Chapter I

Project Feasibility Study

Introduction

The process of setting up a business is preceded by the decision to choose entrepreneurship as a career and identification of promising business ideas upon a careful examination of the entrepreneurial opportunities. Generation of ideas is not enough; the business ideas must stand the scrutiny from techno-economic, financial and legal perspectives. That is, after the initial screening of the ideas that do not seem promising prima facie, you should conduct an in-depth examination of the chosen three-four before settling for the one where you would like to exert your time, money and energies. You should prepare a business plan that will serve as the road map for effective venturing, whether you may require institutional funding (in which case it is necessary to do so) or not. Setting up of new business enterprises is a very challenging task; you are likely to encounter many problems en route. It's advisable to be aware of these problems as to forewarn means to fore arm!

What is a Feasibility Study?

As the name implies, a feasibility study is an analysis of the viability of an idea. The feasibility study focuses on helping answer the essential question of "should we proceed with the proposed project idea?" All activities of the study are directed toward helping answer this question.

A feasibility study is a preliminary study undertaken to determine and document a project's viability. The results of this study are used to make a decision whether to proceed with the project, or table it. If it indeed leads to a project being approved, it will - before the real work of the proposed project starts - be used to ascertain the likelihood of the project's success. It is an analysis of possible alternative solutions to a problem and a recommendation on the best alternative. It, for example, can decide whether an order processing be carried out by a new system more efficiently than the previous one.

Feasibility studies can be used in many ways but primarily focus on proposed business ventures. Prospective investors with a business idea should conduct a feasibility study to determine the viability of their idea before proceeding with the development of the business. Determining early-on that a business idea will not work saves time, money and heartache later.

A feasible business venture is one where the business will generate adequate cash-flow and profits, withstand the risks it will encounter, remain viable in the long-term and meet the goals of the founders. The venture can be a new start-up business, the purchase of an existing business, an expansion of current business operations or a new enterprise for an existing business.

Explanation

A feasibility study could be used to test a new working system, which could be used because:

- The current system may no longer suit its purpose,
- Technological advancement may have rendered the current system redundant,
- The business is expanding, allowing it to cope with extra work load,
- Customers are complaining about the speed and quality of work the business provides,
- Competitors are now winning a big enough market share due to an effective integration of a computerized system.

A list of factors that should be considered in your specific situation for preparation of feasibility study is given below. However, the elements to be included in a feasibility study vary according to the type of business venture and the market. The success of a feasibility study is based on the careful identification and assessment of all of the important issues for business success. Depending on the business project, additional items may also be important. Remember, the basic premise of a feasibility study is to determine the potential for success of a proposed business venture.

Description of the Project

Identification and exploration of business scenarios

- Identify alternative scenarios or business models of what the project may entail and how it might be organized. These may come from the idea assessment or market assessment that you may have already completed.
- Eliminate scenarios and business models that don't make sense.
- Flesh-out the scenario(s) and model(s) that appear to have potential for further exploration.

Definition of the project and alternative scenarios and models

- List the type and quality of product(s) or service(s) to be marketed.
- Outline the general business model (ie. how the business will make money).

- Include the technical processes, size, location, kind of inputs
- Specify the time horizon from the time the project is initiated until it is up and running at capacity.

Relationship to the surrounding geographical area

- Identify economic and social impact on local communities.

Identify environmental impact on the surrounding area.

Within a feasibility study, following areas must be reviewed.

Pre-Feasibility Study

A pre-feasibility study may be conducted first to help sort out relevant alternatives. Before proceeding with a full-blown feasibility study, you may want to do some pre-feasibility analysis of your own. If you find out early-on that the proposed business idea is not feasible, it will save you time and money. However, if the findings lead you to proceed with the feasibility study, your work may have resolved some basic issues. A consultant may help you with the pre-feasibility study, but you should be involved. This is an opportunity for you to understand the issues of business development.

Market Assessment

A market assessment may be conducted to help determine the viability of a proposed product in the marketplace. The market assessment will help you identify opportunities in a market or market segment. If no opportunities are found, there may be no reason to proceed with a feasibility study. If opportunities are found, the market assessment can give focus and direction to the construction of business alternatives to investigate in the feasibility study. A market assessment will provide much of the information for the marketing section of the feasibility study.

Market/Marketing Feasibility

A market, whether a place or not, is the arena for interaction among buyers and sellers.

From seller's point of view, market analysis is primarily concerned with the aggregate demand of the proposed product/service in future and the market share expected to be captured. Success of the proposed project clearly hinges on the continuing support of the customers. However, it is very difficult to identify the market for one's product/service. After all, the whole universe cannot be your market. You have to carefully segment the market according to some criteria such as geographic scope, demographic and psychological profile of the potential customers etc. It is a study of knowing who all comprise your customers.

Market Feasibility can be based on a marketing assessment that you may have already completed. Market Feasibility includes:

Industry description

- Describe the size and scope of the industry, market and/or market segment(s).
- Estimate the future direction of the industry, market and/or market segment(s).
- Describe the nature of the industry, market and/or market segment(s) (stable or going through rapid change and restructuring).
- Identify the life-cycle of the industry, market and/or market segment(s) (emerging, mature)

Industry competitiveness

- Investigate industry concentration (few large producers or many small producers).
- Analyze major competitors.
- Explore barriers/ease of entry of competitors into the market or industry.
- Determine concentration and competitiveness of input suppliers and product/service buyers.
- Identify price competitiveness of product/service.

Market potential

- Will the product be sold into a commodity or differentiated product/service market?
- Identify the demand and usage trends of the market or market segment in which the proposed product or service will participate.
- Examine the potential for emerging, niche or segmented market opportunities.
- Explore the opportunity and potential for a "branded product".
- Assess estimated market usage and potential share of the market or market segment.

Sales projection

- Estimate sales or usage.
- Identify and assess the accuracy of the underlying assumptions in the sales projection.

- Project sales under various assumptions (ie. selling prices, services provided).

Access to market outlets

- Identify the potential buyers of the product/service and the associated marketing costs.
- Investigate the product/service distribution system and the costs involved.

Economic feasibility

This involves questions such as whether the firm can afford to build the system, whether its benefits should substantially exceed its costs, and whether the project has higher priority and profits than other projects that might use the same resources. This also includes whether the project is in the condition to fulfill all the eligibility criteria and the responsibility of both sides in case there are two parties involved in performing any project.

Economics is the study of costs- and- benefits. In regard to the feasibility of the study the entrepreneur is concerned whether the capital cost as well as the cost of the product is justifiable vis-à-vis the price at which it will sell at the market place. For example, technically, silver can be extracted from silver bromide, (a chemical used for processing the X-ray and photo films); but, the cost of extraction is so high that it would not be economically feasible to do so. Likewise, until recently cost of harnessing solar power was prohibitively high. This cost-benefit analysis goes into financial calculations for profitability analysis that is done under financial analysis. At this stage it is also useful to distinguish between the economic and commercial feasibility; whereas economic feasibility leads one to the unit cost of the product, commercial feasibility informs whether enough units would sell.

Apart from the cost-benefit analysis as above, which we also refer to as private cost benefit analysis, it is also useful to do what is known as social- cost-benefit-analysis (SCBA). For example, the entrepreneur may be getting subsidized electricity in which case private cost would be less than social cost. Likewise, exporting units earn precious foreign exchange resulting into social benefits being more than private earnings. Many a time, a project that is worthy on SCBA may find greater favour with the support agencies.

Technical feasibility

This involves questions such as whether the technology needed for the system exists, how difficult it will be to build, and whether the firm has enough experience using that technology. The assessment is based on an outline design of system requirements in terms of Input, Output, Fields, Programs, and Procedures. This can be qualified in terms of volumes of data, trends, frequency of updating, etc. in order to give an introduction to the technical system.

The issues involved in the assessment of technical analysis of the proposed project may be classified into those pertaining to inputs, throughputs and outputs.

• Input Analysis: Input analysis is mainly concerned with the identification, quantification and evaluation of project inputs, that is, machinery and materials. You have to ensure that the right kind and quality of inputs would be available at the right time and cost throughout the life of the project. You have to enter into long-term contracts with the potential suppliers; in many cases you have to cultivate your supply sources. When Macdonald entered India, they developed sustainable sources of supply of potatoes, lettuce and other ingredients for their burgers. The activities involved in developing and retaining supply sources are referred to as supply chain management. Under this analysis you are required to do the following:

Raw materials

- Estimate the amount of raw materials needed.
- Investigate the current and future availability and access to raw materials.
- Assess the quality and cost of raw materials and markets of easily substituted inputs.

Other inputs

- Investigate the availability of labor including wage rates, skill level, etc.
- Assess the potential to access and attract qualified management personnel.

• Throughput Analysis: It refers to the production/operations that you would perform on the inputs to add value. Usually, the inputs received would undergo a process of transformation in several stages of manufacture. Where to locate the facility, what would be the sequence, what would be the layout, what would be the quality control measures, etc. are the issues that are to be looked into for throughput analysis. Under this analysis you are required to do the following:

Determining facility needs

- Estimate the size and type of production facilities.
- Investigate the need for related buildings, equipment, rolling-stock

Suitability of production technology

- Investigate and compare technology providers.
- Determine reliability and competitiveness of technology (proven or unproven, state-of-the-art).
- Identify limitations or constraints of technology.

Availability and suitability of site

- Access to markets.
- Access to raw materials.
- Access to transportation.
- Access to a qualified labor pool.
- Access to production inputs (electricity, natural gas, water, etc.).
- Investigate emissions potential.
- Analyze environmental impact.
- Identify regulatory requirements.
- Explore economic development incentives.
- Explore community receptiveness to having the business located there.

• Output Analysis: this involves product specification in terms of physical features- colour, weight, length, breadth, height; functional features; chemical material properties; as well as standards to be complied with such as BIS, ISO etc.

Financial viability

The objective of financial analysis is to ascertain whether the proposed project will be financially viable in the sense of being able to meet the burden of servicing debt and whether the proposed project will satisfy the return expectations of those who provide the capital. While conducting a financial appraisal certain aspects has to be looked into like:

- Investment outlay and cost of project
- Means of financing
- Projected profitability
- Break- even point
- Cash flows of the project
- Investment worthiness judged in terms of various criteria of merit
- Projected financial position

Under this analysis you are required to do the following:

Estimation of the total capital requirements

- Assess the "seed capital" needs of the business project and how these needs will be met.
- Estimate capital requirements for facilities, equipment and inventories.
- Determine replacement capital requirements and timing for facilities and equipment.
- Estimate working capital needs.
- Estimate start-up capital needs until revenues are realized at full capacity.
- Estimate contingency capital needs (construction delays, technology malfunction, market access delays, etc.
- Estimate other capital needs.

Estimation of equity and credit needs

- Identify alternative equity sources and capital availability -- producers, local investors, angel investors, venture capitalists, etc.
- Identify and assess alternative credit sources -- banks, government (ie. direct loans or loan guarantees), grants, local and state economic development incentives.
- Assess expected financing needs and alternative sources -- interest rates, terms, conditions, covenants, liens, etc.
- Establish debt-to-equity levels.

Budget expected costs and returns of various alternatives

- Estimate expected costs and revenue.
- Estimate the profit margin and expected net profit.
- Estimate the sales or usage needed to break-even.
- Estimate the returns under various production, price and sales levels. This may involve identifying "best case", "typical", and "worst case" scenarios or more sophisticated analysis like a Monte Carlo simulation.
- Assess the reliability of the underlying assumptions of the financial analysis (prices, production, efficiencies, market access, market penetration, etc.)
- Create a benchmark against industry averages and/or competitors (cost, margin, profits, ROI, etc.).
- Identify limitations or constraints of the economic analysis.
- Determine project expected cash flow during the start-up period.
- Identify project an expected income statement, balance sheet, etc. when reaching full operation.

Ecological Analysis

In recent years, environmental concerns have assumed a great deal of significance especially for projects, which have significant ecological implications like power plants and irrigation schemes, and for environment polluting industries (like bulk drugs, chemicals and leather processing). The concerns that are usually addressed include the following:

- What is the likely damage caused by the project to the environment?
- What is the cost of restoration measures required to ensure that the damage to the environment is contained within acceptable limits?

Schedule Feasibility

This involves questions such as how much time is available to build the new system, when it can be built (i.e. during holidays), whether it interferes with normal business operation, etc.

Organizational / Managerial Feasibility

This involves questions such as whether the system has enough support to be implemented successfully, whether it brings an excessive amount of change, and whether the organization is changing too rapidly to absorb it.

Under this analysis you are required to do the following:

Business structure

- Outline alternative business model(s) (how the business will make money).
- Identify the proposed legal structure of the business.
- Identify any potential joint venture partners, alliances or other important stakeholders.
- Identify availability of skilled and experienced business managers.
- Identify availability of consultants and service providers with the skills needed to realize the project, including legal, accounting, industry experts, etc.
- Outline the governance, lines of authority and decision making structure.

Business founders

- Are the people involved of outstanding character?
- Do the founders have the "fire in the belly" required to take the project to completion?
- Do the founders have the skills and ability to complete the project?

- What key individuals will lead the project?
- Is there a reward system for the founders? Is it based on business performance?
- Have the founders organized other successful businesses?

Legal and Administrative Feasibility

Think of the plight of the entrepreneur who worked on the idea of a laundry to cater to hotels and hospitals, finds it eminently feasible only to learn subsequently that 'laundry' does not figure as an industry within the administrative definition of SSI as applicable on that date. Another entrepreneur in Kalyani (West Bengal) developed an Ayurvedic preparation only to find that the office of DIC did not have an expert to validate the project; the product had to be marketed as a confectionary item! What is implied from these examples is that the entrepreneur has to be sure also of the administrative and legal issues involved in the project. These include, choice of the form of business organisation, registration and clearances and approvals from the diverse authorities.

Forms of Organisation

Sole Proprietor: At the time of startup the entrepreneur usually has to handle all functional responsibilities of the venture and handles production, marketing, personnel, finance himself. As a result the vast majority of new businesses start as sole proprietors. This form has the added merit of being free from formalities regarding incorporation or maintenance of accounts or auditing etc.

Partnership: As the business grows the requirements for funds and management will also increase which might lead him to enter into partnership with one or more persons. It is always preferable to have a written agreement in the form of a partnership deed which clearly indicates the names and addresses of the partners, their ages, contribution to capital, profit sharing ratio etc. This form also makes for pooling of skills and responsibilities and spread of risk.

Company: A company can be a private limited company, in which case it can have a minimum of 2 and a maximum of 50 members. It can be a public limited company, which has to have a minimum of 7 members, and there is no maximum limit. This form of organisation provides vast amounts of capital as they, unlike the private limited company, invite the general public to subscribe to its shares and also provide limited liability. The Companies Act of 1956 governs the companies.

Co-operative: A co-operative is an enterprise owned and controlled by people working in it. Generally they are formed for some specific purpose like a housing cooperative society.

Clearances and Approvals:

Setting up of an industrial unit requires the entrepreneur to obtain a number of clearances and approvals regarding land use, pollution control and safety. In this regard, you would be required to interact with the local government authorities such as the municipalities/ village panchayats and state pollution control boards. In case, you wish to avail the incentives accruing to the firms registered under Export Processing Zone/Special Economic Zone (SEZ), Software Technology Park (STP), or 100% Export Oriented Unit you would be required to register as such. Besides, certain products may require specific clearances from the relevant departments/authorities. Box entitled 'Product-Specific Clearances' illustrates a few examples of the necessary clearances and approvals vis-à-vis specific products.

Study Conclusions

The study conclusions contain the information you will use for deciding whether to proceed with creating the business. The major categories this section should include are:

- Identify and describe alternative business scenarios and models.
- Compare and contrast the alternatives based on their business viability.
- Compare and contrast the alternatives based on the goals of the producer group.
- Outline criteria for decision making among alternatives.

Next Step

After the feasibility study has been completed and presented, you should carefully study and analysis the conclusions and underlying assumptions. Next, you will be faced with deciding which course of action to pursue.

Potential courses of action include:

- Choosing the most viable business model, developing a business plan and proceeding with creating and operating a business.
- Identifying additional scenarios for further study.
- Deciding that a viable business opportunity is not available and moving to end the business assessment process.
- Following another course of action.

Don't expect one alternative to "jump off the page" as being the best one. Feasibility studies do not suddenly become positive or negative. As you accumulate information and investigate alternatives, neither a positive nor negative outcome may emerge. The decision of whether to proceed often is not clear cut. Major stumbling blocks may emerge that negate the project. Sometimes these weaknesses can be overcome. Rarely does the analysis come out overwhelmingly positive. The study will help you assess the tradeoff between the risks and rewards of moving forward with the business project.

Remember, it is not the purpose of the feasibility study or the role of the consultant to decide whether or not to proceed with a business idea, it is the role of the project leaders.

Go/No-Go Decision

The go/no-go decision is one of the most critical in business development. It is the point of no return. Once you have definitely decided to pursue a business venture, there is usually no turning back. The feasibility study will be a major information source in making this decision. This indicates the importance of a properly developed feasibility study.

Feasibility Study vs. Business Plan

A feasibility study is not a business plan. The separate roles of the feasibility study and the business plan are frequently misunderstood. The feasibility study provides an investigating function. It addresses the question of "Is this a viable business venture?"

The business plan provides a planning function. The business plan outlines the actions needed to take the proposal from "idea" to "reality."

The feasibility study outlines and analyzes several alternatives or methods of achieving business success. So the feasibility study helps to narrow the scope of the project to identify the best business model. The business plan deals with only one alternative or model. The feasibility study helps to narrow the scope of the project to identify and define two or three scenarios or alternatives. The consultant conducting the feasibility study may work with the group to identify the "best" alternative for their situation. This becomes the basis for the business plan.

The feasibility study is conducted before the business plan. A business plan is prepared only after the business venture has been deemed to be feasible. If a proposed business venture is considered to be feasible, then a business plan constructed that provides a "roadmap" of how the business will be created and developed. The business plan provides the "blueprint" for project implementation. If the venture is deemed not to be feasible, efforts may be made to correct its deficiencies, other alternatives may be explored, or the idea is dropped.

Reasons Given Not to Do a Feasibility Study

Project leaders may find themselves under pressure to skip the "feasibility analysis" step and go directly to building a business. Individuals from within and outside of the project may push to skip this step.

Reasons given for not doing a feasibility analysis include:

- We know it's feasible. An existing business is already doing it.
- Why do another feasibility study when one was done just a few years ago?
- Feasibility studies are just a way for consultants to make money.
- The feasibility analysis has already been done by the business that is going to sell us the equipment.
- Why not just hire a general manager who can do the study?
- Feasibility studies are a waste of time. We need to buy the building, tie up the site and bid on the equipment.

The reasons given above should not dissuade you from conducting a meaningful and accurate feasibility study. Once decisions have been made about proceeding with a proposed business, they are often very difficult to change. You may need to live with these decisions for a long time.

Reasons to Do a Feasibility Study

Conducting a feasibility study is a good business practice. If you examine successful businesses, you will find that they did not go into a new business venture without first thoroughly examining all of the issues and assessing the probability of business success.

Below are other reasons to conduct a feasibility study.

- Gives focus to the project and outline alternatives
- Narrows business alternatives
- Surfaces new opportunities through the investigative process
- Identifies reasons not to proceed
- Enhances the probability of success by addressing and mitigating factors early on that could affect the project
- Provides quality information for decision making
- Helps to increase investment in the company

- Provides documentation that the business venture was thoroughly investigated
- Helps in securing funding from lending institutions and other sources

The feasibility study is a critical step in the business assessment process. If properly conducted, it may be the best investment you ever made.

Business Plan

The feasibility analysis of the chosen 3-4 project ideas would help you zero in on to the one where you would like to commit yourself. Now, is the time to decide in advance on how you intend to go about everything related to the launch of your business and its subsequent operations? The difference between the feasibility report and business plan essentially lies in 'action orientation.' As such, a business plan is a blue print of entrepreneurial intentions. The business plan is a written document that serves as a road map in the entrepreneur's journey from start-up to project implementation. It describes all the relevant elements involved in starting a new business enterprise. It is often an integration of functional plans such as marketing, finance, manufacturing and human resources. Potential investors and suppliers too are interested in a business plan, as it can prove helpful in taking decisions.

Need For a Business Plan

The depth and detail of the business plan depends upon the size of the market, nature of business [manufacturing/trading/service] and degree of competition. For, e.g., an entrepreneur planning to market a new washing machine will need a comprehensive business plan. On the other hand, an entrepreneur who plans to open a general provisions corner store will not need such a comprehensive business plan. Business plan is important due to the following reasons:

(i) It helps the entrepreneur to decide where he wants to go.
(ii) It helps him to determine the viability of the venture.
(iii) It provides guidance to the entrepreneur in planning realistic goals and targets, in organizing and even in identifying possible roadblocks.
(iv) It is a pre-requisite to obtain finance.

While outlining a business plan, you should start with describing about your business and product or services. Then indicate the market you are targeting and the stage of development your company is in. If you get stuck at a particular part of the plan, leave it for a while and get back to it later and finish it. You cannot make a perfect first draft. So just get some thoughts down to start the process. You can always come back and change it or polish it up later. While making a business plan keep the following points in mind.

1. The target audience: While working your business plan, keep in mind the intended audience and why you are writing plan. For example, if you are trying to get debt financing, the emphasis should not be on the huge profit potential but on the certainty that the debt can be repaid.

2. Business strategy: The first part of the business plan should be geared towards helping develop and support solid business strategy. The plan should explain the market, the industry, target customers and competitors. The second half of the business plan should explain how to execute your selected business strategy. Your products, services, marketing and operations should all closely tie in with your strategy.

3. Competition: As an entrepreneur, you need to identify where you will do things in a manner similar to your competitors and where you will do things differently, what will be your real strengths and real weaknesses. Focus your plan on being different than your competitors'. Think over the points-Can you find a unique strategy? Can you position your products differently? Can you use different sales or marketing vehicles? Your business plan should be able to answer these questions.

4. Be realistic: So many business plans do not work in the real life as there are always going to be some unseen expenditures, cost overruns, expensive problems and items that you simply overlooked. So forecast realistically and try to have a contingency reserve.

5. Involvement of people for creating the business plan In seeking funds from banks, venture capitalists or other outside investors, the chances of success are greater if your management team includes a person whose name carries some weight, to get the plan in synchronized fashion, and to get any disagreements, out in the open. The more input people have in creating the plan, the more responsibility they will feel towards it.

6. You should keep your business plan factual and brief.

Outline of a Business Plan

1 Introductory Page

(a) Name and address of business
(b) Name(s) and address (es) of principals
(c) Nature of business
(d) Statement of financing needed
(e) Statement of confidentiality of report

2 Executive Summary – Three to four pages summarizing the complete business plan.

3 Industry Analysis

(a) Future outlook and trends
(b) Analysis of competitors
(c) Market segmentation
(d) Industry forecasts

4 Description of Venture

(a) Product (s)
(b) Services (s)
(c) Size of business
(d) Office equipment and personnel
(e) Background of entrepreneurs

5 Production Plan

(a) Manufacturing process (amount subcontracted)
(b) Physical plant
(c) Machinery and equipment
(d) Names of suppliers of raw materials

6 Marketing Plan

(a) Pricing
(b) Distribution
(c) Production
(d) Product forecasts
(e) Controls

7 Organisational Plan

(a) Form of ownership
(b) Identification of partners or principal shareholders
(c) Authority of principals
(d) Management-team background
(e) Roles and responsibilities of members of organization

8 Assessment of Risk

(a) Evaluate weakness of business
(b) New technologies
(c) Contingency plans

9 Financial Plan

(a) Pro forma income statement
(b) Cash flow projection
(c) Pro forma balance sheet
(d) Break-even analysis
(e) Sources and application of funds

10 Appendix (contains backup material)

(a) Letters
(b) Market research data
(c) Leases or contracts
(d) Price lists from suppliers

You would have noticed that both Project Report and Business Plan appear similar in content. Difference between the two at times lies in the phraseology, some funding agencies prefers to use the latter term to the other. Essentially the difference lies in the action orientation as noted earlier.

Basic Start up Problems

There are many problems involved in the establishment of a small scale enterprise which is given below:

(i) Selection of the Industry: Once a person has decided to start his own business, the first major problem is to select the line of business. This problem can be solved by analyzing the person's aptitudes, propensity to take risk, organizational ability, skills and experience, family background, financial position, Government policy and incentives, infrastructural facilities, advice of consultants etc.

(ii) Product Selection: Another start up problem is the choice of the particular product to be manufactured. This can be decided through a comparative analysis of a few product items with special reference to:

(a) Size and structure of the market
(b) Future demand pattern

(c) Competitive position
(d) Life cycle of the product
(e) Availability of raw materials
(f) Technical aspects of production
(f) Availability of required labour
(g) Government policy and controls

(iii) Choice of Factory Site: The next main problem is to find out a suitable location for the factory.

(iv) Form of Organisation: The proprietor has to select an appropriate form of business organisation for his unit.

(v) Problem of Construction: Construction of factory building involves several problems e.g.

(a) Acquisition of land in the chosen locality.
(b) Architectural design of the building
(c) Appointment of engineers and contractors
(d) Civil work like obtaining power and water connection
(e) Supervision of construction work
(f) Acquisition and installation of machinery and equipment

(vi) Supply of Raw Materials: Appropriate suppliers of raw materials have to be selected. Agreements need to be made with the concerned suppliers.

(vii) Financing the Unit: The funds required for both fixed capital and working capital have to be estimated. Appropriate sources of required funds have to be decided. Arrangements are then made to collect the necessary finance.

(viii) Recruitment and Training of Staff: Staffing of the new unit is another major problem. First of all the quantity and quality of staff required are judged. Then people with required skills are selected. Necessary training arrangements are made for preparing the selected people to handle their jobs efficiently.

(ix) Trial Run: Production is then started on an experimental basis. The difficulties and constraints experienced during the trial run are tackled before starting commercial production.

(x) Marketing: Through necessary prospecting markets for the product are decided. Test marketing is done to judge the acceptability of the product. The experience gained through test marketing is used to make necessary improvements in the product. After that the product is launched in the market.

(xi) Gestation Period: Great care and efforts are required to successfully overcome the problems and risks during the gestation period. Effective control over expenses, time and cost overruns, sales pattern etc. is necessary to ensure that the unit survives the initial expenses and losses. Once the unit starts generating profits the start up problems are by and large over.

Chapter II

Elements of Successful Projects

Introduction

Whenever anyone learns a new field, especially one that is as broad as project management, one of the most effective ways to reduce ones learning curve and focus ones mental energies is to understand what "successful" people do in the field, and, equally important, understand what "not to do."

With this philosophy in mind, we will look at "projects" as a whole and not just the project manager position. We will review the leading causes of "troubled" projects, and we'll discuss the common principles, techniques, and tools underlying most successful projects.

What Exactly Is a "Successful" Project?

You would think it would be relatively straightforward to describe the attributes of a successful project. Well, let's just say this endeavor has kept more than a few "spin doctors," "politicians," and "history revisionists" employed throughout organizations across our great land. Why is this the case? There are several reasons for this.

- There is a lack of universal harmony of what comprises project success metrics. It seems that every project management educational source and organizational process maturity standard has a slightly different definition of project success.
- For many projects, the acceptance and success criteria are never established or agreed to by all key stakeholders.
- In many cases, an organization may define a project as successful even when some of the textbook criteria for project success (such as schedule, cost, client expectations etc) are not completely met.
- In other cases, a "cancelled" project may be a "successful" project if there was a plan for one or more "go/no-go" decision points.

From a utopian, academic standpoint, the "ultimate" successful project would be defined as a project that:

- **Delivered as promised**—Project produced all the stated deliverables.
- **Completed on-time**—Project completed within the approved schedule.

- **Completed within budget**—Project completed under the approved budget.
- **Delivered quality**—Project deliverables met all functional, performance, and quality specifications.
- **Achieved original purpose**—The project achieved its original goals, objectives, and purpose.
- **Met all stakeholder expectations**—The complete expectations of each key stakeholder were met, including all client acceptance criteria, and each key stakeholder accepts the project results without reservation.
- **Maintains "win-win" relationships**—The needs of the project are met with a "people focus" and do not require sacrificing the needs of individual team members or vendors. Participants on successful projects should be enthusiastic when the project is complete and eager to repeat a similar experience.

Learning from Troubled Projects

Before we review the common traits of many successful projects, there's a lot to be learned from "less than successful" projects. The reasons for project troubles can be generally classified in two groups:

- Organizational-level issues and
- Project-level issues.

