MASTER OF BUSINESS ADMINISTRATION

PROJECT MANAGEMENT

STUDY GUIDE

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1. INTRODUCTION TO PROJECT MANAGEMENT STUDY GUIDE

Welcome to ***PROJECT MANAGEMENT***

This module forms a part of the *Masters in Business Administration* (MBA) programme. Upon successful completion of the module you will be able to competently and strategically support and apply project management practices in your role as a manager or leader in the context of emerging and dynamic markets.

Designed and developed for Regent Business School, the module offers students an in-depth look at how today's businesses turn to project management to consistently deliver business results. New projects are constantly being developed as organisations seek new ways to reduce costs, improve processes, increase productivity, and build their bottom line. Managing these diverse projects along with their people, resources, technology, and communication is a difficult endeavour for which the risk of failure is often far too high. An effective solution, created to establish a more centralised management structure for large projects and groups of projects, is project management.

This module contains theory, frameworks, models and exercises on project management. It provides students with an organisational framework to manage people, procedures, and tools to achieve effective project management by leveraging project management standards, allocating resources, establishing consistent performance measures, and reducing duplication of efforts. It is recommended that each section of the module be studied in conjunction with the prescribed textbook and recommended reading.

2. Structure of the Study Guide

This Study Guide is structured in as follows:

Introduction to the Study Guide		*Provides an overview of the Study Guide and how to use it.*
Chapter 1	Project Management Concepts	*This part of the Study Guide details what you are required to learn, each section:* • *Specific learning outcomes* • *Essential reading (textbooks and journal articles)* • *An overview of relevant theory* • *Questions for reflection*
Chapter 2	Project Planning Techniques	
Chapter 3	Scheduling Techniques	
Chapter 4	Monitoring, Evaluation and Reporting	
Chapter 5	Project Cost Management	
Chapter 6	Project Risk Management	
Chapter 7	Quality Management	
Case study	Factory for Expansion	

3. Structure of Each Chapter

Each chapter is structured as follows:

- Specific Learning Outcomes
- Essential (Prescribed) Reading
- Brief Overview of Relevant Theory
- Questions for Reflection

3.1 Specific Learning Outcomes

These are listed at the beginning of each section. It details the specific outcomes that you will be able to competently demonstrate on successful completion of the learning that each particular section requires.

3.2 Essential (Prescribed) Reading

Your essential (prescribed) reading comprises the following:

- ***Prescribed Textbook***

  Kerzner, H (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Wiley & Sons, Inc., Hoboken, New Jersey

- ***Recommended Textbook***

  - Clements, J.P and Guido, J. (2012).Successful Project Management. 6thEdition. Cengage Learning
  - Heizer, J. and Render, B. (2012). “Project Management” (Ch. 3) in Operations Management. 10th Edition. New Jersey: Pearson Education Inc.PMI (2013). A Guide to the Project Management Body of Knowledge (PMBOK Guide). 3rd Edition. Pennsylvania: Project Management Institute.
  - Schwalbe, K. (2009). Introduction to Project Management. 2nd Edition. Boston: Cengage Learning.

3.3 Brief Overview of Relevant Theory

Each section contains a very brief overview of theory relevant to the particular Project Management topic. The purpose of the overview is to introduce you to some of the general and emerging market issues regarding each topic. Once you have read the overview, you need to explore the subject matter further by reading the prescribed textbooks and journal articles listed under “*Essential Reading*” for each section.

3.4 Questions for Reflection

At the end of every section there are questions for reflection. You need to attempt these on completion of your study of the entire section. The questions are designed to enable you to reflect on what you have learnt, and to consider how your new knowledge should be applied in practice.

3.5 Assessments

The formal assessment of Project Management takes the form of an assignment and an exam.

