated with working in projects - and a contributor to personal, family, and organizational difficulties – is **emotional stress**. It is a problem that affects the **performance** and **health** of project workers and that, at one time or another, **every project manager** faces.

Factors Influencing Stress

How much emotional stress a person experiences, and whether that experience is positive or negative, depends on the **fit** between two factors: the demands or threats of the environment, and the adaptive capabilities of the person. In other words, work related stress depends upon a person's perception of the demands or opportunities of the job and his self-perceived abilities, self-confidence, and motivation to perform. A manager faced with impending failure to meet a deadline might **experiences stress** if he feels that the deadline must be met at all costs, but **no stress** if he simply accepts that meeting the deadline is impossible.

Stress is a reaction to **prolonged** internal and environmental conditions that overtax a person's adaptive capabilities. To feel distress (negative stress), an individual's capabilities must be overtaxed. Even when a person has the ability to handle a situation, he will still feel distressed if he lacks self-confidence or cannot make a decision.

Stress in Projects

Among numerous **causes of distress** in projects are rapid pace, anxiety over discrepancies between performance and goals, and impending failure to meet cost, schedule, or contract requirements. The three most important among all are, work overload, role conflict, and interpersonal relations.

Work overload is experienced in **two ways**. One is simply having too much work or doing too many things at once, with time pressures, and long hours. The other is taking on work that exceeds one's ability and knowledge. Overload can be **self induced** by an individual's need to achieve, or it can be **imposed** by the responsibilities of the job. Job induced work overload is prevalent during crash efforts to recover lost ground, and when projects are rushed toward completion. When overload is in balance with abilities, it is positive and motivating. When it exceeds ability, it is distressful.

Role conflict happens, for instance, when a person reports to a functional manager and a project manager, and the two managers impose contradictory or incompatible requirements. It also happens when a person has multiple roles with incompatible requirements. For example, a project manager may find that being a good administrator requires doing things that conflict with his values as a professional engineer. ***Role ambiguity*** results from inadequate or confusing information about what a person need to do to fulfil his job, or about the consequences of not meeting the requirements of job. The person knows neither where he stands nor what to do next.

Role conflict and Role ambiguity are common in projects because workers must interact with and satisfy the expectations of **many people**. Project managers **in particular** might find their work frustrating and stressful because the **authority** they need to carry out project responsibilities is often **inadequate**.

Stress also develops from the demands and pressures of ***interpersonal relations.*** The **boss** who is self-centred and dictatorial causes his workers stress. Irritable, abrasive, or condescending personalities are **hard to work with**; they make others feel unimportant and provoke anxiety.

Stress Management

Most people accept distress as the price of success. However, although stress is inevitable, ***distress*** (negative stress) is not. Project managers should be able to **anticipate** which work demands are more stressful, and try to ameliorate the negative effects.

In general, **means for reducing** negative stress at work are aimed either at changing the **organizational conditions** that cause stress or at helping **people to cope better** with stress. Because stress results from the **interaction** of the people with their environment, both are necessary. Let us now focus on organizational means – methods applied by managers to reduce the stress in projects.

Set reasonable plans and schedules

One way to reduce stress is preplanning and scheduling projects so as to allow for reasonable work hours and time off. **Well-conceived** plans and schedules prepared in advance help *balance the workload*; they *tell workers what is expected and when*, and **help avoid** *ambiguous expectations and work overload*

Modify work demands through participation

The distressful influence of some kinds of leadership styles is well known. **Dictatorial, self-centred leaders** (the too-bossy boss) cause frustration and annoyance; the opposite kind, the do-nothing, **under-stimulating boss** is just as bad. In contrast, there is supporting research that the least stressful style of leadership is **participative**. Participative leaders **set goals** and **define task limits**, but allow workers **considerable flexibility** as to how the goals and limits will be achieved. The reduces stressful work demands.

Social support

One way to reduce stress arising from work roles and relationships is to increase ***social support*** within project teams. Social support is the ***assistance one gets through inter-personal relationships***. Generally, people are better able to cope when *they feel others care about and are willing to help them*. Social support at work comes in the form of **listening and caring**, fairly appraising performance, and giving advice, information, and direct assistance in a task.

Vital sources of social support are family, close friends, and a supportive boss, and co-workers. Social support from managers and co-workers does not necessarily alter the stressor, but it does help people to cope better. **Supportive managers** act as barriers against destructive stress, and their subordinates are less likely to suffer harmful consequences than those with unsupportive managers. Co-worker social support is equally important, though often the group's supportiveness **correlates** with the amount of support **modelled by the leader**. Caught between the **conflicting expectations** of a functional manager and project manager, a person with **supportive co-workers** will be better able to deal with the conflict.

How do people become supportive? Simply telling someone to **be supportive does not work**. Even when managers try to be supportive by giving advice, they often leave the distressed person **worse off**. Giving physical assistance is easy, but giving **true emotional support** is difficult and subtler. **Emphatic listening, understanding, and real concern** are essential parts of support often **missing** in naïve efforts to help. Thus, usually, it is necessary to provide **training** in social support skills and then **reinforce and reward** the usage of these skills. Unfortunately, as with many other **behavioural** aspects of management, **empathy and sensitivity** are considered **"soft"** issues and are devalued as "**non-productive**".