One of the key differences in the two groups is the level of control that the project manager has over these factors. For project-level issues, the project manager has tremendous influence on these matters. In most cases, the project manager can either avoid the issue or take action to resolve it if it does occur. For organizational-level issues, the project manager cannot generally "fix" the problem, but the project manager can certainly have influence on them by asking the right questions, anticipating the associated risks and issues, focusing extra efforts to compensate for the issue, and developing contingency plans to minimize the impact on the project.

Also, please note that these issues are not exclusive. In most cases, there is overlap, and if you have one of these factors present in a project, you will generally have others. Table below summarizes these issues, gives specific examples of each and notes what type of issue it is (organizational, project, or both).

Table: Common Reasons for Troubled Projects

Reason	Example(s)	Type	Key Learning Point
Project not aligned	Project not aligned with business unit or organizational goals; Project not aligned with other projects	Org.	Verify alignment before project kicks off
Lack of management support	Insufficient funding; Insufficient resources; Issues not resolved; Senior mgmt performance criteria not aligned with project success criteria	Org.	Understand project impact of organizational structure; Ensure proper senior mgmt involvement in project organization; Advocate PMO and Steering Committee structures
Lack of stakeholder "buy-in"	Purpose and goals not clear; "Trust" relationship not established; Inadequate communications; Mismatched expectations; All stakeholders not involved	Both	Gain acceptance of project purpose, goals, and success criteria up front; Ensure all stakeholders are identified and consulted; Constantly communicate and validate understanding
Inadequate project sponsor	Inactive, unengaged sponsor; Lack of leadership; Ethical issues; Not handling organizational issues; Not supportive of project management process	Org.	Educate the sponsor on their roles and responsibilities; Gain formal authorization of project and the project manager position; Understand sponsor's motives and incentives
Too many project sponsors	Conflicting project goals; Lack of ownership; Political battles	Org.	Relates to the need for proper project alignment and clear roles and responsibilities
Lack of clarity on roles and responsibilities	Inefficient work efforts; Missed deadlines; Lower team morale; Delayed issue resolution	Both	Use Responsibility Matrix to clarify all roles and responsibilities; Review roles and responsibilities with each individual; Validate expectations in advance
Poor communications	Inconsistent, incomplete, or non-existent status information on key project metrics; Inadequate tracking and monitoring of project progress; Not listening to stakeholder concerns or feedback; Not using proper mediums for certain project communications; Messages are not clear or occur too frequently	Project	Develop a project Communications Plan that is acceptable to all stakeholders; Establish tracking and monitoring mechanisms during planning; Constantly seek questions and feedback; Understand each stake holder's perspective; Clearly set context of each message
Price wars	Due to budget reduction measures or market pressures, management agrees to perform project at or below estimated	Org.	Develop complete, detailed project budgets; Communicate associated risks; Improve negotiating skills

	costs		
Resource conflicts	Lack of dedicated team members; Key resources not available when scheduled	Org.	Develop project Resource Plan; Gain commitments from Resource Managers; Encourage centralized organizational structure for resource planning/ deployment
Inadequate project manager	Lack of leadership; Inexperienced or untrained project manager; Ineffective project manager	Both	Organizational commitment to PM education; Use of PM mentorship programs
Underestimate change impact	Not understanding the complete effects on both existing processes and people that the "change" introduced by the project will have; Not properly preparing or planning for the "change"	Org.	Use project sponsor and business process owners to champion the new process; Involve additional stakeholders to understand their needs and to solicit their support; Plan for the necessary communications and training (change management plan) Plan for the "disruptive" deployment period; Utilize pilot approaches to minimize impact
Inadequate planning	Management does not require or allow time for proper planning; Incomplete scope or deliverables list; Incomplete "work" identification; Lack of detailed schedule; Inadequate risk identification; Assumptions not documented; Lack of schedule and budget contingency	Both	Educate senior mgmt on the value of proper planning; Use standard methodology for project planning; Gain formal acceptance of Project Plan before proceeding; Develop realistic project schedule and budget, as well as tools and processes to keep updated; Identify and document project risks and mitigation strategies
Lack of change control management	Scope of work increases without proper schedule, budget, or resource adjustments; Changes occur to deliverables, schedule, or budget without proper notification and approval	Project	Utilize formal change procedures to properly assess and control communicate any change to the scope, schedule, budget, and targeted project deliverable
Lack of completion criteria	Missed stakeholder expectations; Increased costs or missed deadlines due to re-work; Lack of smooth transition from one phase to another	Both	Ensure success criteria is established during planning phase; Define user acceptance criteria for project deliverables; Define exit criteria for project phases
Inadequate progress tracking	Inability to measure project status and probability for success; Inability to review project at key points to make go/no-go decisions	Both	Establish and execute periodic status meetings and reporting (weekly in most cases); Review project at scheduled intervals against established criteria to determine if project should progress into next phase

Unforeseen technical difficulties	Effort spent resolving technical issues drive missed schedules and increased costs; Unproven technology does not meet user expectations	Project	Structure project to deal with high risk technical challenges early in the project; Prove the technology before making additional investment; Leverage technical expertise to support team capabilities

Learning from Successful Projects

After reviewing what makes a project successful and the common ills that befall many "troubled" projects, you likely have a good sense of the qualities and traits shared by most successful projects. While no two projects are ever the same, and every project has its own unique set of challenges, there is a common core of principles that successful project share. By understanding these, a new project manager can better prioritize and better focus his/her project management efforts. These qualities are generally true about successful projects:

- Project is aligned with organizational goals.
- Project has effective management support.
- Project has effective leadership.
- All key stakeholders are in agreement on the purpose, goals, and objectives of the project.
- All key stakeholders share a common vision on the project results.
- All key stakeholders share realistic expectations for the project results.
- The project results meet the expectations of the key stakeholders.
- Stakeholder expectations are constantly managed and validated throughout the project.
- There is an investment made in proper planning.
- The project scope, approach, and deliverables are clearly defined and agreed upon during planning.
- Each stakeholder and team member’s role(s) and responsibilities are clearly communicated and understood.
- A high priority is placed on accurate and complete work effort estimates.
- A realistic schedule is developed and agreed upon.
- The project team has a strong results-focus and customer-orientation.
- Project communications are consistent, effective, and focused on "understanding."
- Project progress is measured consistently from the current baseline.
- Project issues and subsequent action items are aggressively pursued.
- There is a strong sense of collaboration and teamwork.
- Expectations and changes surrounding scope, quality, schedule, and cost are closely managed.
- Project resources are skilled and available when needed.

- Project team proactively identifies risk and determines mitigation strategies to reduce project exposure.
- Project team anticipates and overcomes obstacles to ensure project meets objectives.

Essential Project Manager Toolkit

While there are many facets of project management and many lessons to be learned from both troubled projects and successful projects, there is an essential set of tangible tools that any project manager needs to have to best manage any project. Table below lists these essential tools and why they are important.

The important principles to remember regarding project management tools are as follows:

- Any planning document needs to be reviewed and agreed to by appropriate project stakeholders and team members.
- Separate documents are not always needed. Smaller projects might combine relevant information (especially "plan" documents) into a single "grouped" document.
- The essential tools represent the key information and thought processes that are needed to effectively manage the project.

Table: Essential Project Manager Tools

Tool	**Description**	**Value**	**Notes**
Project Charter	Authorizes project and the project manager	Provides official notice to the organization	May not always be a formal document; At a minimum, get an email notification
Project Definition Document	Defines project purpose, objectives, success criteria, and scope statement	Key for managing expectations, controlling scope, and completing other planning efforts	Core tool
Requirements Document	Defines the specifications for product/output of the project	Key for managing expectations and controlling scope	Core tool
Project Schedule	Shows all work efforts, properly estimated, with logical dependencies, assigned to responsible resources scheduled against a calendar	Key for directing all project team work efforts; Key for managing expectations; Allows for impact and what-if simulations when things change	Core tool

Status Reports	Periodic reviews of actual performance versus expected performance	Provides essential information to stakeholders; Allows for timely identification of performance variances	See Chapter 10, "Controlling a Project," and Chapter 17, "Managing Project Communications," for more details
Milestone Chart	A summary of the detailed project schedule showing progress against key milestone	Allows stakeholders to see high level project progress on one page	Detailed schedule roll-ups can be difficult to read and interpret; Incorporate into Status Report
Project Organization Chart	Shows all project stakeholders and the working relationships among them	Allows team members to get a better understanding of project roles and organizational dynamics	On smaller projects, may be combined with project plan or project definition document
Responsibility Matrix	Defines all project roles and indicates what responsibilities each role has	Key for managing expectations; Establishes accountability	On smaller projects, may be combined with project plan or project definition document
Communication Plan	Defines the how, what, when, and who regarding the flow of project information to stakeholders	Key for managing expectations; Establishes buy-in	On smaller projects, may be combined with project plan or project definition document
Quality Management Plan	Defines the approaches and methods that will be utilized to manage the quality levels of project processes and results	Key for managing expectations regarding quality, performance, and regulatory compliance matters; Impacts work efforts and project schedule Establishes accountability	On smaller projects, may be combined with project plan or project definition document
Staffing Management Plan	Lists how project resources will be acquired, when they are needed, how much they are needed, and how long they will be needed	Key for building schedule; Key for properly managing resources	May also include role profiles, rates, training needs; On smaller projects, may be combined with project plan or project schedule
Risk Response Plan	Lists each identified risk and the planned response strategy for each	Communicates potential issues in advance Proactive measures help reduce impact to project	On smaller projects, may be combined with project plan or project definition document
Project Plan	Formal, approved document that is used to manage project execution	Includes all other supplemental planning documents; Key output of project planning	On smaller projects, may be combined with project definition document

Deliverable Summary	Defines and lists all deliverables to be produced by the project	Key to managing expectations; Ensures proper visibility, tracking, and reporting of targeted deliverables	May be combined with status reports
Project Log	Captures essential information for each project risk, issue, action item, and change request	Ensures proper visibility, tracking, and reporting of items impacting the project	Core tool
Change Request Form	Captures essential information for any requested change that impacts scope, schedule, or budget	Allows change item to be properly assessed and communicated before action is taken	Core tool
Project Notebook	Used by project manager to maintain official record of important project documents and deliverables	Part of managing project information	Electronic and/or hardcopy versions

Chapter III

Project Scheduling

Introduction

One of the first activities to occur in the development of any project plan is definition of a high level schedule, including the identification of major milestones to show the timing of key accomplishments and interfaces. This initiates a discipline of scheduling for the duration of the project, an important tool for its management. Project managers may rely almost exclusively on the schedule for primary management of a project (since the schedule often has a significant impact on cost). At the other extreme, project managers may despair of getting any useful information from their schedule. The principles of scheduling are sufficiently uncomplicated that project personnel will be able to grasp them. Nevertheless, scheduling requires a dedicated effort and familiarity with many subtle factors that affect the analysis.

Project Scheduling is the process identifying and organizing the tasks of a project into a sequence of events ensuring a harmonious completion of the venture. These events are dependent on the results of their preceding activities, thus interlinking all the activities of the project. This interdependency provides for a major need of effective project scheduling.

Project Scheduling enables the **project manager** to identify risk points, understand the proper linkage of events, assists in **resource planning** and allows the Project Manager to establish goals for the team and the project.

The task of Project Scheduling is a responsibility of various managers. The **Business Area Manager** defines the project activities. The **Project Manager** then organizes the team, works out realistic schedules and resolves any conflicts over resources and priorities. Finally, Business Area Manager assures that the project schedule has been reviewed and agreed on by the **functional managers**.

What is a Schedule and Why Use One?

A simple definition of a schedule is a document that identifies what work must be done to accomplish project objectives on time. It is the time-phased specification of the total plan. The combination of the schedule with the technical plan (the scope of the project) and the financial plan (the budget or cost), forms the total project plan.

The schedule is needed as part of the development of the total plan, but it is also needed for controlling the results against the plan. There are two sides to the answer of "why schedule?" The first is the positive benefit that can be derived from a disciplined scheduling approach, while the flip side is the negative results or penalties that occur without a well-defined schedule. The benefits will be discussed first.

Development and maintenance of a schedule provides an excellent vehicle for communication throughout the duration of a project. Communication includes sharing what the overall plan is, how the plan is to be achieved, who will complete which activities, in what time frames the activities will be completed, and how many resources will be required to achieve those dates. A number of project managers emphasize that the initial planning required for development of a baseline schedule is so important that this single function justifies the creation of a detailed schedule. The schedule also facilitates communication on the status of the project, and is an important link for feedback from the technical disciplines to the project management office. Equally important, the use of a schedule can provide a basis for management by exception by allowing attention to be focused on those activities that are deviating significantly from the original plan or on those activities that are most important towards achieving the project objectives.
Other benefits of good scheduling exist as well. With a formal schedule in place, resources can be applied, analyzed, and allocated or leveled as necessary. Exploration of alternatives is possible through the investigation of "what-if" scenarios, and time/cost tradeoffs are possible through project acceleration/delay studies.

Conversely, negative results are associated with the absence of a scheduling process. It is impossible to know if a planned completion date is realistic or even achievable without a formal schedule. Without advance knowledge of how many resources will be needed, their type, and their timing, it is highly unlikely that they will be available when needed. Coordination of work becomes difficult as each project team member works according to his/her own internal schedule rather than a defined project plan. This results in problems as not everyone's schedule is going to integrate to support project objectives. This eventually leads to slips in the schedule, which result in major cost impacts. As the project duration is extended, costs for administrative and other services rise due to the longer duration of service provision. Escalation impacts are also felt, particularly if there is a long delay or it is a period of high inflation. There is another financial impact which is usually the highest of all: delayed return on investment. Lost revenue due to lack of product availability can amount to hundreds of thousands of dollars a day or more. These considerations make the comparatively cheap cost of operating an effective scheduling system a wise financial investment.

Information Requirements

Certain specific information is required for the development of a schedule. These information requirements are specific and are consistent for all projects. They include:

- The scope of work, defined to the activity level
- Activity interrelationships
- Activity duration
- Resource requirements
- Assigned responsibilities

The first requirement is a detailed scope of work. The development of an adequate schedule is impossible without an adequate scope definition. The second requires that relationships between activities will need to be identified so the impact of a slip in one activity on the rest of the schedule can be determined. The third and fourth requirements, activity duration and resource requirements are interrelated, since most durations are a function of the amount of resources assigned. This is especially true in a production environment. Lastly, knowing who is responsible for particular activities is a requirement so that he/she can provide information on his/her status. Responsibility definition is essential at the start the process, since the responsible person must be the one providing inputs for activity interrelationships, duration, and resource requirements.

Two reasons make it important to involve those responsible for the activities in the generation of the schedule: (1) they are the ones most familiar with the work that needs to be accomplished and can, therefore, provide the best input, and (2) their involvement ensures their participation in the process. The standard response from a person who is late in completing an activity, but who was not involved in the scheduling process, is "I never agreed to that date."

Past jobs should be used as a reality check on inputs gathered from those responsible for the work. A well documented historical data base can be a valuable asset to anyone developing a schedule for a new project, as well as to anyone reviewing that schedule.

Information Processing

Four factors affect the amount of effort related to information processing. First, the level of detail selected for the schedule will directly impact the amount of data generated by the scheduling system and the number of people needed for maintaining it. Second, the scheduling methods must also be selected. This will be discussed at length in this course. Another decision regards the role of automation in the scheduling process. While it is anticipated that all scheduling systems will have a component of automation, many also include a manual aspect such as manually prepared high level summary documents. There is a need for procedures in that instance to ensure that the manual and the automated schedules remain consistent. The fourth and final question related to information processing is how the information is to be displayed. Information display includes not only format, but also a directory of who gets specific information.

Using Results

The point of having a scheduling system is to use the results. Specific purposes of the system include:

- Development of a realistic baseline plan
- Priority definition
- Status reporting
- Problem area identification
- Problem impact analysis
- Corrective action plan support

The baseline plan is the starting point and must accurately reflect the scope of work and the resources available. As the plan is established, it is possible to prioritize work activities based on scheduling and risk assessment techniques.

Priorities are determined by identifying the schedule drivers: those items that directly affect the total length of the schedule. Once the plan is established, the use of the schedule is to employ it as a status reporting document. The comparison of this status with the baseline plan allows development of problem area identification. An effective scheduling system allows the manager to do more than just identify problems; it also provides the capability to identify what the impacts of the problem will be. This allows intelligent analysis of, whether or not, development of alternative plans is warranted. If they are, then the schedule is analyzed to find the alternatives and implement the most effective option.

A carefully developed schedule requires discipline and time, but provides a capable management tool for the life of the project. Without it, successful management of the project may be critically hampered.

Schedule Types

Project Scheduling may also employ various scheduling techniques. The **Gantt technique** is applied for highly repetitive production operations, where work performance of various departments can be combined on a single chart. The

Milestone scheduling system is anther technique where milestones are established in the planning phase. **PERT/Networking** and the **Critical Path Method (CPM)** are designed for scheduling activities in the development phases, both identifying the critical path, float and slack.

Gantt Charts

One of the oldest and simplest forms of scheduling is the Gantt Chart. This form of scheduling traces back to World War I and a man named Henry L. Gantt, who worked in the Frankford Arsenal in 1917. The logistics demands of the war indicated a need for better information to assist the flow of supplies and material. Mr. Gantt therefore devised the scheduling technique that still bears his name.

The Gantt Chart has received widespread use over the years because it is easy to understand and requires a minimum of time to develop and update. An example of a Gantt Chart is pictured in Figure 1-1, below. Time is represented on the horizontal axis and groups of activities are shown on the vertical axis. Status is shown by either filling the bar or by adding another bar below the original. While it takes little effort to produce this type of schedule, it provides little information as well. There are serious shortcomings with this scheduling approach. It does not show critical activities or interdependencies between activities.

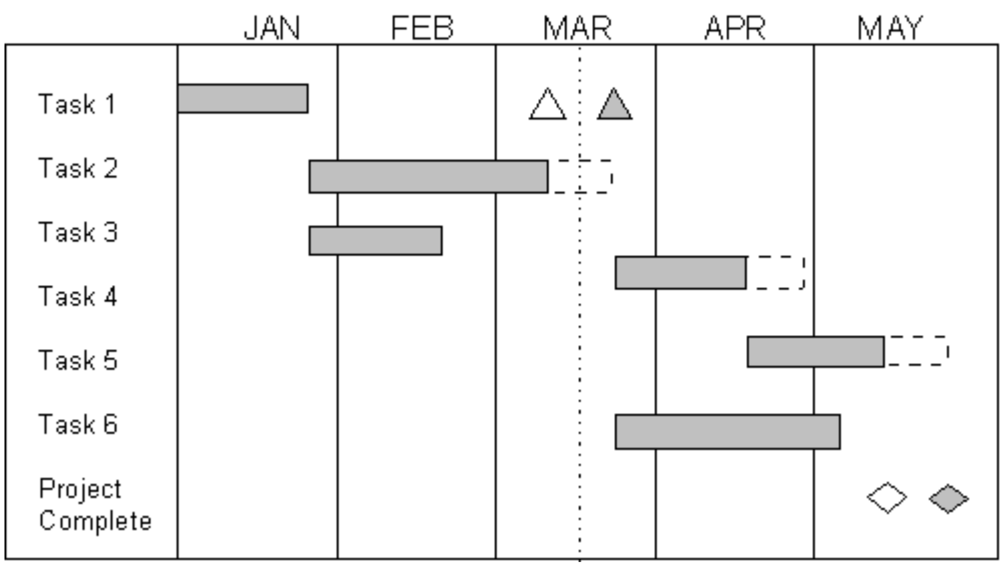


Figure 1-1

That means if one activity is late, we have no indication of what that means to other activities. Status reporting of progress can also be very misleading. There is no indication of the actual start or finish date for any activity.

This format only depicts that an activity has started and finished, but not when it happened or even if it occurred on schedule. There is no possibility of early warning of future schedule slippages.

Gantt charts are the cornerstone of the Gantt technique of scheduling. This was the first formal scheduling system to be used in conjunction with scientific management. The Gantt chart normally looks at first glance like a bar chart. It is however a little more detailed in its representation of facts than we normally associate with the common bar chart.

The Gantt chart normally is constructed with the time graduation shown along the horizontal axis and personnel, organizations, machines, materials shown along the vertical axis. The "open Bar" shows the time units of work which are scheduled for each person, organization, machine... the Gantt Chart is needed to portray the initial schedule as well as to indicate current progress.

Advantages include:

- Direct correlation with time.
- Straight forward relationship with projects involving a limited number of tasks.
- Straight forward integration of subtasks having separate scheduling charts.
- Time schedule is flexible and is expanded to show tasks of shorter nature.
- Progress against the plan is easily reflected.

Disadvantage includes:

- That it does not convey the complex interrelationships that may occur between tasks.

Milestone Charts

Another scheduling technique that arose from the early Gantt Chart efforts is the Milestone Chart. It shows only the point in time for the milestone, without indication of interface activities. It is very useful, however, for reporting status to executive management. Like the Gantt Chart, it is easy to generate and simple to interpret. Milestone Charts also have some additional information not contained in a Gantt Chart, such as indication of schedule slippage and the provision for forecasting completion dates of future milestones.

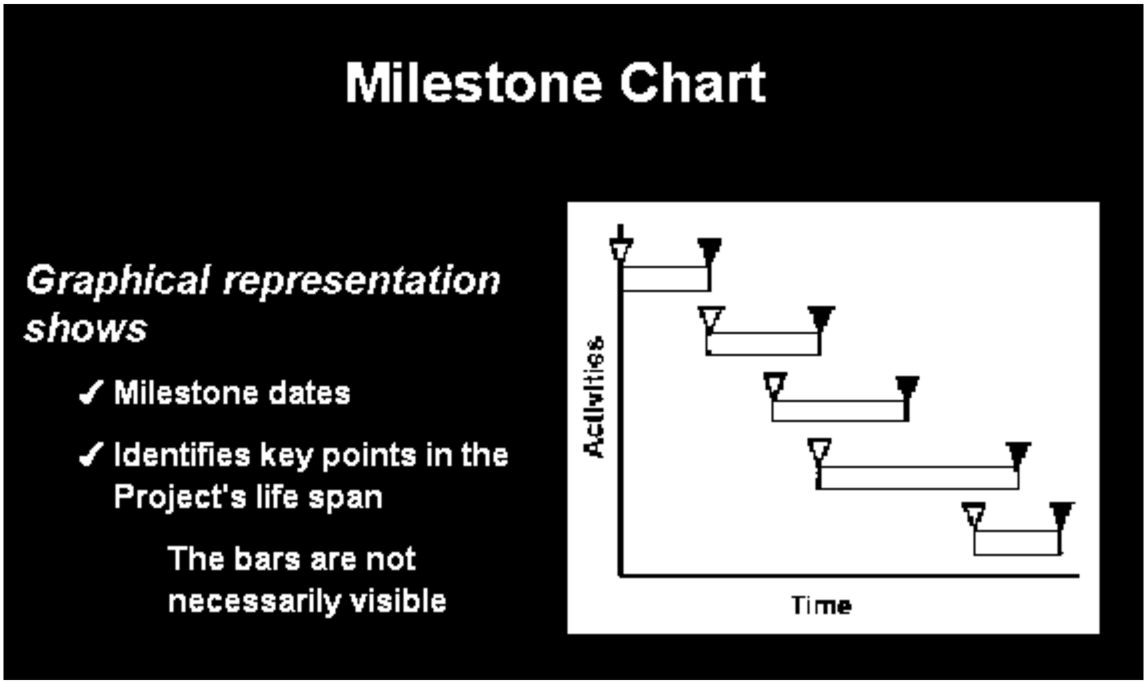


Figure 1-2

Figure 1-2 shows a milestone Chart. The convention of filling in the triangles of completed milestones is used, so that it is possible at a glance to tell what has been achieved and what has not been completed. Inverted triangles are used to show rescheduled dates. Milestone Charts make good summaries, but may not be representative of schedule status if there is no underlying system that supports the forecasted dates.

Milestone Charts are normally used by first and second level management to determine overall status on each major project. It is not a good schedule methodology for day-to-day monitoring of work effort at the detail level. Again, the need to define in writing what constitutes completion of a milestone is required.

Bar Charts

At first glance, the Bar Chart example shown in Figure 1-3 closely resembles the Gantt Chart. However, it embodies some improvements over that earlier technique. Individual activities are shown on their own lines rather than grouped as on the Gantt Chart. This allows a more accurate display of status. Another improvement is the display of the true start and finish dates, with forecasts of future starts and finishes also indicated.

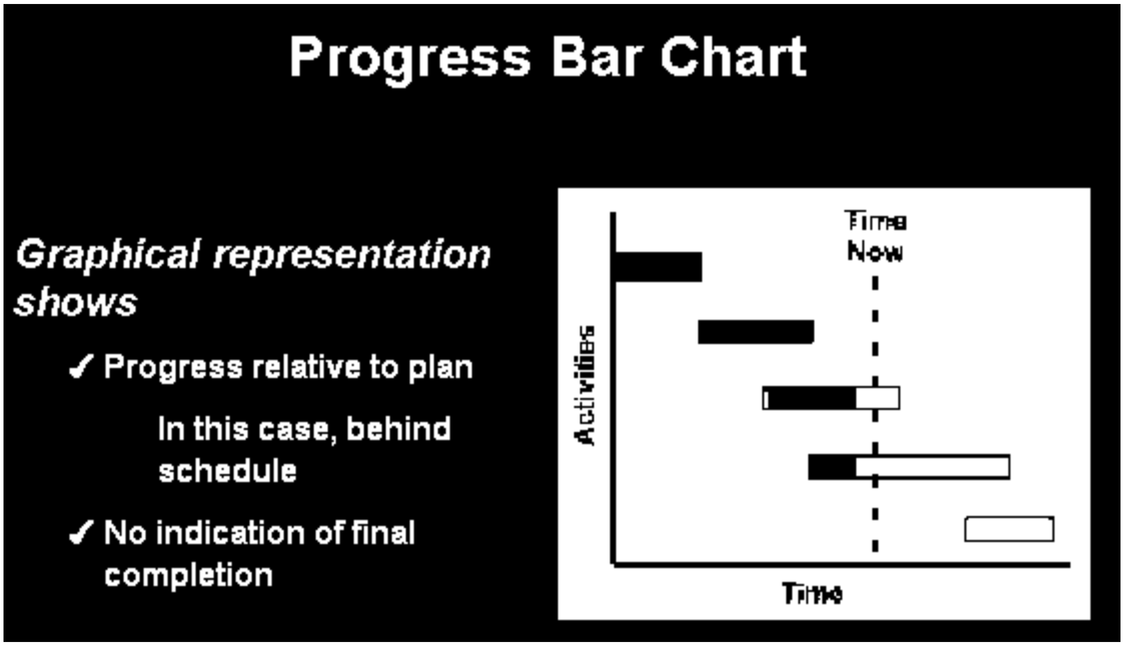


Figure 1-3

This is a very popular display type, and is frequently used to provide a quick picture of more complex information contained within advanced scheduling systems. As with the Milestone Chart, some underlying scheduling system should provide the information presented here. This format does not allow identification of significant problems or formalized early warning capability on its own. The Bar Chart still has the same serious drawback as the Gantt Chart: the inability to reflect status of partially completed activities. Filling in the bar as "time now" advances is hardly an accurate method for reflecting real progress.

Bar Charts are intended for first and second level management to determine overall status on each major project. It is not a good schedule methodology for day-to-day monitoring of work effort at the detailed level.

Combination Chart

As its name implies, this schedule presentation format attempts to combine the advantages of the Milestone Chart and the Bar Chart to allow for better representation of status. By adding objective milestones along the schedule bars, it is possible to indicate partial completion of activities more accurately.