INTEGRATED EXIT LEVEL OUTCOMES & ASSESSMENT CRITERIA

The high exit level outcomes for this essential module, and their associated assessment criteria, are listed below. Specific outcomes for each learning area are detailed at the beginning of each learning area section that follows. The following are the learning outcomes for the module. By the end of the module, the student should be able to:

- Develop strategies using effective project management tools and techniques.
- Establish a set of principles and guidelines for effective project management.
- Design and develop appropriate communication tools and risk management techniques relevant to the project management environment.
- Institutionalise leadership expertise and networking skills required to successfully manage and lead project management teams and project stakeholders.
- Assess the impact and significance of relationships related to the constraints of the project management environment.
- Utilise project quality concepts and apply tools used to monitor and advance project quality at different stages of the project life cycle.
- Formulate effective project scheduling techniques

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CHAPTER 1

PROJECT MANAGEMENT CONCEPTS

Chapter 1 PROJECT MANAGEMENT CONCEPTS

CHAPTER OUTCOMES

After studying this chapter, the student will be able to:

- Explain the project life-cycle phases
- Critically analyse the responsibility of the project manager in dealing with stakeholders and how stakeholders can affect the outcome of the project
- Identify specific objective to be completed within certain specifications
- Distinguish between human and nonhuman resources (i.e., money, people, equipment)
- Comprehend barriers to project management implementation and how to overcome them

Essential Reading

Textbooks:

- Kerzner, H (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Wiley & Sons, Inc., Hoboken, New Jersey, Chapter One and Two

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1.1 Introduction

Overview of Project Management

Project management is coming under increasing importance as executives across the world face increasingly complex challenges. These challenges vary in complexity and some of the contributing factors are as follows:

- Escalation of salaries
- Escalation of prices of raw materials
- Increased unionization
- Increased pressure from shareholders for higher performance as well as greater accountability and responsibility.
- The ever- increasing threat of high inflation.
- Recessions and more volatile economic cycles.
- Lack of borrowing power from financial institutions.

The end results of the above factors have led to early retirement, layoffs and an overall reduction in manpower through attrition Kerzner, (2013: 28). Therefore, the core solution to the above- mentioned problems involves better control and use of existing corporate resources by looking inwards at existing resources rather than outwards for the solution. Executives are therefore looking at the way resources are managed and project management is one of the techniques being utilized. Project management is characterized by methods of restructuring management and adapting special management techniques. Project management is being applied in a variety of sectors ranging from defense, construction, pharmaceuticals to banking. The project management methodology requires a departure from the traditional organizational forms which is hierarchical in structure.

1.2 What is project management

Kerzner, (2013: 28) states that in order to understand project management it is necessary to first gain an understanding of what is a project. A project can be defined as a set of activities and tasks that:

- Have a specific objective to be completed within certain specifications
- Have defined start and end dates
- Have funding limits (if applicable)
- Consume human and nonhuman resources (i.e., money, people, equipment)
- Are multifunctional (i.e., cut across several functional lines)

Project management involves five process groups identified as:

- **Project initiation**
  - Selection of the best project given resource limits
  - Recognizing the benefits of the project
  - Preparation of the documents to sanction the project
  - Assigning of the project manager
- **Project planning**
  - Definition of the work requirements
  - Definition of the quality and quantity of work
  - Definition of the resources needed
  - Scheduling the activities
  - Evaluation of the various risks
- **Project execution**
  - Negotiating for the project team members
  - Directing and managing the work
  - Working with the team members to help them improve

- **Project monitoring and control**
  - Tracking progress

    - Comparing actual outcome to predicted outcome
    - Analyzing variances and impacts
    - Making adjustments
- **Project closure**
    - Verifying that all of the work has been accomplished
    - Contractual closure of the contract
    - Financial closure of the charge numbers
    - Administrative closure of the paperwork

Successful project management can then be defined as having achieved the project objectives:

- Within time
- Within cost
- At the desired performance/technology level
- While utilizing the assigned resources effectively and efficiently
- Accepted by the customer

The potential benefits from project management are:

- Identification of functional responsibilities to ensure that all activities are accounted for, regardless of personnel turnover
- Minimizing the need for continuous reporting
- Identification of time limits for scheduling
- Identification of a methodology for trade-off analysis
- Measurement of accomplishment against plans
- Early identification of problems so that corrective action may follow
- Improved estimating capability for future planning
- Knowing when objectives cannot be met or will be exceeded