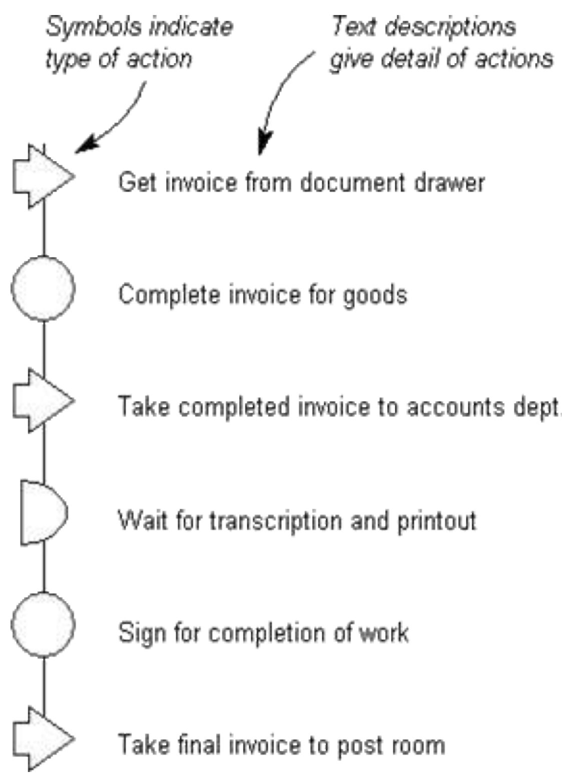
This schedule presentation technique has most of the other shortcomings that limit the usefulness of the Gantt Chart and Bar Chart. Specifically, this format does not allow identification of significant problems or formalized early warning capability on its own. This format also fails to reflect status of partially completed activities.

Modified Gantt/Milestone Chart

A further refinement of Gantt and Milestone Charts is the Modified Gantt/Milestone Chart. Major relationships between milestones are added, providing even greater visibility into schedule status. With this representation, we can anticipate probable delays in the future based on current schedule slips. While this format contains considerably more information than those previously presented, it also requires more effort to develop and is more difficult to interpret. The most difficult part in both development and interpretation is the logic between bar chart lines. Since the detailed plan for accomplishing the work will have many more true relationships, it is difficult to decide which few will be included on a summary chart like this. It is impossible to accurately represent the real logic between all activities in this format, so true status is compromised for the sake of a readable presentation.

Flow Process Chart

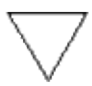
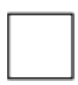
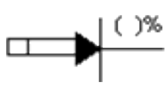
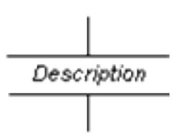
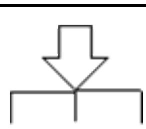
A Process Flow Chart is a pictorial representation of a process, using a variety of symbols connected by lines and arrows. A Process Flow Chart provides a clear picture of each stage of a process, the interrelationship between stages of the process, and the direction of the process flow. The chart can selectively be used to show what happens to selected people, materials or equipment.



Parts of a Flow Process Chart

A particularly useful feature of the chart is that it can be drawn up as the process is happening. Thus you can follow a part around a factory floor, for example, noting how and when it is machined, stored, moved, etc.

The table below shows many of the symbols that may be found in Flow Process Charts.

Symbol	Title	Description
	Operation	A complex action or process (possibly described elsewhere), often changing something.
	Transport	Movement of people or things. May be accompanied by a distance measurement.
	Delay	Idle time of people or machines, or temporary storage of materials.
	Storage	Permanent storage of materials or other items.
	Inspection	Checking of items to ensure correct quality or quantity.
	Combined operation	Overlay symbols for actions which combine types. Put the main activity outside.
	Reject	Rejection of item. Parentheses show percentage of items rejected. Line to right lead to consequent action.
	Differentiated operation	Letter shows type of operation, e.g. C = clerical, M = machine, etc.
	State change	Description indicates change in state, for example a liquid cooling into a solid.
	Alternating processes	Down-arrow indicates one of several possible actions. This can show alternative or simultaneous processes.

How to do it

The following steps should be followed when flow charting a process:

1. Identify the process to be charted and the objective for charting it.

2. Clearly define the steps in the process from beginning to end.

3. Identify each step by the simplest symbols possible.

4. Determine how the steps flow, including any backward flow that may result from outcomes of certain activities.

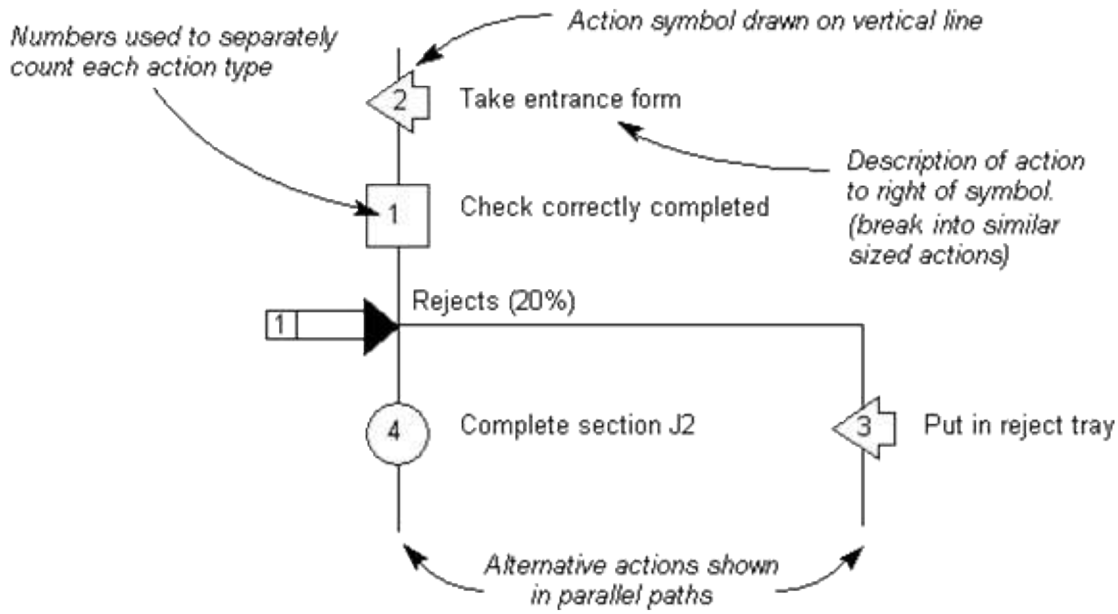
5. Record the steps of the process as it happens, starting at the top of the page, with symbols on the left overlaying a vertical line with appropriate notes about what is happening to the right. Try to record significant activities which are generally of approximately equal size (unless the problem is at the detail level, do not try to capture too much detail).

6. Add all lines and arrows to indicate the relationship between steps and the direction of flow. You can also make the diagram more useful by such tricks as numbering the different action types in sequence (for example so you can see how many times the item under examination was moved) and changing the direction of movement arrows to show input or output activity. You can also put the time taken in each activity to the left of the symbol.

7. Complete the first draft and have if reviewed by those most familiar with the process.

8. Modify the Process Flow Chart as necessary.

Once the Process Flow Chart is complete and accurate, begin the procedure of analyzing the overall process. Look for duplication of activities and non-value added steps throughout the process.



Types of process charts include procedure charts, the process-product chart and the process-man chart. All process charts use geometric symbols to represent tasks and straight lines to illustrate task sequence. Flow Process Chart is one of the first steps toward network diagrams. It shows events and relationships between events rather than activities independently displayed.

Set Back Chart

The Set Back Chart is a supporting tool for the Line of Balance scheduling technique, which will be addressed next. It is the most advanced technique we have yet seen, since it includes activities, logic between the activities, lead times, and total project duration.
This has a time axis but it runs backwards from the final delivery date. The amount of lead time to support each operation is determined, and then time is counted backwards to find out when the previous operation had to have occurred. This approach is used in manufacturing operations and also in procurement processes. It is primarily suited for repetitive operations, such as production.

Set-back charts do not show where the work will be performed and therefore it is considered to belong more to family of process charts then it does to the line-of-balance scheduling methodology to be discussed later. In the manufacturing process when set-back charts are used a standard set of geometric symbols are used to indicate the resource function responsible for the activity.

Line Of Balance

The LOB technique was originated by the Goodyear Company in the early 1940's and was developed by the U.S. Navy in the early 1950's for the programming and control of both repetitive and non-repetitive projects. LOB was first applied to industrial manufacturing and production control, where the objective was to attain or evaluate a production line flow rate of finished products.

The basic concepts of LOB have been applied in the construction industry as a planning and scheduling method. Several attempts either to modify the basic LOB technique or to develop variations named differently have also been made. Examples include velocity diagrams, construction planning technique (CPT), vertical production method (VPM), linear scheduling method (LSM), time space scheduling method (TSSM), and repetitive project model (RPM).

The line-of-balance technique is based on the underlying assumption that the rate of production for an activity is uniform. In other words, the production rate of an activity is linear where time is plotted on one axis, usually horizontal, and units or stages of an activity on the vertical axis. The production rate of an activity is the slope of the production line and is expressed in terms of units per time.

LOB scheduling can be performed more efficiently when the concept of line-of-balance is combined with network technology. Usually, a network diagram for one of the many units to be produced is prepared and incorporated into the LOB schedule.

The LOB method manipulates worker-hour estimates and the optimum sizes of crews to generate the LOB diagram. Worker-hour estimates and optimum crew sizes are usually obtained through direct interaction with a scheduler, the site manager, or related subcontractors who are knowledgeable enough to reflect the actual conditions of a project and of its constituent activities. Once the number of crews and the expected rate of output have been computed for each activity, the LOB diagram can be plotted. The number of units to be produced is plotted against time. Two oblique and parallel lines, whose slope is equal to the actual rate of output will denote the start and finish times respectively of each activity in all the units from the first to the last.

An attempt to develop a computer application was made by Psarros (1987). It was limited to solve the basic LOB problem and was not designed to deal with the many implementation-related problems. This application called SYRUS: A System for Repetitive Unit Scheduling was a pioneering attempt to prove that a computer program can be developed but was not free from flaws.

The second generation of computer programs was developed by Suh in 1993 and is called RUSS. The system has an analysis program written in "C" language. The input that consists of several types of initial information is obtained from the user. The program analyzes a "unit network" that represents the logical relationship among activities performed in one of the many identical units and calculates the production rate of each activity taking maximum productivity and learning effect into consideration.

LOB depicts the required completion of events (horizontal line) versus actual completions (vertical bars) in production operations. This method is used in conjunction with the Set Back Chart and provides an early warning system for schedule problems.

Network Diagrams

The latest and most advanced scheduling technique is schedule networks, and most of the scheduling sections of this course will focus upon this method. Network techniques were introduced on multiple fronts in the late 1950's as Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM), both of which will be discussed in more detail in later units. Network techniques have been applied in virtually every industry and have been applied successfully where there are people assigned who are capable of using it. Many applications have suffered due to insufficient preparation of schedulers who do the work.

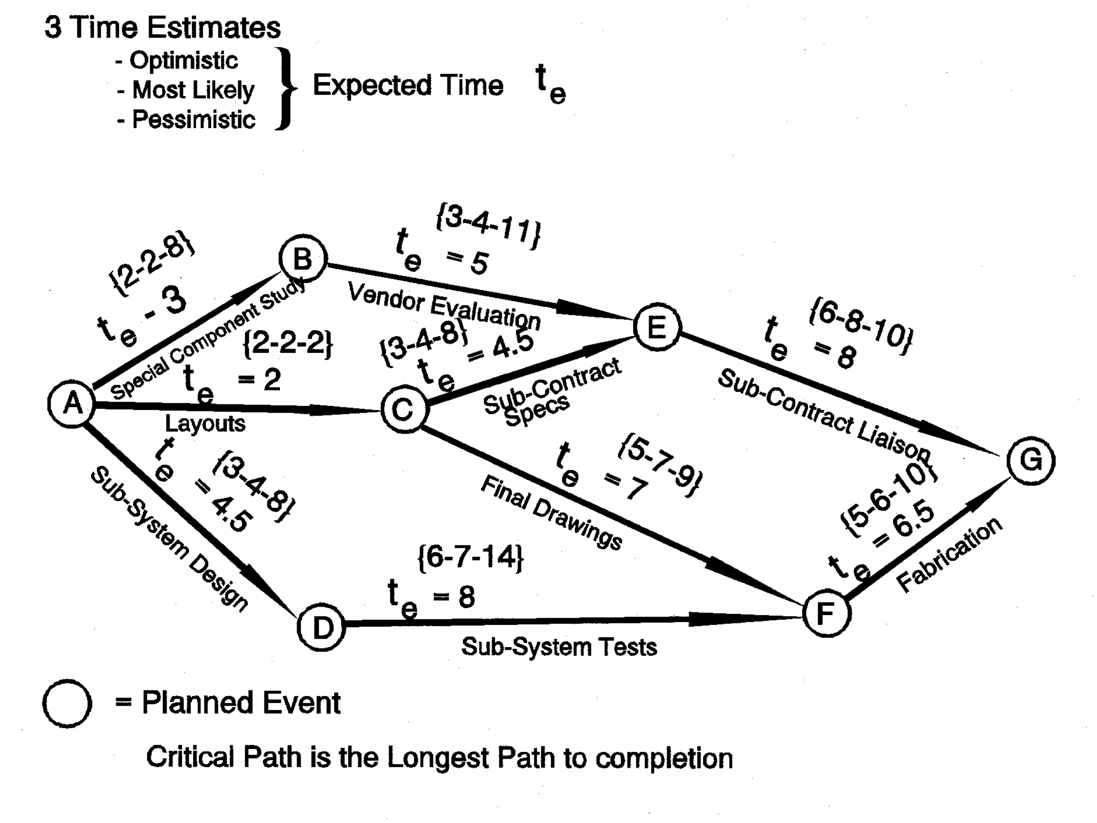
Network diagramming provides the most detailed status information by far of any of the techniques presented here. However, it is also the most complicated, most difficult to interpret, and requires the most training for staff. What does it provide? Network diagramming offers a complete listing of activities as well as interrelationships between those activities. It provides a method for identifying which activities are most critical. It facilitates easy trend analysis and provides an early warning of likely impacts to the project completion date. Network diagramming gives schedulers the ability to analyze resources, to do studies of alternative scenarios for completing the work, and to analyze time/cost tradeoffs. Finally, it creates a good starting point for determining who was responsible for a schedule delay.

PERT {Program Evaluation and Review Technique}

- The PERT chart has distinct advantages for complex projects with interrelated tasks.
- PERT, due to its complexity of time estimations, has given way to more popular CPM methods.

Three Time Estimates:

- OPTIMISTIC - Shortest time; to
- MOST LIKELY - Best Estimate; tM
- PESSIMISTIC - Longest time; tp



Critical Path Method

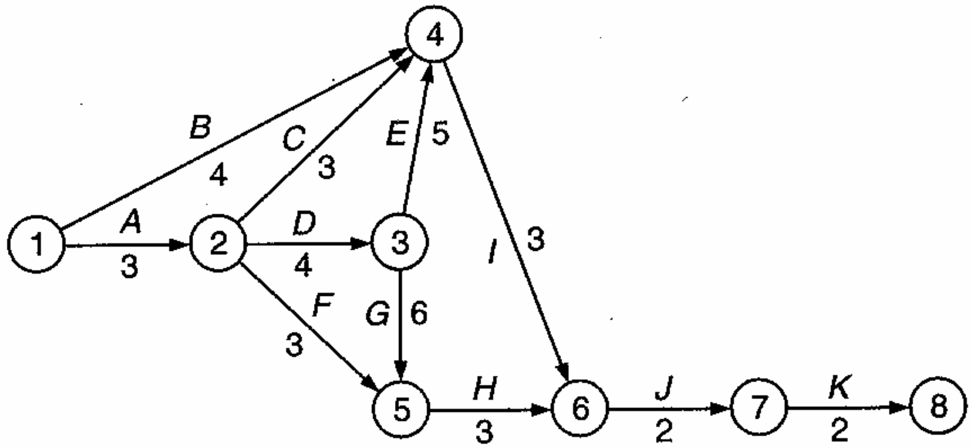
- It has some common characteristics with PERT
- It is defined by activities and events
- An activity is a time-consuming effort that is required to complete part of a project. Shown as an arrow on the diagram
- An event is denoted by a circle and defines the end of one activity and beginning of the next. An event may be a decision point.

Critical Path Method

Terminology

- Earliest Start time (ES)
- Latest Start time (LS)
- Earliest Finish time (EF),

- Duration (D)
  - EF = ES + D
- Latest Finish (LF) LF = LS + D
- Total Float (TF) TF = LS - ES
  - (Slack between the earliest and latest start times)
  - On CP, the total float is zero.



Conclusion

Many possible approaches to scheduling the work for a project are possible. Schedule types range from simple techniques, such as Bar Chart representations, to complex techniques such as the Critical Path Method (CPM). The value of a schedule tool is directly related to the amount of time and effort invested in its development. Thus, while there are many simple presentations that provide a picture of status, they are of limited value in the actual management of a project. The simplicity is achieved at the expense of accuracy. Nevertheless, such easy to understand formats are of use when summarizing status to top management as long as they have a more detailed foundation. On any project, multiple schedule formats are needed to serve differing objectives.

While CPM is the most complex of the scheduling types discussed, it provides far more information than any other approach. Among the additional capabilities that it provides is an objective method for prioritizing activities, easy trend analysis, identification of impacts from individual activity slippages, early warning of possible delays to project completion, the ability to analyze resources, and a mechanism for analyzing time/cost tradeoffs.

A schedule is a document that defines what work must be done to accomplish project objectives on time. A schedule is needed as part of the total project plan and provides an excellent vehicle for communication of status and problems throughout the life of a project. Without a formal schedule, it is impossible to know if a planned completion date is realistic or even achievable.

Development of a schedule presupposes certain information items: detailed scope of work, activity durations, activity relationships, resource requirements and assigned responsibilities at the activity level. Automated tools are almost universally used for processing the large amount of data available from a scheduling system. However, the automated reports may be supplemented with manual documents used for summary status reporting to management and external customers. The output of an effective scheduling system is a powerful tool for project management through priority definition, status reporting, problem area identification, problem impact analysis, and support of corrective action planning.

Objective Criteria

A list of objective criteria judgments for review of a specific scheduling technique to be used could include the following:

Accuracy

The system should provide accurate information, i.e., progress reports should reflect genuine progress. Estimated remaining time is better than percent time completed.

Reliability

Progress data should be consistent regardless of who collects it or when it is collected. A system may be designed to provide accurate information but, through weaknesses in data collection, may not be reliable. Conversely, reliable yet invalid results are possible.

Simplicity

A large number of people are likely to be involved in making entries and drawing reports, graphs, and charts from a scheduling system. Thus, the technique should be easy to explain, understand, and operate.

Universality

Ideally, one scheduling system should be sufficient from beginning to end of a project. All levels of management should be able to use the information in the system, and all relevant control factors should be encompassed by the one system.

Decision Analysis

Since management decision-making involves selecting one course of action from alternatives, it is useful to assess scheduling aspects of the alternatives. A system which enables management to simulate the impact of alternative courses of action can make decision making easier and result in better decisions.

Forecasting

One purpose of collecting data is to assess the ability to accomplish future tasks on schedule. Some scheduling systems are better equipped to provide this kind of advance information.

Updating

Project decisions in dynamic environments shall be based on up-to-date information. The scheduling system should be capable of rapidly and easily incorporating information on project progress.

Flexibility

It is desirable that a scheduling technique easily adapt to changes in the project.

Cost

The scheduling system should provide the required information at the lowest cost. Cost is difficult to measure for several reasons. First, total scheduling costs are needed to compare scheduling techniques; but no one has reached an agreement on what costs to include. For example, in a Gantt System, time standards are as much a part of the cost as is chart preparation. Yet, frequently this factor is not included in estimates of schedule cost, most likely, because, time standards are used for other purposes. Secondly, systems, which are most useful, generally cost more to operate. Thus, the proper cost statistic is not total dollar cost but rather cost per unit of utility or benefit. Cost per unit of utility or benefit is next to impossible to measure. Finally, cost depends largely on the size of the project and involves both fixed and variable costs. Scheduling techniques with high fixed costs thus tend to be more economical in large-scale then in small-scale applications.

Important Elements for Every Schedule

All scheduling starts from a documentation of stated objectives. The contract is normally the vehicle for identifying the stated objectives. While this is a start, in order to use the contract content in the day to day operation of the project, it shall be restated internally. This can be accomplished by a well defined project plan, a work breakdown structure, and a work breakdown structure dictionary.

MILESTONES

A milestone represents a product or an event. A milestone that does not represent a meaningful product or event to the performer is worthless.

Within the authority of the performer means that the individual or group of people working toward the milestone goal shall have control over reaching that goal. We sometimes can share a milestone - i.e. - Project Design Review (PDR) date could be shared between several performers, but it shall still remain within the control of the performer.

A milestone which is not within the control of the performer generally ends up causing problems. A simple example is when a Company Manager tries to measure progress against a milestone calling for delivery of an item by the Government (GFM/GFE) to the program. The Company Manager cannot affect the delivery date only the Government representative can affect the delivery date.

TRACEABILITY

PERT, Line-of-Balance, Gantt, milestone charts are all good techniques which are effective when properly employed. Project scheduling requirements basically seek formality, consistency and discipline throughout the scheduling system regardless of the technique used. All authorized work shall be formally scheduled in a manner which will permit the evaluation of actual progress against contract milestones and which will identify interdependencies of individual tasks. The schedule is necessary for developing a total project plan and for the control of changes to the base project plan.

Specific information data sets are needed before a schedule can be properly constructed. Work scope, ownership interrelationships, time durations are all key sets of data needed prior to the beginning of schedule development.

The scheduling system should contain summary or master schedules which provide for all contractually specified milestones. The summary schedule(s) should be clearly supported by lower level schedules which link the summary to the detail tasks. All lower level schedules shall contain specific start and completion dates which are based on physical accomplishment and are clearly integrable with formal project or organization schedules.

The concept of traceability aids management in control of the project by allowing for easy isolation to any area of project if key milestones begin to move. It also helps when contract changes or internal management directed changes effect the project baseline

"Crashing" the Schedule

Efforts to accelerate a project schedule are commonly grouped under the term "crashing" the schedule. Maybe this term was coined to suggest that there is always some price for driving a project to completion sooner than normal. There are a number of ways to improve the schedule when the management says, we need it sooner!

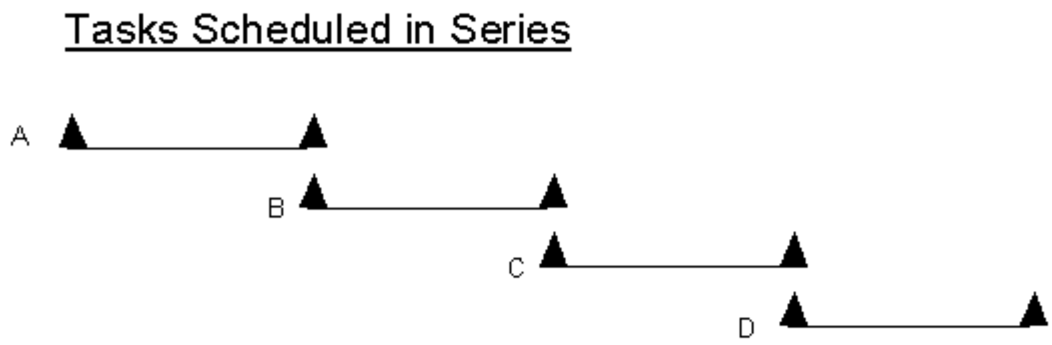
1. Add people to the schedule. Additional staff must be added early in a project or they will slow it down while learning the ropes. If you add people, you may also need to add staff for supervision and coordination, so staff is fully applied.

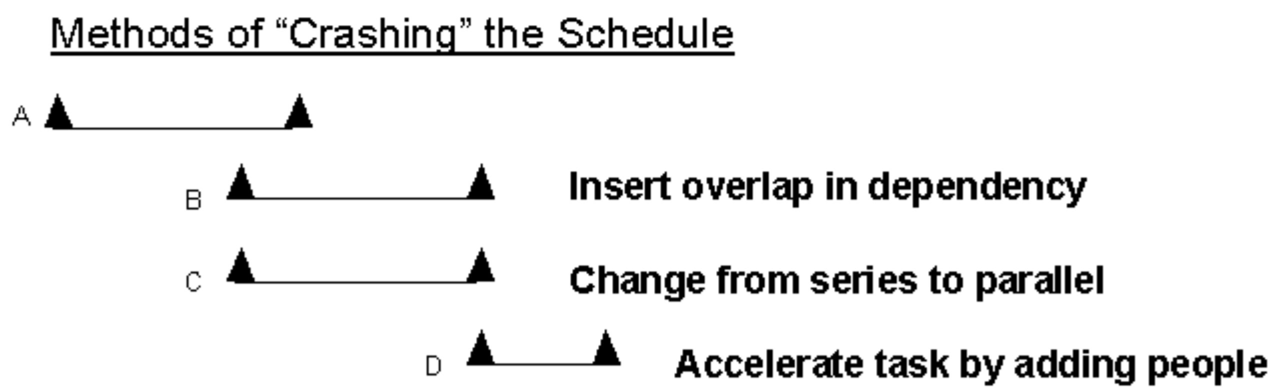
2. Improve productivity and work longer hours. A good team atmosphere with management support can help make this happen. Without positive nourishment of this process, you could lose your team to attrition.

3. Review schedule dependencies and look for opportunities to overlap tasks or make serial tasks concurrent or parallel activities. This requires greater coordination and sometimes involves increased risks which need to be managed carefully.

4. Review the project scope and remove or delay features or functionality from the project critical path.

5. Consider innovative approaches such as a different development methodology, alternative technologies, or out-sourcing options.





Principles of Scheduling

Never give off-the-cuff or unconsidered responses i.e. don't commit to something you can't deliver).

Scheduling is one part prediction and one part expectation management. If you are pressured into picking a date "on-the-fly" at a random meeting you can bet that the date will not only be wrong, it will come back to haunt you. A considered response when you have had time to evaluate all the factors is much better. A date picked out of the air is good to no-one, least of all yourself.

Eliminate uncertainty wherever you can.

The more specific you can be in your project planning, the more accurate your schedule will be. If you leave functionality or other items unspecified in your plan, then you will, at best, only be able to approximate them in the schedule. Don't go overboard, though, there is a balance. If you are spending time adding detail to tasks which will have no impact on the project delivery date, then you are probably wasting your time.

Build in plenty of contingency to cope with variation.

No matter how well specified your project and how accurate your schedule, there will be the inevitable random influences that will wreck your carefully crafted schedule. People get sick, equipment fails and external factors join together in a conspiracy to see that you miss your target date. In order to buy yourself some insurance you should build in an adequate amount of contingency, so that you can cope with unexpected delays.

You should also spread contingency throughout your project timeline and not just place it at the end. If you only have one pool of contingency allocated to the end of your project you are leaving yourself with a large slice of uncertainty. By breaking it up and spreading it throughout your project you allow yourself more options and are able to control the project more closely. You can also "buy back" time when you return unused contingency to the project.

Pick the right level of granularity

When drawing up your schedule it is important to pick the right level of detail. If you are going to require daily updates from your team then it makes sense to break into day-by-day chunks. That way everybody has the same understanding of what must be achieved by when.

On the other hand if your project has large portions of time devoted to similar activities, testing for example, then it may be better to simply block-schedule one or two months of testing. Maybe you can leave the details up to your team, it all depends on the level of control you want.

In most projects I've dealt with my optimum level of granularity is a week. This means that tasks are scheduled on the basis of the number of weeks they take. Week-by-week is much more comfortable for most people since finishing a task by the end of the week seems more natural than finishing it on a Monday or Tuesday.

Day by day scheduling can provoke more overhead than you really need. If a task is scheduled to be completed on Wednesday but due to difficulties it cannot be completed, it is unlikely that it will be finished on the Thursday, even if a team member predicts it to be so. It is more likely it will overrun by a couple of days and finish sometime on Friday, meaning that subsequent tasks can't take place until the next week. If I schedule day-by-day then I spend all of my time updating the schedule and not managing the project. On the other hand if I schedule week-by-week it is much easier to cope with such small variations. If something scheduled for "the week beginning Monday the 21st" is delayed by one, two or even three days, then subsequent tasks can either be moved comfortably or may not even be affected at all (depending on my level of contingency).

The only exception to this is where I need to force the pace of a project. I do this by imposing tighter deadlines, to the day or even down to the hour, for completion of tasks. A higher level of control however implies a higher level of attention and if I do this, I know it has implications for my own work-load as well. On a finer grade of schedule I will need to pay closer attention to individual tasks to ensure their completion.

Schedule for the unexpected

Project management is the art of handling the unknown. Often events and circumstances you could not have foreseen will interrupt the flow of your project. It's your job to take them all in your stride. Schedule for the most likely delays and cope with them should they arise. If experience or instinct tells you that a certain type of task will overrun, then anticipate it, pad it with some contingency and make sure you have adequate resources on hand when it comes up.

A good way to cope with this is to implement a bit of impromptu risk management (see Risk Management). By anticipating likely risks and prioritizing them you will be better able to deal with the unexpected! It also makes a lot of sense to let someone else help assess the risk to your project.