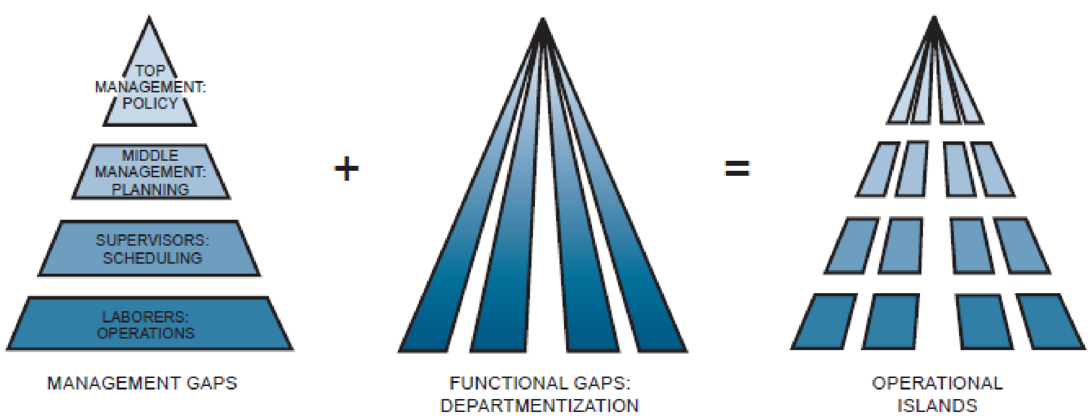
Unfortunately, the benefits cannot be achieved without overcoming obstacles such as:

- Project complexity
- Customer's special requirements and scope changes
- Organizational restructuring

● Project risks
● Changes in technology
● Forward planning and pricing

Project management is designed to make better use of existing resources by getting work to flow horizontally as well as vertically within the company. This approach does not really destroy the vertical, bureaucratic flow of work but simply requires that line organizations talk to one another horizontally so work will be accomplished more smoothly throughout the organization. The vertical flow of work is still the responsibility of the line managers. The horizontal flow of work is the responsibility of the project managers, and their primary effort is to communicate and coordinate activities horizontally between the line organizations. Although this might be the way that some companies are running their projects, this is not project management.

Figure 1.1



Adapted from Kerzner, (2013: 31)

The above figure shows how many companies are structured. There are always "class or prestige" gaps between various levels of management. There are also functional gaps between working units of the organization.

If we superimpose the management gaps on top of the functional gaps, we find that companies are made up of small operational islands that refuse to communicate with one another for fear that giving up information may strengthen their opponents. The project manager's responsibility is to get these islands to communicate cross-functionally toward common goals and objectives.

Figure 1.2

Overview of project management adapted from Kerzner, (2013: 32)

Figure 1.2 is an illustrative representation of project management. The objective of the figure is to show that project management is designed to manage or control company resources on a given activity, within time, within cost, and within performance. Time, cost, and performance are the constraints on the project. If the project is to be accomplished for an outside customer, then the project has a fourth constraint: good customer relations.

The reader should immediately realize that it is possible to manage a project internally within time, cost, and performance and then alienate the customer to such a degree that no further business will be forthcoming.

Executives often select project managers based on who the customer is and what kind of customer relations will be necessary.

Projects exist to produce deliverables. The person ultimately assigned as the project manager may very well be assigned based upon the size, nature, and scope of the deliverables. Deliverables are outputs, or the end result of either the completion of the project or the end of a life-cycle phase of the project. Deliverables are measurable, tangible outputs and can take such form as:

- Hardware Deliverables: These are hardware items, such as a table, a prototype, or a piece of equipment.
- Software Deliverables: These items are similar to hardware deliverables but are usually paper products, such as reports, studies, handouts, or documentation. Some companies do not differentiate between hardware and software deliverables.
- Interim Deliverables: These items can be either hardware or software deliverables and progressively evolve as the project proceeds. An example might be a series of interim reports leading up to the final report.

1.3 Determining Project Success

Project success is dependent on the completion of an activity that falls within the time, cost and performance constraints. The following factors are used to determine the success of a project:

- Within the allocated time period
- Within the budgeted cost
- At the proper performance or specification level
- With acceptance by the customer/user
- With minimum or mutually agreed upon scope changes
- Without disturbing the main work flow of the organization
- Without changing the corporate culture

Scope changes have the potential to destroy a project and must be kept minimal. Necessary scope changes must be approved by both the project manager and the end customer. Project manager must also allow for concessions/ tradeoffs regarding the workflow of the project. Project managers tend to regard themselves as operating individually from the parent organization however this is not always possible and the project manager should abide by the guidelines, policies, procedures and directives of the parent organization.