Chapter IV

Appraisal Of projects

Background

Capital investments tie up significant amounts of resources for long periods of time and consequently the decisions to invest become a critical part of the business plan. Resources are limited. All organizations have to make choices regarding the allocation of human and financial resources for project investments. The appraisal process covers four general situations.

1. Where a single project is being proposed and appraised. Development Banks and large companies undertake this type of analysis all the time. The investment funds are available. The appraisal simply helps determine if the investment is viable, usually according to quantitative financial criteria.

2. Where an organisation has different competing projects for investment and inadequate resources to do them all. The projects are not mutually exclusive; if sufficient funds were available, all the projects could be completed. Investing in one project would not preclude investing in others. An example would be a mining company with a portfolio of 15 capital investment projects at the beginning of the financial year and insufficient funds to invest in all of them. The projects could include buying new drilling machinery, setting up a new computer system, or pursuing joint ventures with smaller mining companies to increase ore reserves. Each project can be appraised and then compared in terms of standard financial criteria. The projects can then be ranked with investment funds allocated to the projects in order of priority. This is a typical capital budgeting process.

An extension of this model is where an organisation has a large number of similar projects and must allocate scarce resources. An example is a government Forest Conservator with 25 potential reforestation projects totalling 450 hectares and only enough resources to do 350 hectares. An appraisal process can rank the separate projects according to investment criteria to help officials make better investment decisions. Site productivity and slope would come into play as these influence forest growth rate and yield. Location to processing mills would also be important as it influences transport costs of logs and hence net returns.

3. Where projects are mutually exclusive. For example, with a given area of bare land, a farmer must choose between forestry, agriculture or perhaps urban development. Selecting one option precludes the other. Each project is appraised individually and compared.

4. Where a project has already been selected (for political reasons usually) and the appraisal is used to help determine the best method of implementation. This situation is very common in developing countries.

Investment appraisal can also be applied to following investment decisions:

- Expansion of buildings, plant, equipment and stock
- New product lines, business diversification and new enterprises
- Cost savings, such as technology versus labour
- Whether or when to replace a piece of capital equipment
- Choosing between alternative investments
- Determining optimum financing options, such as lease versus purchase.

When evaluating projects, whether or not they are competing for that scarce resource, capital, you need to consider the cost of capital, the asset's residual value, the cash flows and timings emanating from the project, taxation including capital allowances, grants, risk and cost benefit.

Financial Appraisal

Term lending institutions try to assess the following in their financial appraisal of a project proposal:

a. Estimate of capital cost
b. Estimate of working results
c. Rate of return
d. Financing pattern

a. Estimate of capital cost:

The assessment of capital cost involves a vigorous check of the financial projections provided by the promoter on the following aspects:

•Padding or under-estimation of costs
•Proper specification of machinery
•Credibility of various suppliers
•Allowances for contingencies
•Inflation factors

b. Estimate of working results:

The projections supplied by the promoters regarding the sales, realizations and profits are assessed by checking whether:

- A realistic market demand forecast has been given
- Price computations for inputs and outputs are based on current quotations and inflationary factors
- An appropriate time schedule for capacity utilization is given
- The cost projections are distinguished between fixed and variable costs appropriately

c. Rate of return:

The norms for the financial viability are generally in the range of:

- Internal Rate of Return (IRR) 15-20%
- Return on Investment (ROI) 20-25%
- Debt-service coverage ratio (DSCR) 1.5 to 2

The above mentioned figures are not mandatory and a certain degree of flexibility is shown on the basis of the nature of the project, risks inherent in the project, and the status of the promoter.

d. Financing pattern:

- A general debt-equity ratio norm of 1.5:1
- Minimum Promoters contribution 20-25% of the project cost
- Stock-exchange listing requirements in cases part of the equity is proposed to be raised from the public
- The financial capability of the promoter

In case of sectors involving standard technologies and having seen numerous projects, norms are readily available for most of the parameters such as the gestation period, build-up of capacity utilization, the unit project cost, cost structure etc. However, in case of other projects, such financial analysis often tends to be based on an aggregation of reasonable assumptions. FIs rework these projections based on the 2-3 parameters where they have standardized assumptions. These could be build-up in capacity utilization, power tariff per unit, etc.

The beauty of Financial Analysis is that the viability of projects can be established by effecting minor changes in assumptions such as growth rates, cost structure, residual value, etc (often at the second or third decimal.).

However, Financial Analysis remains an extremely important step, as it is the standard that influences decision of the financiers. (especially of the public sector). Secondly, the sensitivity analysis conducted as part of such studies forms the basis for identifying the crucial parameters for the success of the project.

Financiers tend to monitor the project progress through these milestones and parameters.

In day-to-day practice the financial institutions have their own independent criteria and credit rating methodology for arriving at the credit rating of each project.

Market Appraisal

- The reasonableness of the demand projections supplied by the promoters are verified by utilizing the findings of available reports/ surveys, industry association/ planning commission/ DGTD projections, and independent market surveys (sometimes commissioned with the expense borne by the promoters).
- Assess the adequacy of the marketing infrastructure planned in terms of promotional effort, distribution network, transport facilities, stock levels, etc.
- Judge the knowledge, experience and competence of the key marketing personnel.

In case of appraisal for projects of SMEs, the market appraisal generally tends to be accorded low importance. The localized/regional nature of these businesses often makes success in marketing more a function of the entrepreneur's attributes or contacts rather than a fundamental demand-supply mismatch in the product (currently met by expensive imports or near substitutes). However, over the past few years most financial institutions, based on their experience of past lending drawn up categories of industries where new projects would be restricted / prohibited. These are clearly stated in the lending policies of the financial institutions.

When the lending policy of an FI categorizes an industry in the prohibited category, it actually means that the risk of financing such projects (in its opinion) is high making such projects an unacceptable risk from the point of a lender. In the event of your project being classified under the Prohibited Category, it would be prudent to review its viability before taking it up for implementation. Also such projects might have to be completely self-financed.

Technical Appraisal

The technical appraisal is done by qualified & experienced personnel (internal or external) and focuses is mainly on the following aspects:

- Product mix
- Capacity

- Process of manufacture
- Engineering know-how and technical collaboration
- Raw materials and consumables
- Location, site and building
- Plant and equipment
- Manpower requirements
- Break-even point

Normally SME projects do not involve breakthrough technology. As a result, the technology aspect is fairly simple to appraise. However, substandard equipment resulting in unsuccessful pilot runs and prolonged rectification process is often a major problem leading to a unit turning sick even prior to commercial operations. What is accorded maximum importance by the FIs is the reputation of the suppliers and the necessity of 2-3 quotes for the key equipment to judge reasonableness of quality and price. Some of the FIs maintain lists of approved suppliers from among whom such equipment will have to be sourced (if available). However such lists also tend to have problems since they are not updated on a regular basis. Consequently, some delays and minor problems are unavoidable in most cases on this count.

Managerial Appraisal

Managerial competence and integrity is an extremely important pre-requisite to translate a project viable on paper into a real life success. Capital markets across the world (and even Indian investors in recent times) factor in the company management in company valuations (in other words share prices).
The following criteria tend to be looked at by the FIs to form a judgement regarding the managerial competence and resourcefulness.

- Track record in earlier projects
- Resourcefulness of the promoter
- Understanding of the business
- Commitment to the project and
- Integrity

Sanction

In the event of the project being assessed as viable, Sanction is accorded for financing to the proposal. The Sanction is an in-principle decision for financing the project and is generally subject to fulfillment of certain terms and conditions. Some of these conditions could be standard ones such as:

- In-principle approval from a bank for working capital
- No Objection certificate from the Pollution Control Board

- Sanction for power from the Electricity Board
- Completion of all documentation formalities creating a charge in favour of the financial institution on all the relevant assets.
- Disbursement shall commence only when the First Investment Clause has been satisfied. First Investment Clause requires the entrepreneur to invest his contribution before approaching the Financial Institutions for disbursement.

Additionally in the event of the Financial Institution being dissatisfied with any particular aspect of the project, then a condition stipulating the fulfillment of the desired change maybe made for disbursement to commence.

Cost-Benefit Analysis: An Overview

Background

Cost-Benefit Analysis (CBA) estimates and totals up the equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile. These projects may be dams and highways or can be training programs and health care systems.

The idea of this economic accounting originated with Jules Dupuit, a French engineer whose 1848 article is still worth reading. The British economist, Alfred Marshall, formulated some of the formal concepts that are at the foundation of CBA. But the practical development of CBA came as a result of the impetus provided by the Federal Navigation Act of 1936. This act required that the U.S. Corps of Engineers carry out projects for the improvement of the waterway system when the total benefits of a project to whomsoever they accrue exceed the costs of that project. Thus, the Corps of Engineers had created systematic methods for measuring such benefits and costs. The engineers of the Corps did this without much, if any, assistance from the economics profession. It wasn't until about twenty years later in the 1950's that economists tried to provide a rigorous, consistent set of methods for measuring benefits and costs and deciding whether a project is worthwhile. Some technical issues of CBA have not been wholly resolved even now but the fundamental presented in the following are well established.

Application of CBA

Cost-benefit analysis is a term that refers both to:

- A formal discipline used to help appraise, or assess, the case for a project or proposal, which itself is a process known as project appraisal; and
- An informal approach to making decisions of any kind.

Under both definitions the process involves, whether explicitly or implicitly, weighing the total expected costs against the total expected benefits of one or more actions in order to choose the best or most profitable option.

Cost-benefit analysis provides a systematic means to enumerate all benefits and all costs, much like a private sector investment analysis. But because it deals with concerns of public policy, it must consider classes of benefits and costs that are more far reaching than a business decision focusing only on net profits.

Principles of Cost Benefit Analysis

One of the problems of CBA is that the computation of many components of benefits and costs is intuitively obvious but that there are others for which intuition fails to suggest methods of measurement. Therefore some basic principles are needed as a guide.

The Rationale Underlying Cost-Benefit Analysis

Cost-benefit analysis is a tool created to aid public policy making. Public policy has two major purposes, (i) to improve efficiency and (ii) to improve equity. A policy is said to be efficient if it maximizes the total net benefits (benefits less costs) available to society, independent of who receives the net benefits. Equity, on the other hand, is not concerned with the "size of the pie", but on how the pie is distributed among the members of society. Cost-benefit analysis has traditionally been focused on efficiency--on providing policy makers with an indication of the magnitude of net benefits associated with a particular project or policy. Although cost-benefit analysis is not specifically designed as a tool for evaluating equity, the cost-benefit analyst should also track the distribution of costs and benefits among the various segments of society. In an ideal world, the analyst would attempt to determine how benefits are distributed by age, sex, income, race, geographic location, and time. At a minimum, the analysis should attempt to ascertain, to the degree possible, if imbalances between benefits and costs are present for those segments of the population which are most vulnerable.

Efficiency

Economic efficiency is a measure of the net contribution of an activity or project to overall social welfare. Thus, economic efficiency is designed to answer the question of whether the redistribution of resources implied by a project results in a betterment of society. For example, flood protection may be enhanced by inexpensive educational programs that inform citizens as to their rights under federal programs, such as flood insurance. Alternatively, communities can be moved to less flood prone areas. Another project may call for increasing taxes to build a levy that would protect property values and other aspects of quality of life by preventing flooding. However, levies also disrupt local ecosystems, increase downstream flooding and can damage or destroy other valuable resources, as well as costing significant amounts to construct. In the case of the educational program social betterment may be readily apparent, but for either the relocation or the levy program, more careful consideration of costs, benefits, and their distribution is necessary.

While there could be many definitions of what constitutes the best outcome, economists have focused on two particular criteria. The first of these criteria is called a Pareto improvement, while the second is called a potential Pareto improvement.

A project is said to constitute a Pareto improvement if it improves the quality of life for some people, but does not make anybody worse off. Clearly, society should pursue all attainable Pareto improvements, because they help some people, but do not hurt anybody. However, in a complex, modern society with countries having hundreds of millions of people, and cities having millions of people, every project or policy in all likelihood will disadvantage some segment of society. This is particularly true because the provision of public goods is generally financed by tax rupees, so there is some cost to everybody who pays taxes. If policy makers rigidly applied the concept of a Pareto improvement for screening potential projects or policies, it is unlikely that any policies or projects would meet these criteria and be implemented.

Consequently, economists have suggested less stringent criteria for determining if a project or policy improves the welfare of society as a whole. This criterion is that of the potential Pareto improvement. A policy or project is said to constitute a potential Pareto improvement if those who benefit as a result of the project or policy gain by more than the losses of those who were made worse off as a result of the project or policy. This type of arrangement of costs and benefits is called a potential Pareto improvement, because those who gain could compensate the losers for their losses, and still be better off. In fact, if the winners did compensate the losers, the potential Pareto improvement would become an actual Pareto improvement.

Most economists who examine public policy issues advocate the use of the potential Pareto improvement criterion as the determinant of whether a project or policy improves the welfare of society as a whole. They argue that because there is such a large portfolio of projects and policies, everybody benefits from some policies and incurs costs from other policies. Consequently, we should just search for the maximum difference between gains and losses, and use other mechanisms to address equity issues. Over a large number of decisions and a large number of citizens, it is argued, everybody benefits because resource allocation decisions systematically seek to obtain the greatest benefit at the least cost.

Equity

Unlike efficiency, which seeks aggregate gains, equity seeks to determine if costs and benefits are systematically reallocated in ways that discriminate against citizens least able to protect themselves, or in favor of citizens who already enjoy advantage. Thus, some potential Pareto improvements may be deemed undesirable no matter how large the difference between gains and losses.

With regard to the flood program, the final decision, as to an information program, a relocation program, or a levy program, might consider whether or not readily identifiable subgroups of the population, like the poor or the elderly, systematically occupy flood plains. If they do, the social desirability of protecting vulnerable citizens might swing the weight of the decision away from that delivering the greatest net benefits. These concerns have become much more visible as it is recognized that market forces, combined with environmental policies, can have unforeseen and undesirable consequences. Such considerations are often referred to as environmental justice.

A Common Unit of Measurement

In order to reach a conclusion as to the desirability of a project all aspects of the project, positive and negative, must be expressed in terms of a common unit; i.e., there must be a "bottom line." The most convenient common unit is money. This means that all benefits and costs of a project should be measured in terms of their equivalent money value. A program may provide benefits which are not directly expressed in terms of Rupees but there is some amount of money the recipients of the benefits would consider just as good as the project's benefits. For example, a project may provide for the elderly in an area a free monthly visit to a doctor. The value of that benefit to an elderly recipient is the minimum amount of money that that recipient would take instead of the medical care. This could be less than the market value of the medical care provided. It is assumed that more esoteric benefits such as from preserving open space or historic sites have a finite equivalent money value to the public.

Cost-Benefit Analysis and Time

In many applications of cost-benefit analysis, the analyst must measure the net benefits of projects or policies that generate costs and benefits over a period of time, with costs and benefits often occurring in different time periods. This increases the complexity of the analysis, because a rupee of costs or benefits ten years from today is not directly comparable to a rupee of costs or benefits today.

Because comparisons require a common metric, cost-benefit analysis uses a process called discounting to express all future costs and benefits in their present value equivalent. This takes place by discounting costs and benefits in each future time period and summing them to arrive at a present value. For example, at a ten percent discount rate, the present value of one rupee ten years from now is 37 paise and the present value of one rupee fifty years into the future is 0.67 paise. In general, the longer the time frame, and the higher the discount rate, the smaller will be the impact of any given year on total net benefits.

This gives rise to one of cost-benefit analysis's weaknesses. Because the discounting process calculates its results from the present generation's perspective, one needs to be concerned about inter temporal equity issues, that is, to the fairness of the decision to future generations. In fact, costs that occur far into the future may be given little weight in traditional cost-benefit analysis. Sustainability has developed as an additional consideration for public policy decision making precisely because of the concern that the process of discounting may steer us towards policies that overly emphasize short term gain. Like the consideration of efficiency, consideration of sustainability provides the decision maker with additional information, but does not by itself make the decision.

CBA Valuations Should Represent Consumers or Producers Valuations As Revealed by Their Actual Behavior

The valuation of benefits and costs should reflect preferences revealed by choices which have been made. For example, improvements in transportation frequently involve saving time. The question is how to measure the money value of that time saved. The value should not be merely what transportation planners think time should be worth or even what people say their time is worth. The value of time should be that which the public reveals their time is worth through choices involving tradeoffs between time and money. If people have a choice of parking close to their destination for a fee of Rs. 5 or parking farther away and spending 5 minutes more walking and they always choose to spend the money and save the time and effort then they have revealed that their time is more valuable to them than Rs. 1 per minute. If they were indifferent between the two choices they would have revealed that the value of their time to them was exactly Rs. 1 per minute.

The most challenging part of CBA is finding past choices which reveal the tradeoffs and equivalencies in preferences. For example, the valuation of the benefit of cleaner air could be established by finding how much less people paid for housing in more polluted areas which otherwise was identical in characteristics and location to housing in less polluted areas. Generally the value of cleaner air to people as revealed by the hard market choices seems to be less than their rhetorical valuation of clean air.

Benefits Are Usually Measured by Market Choices

When consumers make purchases at market prices they reveal that the things they buy are at least as beneficial to them as the money they relinquish. Consumers will increase their consumption of any commodity up to the point where the benefit of an additional unit (marginal benefit) is equal to the marginal cost to them of that unit, the market price. Therefore for any consumer buying some of a commodity, the marginal benefit is equal to the market price. The marginal benefit will decline with the amount consumed just as the market price has to decline to get consumers to consume a greater quantity of the commodity. The relationship between the market price and the quantity consumed is called the demand schedule. Thus the demand schedule provides the information about marginal benefit that is needed to place a money value on an increase in consumption.

Some Measurements of Benefits Require the Valuation of Human Life

It is sometimes necessary in CBA to evaluate the benefit of saving human lives. There is considerable antipathy in the general public to the idea of placing a rupee value on human life. Economists recognize that it is impossible to fund every project which promises to save a human life and that some rational basis is needed to select which projects are approved and which are turned down. The controversy is defused when it is recognized that the benefit of such projects is in reducing the risk of death. There are many cases in which people voluntarily accept increased risks in return for higher pay, such as in the oil fields or mining, or for time savings in higher speed in automobile travel. These choices can be used to estimate the personal cost people place on increased risk and thus the value to them of reduced risk. This computation is equivalent to placing an economic value on the expected number of lives saved.

The Analysis of a Project Should Involve a With Versus Without Comparison

The impact of a project is the difference between what the situation in the study area would be with and without the project. This means that when a project is being evaluated the analysis must estimate not only what the situation would be with the project but also what it would be without the project. For example, in determining the impact of a fixed rapid transit system (RTS), the number of rides that would have been taken on an expansion of the bus system should be deducted from the rides provided by RTS and likewise the additional costs of such an expanded bus system would be deducted from the costs of RTS. In other words, the alternative to the project must be explicitly specified and considered in the evaluation of the project. Note that the with-and-without comparison is not the same as a before-and-after comparison.

Another example shows the importance of considering the impacts of a project and a with-and-without comparison. Suppose an irrigation project proposes to increase cotton production in Surendranagar District. If the Department of Agriculture of Government of Gujarat limits the cotton production in the State by a system of quotas then expanded cotton production in Surendranagar might be offset by a reduction in the cotton production quota for Rajkot District. Thus the impact of the project on cotton production in Gujarat might be zero rather than being the amount of cotton produced by the project.

Double Counting of Benefits or Costs Must be Avoided

Sometimes an impact of a project can be measured in two or more ways. For example, when an improved highway reduces travel time and the risk of injury the value of property in areas served by the highway will be enhanced. The increase in property values due to the project is a very good way, at least in principle, to measure the benefits of a project. But if the increased property values are included then it is unnecessary to include the value of the time and lives saved by the improvement in the highway. The property value went up because of the benefits of the time saving and the reduced risks. To include both the increase in property values and the time saving and risk reduction would involve double counting.

Choice of Input Values

Carrying out the present value calculation is mechanical, but the choices of values for input variables will ultimately determine the results of the analysis. Choices may be divided into parameter values and benefit and cost values. Parameter choices include:

- the discount rate
- future rates of economic growth
- future rates of population growth
- future rates of inflation
- future rates of technological change

Benefit and cost choices include:

- Benefits
    - monetary values for marketed goods
    - monetary values for non-marketed directly used goods
    - monetary values for non-marketed passively used goods
    - goods for which monetary values cannot be measured

- Costs
    - monetary values for marketed input goods
    - monetary values for non-marketed directly used goods that must be given up
    - monetary values for non-marketed passively used goods that must be given up
    - costs for which monetary values cannot be measured

Because the values chosen for these variables will significantly influence the final values calculated, the decision maker must satisfy herself that the values chosen are reasonable.

Dealing with Uncertainty

In addition, there is uncertainty in every variable estimated, including the most important categories of costs and benefits. For these reasons, it is important that a cost-benefit analysis does not present a single number as the sole estimate of net present values. Rather sensitivity and scenario analysis should be conducted to illustrate how the results change with different analytical choices and with variation in the uncertain levels of key costs and benefits. Finally, it should be noted that the cost-benefit approach, in itself, is a choice. In business decisions, other simpler models are commonly applied.

Choosing among Alternatives

Cost-benefit analysis is a tool for choosing among a discrete set of alternatives. For example, there may be several alternatives for dealing with a contaminated waste site. The site can be left the way it is, the waste can be contained, or the site can be completely remediated. Both the containment alternative and the remediation alternative may be further divided into alternatives based on options available in the technologies to accomplish each goal. Notice that by convention one of the alternatives to be examined is the option of doing nothing. Other types of environmental decisions which involve the comparison of a discrete number of alternatives include modifications of the transportation system, upgrades of sewer systems, alternative land uses, alternative uses of brown field areas, and the development of locally undesirable land uses such as waste storage or disposal areas, power production facilities, and other polluting facilities.

Choosing from a Continuum

In contrast, many environmental decisions do not involve the choice among a discrete number of alternatives, but rather involve a choice from a continuous distribution of an environmental variable. For example, there exists a continuous distribution of potential levels of dissolved oxygen in a particular river, yet decision makers must choose a single level, which ideally would maximize regional quality of life. Marginal damage function analysis is a tool that is related to cost-benefit analysis that is designed to help decision makers with this type of choice.

Methods for Determination of Value from Capital Projects

1. The Rationale for Special Inter temporal Methods
2. Commonly Used Measures for Inter temporal Comparisons
3. Which is the Best Method?

Once estimates of benefits and costs associated with a project have been identified and estimated, they must be analyzed to determine the capital value of the project. This value is derived from the stream of net benefits the project is expected to generate in the future. These net benefits are usually expressed in monetary terms and are generally referred to as cash flows, or to emphasize the inclusion of non-marketed benefits and costs, as cost-benefit flows. Net benefit implies that the benefits of any capital project are subtracted from the costs associated with that project in a given time period.

Once a capital value is determined for each potential capital project, projects under consideration can be ranked according to that value. This process requires that the potential capital projects be compared using an unbiased measure. It should be recognized that any method chosen to aggregate values over time is a model, that is, an analytical tool that simplifies the analysis at hand. Several different models are commonly employed in government and industry to compare the capital values of projects. However, individual measures can lead to different rankings depending on the specific circumstances of the analysis. If the ranking can change arbitrarily depending upon the method chosen, the ranking is said to be biased. Whereas, no single model is perfect, some are clearly better than others.

The Rationale for Special evaluation Methods

The goal of the capital project evaluation process is to ensure that, from a number of alternative choices, the project or set of projects chosen generates the greatest economic value to society. Because capital projects have economic lives that extend into the future, the value of time must be taken into account. This is commonly referred to as calculating the time value of money. Time influences value because by choosing to invest in a specific capital project, other choices are forgone. For example, if someone were to borrow Rs.10,000 from you today, promising to repay the amount at the end of a ten-year period, would you accept the proposition? Probably not, because you would realize that the rupees repaid to you in the future would not be equal in value to the rupees you lent today. Some, but not all of this discrepancy can be explained by expected inflation. However, even if there were no inflation you probably would not accept the proposal. The reason is simple. If you lent Rs.10,000 you would lose the option of using it yourself during the period it is lent. Time has value because you must be compensated for your lost ability to use the Rs.10,000 while the borrower uses it. The rate you must be paid for the forgone use of the money depends on many circumstances that are discussed in the Choice of Discount Rate.

In addition to the time value of money, several other factors must be incorporated into any acceptable measure of value. First, all future cost-benefit flows should be taken into account. Failure to consider all future cost-benefit flows could lead to the choice of a project with large initial benefits and larger, but unidentified, subsequent costs. Second, any measure of value should incorporate the risk associated with the stream of cost-benefit flows. The following example illustrates the importance of risk.

Suppose you have a choice of spinning two wheels of fortune. Wheel "A" has ten spaces that are each worth Rs.10,000. Wheel "B" has ten spaces, nine of which are worth nothing and one of which is worth Rs.100,000. The expected value of spinning each wheel is the same (Rs.10,000) but the risk associated with each is not. Which wheel would you spin if the distribution of prizes were not told to you, only the expected value? Given the lack of information concerning the relative riskiness of spinning "A" versus "B" it could be expected that each wheel would be chosen half of the time. Each spin of wheel "B" means the unintended acceptance of risk. This is analogous to ignoring risk when determining which project(s) to choose. Risk associated with future benefit streams is usually explicitly incorporated into the discount rate.

To summarize, any measure of value chosen should meet the following criteria:

- Incorporate the value of time.
- Reflect all future cost-benefit flows.
- Incorporate risk into the calculation of the value.

By adhering to these criteria, the decision maker can be assured that the project(s) chosen will yield the greatest economic value.

Commonly Used Measures for Comparisons

Several measures are commonly employed to determine the value of a capital project. These are: (1) the payback, (2) discounted payback, (3) internal rate of return (IRR), (4) modified internal rate of return (MIRR) and (5) net present value (NPV). These sections detail how each measure is calculated and how each compares to the criteria listed above.

Payback

The payback method is the simplest measure to calculate and the least consistent with the criteria listed above. The payback method simply calculates how many periods into the future it takes for a capital project to repay the initial investment. For example, suppose we examine two potential projects given the following cost-benefit flow streams for each.

	Project A	**Project B**
Year	**Cost-Benefit Flow**	**Cost-Benefit Flow**
0	-Rs.1,000	-Rs.1,000
1	Rs.400	Rs.200
2	Rs.400	Rs.400
3	Rs.300	Rs.500
4	Rs.100	-Rs.200

Each project would repay the initial investment of Rs.1,000 during or at the end of year 3. However, this does not mean that the two projects are equal. This is most easily seen by examining project B. Notice the negative cost-benefit flow at the end of period 4 is not included in the analysis. Taking into account entire flow of costs, the sum of the costs exceeds the sum of the benefits by an undiscounted Rs.100. The payback method for determining value does not meet the criteria established above. It fails to account for all cost and benefit flows. Further, the payback method does not take into consideration the time value of money. Finally, risk is not considered.

Despite these limitations, the payback period is used in both the private and public sector. The payback period is considered more of an indication of risk rather than an investment criterion.

Advantages are that it is simple, requires little information, and links the project to liquidity that is the project’s ability to earn cash. It is usually applied to compare and rank competing projects.

Decision criteria

The decision criterion is to minimise the payback period.

ARR

The ARR is the accounting profit as a percentage of the capital employed.   . For example, if the capital cost is Rs 20,000 and the annual net cash flows from this investment are Rs 2,000 (net cash flows less straight line depreciation over 10 years), the ARR is 10 per cent.

The advantages of the ARR are again its simplicity and its concern with profitability, however it still has the disadvantage of ignoring the time value of money and also is dependent on the depreciation policy adopted by the business.

Discounted Payback

The discounted payback method attempts to rectify one of the shortcomings of the payback method, the incorporation of the time value of money. The cost-benefit flows are discounted to reflect the value of time. For example, suppose the appropriate discount rate is 5%. The net benefit stream for projects A and B can be recalculated to reflect this new piece of information. The present value (the value of some future amount in today's rupees given a discount rate) is calculated using the following formula:

$$PV = FV(\frac{1}{1+r})^t$$

The symbols represent present value (PV), future value (FV) and the discount rate (r) expressed as a percentage. The number of periods from today (period 0) the net benefit accrues is the number of discounting periods, t. Again, let us examine the cost-benefit flow streams of projects A and B.