1.4 Relationship between a project manager and line manager

According to Kerzner, (2013: 34) an organization has six resources as stipulated below:

- Money
- Manpower
- Equipment
- Facilities
- Materials
- Information Technology

The project manager does not control any of the above resources directly, these resources are controlled by line managers. Project managers must, therefore, negotiate with line managers for all project resources. When we say that project managers control project resources, we really mean that they control those resources (which are temporarily loaned to them) through line managers.
Today, we have a new breed of project manager. Years ago, virtually all project managers were engineers with advanced degrees. These people had a command of technology rather than merely an understanding of technology.
If the line manager believed that the project manager did in fact possess a command of technology, then the line manager would allow the assigned functional employees to take direction from the project manager. The result was that project managers were expected to manage people.

Most project managers today have an understanding of technology rather than a command of technology. As a result, the accountability for the success of the project is now viewed as shared accountability between the project manager and all affected line managers.

With shared accountability, the line managers must now have a good understanding of project management. Project managers are now expected to focus more so on managing the project's deliverables rather than providing technical direction to the project team. Management of the assigned resources is more often than not a line function. Another important fact is that project managers are treated as though they are managing part of a business rather than simply a project, and as such are expected to make sound business decisions as well as project decisions. Project managers must understand business principles.

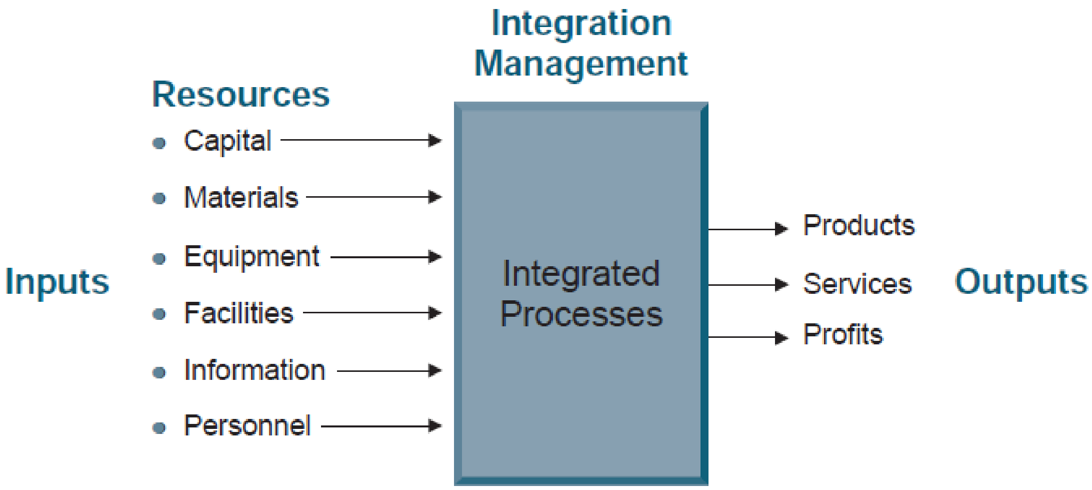
1.5 Describing the project manager's role

The project manager according to Kerzner, (2013: 38) is responsible for coordinating and integrating activities across multiple functional lines. The integration of these activities include:

- Integrating the activities necessary to develop a project plan
- Integrating the activities necessary to execute the plan
- Integrating the activities necessary to make changes to the plan

These integrative responsibilities are shown in Figure 1.3 where the project manager must convert the inputs (i.e., resources) into outputs of products, services, and ultimately profits. In order to do this, the project manager needs strong communicative and interpersonal skills, must become familiar with the operations of each line organization, and must have knowledge of the technology being used.

Figure 1.3



Adapted from Kerzner, (2013: 38)

The project manager's job is not an easy one. Project managers may have increasing responsibility, but very little authority. This lack of authority can force them to "negotiate" with upper-level management as well as functional management for control of company resources. They may often be treated as outsiders by the formal organization. In the project environment, everything seems to revolve about the project manager.

Although the project organization is a specialized, task-oriented entity, it cannot exist apart from the traditional structure of the organization. The project manager, therefore, must walk the fence between the two organizations. The term interface management is often used for this role, which can be described as managing relationships:

- Within the project team
- Between the project team and the functional organizations
- Between the project team and senior management
- Between the project team and the customer's organization, whether an internal or external organization.

To be effective as a project manager, an individual must have management as well as technical skills. Because engineers often consider their careers limited in the functional disciplines, they look toward project management and project engineering as career path opportunities. But becoming a manager entails learning about psychology, human behavior, organizational behavior, interpersonal relations, and communications. MBA programs have come to the rescue of individuals desiring the background to be effective project managers.

1.6 The project life cycle

Table 1.1 shows the typical life-cycle phases that an organization goes through to implement project management. In the first phase, the Embryonic Phase, the organization recognizes the apparent need for project management. This recognition normally takes place at the lower and middle levels of management where the project activities actually take place. The executives are then informed of the need and assess the situation.

There are six driving forces that lead executives to recognize the need for project management:

- Capital projects
- Customer expectations
- Competitiveness
- Executive understanding
- New project development
- Efficiency and effectiveness

Table 1.1: Life Cycle Phases for Project Management

Embryonic Phase	Executive Management Acceptance Phase	Line Management Acceptance Phase	Growth Phase	Maturity Phase
• Recognize need	• Visible executive support	• Line management support	• Use of life-cycle phases	• Development of a management cost/ schedule control system
• Recognize benefits	• Executive understanding of project management	• Line management commitment	• Development of a project management methodology	• Integrating cost and schedule control
• Recognize applications	• Project sponsorship	• Line management education	• Commitment to planning	• Developing an educational program to enhance project management skills
• Recognize what must be done	• Willingness to change way of doing business	• Willingness to release employees for project management training	• Minimization of "creeping scope"	
			• Selection of a project tracking system	

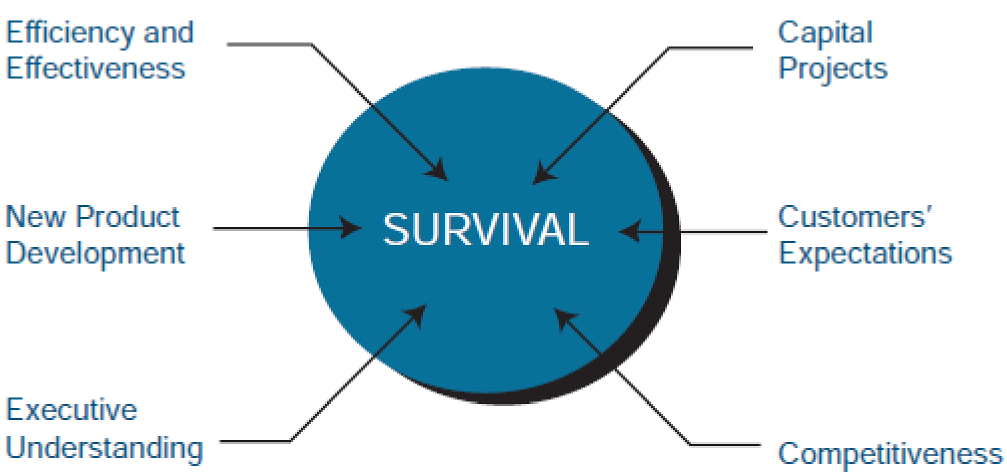
Adapted from Kerzner, (2013: 46)

Manufacturing companies are driven to project management because of large capital projects or a multitude of simultaneous projects. Executives soon realize the impact on cash flow and that slippages in the schedule could end up idling workers.

Companies that sell products or services, including installation, to their clients must have good project management practices. These companies are usually non–project-driven but function as though they were project-driven. These companies now sell solutions to their customers rather than products. It is almost impossible to sell complete solutions to customers without having superior project management practices because what you are actually selling is your project management expertise. There are two situations where competitiveness becomes the driving force: internal projects and external (outside customer) projects. Internally, companies get into trouble when the organization realizes that much of the work can be outsourced for less than it would cost to perform the work themselves. Externally, companies get into trouble when they are no longer competitive on price or quality, or simply cannot increase their market share.

Executive understanding is the driving force in those organizations that have a rigid traditional structure that performs routine, repetitive activities. These organizations are quite resistant to change unless driven by the executives. This driving force can exist in conjunction with any of the other driving forces. New product development is the driving force for those organizations that are heavily invested in Research and Development R&D activities. Given that only a small percentage of R&D projects ever make it into commercialization where the R&D costs can be recovered, project management becomes a necessity. Project management can also be used as an early warning system that a project should be cancelled. Efficiency and effectiveness, as driving forces, can exist in conjunction with any other driving forces. Efficiency and effectiveness take on paramount importance for small companies experiencing growing pains. Project management can be used to help such companies remain competitive during periods of growth and to assist in determining capacity constraints. Because of the inter-relatedness of these driving forces, some people contend that the only true driving force is survival.