	Project A			**Project B**		
Year	**Net Benefit**	**Discounted Cost-Benefit Flow**	**Running Total**	**Net Benefits**	**Discounted Cost-Benefit Flow**	**Running Total**
0	-Rs.1,000			-Rs.1,000		
1	Rs.400	Rs.381	Rs.381	Rs.200	Rs.190	Rs.190
2	Rs.400	Rs.363	Rs.744	Rs.400	Rs.363	Rs.553
3	Rs.300	Rs.259	Rs.1,003	Rs.500	Rs.432	Rs.985
4	Rs.100	Rs.82	Rs.1,085	-Rs.200	-Rs.165	Rs.820

By incorporating the time value of money into our calculations, it can be seen that project B no longer pays back its initial investment. Project A still pays back in year 3. While the discounted payback method is consistent with part of our criteria, it fails to take into account all of the cost-benefit flows generated by the proposed projects.

Both the payback and discounted payback methods for determining value of capital projects are inconsistent with our criteria. Although occasionally employed in industry as a thumbnail measure of a project's value, neither is consistent or fully acceptable for evaluating capital projects.

Net Present Value

Net present value is probably the most common approach for appraising projects using discounted cash flows in both the private and public sectors. The present value of all benefits is compared to the present value of all costs. Alternatively, net cash flows are first calculated for each year of the project and then discounted to the present. NPV requires the selection of a discount rate.

Net present value (NPV) is similar to the **discounted payback** method in that the cost-benefit flows are discounted to reflect the time value of money. However, unlike the discounted payback method, NPV considers all future cost-benefit flows. The method yields one value that is easily interpreted. If the value is positive, the project yields benefits that exceed its costs. If the value is negative, costs exceed benefits. The discounting calculations are based on the same formula that is used to discount cost-benefit flows in the discounted payback method. The method is illustrated by the following example. In this case a discount rate of 10 percent is assumed.

Project C			**Project D**	
Year	**Net Benefit**	**Discounted Cost-Benefit Flow**	**Net Benefit**	**Discounted/Cost Flow**
0	-Rs.10,000	-Rs.10,000	-Rs.10,000	-Rs.10,000
1	Rs.5,000	Rs.4,545	Rs.1,000	Rs.909
2	Rs.5,000	Rs.4,132	Rs.1,000	Rs.751
3	Rs.5,000	Rs.3,757	Rs.1,000	Rs.751
4	Rs.5,000	Rs.3,415	Rs.17,000	Rs.13,660
	Present Net Value	**Rs.5,849**		**Rs.6,146**

Both projects have positive NPV's and are both winners. However, NPV easily allows us to compare projects. Suppose we could only pick one project. Clearly, we would choose project D, because it has the greatest NPV. NPV is also consistent with our criteria. The method accounts for the time value of money through discounting. It also considers all of the expected future cost-benefit flows. Further, the discount rate can be adjusted on a project by project basis to reflect the inherent risk of each.

Decision criteria

It goes without saying that for the project to be worthwhile the NPV must be positive and the higher the NPV the more attractive is the investment in the project.

For a single project, acceptability requires that NPV > 0. This would reflect a project where the present value of incremental benefits exceeds the present value of all capital and recurrent costs. For a capital budgeting process, where multiple projects are being appraised and limited budgets mean that some projects cannot be funded, NPV can be used to rank projects in order of priority. The objective is maximisation of NPV. Where budget rationing exists, NPV is probably the preferred method of appraising projects. NPV addresses efficiency objectives.

Internal Rate of Return

The IRR or yield of a project is the rate of return at which the present value of the net cash inflows equals the initial cost, which is the same as the discount rate which produces a NPV of zero. For an investment to be worthwhile the IRR must be greater than the cost of capital.

In other words, the IRR is the rate at which the PV of measured benefits equals the PV of measured costs. Where IRR is used in a broader economic analysis, the term "economic IRR" or EIRR is often coined. IRR can be used to appraise individual projects, or provide information to help make decisions about appraising and ranking multiple investment opportunities.

It is often difficult to determine the rate at which future benefits should be discounted to today's rupees. In addition, decision makers are often more comfortable with value expressed in percentage terms rather than some other metric. The internal rate of return (IRR) is a method for determining value that does not depend on the determination of a discount rate and that expresses value in terms of a percentage. Essentially, the method requires the calculation of a discount rate such that the discounted value of future cost-benefit flows exactly equals the initial investment. In other words, the present value of costs minus the present value of benefits equals zero. Let's look again at projects C and D.

	Project C		**Project D**	
Year	**Net Benefit**	**Discounted Cost-Benefit Flow**	**Net Benefit**	**Discounted Cost-Benefit Flow**
0	-Rs.10,000	-Rs.10,000	-Rs.10,000	-Rs.10,000
1	Rs.5,000	Rs.4,545	Rs.1,000	Rs.909
2	Rs.5,000	Rs.4,132	Rs.1,000	Rs.826
3	Rs.5,000	Rs.3,757	Rs.1,000	Rs.751
4	Rs.5,000	Rs.3.415	Rs.20,000	Rs.13,660
	Net Present Value	**Rs.5,849**		**Rs.6,146**

To calculate the IRR it is necessary to find the discount rate that would equate the initial investment with the future cost-benefit flows. This can be expressed mathematically as:

$$\$10,000 = \$5000\left(\frac{1}{1+r}\right)^1 + \$5000\left(\frac{1}{1+r}\right)^2 + \$5000\left(\frac{1}{1+r}\right)^3 + \$5000\left(\frac{1}{1+r}\right)^4$$

This calculation requires a financial calculator, computer, or trial and error. The answer is slightly greater than 35%. To determine whether or not project C is a winner, the calculated IRR must be compared to a minimum acceptable rate of return that should reflect the time value of money, risk, etc. The minimum acceptable rate of return is referred to as the hurdle rate. The decision to accept or reject project C depends upon whether or not the IRR exceeds the hurdle rate.

IRR is based on the assumption that the cost-benefit flows are reinvested at the internal rate of return. If we are examining projects that are mutually exclusive, IRR may yield results that are inconsistent with a ranking based on the NPV method. For example, if we calculate the IRR of project D, we find it to be roughly 25%. Given this result, we would choose C over D. Recall that when comparing projects C and D via their respective NPV's, project D was superior. At first this inconsistency may seem surprising. However, one should note the effect of the timing of the cost-benefit flows on the IRR calculation. Any project that has relatively large positive cost-benefit flows early in its life will generate a relatively large IRR.

Finally, the use of IRR as a measure for choosing between projects is inappropriate when capital rationing exists. This problem is again due to the assumption that the cost-benefit flows are reinvested at the internal rate of return rather than at the cost of capital as in NPV. What this implies for the decision maker is that the ranking of projects will depend as much on their relative size and the timing of their cost-benefit flows as it will on the actual cost-benefit flows, where the actual flows should be the only determinant of acceptance or rejection. By example, suppose we are comparing the following set of projects:

Project	**Investment**	**NPV**	**IRR/Year**
A	Rs.1,000,000	Rs.50,000	20%
B	Rs.2,000,000	Rs.150,000	18%
C	Rs.4,000,000	Rs.300,000	16%
D	Rs.7,000,000	Rs.800,000	15%

If there were no capital rationing, we would select all four projects since each has a positive NPV and would increase our wealth by Rs.1.3 million. However, if we impose a capital budget of Rs.7 million, the choice depends on the method of examination. If we use internal rate of return, projects A, B, and C would be chosen. However, if we use NPV, project D would be chosen. The choice of Project D is optimal because it increases our wealth by Rs.800,000 rather than Rs.500,000.

The inconsistency implies that the usefulness of the IRR method is limited. Further, difficulty arises when calculating the IRR of a project that has negative cost-benefit flows after the first period. Due to the mathematics of the calculations, it is possible under these circumstances to calculate multiple IRR's that equate the net present value of costs with the net present value of benefits. This is clearly an undesirable situation.

Decision criteria

With individual projects, the appraisal must compare the IRR with a pre-selected rate of return, often called the hurdle rate. This hurdle rate usually represents the organisation's cost of capital. The objective then is for the project to earn an IRR equal to or greater than this "hurdle rate". If an organisation is using the World Bank's opportunity cost of capital of say, 12 percent, and the project has an IRR of only 8 percent; the project would be rejected. If on the other hand, the project IRR were 15 percent, it would be accepted on this criterion. For mutually exclusive projects or where we want to rank similar projects (with limited budgets), the IRR is usually used in conjunction with NPV. In this case, NPV is the first decision criteria and IRR can show relative efficiency among projects. Most spreadsheet packages include a financial function to calculate IRR. Manual calculation can be done, but is time consuming and not as accurate.

The advantages of the discounting methods are that they are concerned with profitability and the time value of money. They also provide a common denominator, being today's value, for variable lengths of investment

Their disadvantages relate to the complicated (relative) nature of the calculations, the choice of the rate of discount to apply, giving rise to the possibility of multiple solutions existing and the assumption that cash surpluses can be reinvested at the same rate.

Modified Internal Rate of Return

Modified internal rate of return is a technique that allows for the calculation of an internal rate of return when negative expected cost-benefit flows occur after the initial period. The method requires the compounding of all positive cost-benefit flows to the last period of project life and the discounting of all negative cost-benefit flows to the first period, at a given discount rate. The formula for compounding values forward is:

$$FV = PV\,(1+r)^{T-t}$$

Again, FV is the future value, PV is present value, r is the appropriate discount rate, t is the number of compounding periods, and T is the final period (4 in the example below). Once the positive cost-benefit flows have been compounded forward and the negative cost-benefit flows have been discounted back, the MIRR can be calculated. An example will illustrate the steps employed in the calculation. A discount rate of 6 percent is assumed.

Project Z

Year	**Cost-Benefit Flow**	**Present Value**	**Future Value**
0	-Rs.1,000	-Rs.1,000	
1	Rs.400		Rs.476
2	Rs.500		Rs.562
3	Rs.600		Rs.636
4	-Rs.200	-Rs.158	
Total		**-Rs.1,158**	**Rs.1,674**

Once the initial calculations have been completed, the final step is to determine a MIRR that equates the positive cost-benefit flows with the present value of the negative cost-benefit flows. This can be mathematically expressed as:

$$\$1,158 = \$1,674 \left(\frac{1}{1 + \text{MIRR}}\right)^4$$

In this instance, the MIRR equals approximately 9 percent. This does not in and of itself indicate whether the project is a winner. The decision rule for utilizing the MIRR method is similar to the decision rule employed for the IRR method. If the MIRR is greater than the hurdle rate, accept. If it is less than the hurdle rate, reject.

While the MIRR method does eliminate the potential for calculating multiple IRR when projects have negative cost-benefit flows late in their useful lives, it does not eliminate the problems that arise from mutually exclusive projects or capital rationing.

3. Which is the Best Method?

The preceding discussion of various methods commonly employed to determine the value of capital projects detailed many of the problems associated with each method. In general, the following table outlines under what circumstances any given method is consistent with our criteria.

Table 1: Comparing Methods of Valuation under Various Scenarios

Method	**Independent Projects**	**Mutually Exclusive Projects**	***Capital Rationing**	***Scale Differences**
IRR	Acceptable	Not Acceptable	Not Acceptable	Not Acceptable
MIRR	Acceptable	Not Acceptable	Not Acceptable	Not Acceptable
NPV	Acceptable	Acceptable	Acceptable	Acceptable
Payback	Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable
Discounted	Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable

* Scale differences refer to the relative size of the cost-benefit flows. When comparing projects that vary in size dramatically (i.e., thousand rupee cost-

benefit flows versus million rupee cost-benefit flows) only NPV yields results consistent with our criteria.

The NPV is the only method that is both consistent with our criteria and acceptable given any set of circumstances that affect the comparison of projects under consideration. While not as easy to calculate as the payback method, NPV is computationally easier than either the IRR or the MIRR. Finally, NPV provides a simple basis upon which to accept or reject projects and to compare across projects.

Financial Ratios

Various financial ratios are calculated for the past and future data provided to them by the promoters after checking the veracity of the same. The various ratios, which are frequently calculated include:

Current ratio:

[(Receivables + material and finished good inventory)/ (creditors for goods and expenses)]

Long term debt-equity ratio

[Long Term Debt/ Net worth]

Interest coverage ratio

[(Profit Before Interest – Provision for Tax)]/(Interest payments due for the year]

Fixed assets coverage ratio

[Fixed Assets/ (Term loan and other long term debt obligations)]

Debt-service coverage ratio

[{(Profit before interest- Provision for taxes) +Depreciation}/ {Interest repayments + (Principle Repayments*(1-effective tax rate))}]

The minimum or maximum values for some of the ratios are as follows:

Long-term debt-equity ratio (Maximum allowable)	2
Current ratio (Minimum)	1.33
Interest cover ratio (Minimum)	2
Fixed asset coverage ratio (Minimum)	1.25

The above values are taken as standard though a certain amount of flexibility is exercised depending on the perception and personal judgment of the appraising officer. A rating is assigned to the project based on the scores of the different ratios. A cut-off rating determines financing decision (whether the project would financed or not). Above the rating, the projects maybe categorized into excellent, good and average. Based on this and the project characteristics, the final terms and conditions of financial assistance are decided upon like:

- Moratorium
- Repayment period
- Availability period
- Security (like pari-passu charge, first charge, personal guarantee, corporate guarantee etc.)
- Interest rate

All the expenses like service fee, processing fee, document fee and other expenses like inspection of site, factory, etc. are charged to the applicant and is a source of income for the lending institution.

Comparing Projects with Different Economic Lives

1. The Replacement Chain Method
2. Equivalent Annual Annuity Method

Calculating net present values for projects with different life spans can also lead to incorrect decisions unless adjustments are made. There are two accepted techniques for dealing with this problem: (1) the Replacement Chain Method and (2) the Equivalent Annual Annuity Method. Essentially, each method transforms the decision variable (NPV) into a common metric for projects of different life spans. NPV in itself does not accomplish this.

1. The Replacement Chain Method

This method requires that a common life span be found for the projects under consideration. For example, suppose we have two projects, A and B, with lives of

3 and 5 years respectively. The common life span would be 15 years, the least common multiple. The method requires us to assume the project could be replaced indefinitely. Thus the cost-benefit flows would simply be repeated 5 times for project A, and 3 times for project B. NPV's would then be calculated for each project. This method is theoretically valid but difficult to implement for multiple projects.

For example, suppose we are confronted with the following choice between project A and project B. (Note the cost-benefit flows are discounted at a rate of 5% annually.)

Cost-Benefit flows for Projects A and B

Year	**Project A**	**NPV**	**Project B**	**NPV**
0	-Rs.10,000	-Rs.10,000	-Rs.10,000	-Rs.10,000
1	Rs.4,500	Rs.4,286	Rs.3,000	Rs.2,857
2	Rs.4,500	Rs.4,082	Rs.3,000	Rs.2,271
3	Rs.4,500	Rs.3,887	Rs.3,000	Rs.2,591
4			Rs.3,000	Rs.2,468
5			Rs.3,000	Rs.2,351
NPV		Rs.2,255		Rs.2,988

Project A has a NPV of Rs.2,255, while Project B has a NPV of Rs.2,988. If we were to end our discussion at this point, then we would choose Project B. However, let us instead examine the effect of applying the Replacement Chain method to the problem.

The common life span of Project A and B is 15 years. If we assume that each project can be repeated, we can simply repeat the stream of cost-benefit flows each generates. For Project A, this implies that the stream of cost-benefit flows will be repeated 5 times. For Project B, the stream of cost-benefit flows must be repeated 3 times. The result is two projects each with fifteen year useful lives. The new NPV for Project A is Rs.8,593 and the NPV of Project B is Rs.7,165. The most common mistake made when calculating the Replacement Chain method is failure to repeat the initial cash outflow. Finally, this method is particularly cumbersome if multiple projects of different useful lives must be compared. If this is the case, the Equivalent Annual Annuity method is preferable.

2. Equivalent Annual Annuity Method

The Equivalent Annual Annuity method begins with the calculation of the NPV of each project under consideration. This value is converted to an annuity given the number of years in the project's life span. That is, given the number of years and the discount rate, there is an amount which if paid at regular intervals for the same period would equal the NPV. The annuity can be calculated using the following formula:

$$\textbf{Annunity} = \textbf{NPV}/(\sum_{t=1}^{T} (1/1+r)^{t})$$

Where the symbols represent the expected value (EV), expenditure (EX), probability and event occurring (Pr), payout (PyO, and all possible events (i =>n).

NPV is the calculated net present value of the project, t is the period, T is the final period, and r is the discount rate. The next step is to calculate the value of the annuity in present value terms as if it were going to last forever. The result would be a value that could be compared with other similar values calculated for projects under consideration.

The following is an example of the Equivalent Annual Annuity method based on the cost-benefit flows for projects A and B. First, we assume that the projects can be replaced infinitely rather than a finite replacement as in the Replacement Chain method. The first step is to determine an annuity value that would be equivalent to the project's NPV. For example, we would determine an amount to be received annually for three years that would equal the NPV of project A, Rs.2,254.62. Using the same 5 percent discount rate and a three year time frame, this annuity is calculated to be Rs.897.93. However, we want to compare Project A to Project B, so we must determine the value of this annuity as if we could indefinitely replace the investment. This is done by calculating the value of the annuity as if it were a perpetuity (perpetuity is an annuity which is expected to continue forever). The formula for this calculation is:

Present Value of Perpetuity = cost-benefit flow per period/discount rate per period

Using this equation, Projects A has a NPV in perpetuity of Rs.16,558.61 and B has a NPV in perpetuity of Rs.13,804.97. Again, Project A is the superior project. This is intuitive if we observe that the cost-benefit flows generated by project A are clearly superior to Project B, but do not continue for as long.

The comparison of projects with different life spans is really an issue of apples and oranges. A comparison of projects with different life spans made without adjusting the NPV's is a faulty comparison. The Equivalent Annual Annuity method is computationally superior and easier to implement when multiple projects must be compared.

Risk and Uncertainty in Cost-Benefit Analysis

1. Risk versus Uncertainty
2. Expected Value Analysis
3. Sensitivity Analysis
4. Options Analysis
5. Conclusion

A famous quote attributed to Pliny the Elder is that "the only certainty is uncertainty." This statement clearly describes cost-benefit analysis, where lack of information about the consequences of actions and the benefits and costs of these consequences often confounds the analysis. This essay has two primary purposes. The first purpose is to give the decision maker and the analyst conducting cost-benefit analysis a better understanding of the nature of risk and uncertainty and the ways they can manifest themselves in cost-benefit analysis. The second purpose is to outline methods for incorporating uncertainty into cost-benefit analysis and into decision making processes that use cost-benefit analyses as inputs.

1. Risk versus Uncertainty

Risk and uncertainty are often used interchangeably in casual discussion, but they have very different technical meanings. Risk is defined as the variation in potential outcomes to which an associated probability can be assigned. In statistical terms, the distribution of the variable is known, but not the value from the distribution which will be realized. In poker terms, you know the probability of being dealt the ace of spades, but you do not know if the next card that will be dealt is the ace of spades. In sharp contrast, uncertainty is a lack of knowledge concerning the distribution of the variable. Not only do you not know the next card to be dealt, but you may not know how many cards are in the deck, or how many of those cards are aces of spades.

In life, as in cards, risk is less of a problem that uncertainty. Because risk is associated with probability, risk can be accommodated through the purchase of insurance or hedging. For example, when a Black Jack dealer is showing an ace, the other players may purchase insurance to protect against the dealer having twenty-one. Given the number of cards and the distribution of those cards, the likelihood the dealer has twenty-one could be calculated. Once calculated, the players would know whether or not it was prudent to purchase insurance. Similarly, you do not know if you will be in an automobile accident next year. But because the probability of being in an accident is known, you can buy insurance to protect against that unfortunate outcome.

Uncertainty on the other hand, is the lack of knowledge concerning the probability distribution of future events. This implies that insurance is unavailable to protect against negative outcomes. Therefore, it is essential that the analyst must incorporate uncertainty into the cost-benefit analysis and that the decision maker incorporate uncertainty into the decision process. A lack of knowledge does not preclude making assumptions concerning potential outcomes that should be taken into consideration. Imagine, for example, that a municipality is considering building garbage to energy incineration plant. An analyst examining the viability of the project could hypothesize that the future would look very similar to the present. That is, population would remain stable, incomes in the municipality would remain constant relative to prices, the volume of garbage would remain relatively stable, the price of energy would not change, and the town's preferences for environmental quality would not change. However, it should be expected that at least one, if not all, of these characteristics will change over the life of the incineration plant. Nevertheless, uncertainty is an attribute of virtually all decision process.

How do we treat uncertainty about key variables in cost benefit analysis? There are three major methods for doing this:

- expected value analysis
- sensitivity analysis
- evaluating "options"

2. Expected Value Analysis

Expected value analysis is designed to deal with risk and uncertainty by assigning probability estimates to alternative outcomes and then using these probability estimates to compute an expected outcome. The value of each outcome is multiplied by its probability and the expected value is computed according to the following formula:

$$EV = -EX + \sum_{i=1}^{n} (Pr)(Py0)$$

For example, if you by a lottery ticket for one rupee with a 1 in 60,000 chance of winning Rs.10,000 and a 1 in 600,000 chance of winning Rs.100,000, the expected value of your decision to purchase the lottery ticket is

$$EV = -\$1.00 + \left(\frac{1}{60000}\right)(\$10000) + \left(\frac{1}{600000}\right)(\$100000) = -\$0.60$$

In our example of the incineration plant, we only know the current price of electricity, but we can attach probabilities to potential future prices. For example, assume that the current price is Rs.0.08 per kilowatt hour, and we think that there is a fifty percent chance that it stays the same in 20 years, a 25 percent chance that it falls to Rs.0.06 and a 25 percent change that it increases to Rs.0.20. Then the expected price of energy 20 years in the future is

E (Future Price) = (0.5)(Rs.0.08) + (0.25)(Rs.0.06) + (0.25)(Rs.0.20) = Rs.0.105

Of course, a key question here is how to formulate the probability estimates. For variables such as energy prices and population growth, one can look to well developed forecasting models that predict these variables and have standard errors associated with the estimates. However, many times the analyst or decision maker will be confronted with variables for which there are no such forecasting models, such as the growth in the per capita volume of garbage. In this case, the analysts (or experts that the analyst recruits) will need to make subjective probability estimates. The analyst or the expert would take into account various factors such as the changing age distribution of the population, predicted changes in income, and how they feel attitudes will change towards the environment and towards convenience products and make forecasts or future garbage streams and subjectively attach probability estimates to those forecasts.

Although expected value analysis incorporates aspects of the probabilistic nature of important variables, it does not usually incorporate all of the information that is known about the uncertainty of the variable. Thus, although the development of subjective probabilities is one way of treating uncertainty, it is not a complete treatment. One reason for this is though probabilities are estimated, the method does not seek to evaluate the quality of the information underlying the probability estimates. The importance of this can be better understood by looking at the type of probability example normally presented in statistics textbooks. Imagine that there is a box with 100 balls in it, some red and some blue. In the absence of any additional information, one would formulate a subjective probability estimate that the probability of drawing a red ball from the box is 50 percent. Now imagine that you are told that of the 100 balls, at least 10 are red and at least ten are blue. Your subjective probability estimate remains as a 50 percent chance of drawing a red ball, but you have additional information as well. Now you know that there is no less than a 10 percent chance of drawing a red ball, and no greater than a 90 percent chance. In both cases, the subjective probability estimate is 50 percent, but there is more information in the second case, and it is essential that this information be incorporated into the decision making process.

Unfortunately, this type of information is not incorporated into the typical expected value analysis, so that no distinction is made between a 50 percent probability which represents the best guess from a spread of 0 to 100 percent, and a 50 percent probability which represents the best guess between 45 and 55 percent. Either subjective upper and lower probability estimates or confidence intervals, or sensitivity analysis should be employed to better characterize the risk and uncertainty associated with proposed projects.

One reason that these observations are important is that whereas expected value analysis indicates a "most likely value" it incorporates the assumption that such a value results from a series of repeat events. Thus, if the frequency of aces in a deck of cards is 4, the probability of drawing an ace is 1 in 13, but for 48 other draws, a card other than an ace will be drawn. The expected value analysis abstracts from this process, in reality, there may be only one opportunity to draw. In other words, the ability to calculate an expected value is different than possessing the ability to hedge.

Another attribute of expected value analysis is that it assumes that the decision maker places the same weights on gains as on losses whereas, in fact, the weights may be different. This is simply to say that an individual may suffer harm from a bet in which Rs.1,000 is lost that is greater than the well being he feels from winning a Rs.1,000 bet. The analysis must also be careful to specify the source of harm or well being properly. Whereas an individual may place an equal value on an hour of her time saved or wasted, she will not be indifferent between arriving for a plane 15 minutes early or 15 minutes late.

Finally, individuals may evaluate risky situations differently than certain ones. An individual who declines a "fair" wager, for example, is said to be risk averse. In general, individuals tend to be risk averse. Nevertheless, it can be argued that society as a whole should be risk neutral in evaluating uncertain events.

3. Sensitivity Analysis

Sensitivity analysis is a method for analyzing uncertainty by changing input variables and observing the sensitivity of the result. For example, if a positive present value is calculated for a range of discount rates, the analyst can conclude that uncertainty over which discount rate to use does not factor heavily in the analysis. The method can be employed either on a variable-by- variable analysis basis or by changing groups of variables at once using scenario analysis. These are closely related techniques that offer several advantages over other methods for examining the affects of uncertainty. This section explains how both sensitivity and scenario analysis can be employed in cost-benefit analysis to provide decision makers with improved information. The discussion covers the methods of calculation, and advantages and disadvantages of each technique. Lastly, alternative methods for incorporating uncertainty are mentioned.

Variable-by-Variable Analysis

Sensitivity analysis is a simple and effective means for analyzing uncertainty that isolates the affect of a change in one variable on the cost-benefit ratio. This method is also referred to as the variable-by-variable approach. There are four steps to employing the variable-by-variable approach.

1. List all of the important factors that affect the cost-benefit flows.
2. For each factor define a range of possible values. The range usually consists of three to five values. These can be based on any relative measure. For example, estimates for each factor could be prepared under "optimistic', "most likely", or "pessimistic" future states of the world. In practice, these values are usually based on past experience with similar projects or expert opinion. Occasionally, the range is even expressed as one or two standard deviations from a mean or expected value.
3. Calculate cost-benefit ratios or net present values for each value of each factor holding all other factors at their expected or most likely values. This means that if there are three factors and three estimates for each factor seven different benefit/cost ratios will be calculated.
4. The resulting cost-benefit ratios or NPV's should be examined to determine the degree of overall variation and which factor or factors is/are most responsible for variation in the estimates.

This process can be illustrated by examining the decision of whether or not to build a new baseball stadium, where there is uncertainty about the costs of construction, as well as the degree of fan enthusiasm for attending games in the new stadium. The table below illustrates steps one and two of the method employing this example.

Factor	**Optimistic**	**Most likely**	**Pessimistic**
Ticket Sales	1,000	400	100
Concessions	200	120	30
Construction Costs	100	250	300

The first column lists the factors believed to be most important in the determination of cost-benefit flows. The numerical values are the estimates of the cost-benefit flows generated under various assumptions. Once values for each factor have been determined, the next step is to calculate a net present value or cost-benefit ratio using the most likely values for each. Then additional net present values or cost-benefit ratios are calculated by allowing one factor to vary while the others are held constant at their most likely values. If we assume that the values in the table are already expressed in present value terms, we can calculate a series of cost-benefit ratios. These are shown in the following table.

Factor	Optimistic	Most likely	Pessimistic
Ticket Sales	4.48	2.08	.88
Concessions	2.4	2.08	1.72
Construction Costs	5.2	2.08	1.73

The results show how sensitive the cost-benefit ratios are to changes in individual factors. For example, little variation is caused by fluctuations in the revenues from concession sales. On the other hand, the cost-benefit ratios are very sensitive to changes in either construction costs or ticket sales. However, only the combination of pessimistic ticket sales and most likely estimates for concessions and construction costs fails to generate a positive cost-benefit ratio.

Scenario Analysis

Scenario analysis is based on the assumption that factors affecting cost-benefit flows do not operate independently of one another as is assumed in the variable-by-variable approach. For example, it is unlikely that ticket sales and concessions are independent factors. Greater ticket sales should imply greater concession sales. Of course, fewer ticket sales imply fewer concession sales as well. This realization allows us to combine levels of various factors in consistent combinations. If we reexamine the baseball stadium example using scenario analysis, the problem can be both simplified and offer better information on which to base a decision.