Figure 1.4



Adapted from Kerzner, (2013: 47)

This is illustrated generically in Figure 1.4. Non–project-driven and hybrid organizations move quickly to maturity if increased internal efficiencies and effectiveness are needed.

Competitiveness is the slowest path because these types of organizations do not recognize that project management affects their competitive position directly. For project-driven organizations, the path is reversed. Competitiveness is the name of the game and the vehicle used is project management. Once the organization perceives the need for project management, it enters the second life-cycle phase of Table 1.1, Executive Acceptance. Project management cannot be implemented rapidly in the near term without executive support. Furthermore, the support must be visible to all.

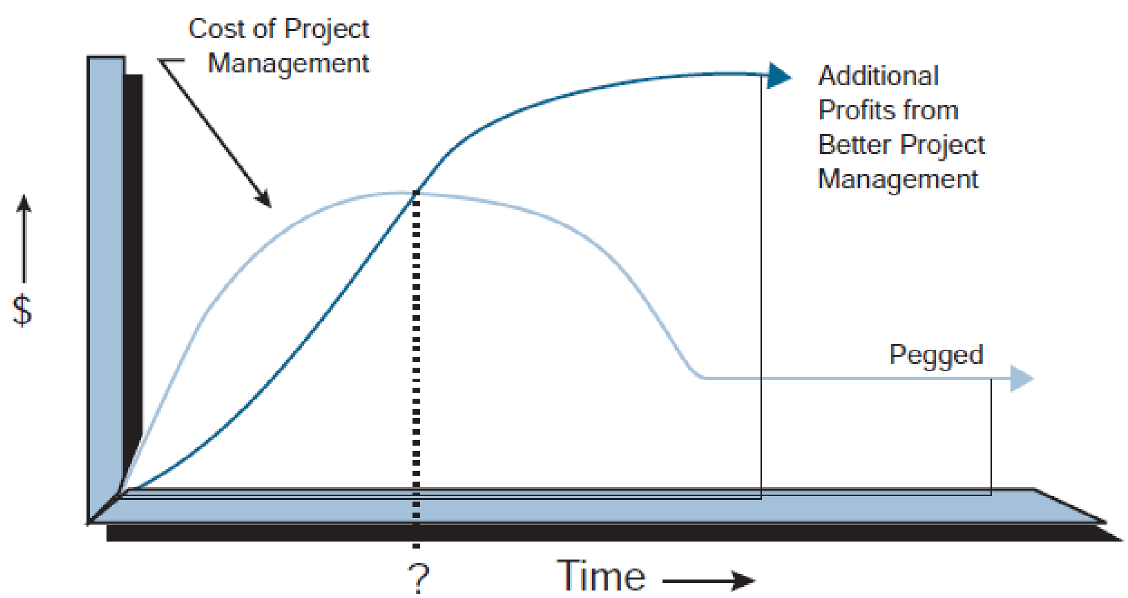
The third life-cycle phase is Line Management Acceptance. It is highly unlikely that any line manager would actively support the implementation of project management without first recognizing the same support coming from above. Even minimal line management support will still cause project management to struggle.

The fourth life-cycle phase is the Growth Phase, where the organization becomes committed to the development of the corporate tools for project management. This includes the project management methodology for planning, scheduling, and controlling, as well as selection of the appropriate supporting software. Portions of this phase can begin during earlier phases. The fifth life-cycle phase is Maturity. In this phase, the organization begins using the tools developed in the previous phase. Here, the organization must be totally dedicated to project management. The organization must develop a reasonable project management curriculum to provide the appropriate training and education in support of the tools, as well as the expected organizational behavior. By the 1990s, companies finally began to recognize the benefits of project management.

Management is just the starting point. The question now becomes, “How long will it take us to achieve these benefits?”

This can be partially answered from Figure 1.5. In the beginning of the implementation process, there will be added expenses to develop the project management methodology and establish the support systems for planning, scheduling, and control. Eventually, the cost will level off and become pegged. The question mark in Figure 1–5 is the point at which the benefits equal the cost of implementation. This point can be pushed to the left through training and education.

Figure 1.5



Adapted from Kerzner, (2013: 49)

1.7 Conclusion

In the past decade, organizations have become more aware of the fact that America's most formidable weapon is its manufacturing ability, and yet more and more work seems to be departing for Southeast Asia and the Far East. If America and other countries are to remain competitive, then survival may depend on the manufacturing of a quality product and a rapid introduction into the marketplace.