Assume we have divided the potential future states of the world into best, worst and most likely scenarios. The best case scenario is based on the lowest estimate for construction costs and the most optimistic estimates for ticket and concession sales. The worst case scenario is obviously based upon the most pessimistic estimates for construction costs, ticket sales, and concessions. Again, refer to the table below.

Scenario	Best Case	Most Likely	Worst Case
Cost-Benefit Ratio	12	2.08	0.3

Comparing the results shown in the table above with the results of the variable-by-variable approach the most striking difference is the degree of variation. The lowest cost-benefit ratio calculated using the variable-by-variable approach was 0.88, which is significantly greater than the worst case scenario outcome of 0.3.

The greatest cost-benefit ratio calculated using the variable-by-variable approach was 5.2, which is less than half the value calculated given the best case scenario. The scenario approach allows the decision maker to observe under which scenario or group of factors the proposed project performs best, worst, etc.

Advantages and Disadvantages

Sensitivity analysis has several advantages. First, it is relatively easy to compute the necessary information required for either approach. In fact, the researcher can simply assume a range of values around the most likely case, without undertaking a great deal of work. This is less true for scenario analysis than sensitivity analysis. Second, the process provides more information upon which to base a decision. In particular, it provides a notion of where the impacts of uncertainty are important for the analysis and where they are not. This could cause the analyst to gather additional information. Third, because the process requires a careful examination of the factors most likely to influence the cost-benefit flows, the analysts is better informed as to what the results of the analysis truly represent. Finally, the potential interaction of factors is revealed when scenario analysis is employed.

Several disadvantages are also prevalent. First, the determination of values that correspond to variations in key factors is based upon the best information at the disposal of the analyst. Inevitably, this implies the reliance on ad hoc methods for determining pessimistic, optimistic and most likely estimates. Also, the lack of a systematic method for determining the appropriate combination of factors used to define given scenarios limits the reliability of sensitivity analysis. Finally, while the variable-by-variable approach fails to account for factor interaction, the scenario approach usually only includes a small number of potential scenarios.

4. Options Analysis

Options analysis is a general term that refers to the analysts stepping back from the analysis and asking if the analysis is framed in the only way possible or if there are additional options that could better manage the uncertainty faced by the analysis. In general, two types of options analysis are available, one is sequential decision analysis and the other is the approach of irreversible investment theory.

Sequential Decision Analysis

Sometimes activities that appear to be all or none decisions can, in fact, be subdivided into parts, such that information gained during the early parts of the activity can be used to reduce the uncertainty in the later parts of the activity. Such division can sometimes be very trivial. For example, in years past, no one financed a home other than by using a note with a fixed rate of interest over the life of the note. Whereas, this appeared to benefit the homeowner, because the same interest rate would be used, what in fact occurred was that the lender was bearing the risk that other factors, like inflation, would remain constant over the life of the loan. The lender charged a risk premium for this service. When uncertainty over inflation increased, borrowers became aware that by using variable rate mortgages they could often decrease their costs of borrowing. In exchange for these lower costs, the borrowers engaged in risk sharing with the lenders. What in fact was done was the longer term note was effectively broken into a set of shorter term notes with provision to adjust the interest rate as each note came due.

This same principle can be used in many other circumstances. As an example, a utility company, uncertain about the future growth of its electrical load might purchase smaller generators over time, rather than one large generator. A waste clean up activity might divide the larger task into segments. For example, rather than write a single contract to analyze a waste problem and then clean it up, two contracts, one to analyze the problem and a second, to clean up, based on information from the first task, might be employed. Whereas these are simple examples, the important point is that not all environmental decisions are all or none, like a decision to build a dam. Many can be profitably subdivided with resulting decreases in uncertainty.

Irreversible Investment Analysis

In recent years new developments in the theory of investment have led to some very powerful, yet often very simple, observations that are relevant for environmental decision making. The first is that even though cost-benefit analyses are typically framed as whether or not to undertake a project, the analysis might also seek to answer the question when to undertake it. Often projects are posed as now or never. Sometimes, when waiting is possible uncertainty can be resolved at little or no cost. For example, consider the decision by a commuter to purchase an electric car. A cost-benefit analysis would develop data about the expected life of the electric car, the expected costs of alternative means of commuting, and how satisfactory each mode would be. The electric car, might prove to be the most cost effective of the alternatives. But, in fact, the savings calculated by the analysis would eventually be available six months or twelve months hence. Furthermore, over this time period, the commuter could observe the experiences of others with the electric car and the alternatives. The insight of irreversible investment theory is that if uncertain events prove unfavorable, the value of the investment may be totally lost, whereas the cost of waiting may be only the savings given up until the decision is finally made.

This same type of reasoning can be applied to environmental decisions that are irreversible, in the sense that they require the sacrifice of some irreplaceable environmental asset. Hence, if science is uncertain about the role of a particular element of a larger ecosystem, with the potential for high costs if uncertainty resolves unfavorably, there can be significant value to waiting until uncertainty is resolved.

5. Conclusion

All decisions, save the most trivial, are decisions under uncertainty. Hence, the decision maker will never have the assurance, nor the peace of mind, of knowing for sure what the entire consequences of an action may be. Nonetheless, there are ways to hedge against risk and to reduce uncertainty, and we have reviewed several here. The reader should not assume we have exhausted the possibilities. The decision analysis literature is replete with tools and techniques to manage the information content of an analysis. Nevertheless, by applying the basic cost-benefit framework with care, a great deal of uncertainty can be reduced and the probability of an optimal decision increased.

Chapter V

Risk analysis

Definitions

Risk = probability of event x cost of event

Risk analysis = risk assessment + risk management + risk communication.

'Risk analysis' is employed in its broadest sense to include:

Risk assessment

It involves identifying sources of potential harm, assessing the likelihood that harm will occur and the consequences if harm does occur.

Risk management

It evaluates which risks identified in the risk assessment process require management and selects and implements the plans or actions that are required to ensure that those risks are controlled.

Risk communication

It involves an interactive dialogue between stakeholders and risk assessors and risk managers which actively informs the other processes.

Evaluating and Managing the Risks You Face

Almost everything we do in today's business world involves a risk of some kind: customer habits change, new competitors appear, and factors outside your control could delay your project. But formal risk analysis and risk management can help you to assess these risks and decide what actions to take to minimize disruptions to your plans. They will also help you to decide whether the strategies you could use to control risk are cost-effective.

Steps to be followed in carrying out a risk analysis

1. Identification of Threats

The first stage of a risk analysis is to identify threats facing you. Threats may be:

- **Human** - from individuals or organizations, illness, death, etc.
- **Operational** - from disruption to supplies and operations, loss of access to essential assets, failures in distribution, etc.
- **Reputational** - from loss of business partner or employee confidence, or damage to reputation in the market.
- **Procedural** - from failures of accountability, internal systems and controls, organization, fraud, etc.
- **Project** - risks of cost over-runs, jobs taking too long, of insufficient product or service quality, etc.
- **Financial** - from business failure, stock market, interest rates, unemployment, etc.
- **Technical** - from advances in technology, technical failure, etc.
- **Natural** - threats from weather, natural disaster, accident, disease, etc.
- **Political** - from changes in tax regimes, public opinion, government policy, foreign influence, etc.
- **Others** - Porter's Five Forces analysis may help you identify other risks.

This analysis of threat is important because it is so easy to overlook important threats. One way of trying to capture them all is to use a number of different approaches:

- Firstly, run through a list such as the one above, to see if any apply
- Secondly, think through the systems, organizations or structures you operate, and analyze risks to any part of those
- See if you can see any vulnerabilities within these systems or structures
- Ask other people, who might have different perspectives.

2. Estimation of Risk

Once you have identified the threats you face, the next step is to work out the likelihood of the threat being realized and to assess its impact. One approach to this is to make your best estimate of the probability of the event occurring, and to multiply this by the amount it will cost you to set things right if it happens. This gives you a value for the risk.

3. Managing Risk

Once you have worked out the value of risks you face, you can start to look at ways of managing them. When you are doing this, it is important to choose cost effective approaches - in most cases, there is no point in spending more to eliminating a risk than the cost of the event if it occurs. Often, it may be better to accept the risk than to use excessive resources to eliminate it.

Risk may be managed in a number of ways:

- By using existing assets:

Here existing resources can be used to counter risk. This may involve improvements to existing methods and systems, changes in responsibilities, improvements to accountability and internal controls, etc.

- By contingency planning:

You may decide to accept a risk, but choose to develop a plan to minimize its effects if it happens. A good contingency plan will allow you to take action immediately, with the minimum of project control if you find yourself in a crisis management situation. Contingency plans also form a key part of Business Continuity Planning (BCP) or Business Continuity management (BCM).

- By investing in new resources:

Your risk analysis should give you the basis for deciding whether to bring in additional resources to counter the risk. This can also include insuring the risk: Here you pay someone else to carry part of the risk - this is particularly important where the risk is so great as to threaten your or your organization's solvency.

4. Reviews

Once you have carried out a risk analysis and management exercise, it may be worth carrying out regular reviews. These might involve formal reviews of the risk analysis, or may involve testing systems and plans appropriately.

Porter's Five Forces Assessing the Balance of Power in a Business Situation

The Porter's 5 Forces tool is a simple but powerful tool for understanding where power lies in a business situation. This is useful, because it helps you understand both the strength of your current competitive position, and the strength of a position you're looking to move into.

With a clear understanding of where power lies, you can take fair advantage of a situation of strength, improve a situation of weakness, and avoid taking wrong steps. This makes it an important part of your planning toolkit.

Conventionally, the tool is used to identify whether new products, services or businesses have the potential to be profitable. However it can be very illuminating when used to understand the balance of power in other situations too.

Five Forces Analysis assumes that there are five important forces that determine competitive power in a situation. These are:

1. **Supplier Power:** Here you assess how easy it is for suppliers to drive up prices. This is driven by the number of suppliers of each key input, the uniqueness of their product or service, their strength and control over you, the cost of switching from one to another, and so on. The fewer the supplier choices you have, and the more you need suppliers' help, the more powerful your suppliers are.

2. **Buyer Power:** Here you ask yourself how easy it is for buyers to drive prices down. Again, this is driven by the number of buyers, the importance of each individual buyer to your business, the cost to them of switching from your products and services to those of someone else, and so on. If you deal with few, powerful buyers, they are often able to dictate terms to you.

3. **Competitive Rivalry:** What is important here is the number and capability of your competitors – if you have many competitors, and they offer equally attractive products and services, then you'll most likely have little power in the situation. If suppliers and buyers don't get a good deal from you, they'll go elsewhere. On the other hand, if no-one else can do what you do, then you can often have tremendous strength.

4. **Threat of Substitution:** This is affected by the ability of your customers to find a different way of doing what you do – for example, if you supply a unique software product that automates an important process, people may substitute by doing the process manually or by outsourcing it. If substitution is easy and substitution is viable, then this weakens your power.

5. **Threat of New Entry:** Power is also affected by the ability of people to enter your market. If it costs little in time or money to enter your market and compete effectively, if there are few economies of scale in place, or if you have little protection for your key technologies, then new competitors can quickly enter your market and weaken your position. If you have strong and durable barriers to entry, then you can preserve a favorable position and take fair advantage of it.

Porter's Five Forces Analysis is an important tool for assessing the potential for profitability in an industry. With a little adaptation, it is also useful as a way of assessing the balance of power in more general situations.

It works by looking at the strength of five important forces that affect competition:

- Supplier Power: The power of suppliers to drive up the prices of your inputs;
- Buyer Power: The power of your customers to drive down your prices;
- Competitive Rivalry: The strength of competition in the industry;
- The Threat of Substitution: The extent to which different products and services can be used in place of your own; and
- The Threat of New Entry: The ease with which new competitors can enter the market if they see that you are making good profits (and then drive your prices down).

By thinking through how each force affects you, and by identifying the strength and direction of each force, you can quickly assess the strength of the position and your ability to make a sustained profit in the industry. You can then look at how you can affect each of the forces to move the balance of power more in your favor.

Project Risk Analysis & Management

Project Risk Analysis and Management is a process which enables the analysis and management of the risks associated with a project. Properly undertaken it will increase the likelihood of successful completion of a project to cost, time and performance objectives. Risks for which there is ample data can be assessed statistically. However, no two projects are the same. Often things go wrong for reasons unique to a particular project, industry or working environment. Dealing with risks in projects is therefore different from situations where there is sufficient data to adopt an actuarial approach. Because projects invariably involve a strong technical, engineering, innovative or strategic content a systematic process has proven preferable to an intuitive approach.

What Is Involved

The first step is to recognise that risk exists as a consequence of uncertainty. In any project there will be risks and uncertainties of various types as illustrated by the following examples:

. The management and financial authority structure are not yet established
. The technology is not yet proven
. Industrial relations problems seem likely
. Resources may not be available at the required level.

All uncertainty produces an exposure to risk which, in project management terms, may cause a failure to:

. Keep within budget
. Achieve the required completion date
. Achieve the required performance objective.

Project Risk Analysis and Management helps to remove or reduce the risks which threaten the achievement of project objectives.

The Project Risk Analysis and Management Process

In order to simplify the process, the overall process is divided into two constituents or stages:

. Risk Analysis
. Risk Management.

Risk Analysis

This stage of the process is generally split into two 'sub-stages'; a qualitative analysis 'sub-stage' that focuses on identification and subjective assessment of risks and a quantitative analysis 'sub-stage' that focuses on an objective assessment of the risks.

Qualitative Analysis

A Qualitative Analysis allows the main risk sources or factors to be identified. This can be done, for example, with the aid of check lists, interviews or brainstorming sessions. This is usually associated with some form of assessment which could be the description of each risk and its impacts or a subjective labelling of each risk (e.g. high/low) in terms of both its impact and its probability of occurrence.

A sound aim is to identify the key risks for each project (or part-project on large projects) which are then analysed and managed in more detail.

Quantitative Analysis

A Quantitative Analysis often involves more sophisticated techniques, usually requiring computer software. To some people this is the most formal aspect of the whole process requiring:

. Measurement of uncertainty in cost and time estimates

. Probabilistic combination of individual uncertainties.

Such techniques can be applied with varying levels of effort ranging from modest to extensively thorough. It is recommended that new users start slowly, perhaps even ignoring this 'sub-stage', until a climate of acceptability has been developed for Project Risk Analysis and Management in the organisation.

An initial qualitative analysis is essential. It brings considerable benefit in terms of understanding the project and its problems irrespective of whether or not a quantitative analysis is carried out. It may also serve to highlight possibilities for risk 'closure' i.e. the development of a specific plan to deal with a specific risk issue.

Experience has shown that qualitative analysis - Identifying and Assessing Risks - usually leads to an initial, if simple, level of quantitative analysis. If, for any reason - such as time or resource pressure or cost constraints - both a qualitative and quantitative analysis are impossible, it is the qualitative analysis that should remain.

It should be noted that procedures for decision making will need to be modified if risk analysis is adopted.

Risk Management

This stage of the process involves the formulation of management responses to the main risks. Risk Management may start during the qualitative analysis phase as the need to respond to risks may be urgent and the solution fairly obvious. Iteration between the Risk Analysis and Risk Management stages is likely.

Risk Management can involve:

- Identifying preventive measures to avoid a risk or to reduce its effect
- Establishing contingency plans to deal with risks if they should occur
- Initiating further investigations to reduce uncertainty through better information
- Considering risk transfer to insurers
- Considering risk allocation in contracts
- Setting contingencies in cost estimates, float in programmes and tolerances or 'space' in performance specifications.

Why Is It Used?

There are many reasons for using Project Risk Analysis and Management, but the main reason is that it can provide significant benefits far in excess of the cost of performing it.

Benefits

The benefits gained from using Project Risk Analysis and Management techniques serve not only the project but also other parties such as the organisation and its customers. Some examples of the main benefits are:

- Increased understanding of the project, which in turn leads to the formulation of more realistic plans, in terms of both cost estimates and timescales
- Increased understanding of the risks in a project and their possible impact, which can lead to the minimisation of risks for a party and/or the allocation of risks to the party best able to handle them
- Understanding of how risks in a project can lead to the use of a more suitable type of contract
- Independent view of the project risks which can help to justify decisions and enable more efficient and effective management of the risks
- Knowledge of the risks in a project which allows assessment of contingencies that actually reflect the risks and which also tends to discourage the acceptance of financially unsound projects
- Contribution to the build-up of statistical information of historical risks that will assist in better modelling of future projects
- Facilitation of greater, but more rational, risk taking, thus increasing the benefits that can be gained from risk taking
- Assistance in the distinction between good luck and good management and bad luck and bad management.

Who benefits from its use?

- An organisation and its senior management for whom knowledge of the risks attached to proposed projects is important when considering the sanction of capital expenditure and capital budgets
- Clients, both internal and external, as they are more likely to get what they want, when they want it and for a cost they can afford
- Project managers who want to improve the quality of their work i.e. they want to bring their projects in to cost, on time and to the required performance.

What are the costs of using it?

The costs of using Project Risk Analysis and Management techniques vary according to the scope of the work and the commitment to the process. Below are some example costs, timescales and resource requirements for carrying out the process.

Cost

The cost of using the process can be as little as the cost of one or two days of a person's time up to a maximum of 5-10% of the management costs of the project, even this higher cost, as a percentage of the total project cost, is relatively small. It can be argued that the cost incurred is an investment if risks are identified during the process that may otherwise have remained unidentified until it was too late to react.

Time

The time taken to carry out a risk analysis is partially dependent upon the availability of information. A detailed cost and time risk analysis usually requires anywhere from one to three months depending upon the scale and complexity of the project and the extent of planning and cost preparation already carried out. However, as indicated above, a useful analysis can take as little as one or two days.

Resources

The minimum resource requirement is obviously just one person within an organization with experience of using Project Risk Analysis and Management techniques. However, if expertise does not exist within the organisation it can be readily acquired from outside consultants. It is likely that once Project Risk Analysis and Management has been introduced to an organisation, in-house expertise will develop rapidly.

Project Risk Analysis and Management is relevant to all projects and is an integral part of project management. This can make it very difficult to separate the costs of performing it. Some organisations treat these costs as an overhead to the organisation, and not to the project.

When Should It Be Used and Who Should Do It?

Project Risk Analysis and Management is a continuous process that can be started at almost any stage in the life-cycle of a project and can be continued until the costs of using it are greater than the potential benefits to be gained. As time progresses, the effectiveness of using Project Risk Analysis and Management tends to diminish, therefore it is most beneficial to use it in the earlier stages of project. There are five points in a project where particular benefits can be achieved by using it.

. Feasibility Study - At this stage the project is most flexible enabling changes to be made which can reduce the risks at a relatively low cost. It can also help in deciding between various implementation options for the project.

. Sanction - The client can make use of it to view the risk exposure associated with the project and can check that all possible steps to reduce or manage the risks have been taken. If a quantitative analysis has been carried out then the client will be able to understand the 'chance' that he has of achieving the project objectives (cost, time and performance).

. Tendering - The contractor can make use of it to ensure that all risks have been identified and to help him set his risk contingency or check his risk exposure.

. Post Tender - The client can make use of it to ensure that all risks have been identified by the contractor and to assess the likelihood of tendered programmes being achieved. . At Intervals During Implementation - It can help to improve the likelihood of completing the project to cost and timescale if all risks are identified and are correctly managed as they occur.

Which projects are suitable?

All projects contain risk and risk analysis and management is an integral part of project or business management. Attend any conference or read any literature on risk and it is clear that the most extensive applications have occurred on large capital projects such as defence, oil and gas, aerospace and civil engineering - these projects have been the proving ground for many of the techniques.

However the process has been applied to smaller construction projects. In other fields there are examples of risk analysis and management applied to insurance, IT projects and software development and projects for organisational change. The only general guidance is that the more the risks or more innovative the project the greater will be the benefits. On small projects, the budget will probably justify only a low level of application, perhaps omitting the quantitative analysis.

What type of project?

It can be used on any type of project, but it is more beneficial for some projects than others. Some examples of projects which would benefit from Project Risk Analysis and Management are:

. Innovative, new technology projects
. Projects requiring large capital outlay or investment
. Fast-track projects
. Projects which interrupt crucial revenue streams
. Unusual agreements (legal, insurance or contractual)
. Projects with sensitive issues (environment/ relocation)
. Projects with stringent requirements (regulatory/safety)
. Projects with important political/economic/ financial parameters.

When should it be done?

There are a few circumstances when it is particularly advisable to use Project Risk Analysis and Management techniques, these are:

. When there are specific targets that must be met
. When there is an unexpected new development in a project
. At points of change in the life-cycle of a project.

When shouldn't it be done?

There are no particular circumstances under which Project Risk Analysis and Management techniques should not be used except perhaps for repeat projects, where such analyses have already been carried out, unless, of course, there are specific differences between the projects. In the presence of uncertainty, where severe constraints give rise to significant risk, the absence of relevant data may make a quantitative assessment not worthwhile. However, such circumstances must never prevent a rigorous qualitative analysis being carried out.

Who should do it?

Many people advocate the use of an independent expert or external consultant to ensure that they receive an unbiased view, whereas others suggest that Project Risk Analysis and Management support should be an internal function. Opinions differ widely at this stage but essentially anyone can do it provided consideration is given to the 'angle' from which they are viewing the project. In any event, the project management team should be closely involved in the analytical process to ensure validity of the analysis and also to allow them to believe in the results.

How to Do It - Techniques and Methods

Project Risk Analysis and Management can be split into its two constituents or stages - Risk Analysis (Qualitative and Quantitative) and Risk Management. There is no one technique or method for carrying out either stage of the process. Some of the techniques and methods that can be employed are detailed below.

Qualitative Risk Analysis

The first phase of the qualitative analysis is identification. This is considered by some as the most important element of the process since once a risk has been identified it is possible to do something about it. Identification can be achieved by:

. Interviewing key members of the project team
. Organizing brainstorming meetings with all interested parties
. By using the personal experience of the risk analyst
. Reviewing past corporate experience if appraisal records are kept.

All of the above methods are greatly enhanced by the use of check lists which can either be generic in nature i.e. applicable to any project or specific to the type of project being analysed.

Once identified, the risks are then subjected to an initial assessment that categorises the risks into high/low probability of occurrence and major/ minor impact on the project should the risk materialise. It is often advisable to prepare initial responses to each identified risk, especially if risks are identified that require urgent attention. The analysis may be terminated during this phase if the assessment immediately suggests a way in which many identified risks can be mitigated.

It may be necessary to revisit the identification phase after the assessment phase to see if any consequential 'secondary' risks can be identified: a secondary risk may result from a proposed response to an initial risk and might therefore lead to the response being unsuccessful. The necessity of doing this will largely be dependent on the size and/or complexity of the project.

Quantitative Risk Analysis

Once all risks have been identified, during the qualitative analysis, it may be appropriate to enter into a detailed quantitative analysis. This will enable the impacts of the risks to be quantified against the three basic project success criteria: cost, time and performance. Several techniques have been developed for analysing the effect of risks on the final cost and time-scale of projects.

However, such techniques do not always readily apply themselves to the analysis of performance objectives.

The main techniques currently in use are:

. **Sensitivity Analysis** often considered to be the simplest form of risk analysis. Essentially, it simply determines the effect on the whole project of changing one of its risk variables such as delays in design or the cost of materials. Its importance is that it often highlights how the effect of a single change in one risk variable can produce a marked difference in the project outcome.

In practice, a sensitivity analysis will be performed for more than one risk, perhaps all identified risks, in order to establish those which have a potentially high impact on the cost or time-scale of the project. The technique can also be used to address the impact of risk on the economic return of a project.

. **Probabilistic Analysis** specifies a probability distribution for each risk and then considers the effect of risks in combination. This is perhaps the most common method of performing a quantitative risk analysis and is the one most people consider, incorrectly, to be synonymous with the whole Project Risk Analysis and Management process. In fact, as this Guide illustrates, it is but one facet of that process.

The most common form of probabilistic analysis uses 'sampling techniques', usually referred to as 'Monte Carlo Simulation'. This method relies on the random calculation of values that fall within a specified probability distribution often described by using three estimates: minimum or optimistic, mean or most likely and maximum or pessimistic. The overall outcome for the project is derived by the combination of values selected for each one of the risks. The calculation is repeated a number of times, perhaps between 100 and 1000, to obtain the probability distribution of the project outcome.

It is usual to carry out a probabilistic time analysis with the aid of a CPM network to model the project schedule. The same method can be used for probabilistic cost analysis especially when the cost estimate can be broken down into the same categories or activities as the schedule and when cost risks are related to time risks. If an independent cost analysis is undertaken then It may be appropriate to use a spreadsheet method.

Another technique is the Controlled Interval and Memory Method for combining probability distributions which provides an alternative to Monte Carlo Simulation. This technique can offer greater precision for much less computerized effort if either complex CPM networks or 'feedback loops' are not involved.

. **Influence Diagrams** are a relatively new technique for risk analysis. They provide a powerful means of constructing models of the issues in a project which are subject to risk. As a result influence diagrams are now used as the user interface to a computer based risk modelling tool thus allowing the development of very complex risk models that can be used to analyse the cost, time and economic parameters of projects.

. **Decision Trees** are another graphical method of structuring models. They bring together the information needed to make project decisions and show the present possible courses of action and all future possible outcomes. Each outcome must be given a probability value indicating its likelihood of occurrence. This form of risk analysis is often used in the cost risk analysis of projects.

Risk Management

Risk management uses the information collected during the risk analysis phase to make decisions on how to improve the probability of the project achieving its cost, time and performance objectives. This is done by reducing the risk where advantageous to do so and monitoring and managing the risk which remains.

The project manager uses the information at his disposal to choose between the feasible responses to each risk identified during the qualitative phase. This may involve amending the project plans to reduce the risk e.g. moving high risk activities off the critical path, developing contingency plans to allow rapid response if certain risks occur or setting up monitoring procedures for critical areas in order to get early warning of risks occurring.

There are two types of response to a risk immediate and contingency which can be defined as follows:

. Immediate response: an alteration to the project plan such that the identified risk is mitigated or eliminated
. Contingency response: a provision in the project plan for a course of action that will only be implemented should the adverse consequences of the identified risk materialise.

Responses to risks can do one or a combination of five things:

. Remove - risks that can be eliminated from the project and therefore no longer propose a threat
. Reduce - risks that can be decreased by taking certain actions immediately
. Avoid - risks that can be mitigated by taking contingency actions should they occur

. Transfer - risks can be passed on to other parties, unfortunately this does not normally eliminate the risk it just makes someone else worry about it
. Acceptance - the benefits that can be gained from taking the risk should be balanced against the penalties.

The risk management phase begins immediately the qualitative analysis is complete and is then a continuing process through the complete life-cycle of the project. The information gained during the quantitative analysis allows the project manager to trade off taking actions now against the likelihood and impact of risk occurring. The project manager may choose to immediately amend his overall time and cost plan in order to increase the probability of achieving his time and cost objectives.

Methods of Risk Analysis

Affinity Diagram

The affinity diagram is an analytical tool that allows a group of people to systematically generate a large volume of ideas, opinions, or inputs about a problem or issue and organize these into meaningful categories. It helps break old patterns of thought, reveal new patterns and generate more creative ways of thinking.

Agent-Based Simulation Modeling

Agent based simulation modeling, sometimes referred to as multi-agent modeling, covers several rather different types of modeling. What they all have in common is that they develop a simulated history out of the interactions of individual agents with one another and/or their environment. Agents typically have the following properties: autonomy (operating without others controlling their actions and internal states), social ability (interacting with other agents), reactivity (perceiving their environment and reacting to it), and pro-activity (engaging in goal directed behavior).

Analogy

An analogy helps to understand new and unknown situations in terms of what is already known. Historical analogies are used to explain or make a prediction about a current or future event based on past events. The past event is used as a source, while the present or future situation is the target of the analogy.

Bayesian Analysis

Bayesian analysis is a statistical inference in which probabilities are interpreted not as frequencies or proportions or the like, but rather as degrees of belief. Bayesian inference provides a logical, quantitative framework for the process of integrating accumulating information. It is applied in a multitude of scientific, technological, and policy settings.

Brainstorming

Brainstorming is a general data gathering and creativity technique that can be used to identify risks, ideas, or solutions to issues by using a group of team members or subject-matter experts. Typically, a brainstorming session is structured so that each participant's ideas are recorded for later analysis.

Cause-Consequence/Effect Analysis

Cause-effect analysis is a predictive or diagnostic analytical tool to explore the root causes or factors that contribute to positive or negative effects or outcomes. It is a very good method for finding potential risks. Its most typical form is the Ishikawa-Diagram, named after Kaoro Ishikawa who introduced cause-effect diagrams, also called "fishbone"-diagram.

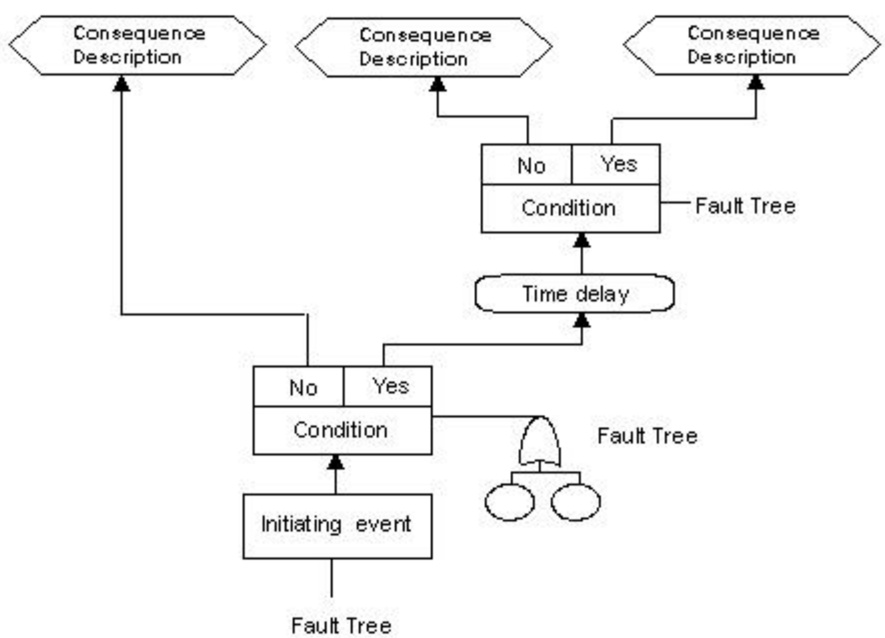


Figure 2: A typical Cause-Consequence Analysis

It is a Tree based risk analysis technique**.** Cause-consequence analysis (CCA is a blend of fault tree and event tree analysis. This technique combines cause analysis (described by fault trees) and consequence analysis (described by event trees), and hence deductive and inductive analysis is used. The purpose of CCA is to identify chains of events that can result in undesirable consequences. With the probabilities of the various events in the CCA diagram, the probabilities of the various consequences can be calculated, thus establishing the risk level of the system. Figure 2 below shows a typical CCA.

This technique was invented by RISO Laboratories in Denmark to be used in risk analysis of nuclear power stations. However, it can also be adapted by the other industries in the estimation of the safety of protective or other systems. Details on how to carry out cause consequence analysis as well as the benefits and restrictions of it are documented in literature.

Cognitive Mapping

Cognitive maps try to capture the key factors which drive an issue, and the inter-relationships and feedbacks between them. They can be applied to either the prospects for countries or regions, or the strategic decisions of individual companies, governments or organizations.

Cost-Effectiveness Analysis (CEA)

CEA is a comparison of alternative ways of achieving an already specified target so as to achieve this target at the lowest possible costs. In contrast to the CBA, the benefits are constant and the aim of the analysis is to minimize the costs associated with achieving a specific objective.

Cost-Benefit Analysis (CBA)

CBA is a formal quantitative procedure comparing costs and benefits of a proposed project or act under a set of pre-established rules. To determine a rank ordering of projects to maximize rate of return when available funds are unlimited, the quotient of benefits divided by costs is the appropriate form; to maximize absolute return given limited resources, benefits-costs is the appropriate form.

Cross-Impact Analysis

Cross-Impact Analysis is a systematic way to examine possible future developments and their interactions. This method is concerned with the identification of possible outcomes rather than with the understanding of what is or what was. It addresses Delphi’s lack of a mechanism for discovering mutually exclusive or conflicting because it takes into consideration interdependencies between events and developments and leads to more consistent and accurate forecasts.

Decision Conferencing

Decision conferencing is a series of intensive working meetings, called decision conferences, attended by groups of people who are concerned about some complex issues facing their organization. There are no prepared presentations or fixed agenda; the meetings are conducted as live, working sessions lasting from one to three days.

Decision Tree Analysis

The decision tree is a diagram that describes a decision under consideration and the implications of choosing one or another of the available alternatives. It is used when some future scenarios or outcomes of actions are uncertain. It incorporates probabilities and the costs or rewards of each logical path of events and future decisions, and uses expected monetary value analysis to help the organization identify the relative values of alternate actions.

Delphi Technique

This is an information gathering technique used as a way to reach a consensus of experts on a subject. Experts on the subject participate in this technique anonymously. A facilitator uses a questionnaire to solicit ideas about the important points related to the subject. The responses are summarized and are then re-circulated to the experts for further comment. Consensus may be reached in a few rounds of this process. The Delphi technique helps reduce bias in data and keeps any person from having undue influence on the outcome.

Digraph/Fault Graph

It is a Methodology for analysis of dynamic system. The fault graph method/digraph matrix analysis uses the mathematics and language of graph theory such as "path set" (a set of models traveled on a path) and "reachability" (the complete set of all possible paths between any two nodes).

This method is similar to a GO chart but uses AND and OR gates instead. The connectivity matrix, derived from adjacency matrix for the system, shows whether a fault node will lead to the top event. These matrices are then computer analysed to give singletons (single components that can cause system failure) or doubletons (pairs of components that can cause system failure).

Digraph method allows cycles and feed back loops which make it attractive for dynamic system.

Dynamic Event Tree Analysis Method

It is a Methodology for analysis of dynamic system. Dynamic event tree analysis method (DETAM) is an approach that treats time-dependent evolution of plant hardware states, process variable values, and operator states over the course of a scenario. In general, a dynamic event tree is an event tree in which branching is allowed at different points in time. This approach is defined by five characteristics set: (a) branching set (b) set of variables defining the system state, (c) branching rules, (d) sequence expansion rule and (e) quantification tools. The branching set refers to the set of variables that determine the space of possible branches at any node in the tree. Branching rules, on the other hand, refer to rules used to determine when a branching should take place (a constant time step). The sequence expansion rules are used to limit the number of sequences.

This approach can be used to represent a wide variety of operator behaviours, model the consequences of operator actions and also served as a framework for the analyst to employ a causal model for errors of commission. Thus it allows the testing of emergency procedures and identify where and how changes can be made to improve their effectiveness. An analysis of the accident sequence for a steam generator tube rupture is presented in literature.
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Dynamic Event Logic Analytical Methodology

It is a Methodology for analysis of dynamic system. The dynamic event logic analytical methodology (DYLAM provides an integrated framework to explicitly treat time, process variables and system behaviour. A DYLAM will usually comprise the following procedures: (a) component modeling, (b) system equation resolution algorithms, (c) setting of TOP conditions and (d) event sequence generation and analysis.

DYLAM is useful for the description of dynamic incident scenarios and for reliability assessment of systems whose mission is defined in terms of values of process variables to be kept within certain limits in time. This technique can also be used for identification of system behaviour and thus, as a design tool for implementing protections and operator procedures.

It is important to note that system specific DYLAM simulator must be created to analyse each particular problem. Furthermore, input data such as probabilities of a component being in certain state at transient initiation, independency of such probabilities, transition rates between different states, and conditional probability matrices for dependencies among states and process variables need to be provided to run the DYLAM package. An application of DYLAM on a reservoir problem is given in literature

Environmental Scanning

Environmental scanning (also called environmental assessment) is the acquisition and use of information about events, trends and relationships in an organization's external environment. Information is collected from many different sources, such as newspapers, magazines, reports, conferences, etc. Scanning includes technology, economic conditions, political and regulatory environment, or social and demographic trends.

Event tree analysis

It is a Tree based risk analysis technique**.** Event tree analysis is a method for illustrating the sequence of outcomes which may arise after the occurrence of a selected initial event. This technique, unlike fault tree uses inductive logic. It is mainly used in consequence analysis for pre-incident and post-incident application. The left side connects with the initiator, the right side with plant damage state; the top defines the systems; nodes (dots) call for branching probabilities obtained from the system analysis. If the path goes up at the node, the system succeeded, if down, it failed.

ETA is based on a binary logic, in which an event either has or has not happened or a component has or has not failed. It is valuable in analyzing the consequences arising from a failure or undesired event. An event tree begins with an initiating event and the consequences of the event are then followed through a series of possible paths. Each path is assigned a probability of occurrence and the probability of the various possible outcomes can be calculated.

ETA has seen application in the nuclear industries for operability analysis of nuclear power plant as well as accident sequence in the Three Mile Island-2 reactor's accident.

Expected Monetary Value (EMV) Analysis

EMV is a statistical technique that calculates the average outcome when the future includes scenarios that may or may not happen. A common use of this technique is within decision tree analysis.

Expert Judgment

Judgment provided based upon expertise in an application area, knowledge area, discipline, industry, etc. as appropriate for the activity being reformed. Such expertise may be provided by any group or person with specialized education, knowledge, skill, experience, or training, and is available from many sources, including: other units within the performing organization; consultants; stakeholders, including customers; professional and technical associations; and industry groups

Extreme Event Analysis

Especially on extreme events (the tail of the probability distribution function), historical, statistical, or experimental data are very often sparse. The statistics of extremes is a body of statistical theory that attempts to overcome this shortage by classifying most probability distributions into three families on the basis how fast their tails decay to zero.

Failure Mode and Effects Analysis (FMEA/FMECA)

It is qualitative risk analysis method. This method was developed in the 1950s by reliability engineers to determine problems that could arise from malfunctions of military system. Failure mode and effects analysis is a procedure by which each potential failure mode in a system is analysed to determine its effect on the system and to classify it according to its severity.

When the FMEA is extended by a criticality analysis, the technique is then called failure mode and effects criticality analysis (FMECA). Failure mode and effects analysis has gained wide acceptance by the aerospace and the military industries. In fact, the technique has adapted itself in other form such as misuse mode and effects analysis.

FMEA is an analytical procedure in which each potential failure mode in every component of a system is analyzed to determine its effect on the reliability of that component and, by itself or in combination with other possible failure modes, on the reliability of the system and on the required function of the component. For each potential failure, an estimate is made of its effect on the total system and of its impact. In addition, a review is undertaken of the action planned to minimize the probability of failure and to minimize its effects.

Fault tree analysis

It is a Tree based risk analysis technique**.** The concept of fault tree analysis (FTA was originated by Bell Telephone Laboratories in 1962 as a technique with which to perform a safety evaluation of the Minutemen Intercontinental Ballistic Missile Launch Control System. A fault tree is a logical diagram which shows the relation between system failure, ie. a specific undesirable event in the system, and failures of the components of the system. It is a technique based on deductive logic. An undesirable event is first defined and causal relationships of the failures leading to that event are then identified.

FTA is a technique that provides a systematic description of the combination of possible occurrences in a system, which can result in an undesirable outcome. This method can combine hardware failures and human failures. The most serious outcome is selected as the top event. A fault tree is then constructed by relating the sequences of events, which individually or in combination, could lead to the top event. The tree is constructed by deducing the preconditions for the top event and then successively for the next levels of events, until the basic causes are identified.

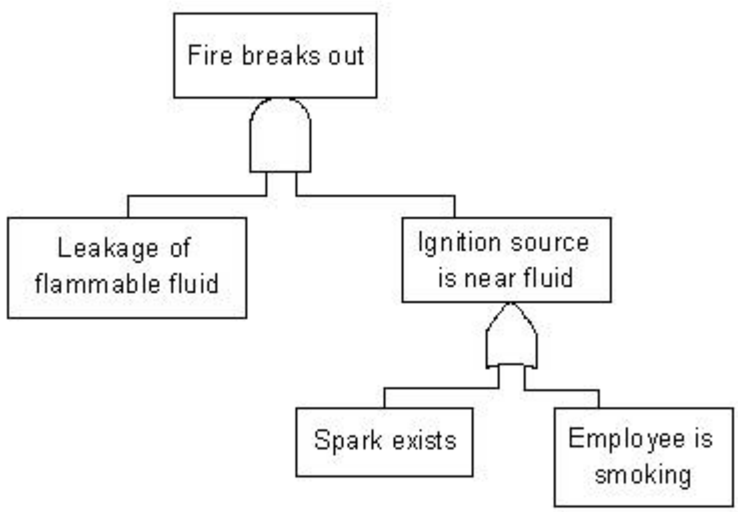


Figure 1 : A fault tree depicting the event "Fire breaks out".

Fault tree can be used in qualitative or quantitative risk analysis. The difference in them is that the qualitative fault tree is looser in structure and does not require use of the same rigorous logic as the formal fault tree. Figure 1 shows a fault tree with top event "Fire breaks out". This method is used in a wide range of industries and there is extensive support in the form of published literature and software packages, such as CARA.

Focus Groups

Focus groups are a form of group interview, an open-ended, structured discussion with a representative group. One or more interviews with 3 to 12 participants are conducted. Although group interviews are often used to collect data from several people simultaneously, focus groups explicitly use group interaction as part of the Page 4/7 method. People are encouraged to talk to one another, asking questions, exchanging anecdotes, and commenting on each others' experiences and points of view.

Forecasts

Forecasts are estimates or predictions of conditions and events in the future based on information and knowledge available at the time of the forecast. Forecasts are updated and reissued based on new information provided. The information is based on the past experience and the expected future.

GO method

It is a Methodology for analysis of dynamic system. The GO method is a success-oriented system analysis that uses seventeen operators to aid in model construction. It was developed by Kaman Sciences Corporation during the 1960s for reliability analysis of electronics for the Department of Defense in U.S

The GO model can be constructed from engineering drawings by replacing system elements with one or more GO operators. Such operators are of three basic types: (1) independent, (2) dependent, and (3) logic. Independent operators are used to model components requiring no input and the independent operators, require at least one input in order to have an output. Logic operators, on the other hand, combine the operators into the success logic of the system being modeled. With the probability data for each independent and dependent operator, the probability of successful operation can then be calculated.

The GO method is used in practical application where the boundary conditions for the system to be modeled are well defined by a system schematic or other design documents. However, the failure modes are implicitly modeled, making it unsuitable for detailed analysis of failure modes beyond the level of component events shown in the system drawing. Furthermore, it does not treat common cause failures nor provide structural information (i.e the minimum cut sets) regarding the system. A brief description of GO flow, which is based on GO method, is documented in literature.

Hazard and Operability studies (HAZOP)

It is qualitative risk analysis method. The HAZOP technique was developed in the early 1970s by Imperial Chemical Industries Ltd. HAZOP can be defined as the application of a formal systematic critical examination of the process and engineering intentions of new or existing facilities to assess the hazard potential that arise from deviation in design specifications and the consequential effects on the facilities as a whole.

This technique is usually performed using a set of guidewords: NO/NOT, MORE OR/LESS OF, AS WELL AS, PART OF REVERSE, AND OTHER THAN. From these guidewords, a scenario that may result in a hazard or an operational problem is identified. Consider the possible flow problems in a process line, the guide word MORE OF will correspond to high flow rate, while that for LESS THAN, low flow rate. The consequences of the hazard and measures to reduce the frequency with which the hazard will occur are then discussed. This technique had gained wide acceptance in the process industries as an effective tool for plant safety and operability improvements.

HAZOPs are structured critical examinations of plant or processes undertaken by an experienced team of company staff in order to identify all possible deviations from an intended design, along with the consequent undesirable effects concerning safety, operability, and the environment. The possible deviations are generated by rigorous questioning, prompted by a series of standard 'guidewords' applied to the intended design.

Hierarchical Holographic Modeling (HHM)

HHM is as systemic approach for risk identification. The HHM methodology is grounded on the premise that in the process of modeling large-scale and complex systems, more than one mathematical or conceptual model is likely to emerge. Each of these models may adopt a specific view. Through HHM, multiple models can be developed and coordinated to capture the essence of the many dimensions, visions, and perspectives of infrastructure systems.

Human Reliability Analysis (HRA)

HRA estimates the likelihood of human actions that may prevent hazardous events not being taken when needed, or other human actions that may cause hazardous events occurring. Both types of action are commonly called 'human errors' in HRA, implying that an action was omitted or taken that adversely influenced safety. Results of HRA's are often used as inputs to PRA's.

Influence Diagram

An influence diagram, also called a relevance diagram, is a visual representation of a decision problem. It offers an intuitive way to identify and display the essential elements, including decisions, uncertainties, and objectives, and how they influence each other.

Management Oversight Risk Tree

It is a Tree based risk analysis technique**.** Management oversight risk tree (MORT) was developed in the early 1970s for the U.S. Energy Research and Development Administration as safety analysis method that would be compatible with complex, goal-oriented management systems. MORT is a diagram which arranges safety program elements in an orderly and logical manner. Its analysis is carried out by means of fault tree, where the top event is "Damage, destruction, other costs, lost production or reduced credibility of the enterprise in the eyes of society". The tree gives an overview of the causes of the top event from management oversights and omissions or from assumed risks or both.

The MORT tree has more than 1500 possible basic events inputed to 100 generic events which have being increasing identified in the fields of accident prevention, administration and management. A generic MORT diagram is included at the end of this report. MORT is used in the analysis or investigation of accidents and events, and evaluation of safety programs. Its usefulness was revealed in literature, "Normal investigations revealed an average of 18 problems (and recommendations). Complementary investigations with MORT analysis revealed additional 20 contributions per case".

Markov Modeling

It is a Methodology for analysis of dynamic system. Markov modeling is a classical modeling technique used for assessing the time-dependent behaviour of many dynamic systems. In a 'Markov chain' processes, transitions between states are assumed to occur only at discrete points in time. On the other hand, in a 'discrete Markov process', transitions between states are allowed to occur at any point in time. For process system, the discrete system states can be defined in terms of ranges of process variables as well as component status.

This methodology also incorporates time explicitly, and can be extended to cover situations where problem parameters are time independent. The state probabilities of the system P (t) in a continuous Markov system analysis are obtained by the solution of a coupled set of first order, constant coefficient differential equations:

$$dP/dt = M.P(t),$$

Where M is the matrix of coefficients whose off-diagonal elements are the transition rate and whose diagonal elements are such that the matrix columns sum to zero. An application of Markov modeling to a hold-up tank problem is discussed in literature, while Pate-Cornell (1993) used the technique to study the fire propagation for a subsystem on board a off-shore platform in.

Monte-Carlo Simulation

Monte-Carlo simulation is a type of "what-if" simulation that uses random numbers to measure the effects of uncertainty on decision-making processes. While traditional what-if reveals what is possible, Monte-Carlo simulation reveals what is probable. Traditional scenario analyses do not include the likelihood of occurrence of a range of possible outcomes, which is the benefit of Monte-Carlo.

Morphological Analysis

This is a method for exploring all the possible solutions to a multi-dimensional, non-quantified problem complex.

Pair-wise Comparisons

Pair-wise analysis is a method for comparing and choosing the most appropriate solution or option. Options are compared against each other on a number of criteria (e.g. performance objectives) to determine the relative order (ranking). The comparisons can be qualitative or quantitative and different weightings can be applied for each individual objective.

PEST (Political, Economic, Socio-Cultural, Technological) Analysis

PEST Analysis is a simple tool to identify all the relevant information in the political, economic, socio-cultural, and technological environment.

Plus-Minus Implications (PMI)

PMI is an improvement of the simple "weighing pros and cons"-technique. All the positive results, negative effects, and possible implications of taking a specific action are written down, before each of the points is assigned a positive or a negative score.

Preliminary Risk Analysis

Preliminary Risk Analysis or hazard analysis is a qualitative technique which involves a disciplined analysis of the event sequences which could transform a potential hazard into an accident. In this technique, the possible undesirable events are identified first and then analysed separately. For each undesirable events or hazards, possible improvements, or preventive measures are then formulated. It ranks the identified accidental events according to their severity and identifies the required hazard controls and follow-up actions.

The result from this methodology provides a basis for determining which categories of hazard should be looked into more closely and which analysis methods are most suitable. Such an analysis also proved valuable in the working environment to which activities lacking safety measures can be readily identified. With the aid of a frequency/ consequence diagram, the identified hazards can then be ranked according to risk, allowing measures to be prioritized to prevent accidents.

Probabilistic Risk Assessment (PRA)

PRA, also called Quantitative Risk Assessment (QRA), is a systematic and comprehensive methodology to evaluate risks associated with every life-cycle aspect of a complex engineered technological entity. It asks what can go wrong with the studied entity or what are the initiators or initiating events, what and how severe are the potential detriments or the consequences of the occurrence of the initiator, and how likely are these undesirable consequences or what are their probabilities or frequencies? The final result of a PRA is given in the form of a risk curve and the associated uncertainties.

Probability and Impact Matrix

A way to determine whether a risk is considered low, moderate, or high by combining the two dimensions of a risk: its probability of occurrence, and its impact on objectives if it occurs.

Quantitative Risk Assessment (QRA),

See Probabilistic Risk Assessment (PRA).

Relevance Diagram

See influence diagram.

Risk Matrix

See Probability and Impact Matrix.

Safety Management Organization Review Technique

It is a Tree based risk analysis technique**.** Safety management organization review technique (SMORT) is a simplified modification of MORT developed in Scandinavia. This technique is structured by means of analysis levels with associated checklists, while MORT is based on a comprehensive tree structure.

Owing to its structured analytical process, SMORT is classified as one of the tree based methodologies.

The SMORT analysis includes data collection based on the checklists and their associated questions, in addition to evaluation of results. The information can be collected from interviews, studies of documents and investigations. This technique can be used to perform detailed investigation of accidents and near misses. It also served well as a method for safety audits and planning of safety measures.

Scenario Analysis

Scenario analysis is a process of analyzing possible future events by considering alternative possible outcomes (scenarios). It is designed to allow improved decision-making by allowing more complete consideration of outcomes and their implications.

Sensitivity Analysis

A quantitative risk analysis and modeling technique used to help determine which risks have the most potential impact. It examines the extent to which the uncertainty of each element affects the objective examined when all other uncertain elements are held at their baseline values. The typical display of results is in the form of a tornado diagram.

Simulation

A simulation uses a model that translates the uncertainties specified at a detailed level into their potential impact on objectives that are expressed. Simulations use computer models and estimates of risk.

SWOT Analysis

This information gathering technique examines the project from the perspective of each project's strengths, weaknesses, opportunities, and threats to increase the breadth of the risks considered by risk management.

Trend Analysis

An analytical technique that uses mathematical models to forecast future outcomes based on historical results. It is a method of determining the variance from a baseline parameter by using prior period's data and projecting how much that parameter's variance from baseline might be at some future point if no changes are made.

Uncertainty Radial Chart

Uncertainty radial charts provide a simple approach for assessing the relative importance of different uncertainties affecting a decision. The type of uncertainty is indicated by the position on the chart, relative to different axes; the strength of uncertainty is indicated by the size of the symbol used; and the relevance of the uncertainty is indicated by the distance of the symbol from the center of the chart.

Chapter V

PERT and CPM

Project Management

Project management is distinguished from production management primarily by the non repetitive nature of the work; a project is usually a one time effort. Although similar work may have been done previously, or may be done in the future. It is not usually repeated in the identical manner such as cars or TV sets being manufactured on a production line. The management of projects is more complicated than the management of a production line due to the following characteristics, generally typical of all projects to a greater or lesser degree.

1. The duration of a project lasts weeks, months, or even years. During such a long period, many changes may occur, most of which are difficult to predict. Such changes may have a significant impact on project costs, technology and resources. The longer the duration of the project, uncertain are the execution times and costs.
2. A project is complex in nature, involving many interrelated activities and participants from both within the organization and outside it (e.g., suppliers, subcontractors).
3. Delays in completion time may be very costly. Penalties for delays may amount to thousands of dollars per day. Completing projects late may result in lost opportunities and ill will as well.
4. Project activities are sequential. Some activities cannot start until others are completed.
5. Projects are typically a unique undertaking, something that has not been encountered previously.

There are some formal tools to aid project management. Two of the best known tools that fill this need are **PERT** (Program Evaluation Review Technique) and **CPM** (Critical Path Method). These are also called arrow diagram, activity network diagram, network diagram, activity chart and node diagram.

Brief History of CPM/PERT

CPM/PERT or Network Analysis as the technique is sometimes called, developed along two parallel streams, one industrial and the other military. CPM was the discovery of M.R.Walker of E.I.Du Pont de Nemours & Co. and J.E.Kelly of Remington Rand in 1957. The computation was designed for the UNIVAC-I computer. The first test was made in 1958, when CPM was applied to the construction of a new chemical plant. In March 1959, the method was applied to a maintenance shut-down at the Du Pont works in Louisville, Kentucky. Unproductive time was reduced from 125 to 93 hours.

PERT was devised in 1958 for the POLARIS missile program by the Program Evaluation Branch of the Special Projects office of the U.S.Navy, helped by the Lockheed Missile Systems division and the Consultant firm of Booz-Allen & Hamilton. The calculations were so arranged so that they could be carried out on the IBM Naval Ordinance Research Computer (NORC) at Dahlgren, Virginia.

The Purpose of PERT/CPM

Due to the complex nature of most projects, it is very difficult to completely innate the delays and the cost overruns. However, with the appropriate management systems for planning, organizing, and controlling, it is possible reduce them to a reasonable level. The problem is that the cost of implementing and executing such systems can exceed their benefits because of the large amount of monitoring and reporting that is required.

The major purpose of PERT and CPM is to objectively identify these critical activities. Further, these techniques can tell us how close the remaining activities are to becoming critical. (This available delay is called slack or float.).

The Advantages of PERT and CPM

Detailed planning: The use of PERT and CPM forces management to plan in detail and to define what must be done to accomplish objectives on time.

Commitments and communications: Management is forced to plan and make commitments regarding execution times and completion dates. The tools also provide for better communication among the various departments in an organization and between suppliers and the client.

Efficient monitoring and control: The number of critical activities in a network (especially in a large one) is only a small portion of the total activities. Identification of the critical activities enables the use of an efficient monitoring system (mainly record-keeping and reports) concentrating only on the critical activities.

Identifying potential problem areas: The critical activities are also more likely to become problem areas. Once identified, contingency plans may be devised.

Proper use of resources: Employing PERT or CPM enables management to use resources more wisely by examination of the overall plan. Resources can he transferred to bottleneck or trouble areas from other activities.

Rescheduling: The tools enable management to follow up and correct deviations from schedule as soon as they are detected, thus minimizing delays.

Government contracts: Several government agencies require the submission of a PERT or CPM plan with bids.

Easily understood: CPM and PERT can be easily understood because they provide a method for visualizing an entire project. Therefore management can explain the tools to supervisors and employees in such a way that the chances of implementation are increased.

Adaptable to computers: PERT and CPM are easily adaptable to computer use. Large projects can be planned by computers in seconds is even capable of diagramming the networks.

Tools for decision making: PERT and CPM allow management to check the effectiveness and efficiency of alternative ways of executing projects by examining possible trade-offs among resources (usually time and cost).

Assess probability of completion (in PERT only): The probabilities of successfully meeting deadlines, finishing early, or finishing late can be assessed by the use of PERT.

Cost-time trade-offs (in CPM only): CPM enables management to evaluate trade-offs between the cost of executing a job in a normal way or expediting activities (called crashing) at a higher cost so as to finish earlier.

CPM and PERT: Similarities and Differences

Both CPM and PERT (Program Evaluation and Review Technique) provide the user with project management tools to plan, monitor, and update their project as it progresses. There are many similarities and differences between the two, however.

Similarities between PERT and CPM

- Both follow the same steps and use network diagrams
- Both are used to plan the scheduling of individual activities that make up a project
- They can be used to determine the earliest/latest start and finish times for each activity.

- Extensions of both PERT and CPM allow the user to manage other resources in addition to time and money, to trade off resources, to analyze different types of schedules, and to balance the use of resources.

Differences between PERT and CPM

- PERT is probabilistic whereas CPM is deterministic
  (In PERT, three estimates are used to form a weighted average of the expected completion time, based on a probability distribution of completion times. Therefore, PERT is considered a probabilistic tool. In CPM, there is only one estimate of duration; that is, CPM is a deterministic tool.)
- In CPM, estimates of activity duration are based on historical data
- In PERT, estimates are uncertain and we talk of ranges of duration and the probability that an activity duration will fall into that range
- CPM concentrates on Time/Cost trade off.
  (CPM allows an explicit estimate of costs in addition to time. Thus, while PERT is basically a tool for planning and control of time, CPM can be used to control both the time and the cost of the project.)

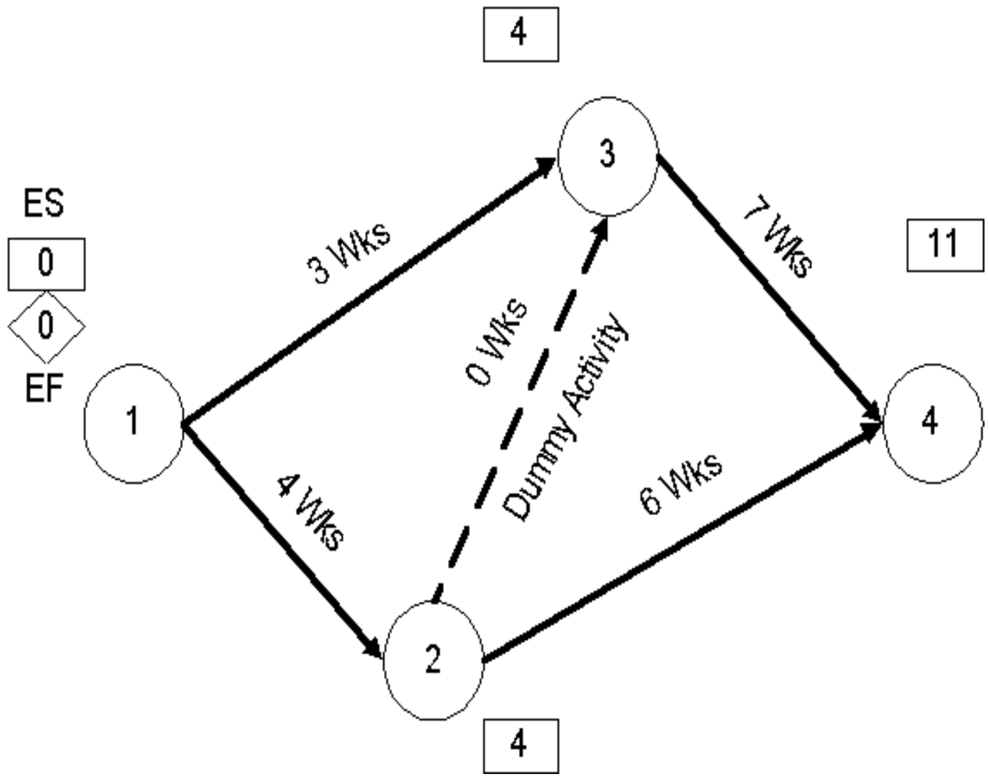
PERT terminology and conventions

Conventions

- A PERT chart is a tool that facilitates decision making;
- Two consecutive events in a PERT chart are linked by activities, which are conventionally represented as arrows in the PERT diagram.
- The events are presented in a logical sequence and no activity can commence until its immediately preceding event is completed.
- The planner decides which milestones should be PERT events and also decides their "proper" sequence.
- A PERT chart may have multiple pages with many sub-tasks.

Terminology

- Project: A project is a collection of activities and events with a definable beginning and a definable end (the goal). For example: getting a college degree, patenting an invention, building a bridge, or installing new machinery.
- Network: A network is a logical and chronological set of activities and events, graphically illustrating relationships among the various activities and events of the project.



- A PERT event: is a point that marks the start or completion of one (or more) tasks. It consumes no time, and uses no resources. It marks the completion of one (or more) tasks, and is not "reached" until all of the activities leading to that event have been completed. An event is a specific accomplishment at a recognizable point in time; a milestone, a checkpoint; for example, passing a course at a university, submission of engineering drafts, completion of a span on a bridge, or the arrival of a new machine. An event can be viewed as a goal attained, while the activities leading to it can be viewed as the means of achieving it. For example events 1, 2, 3 and 4 in the above diagram.
- A predecessor event: an event (or events) that immediately precedes some other event without any other events intervening. It may be the consequence of more than one activity. For example event 1 is predecessor to events 2 and 3 and events 2 and 3 are predecessor to event 4 in the above diagram.
- A successor event: an event (or events) that immediately follows some other event without any other events intervening. It may be the consequence of more than one activity. For example event 2 is a successor event to event 1.
- A PERT activity: is the actual performance of a task. It consumes time, it requires resources (such as labour, materials, space, machinery), and it can be understood as representing the time, effort, and resources required to move from one event to another. A PERT activity cannot be

completed until the event preceding it has occurred. Examples of activities are: studying for an examination, designing a part, connecting bridge girders, or training an employee. For example activities 1-2, 1-3, 3-4, 2-4 in the above diagram.

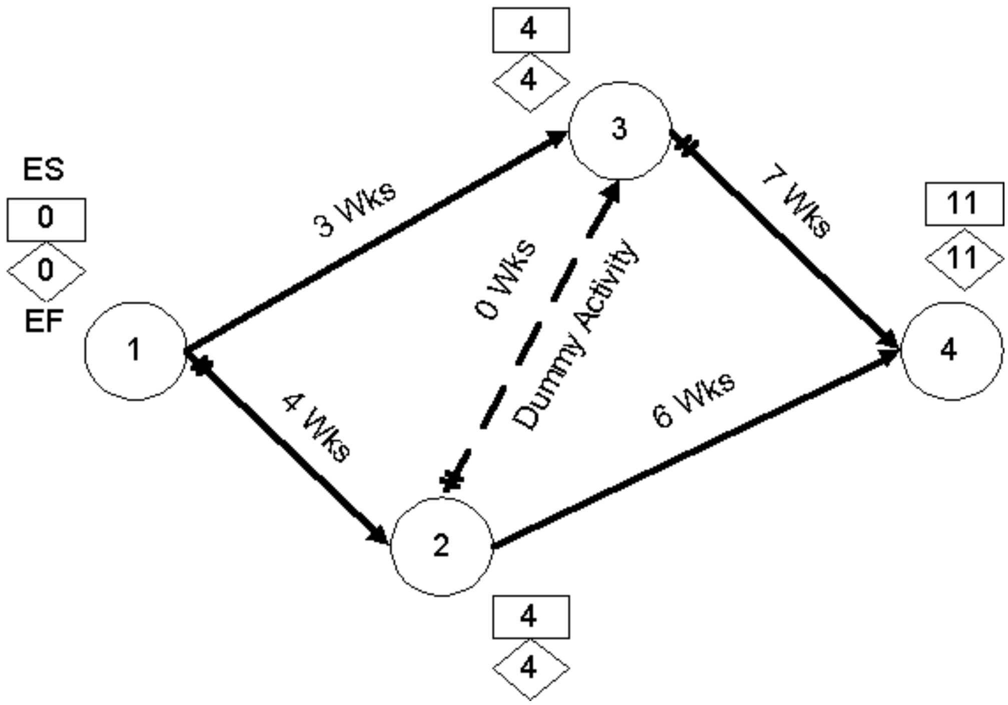
- Parallel or concurrent activities: Two or more activities which can be started at the same time are called parallel activities. For example activities between nodes 1 and 2 and nodes 1 and 3 are not dependent on the completion of one to start the other and can be undertaken simultaneously. These activities are called parallel or concurrent activities.
- Dependent or serial activities: Those activities which must be completed in sequence are called dependent or serial activities. In the diagram, for example, the activities between nodes 1, 2, and 4 must be completed in sequence. These are called dependent or serial activities.
- Dummy activities: Activities that must be completed in sequence but that don't require resources or completion time are considered to have event dependency. These are represented by dotted lines with arrows and are called dummy activities. For example, the dashed arrow linking nodes 2 and 3 indicates that the activity 2-3 must be completed before the activity 3-4 can take place.
- Critical activity**:** A critical activity is an activity that, if even slightly delayed, will hold up the scheduled completion date of the entire project. For example activities 1-2 and 3-4 in the above diagram.
- Path: A path is a series of adjacent activities leading from one event to another. For example path 1-2-4, path 1-3-4 and path 1-2-3-4 in the above diagram.
- Critical Path: the longest possible continuous pathway taken from the initial event to the terminal event. It is the sequence of critical activities that forms a continuous path between the start of a project and its completion.It determines the total calendar time required for the project; and, therefore, any time delays along the critical path will delay the reaching of the terminal event by at least the same amount. For example path 1-2-3-4 in the above diagram.
- Optimistic time (O): the minimum possible time required to accomplish a task, assuming everything proceeds better than is normally expected.
- Pessimistic time (P): the maximum possible time required to accomplish a task, assuming everything goes wrong (but excluding major catastrophes).
- Most likely time (M): the best estimate of the time required to accomplish a task, assuming everything proceeds as normal.
- Expected time (T_E): the best estimate of the time required to accomplish a task, assuming everything proceeds as normal (the implication being that the expected time is the average time the task would require if the task were repeated on a number of occasions over an extended period of time).

$T_E = (O + 4M + P) \div 6$

- Earliest start time: It is the earliest time by which an activity can be started. For example the earliest start time at event 1 is zero or the earliest start time for activity 1-2 and activity 1-3 is zero. However, at Event 3, we have to evaluate two predecessor activities - Activity 1-3 and Activity 2-3, both of which are predecessor activities. Activity 1-3 gives us an Earliest Start time of 3 weeks at Event 3. However, Activity 2-3 also has to be completed before Event 3 can begin. Along this route, the Earliest Start time would be 4+0=4. The rule is to take the longer (bigger) of the two Earliest Starts. So the Earliest Start time at event 3 is 4.Similarly, at Event 4, we find we have to evaluate two predecessor activities - Activity 2-4 and Activity 3-4. Along Activity 2-4, the Earliest Start at Event 4 would be 10 wks, but along Activity 3-4, the Earliest Start at Event 4 would be 11 wks. Since 11 wks is larger than 10 wks, we select it as the Earliest Start at Event 4.
- Earliest finish time: It is the earliest time by which an activity can be completed. It is calculated as EFT = EST+ duration of an activity. In above example EFT for activity 1-2 is 4 weeks and for activity 1-3 is 3 weeks.
- Latest finish time: It is the latest time by which an activity must be completed to complete the project in time. It is calculated by moving in backward direction in a network diagram as shown below:

The Backward Pass - Latest Finish Time Rule

To make the Backward Pass, we begin at the sink or the final event and work backwards to the first event.



At Event 3 there is only one activity, Activity 3-4 in the backward pass, and we find that the value is 11-7 = 4 weeks. However at Event 2 we have to evaluate 2 activities, 2-3 and 2-4. We find that the backward pass through 2-4 gives us a value of 11-6 = 5 while 2-3 gives us 4-0 = 4. We take the **smaller value** of 4 on the backward pass.

- Latest start time: It is the latest possible time by which an activity can start without delaying the project completion date. It is calculated as LST = (LFT – duration of that activity).
- Lead time: the time by which a predecessor event must be completed in order to allow sufficient time for the activities that must elapse before a specific PERT event is reached to be completed.
- Lag time: the earliest time by which a successor event can follow a specific PERT event.
- Slack: the slack of an event is a measure of the excess time and resources available in achieving this event. Positive slack (+) would indicate ahead of schedule; negative slack would indicate behind schedule; and zero slack would indicate on schedule.

Tabulation & Analysis of Activities

We are now ready to tabulate the various events and calculate the Earliest and Latest Start and Finish times. We are also now ready to compute the SLACK or TOTAL FLOAT, which is defined as the difference between the Latest Start and Earliest Start.

Event	**Duration**(Weeks)	**Earliest Start**	**Earliest Finish**	**Latest Start**	**Latest Finish**	**Total Float**
1-2	4	0	4	0	4	0
2-3	0	4	4	4	4	0
3-4	7	4	11	4	11	0
1-3	3	0	3	1	4	1
2-4	6	4	10	5	11	1

- The Earliest Start is the value in the rectangle near the tail of each activity
- The Earliest Finish is = Earliest Start + Duration
- The Latest Finish is the value in the diamond at the head of each activity
- The Latest Start is = Latest Finish - Duration

There are two important types of Float or Slack. These are Total Float and Free Float.

TOTAL FLOAT is the spare time available when all preceding activities occur at the **earliest** possible times and all succeeding activities occur at the **latest** possible times.

- Total Float = Latest Start - Earliest Start

Activities with zero Total float are on the Critical Path

FREE FLOAT is the spare time available when all preceding activities occur at the **earliest** possible times and all succeeding activities occur at the **earliest** possible times.

When an activity has zero Total float, Free float will also be zero.

There are various other types of float (Independent, Early Free, Early Interfering, Late Free, Late Interfering), and float can also be negative. We shall not go into these situations at present for the sake of simplicity and be concerned only with Total Float for the time being.

Drawing the Network

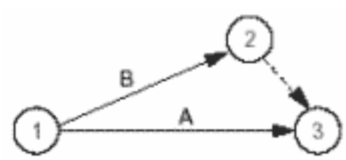
1. List all the necessary tasks in the project or process. One convenient method is to write each task on the top half of a card or sticky note. Across the middle of the card, draw a horizontal arrow pointing right.

2. Determine the correct sequence of the tasks. Do this by asking three questions for each task:
    a. Which tasks must happen before this one can begin?
    b. Which tasks can be done at the same time as this one?
    c. Which tasks should happen immediately after this one?
3. It can be useful to create a table with four columns —prior tasks, this task, simultaneous tasks, following tasks.
4. Diagram the network of tasks. Time should flow from left to right and concurrent tasks should be vertically aligned.
5. Between each two tasks, draw circles for "events." An event marks the beginning or end of a task. Thus, events are nodes that separate tasks.
6. Look for three common problem situations and redraw them using "dummies" or extra events. A dummy is an arrow drawn with dotted lines used to separate tasks that would otherwise start and stop with the same events or to show logical sequence. Dummies are not real tasks.

Problem situations:

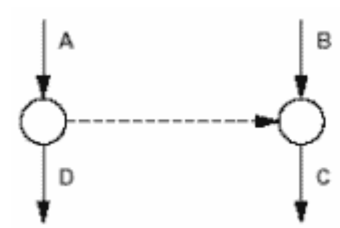
Two simultaneous tasks start and end at the same event. **Solution:** Use a dummy and an extra event to separate them. In Figure 1, event 2 and the dummy between 2 and 3 have been added to separate tasks A and B.

Figure 1: Dummy separating simultaneous tasks



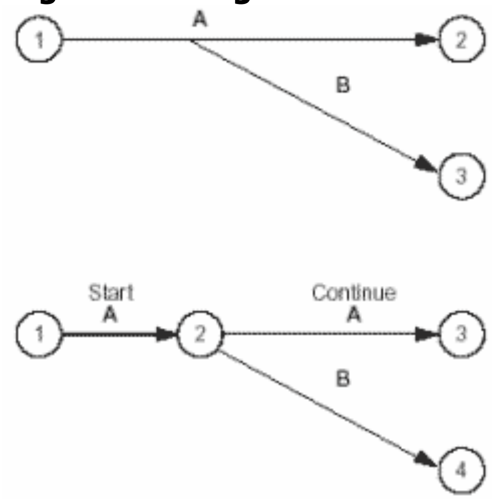
Task C cannot start until both tasks A and B are complete; a fourth task, D, cannot start until A is complete, but need not wait for B. (Figure 2.)

Figure 2: Dummy keeping sequence correct



Solution: Use a dummy between the end of task A and the beginning of task C.

Figure 3: Using an extra event

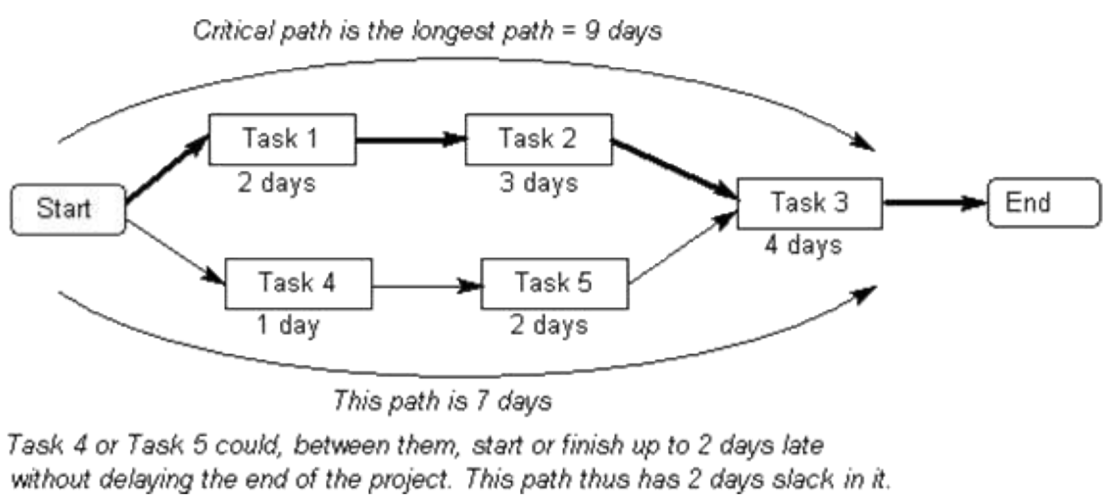


A second task can be started before part of a first task is done. **Solution:** Add an extra event where the second task can begin and use multiple arrows to break the first task into two subtasks. In Figure 3, event 2 was added, splitting task A.

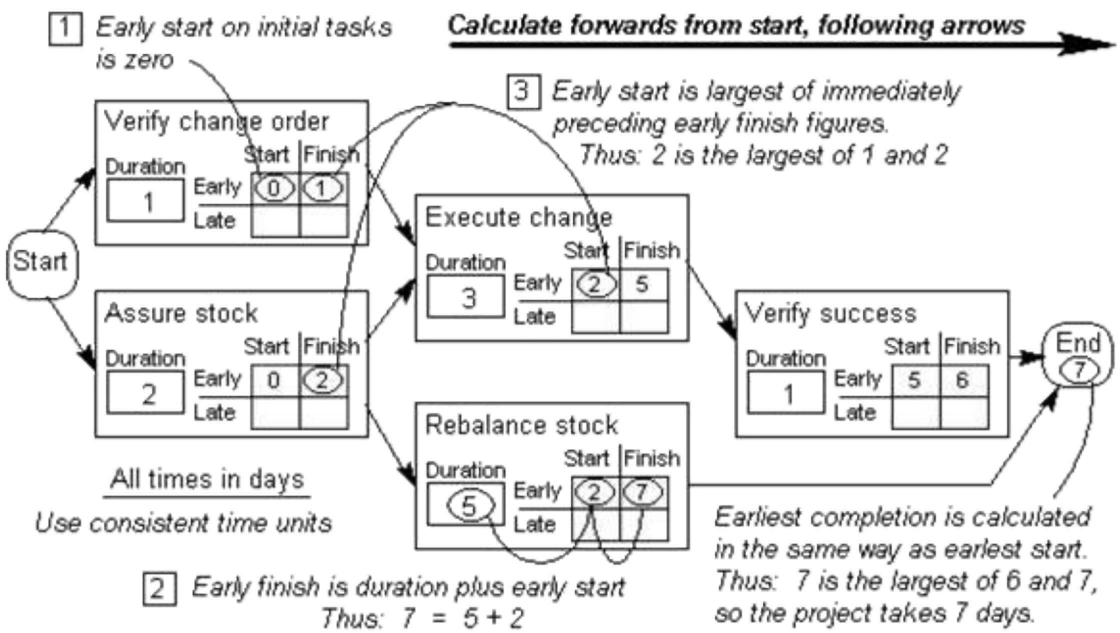
10. When the network is correct, label all events in sequence with event numbers in the circles. It can be useful to label all tasks in sequence, using letters.

Scheduling: Critical Path Method (CPM)

11. Determine task times—the best estimate of the time that each task should require. Use one measuring unit (hours, days or weeks) throughout, for consistency. Write the time on each task's arrow.
12. Determine the "critical path," the longest path from the beginning to the end of the project. Mark the critical path with a heavy line or color. Calculate the length of the critical path: the sum of all the task times on the path.

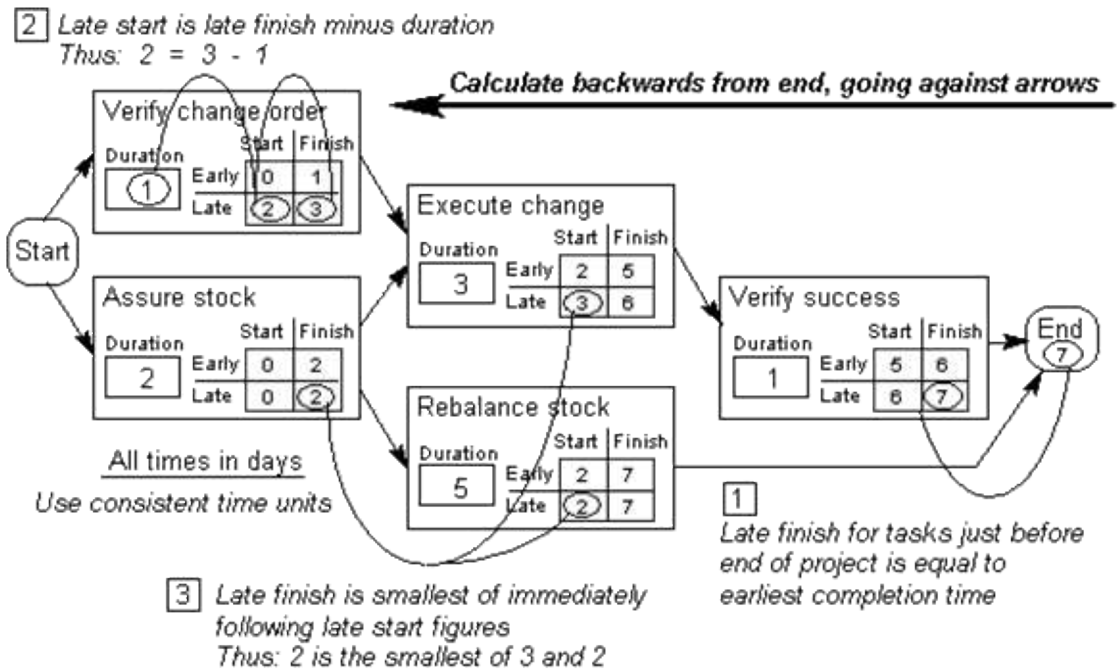


13. Calculate the earliest times each task can start and finish, based on how long preceding tasks take. These are called earliest start (ES) and earliest finish (EF). Starting with the tasks at the beginning of the diagram, complete the early start and early finish for each task in turn, following the arrows to the next task, as in the figure below. The early start of a task is the same as the early finish of the preceding task. If there is more than one predecessor task, then there are several possible early start figures. Select the largest of these. The early finish for each task is equal to the early start plus the duration of the task. The final calculation is for the earliest completion time for the project. This is calculated in the same way as the early start date.
For each task:
Earliest start (ES) = the largest EF of the tasks leading into this one
Earliest finish (EF) = ES + task time for this task



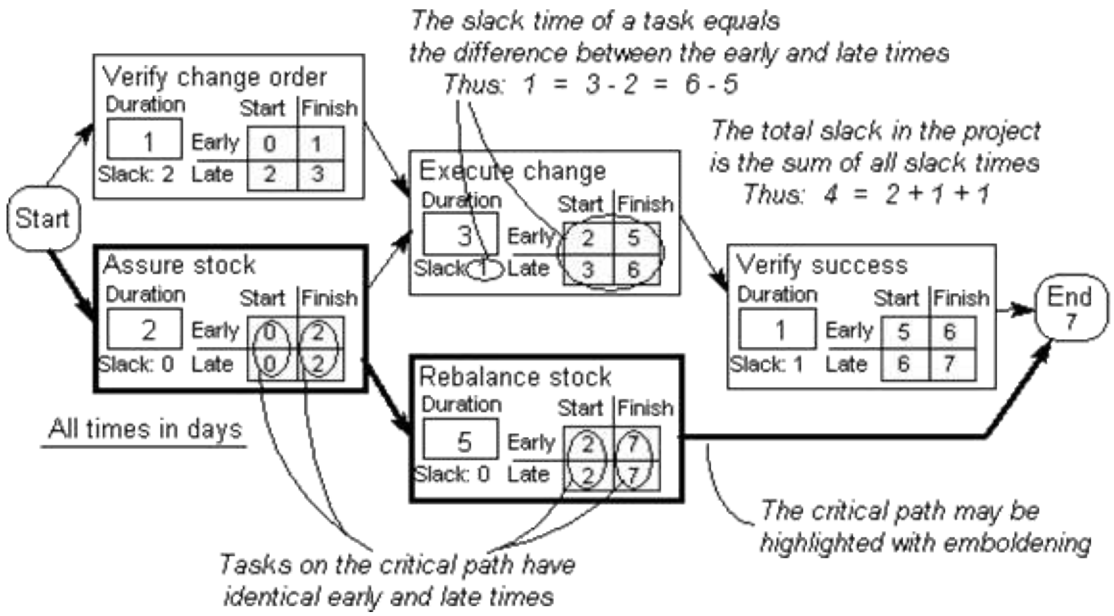
14. Calculate the latest times each task can start and finish without upsetting the project schedule, based on how long later tasks will take. These are called latest start (LS) and latest finish (LF). Starting with the tasks at the end of the diagram, calculate the late start and late finish for each task in turn, following the arrows in the reverse direction to the previous task, as in the diagram below. The late finish is the same as the late start of the succeeding task (for the final tasks in the project, this is equal to the earliest completion date). If there is more than one successor task, then there are several possible late figures. Select the smallest of these. The late start for each task is the late finish minus the duration of the task. The final calculation is for the earliest completion time for the project. This is calculated in the same way as the early start date.

Latest finish (LF) = the smallest LS of all tasks immediately following this one
Latest start (LS) = LF – task time for this task



15. Calculate slack times for each task and for the entire project. Total slack is the time a job could be postponed without delaying the project schedule. Now find the slack time (or 'float') for each task by subtracting the early start from the late start. The slack time is the amount of time the task can be slipped by without affecting the end date of the process. The critical path can now be identified as all paths through the network where the slack time is zero.

Total slack = LS – ES = LF – EF
Free slack is the time a task could be postponed without affecting the early start of any job following it.
Free slack = the earliest ES of all tasks immediately following this one – EF



PERT/CPM Exercises

(1) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	4
B	-	3
C	-	7
D	A	9
E	B	6
F	C	8
G	D,E	2
H	F	4

---

(2) What effect would the following change have on the network in (1) above?

Activity	Precedence	Duration (Days)
I	G	6

---

(3) What effect would the following change have on the network in (1) above?

Activity	Precedence	Duration (Days)
F	B	8

(4) What effect would the following change have on the network in (1) above?

Activity	Precedence	Duration (Days)
E	B,C	6
I	G,F	6

(5) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	6
B	A	6
C	A	4
D	A	9
E	B,C	6
F	E	7
G	E	6
H	F,G	4
I	D	6

(6) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	6
B	-	2
C	A	3
D	D	3
E	C	4
F	D,A	3
G	E	6
H	E,F	4
I	G,H	1
J	I	2

(7) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	3
B	A	5
C	A	6
D	B	8
E	A,C	6
F	D	3
G	E	5
H	D,G	

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(8) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	8
B	-	12
C	A	2
D	B	4
E	B,C	4
F	B,C	16
G	C	7
K	F	2
L	F,G	2
M	E,G	3

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(9) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	8
B	-	8
C	A	5
D	A	9
E	A	6
F	B,C	8
G	C	7
K	F	7
L	F,G	10
M	E,G	6

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(10) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	14
B	A	22
C	B	10
D	B	16
E	B	12
F	C	10
G	C	6
H	F,G	8
I	D,E,H	24
J	I	16

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(11) Draw a PERT/CPM network, identify float times and the Critical Path for the following project:

Activity	Precedence	Duration (Days)
A	-	1
B	A	3
C	B	2
D	B	2
E	B	4
F	D	1
G	C,F	4
H	F	2
I	F	1
J	C,E,H,I	8
K	G,J	2
L	K	2
M	G,J	4
N	L,M	2

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(12) Draw a PERT/CPM network, identify float times and the Critical Path for the following project: (ASA, Summer 1993.)

Activity	Precedence	Duration (Days)
A	-	5
B	-	9
C	A	2

D	A	4
E	A	6
F	B	9
G	C,D,E	8
H	E,F	8
I	F	4
J	G	9
K	G,H	6
L	I	5

(13) Draw a PERT/CPM network, identify float times and the Critical Path for the following project: (ASA, Summer 1994.)

Activity	Precedence	Duration (Days)
A	-	3
B	-	7
C	A	9
D	A,B	4
E	C	7
F	C,D	5
G	E	6
H	A,B	3
I	D,H	6
J	F	4