Today, companies are under tremendous pressure to rapidly introduce new products because product life cycles are becoming shorter. As a result, organizations no longer have the luxury of performing work in series. Concurrent or simultaneous engineering is an attempt to accomplish work in parallel rather than in series. This requires that marketing, R&D, engineering, and production are all actively involved in the early project phases and making plans even before the product design has been finalized. This concept of current engineering will accelerate product development, but it does come with serious and potentially costly risks, the largest one being the cost of rework. Almost everyone agrees that the best way to reduce or minimize risks is for the organization to plan better. Since project management is one of the best methodologies to foster better planning, it is little wonder that more organizations are accepting project management as a way of life.

REFLECTION QUESTIONS

1.1In the project environment, cause-and-effect relationships are almost always readily apparent. Good project management will examine the effect in order to better understand the cause and possibly prevent it from occurring again. Below are causes and effects. For each one of the effects, analyze the possible cause or causes that may have existed to create this situation

1.2 Consider an organization that is composed of upper-level managers, middle- and lower level managers, and laborers. Which of the groups should have first insight that an organizational restructuring toward project management may be necessary?

1.3 How would you defend the statement that a project manager must help himself?

1.4 Will project management work in all companies? If not, identify those companies in which project management may not be applicable and defend your answers.

1.5 Evaluate whether in a project organization there might be a conflict in opinions over whether the project managers or functional managers contribute to profits?

1.6 What attributes should a project manager have? Can an individual be trained to become a project manager? If a company were changing over to a project management structure, would it be better to promote and train from within or hire from the outside?

1.7 Do you think that functional managers would make good project managers?

1.8 What types of projects might be more appropriate for functional management rather than
project management, and vice versa?

1.9 Do you think that there would be a shift in the relative degree of importance of the following
terms in a project management environment as opposed to a traditional management environment?

a. Time management

b. Communications

c. Motivation

1.9 Classical management has often been defined as a process in which the manager does not necessarily perform things for himself, but accomplishes objectives through others in a group situation.

Does this definition also apply to project management?

CHAPTER 2

PROJECT PLANNING TECHNIQUES

Chapter 2 Project Planning Techniques

CHAPTER OUTCOMES

Upon completion of this Chapter, students should be able to:

- Comprehend the proposal preparation
- Critically analyse participants' roles in the planning process
- Distinguish between a scope and project scope
- Examine project specifications
- Formulate a scope statement
- Construct a statement of work

Essential Reading

Textbooks:

- Kerzner, H (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Wiley & Sons, Inc., Hoboken, New Jersey, Chapter Eleven

2.1Introduction

Planning is an integral part of the project manager’s duties and also includes integrating and executing the plans. All projects necessitate formal, detailed planning due to their short duration and prioritized control of resources. The integration of planning activities is therefore crucial because each functional unit may develop its own planning documentation in isolation of other functional units.
Planning can be defined as the function of selecting the organizations objectives and establishing policies, procedures and programmes for implementing them. Planning is a pre- determined course of action that entails a fore casted environment. The requirements of the project set’s the milestones and if these milestones are not achievable the project manager may have to develop alternatives. The project manager is therefore central to successful project planning. A key objective of central planning is to completely define all work required usually through a scope of work document so that the plan is readily identifiable to each project participant. This is necessary because:

- If the task is well understood prior to being performed, much of the work can be preplanned.
- If the task is not understood, then during the actual task execution more knowledge is gained that, in turn, leads to changes in resource allocations, schedules, and priorities.
- The more uncertain the task, the greater the amount of information that must be processed in order to ensure effective performance.
  Kerzner, (2013: 412)

These considerations are important in a project environment because each project can be different from the others, requiring a variety of different resources, but having to be performed under time, cost, and performance constraints with little margin for error. Figure 2.1 identifies the type of project planning required to establish an effective monitoring and control system. The boxes at the top represent the planning activities, and the lower boxes identify the “tracking” or monitoring of the planned activities.

There are two proverbs that affect project planning:

● Failing to plan is planning to fail.

● The primary benefit of not planning is that failure will then come as a complete surprise rather than being preceded by periods of worry and depression as stated by Kerzner, (2013: 438).

Without proper planning, programs and projects can start off "on the wrong foot." Consequences of poor planning include:

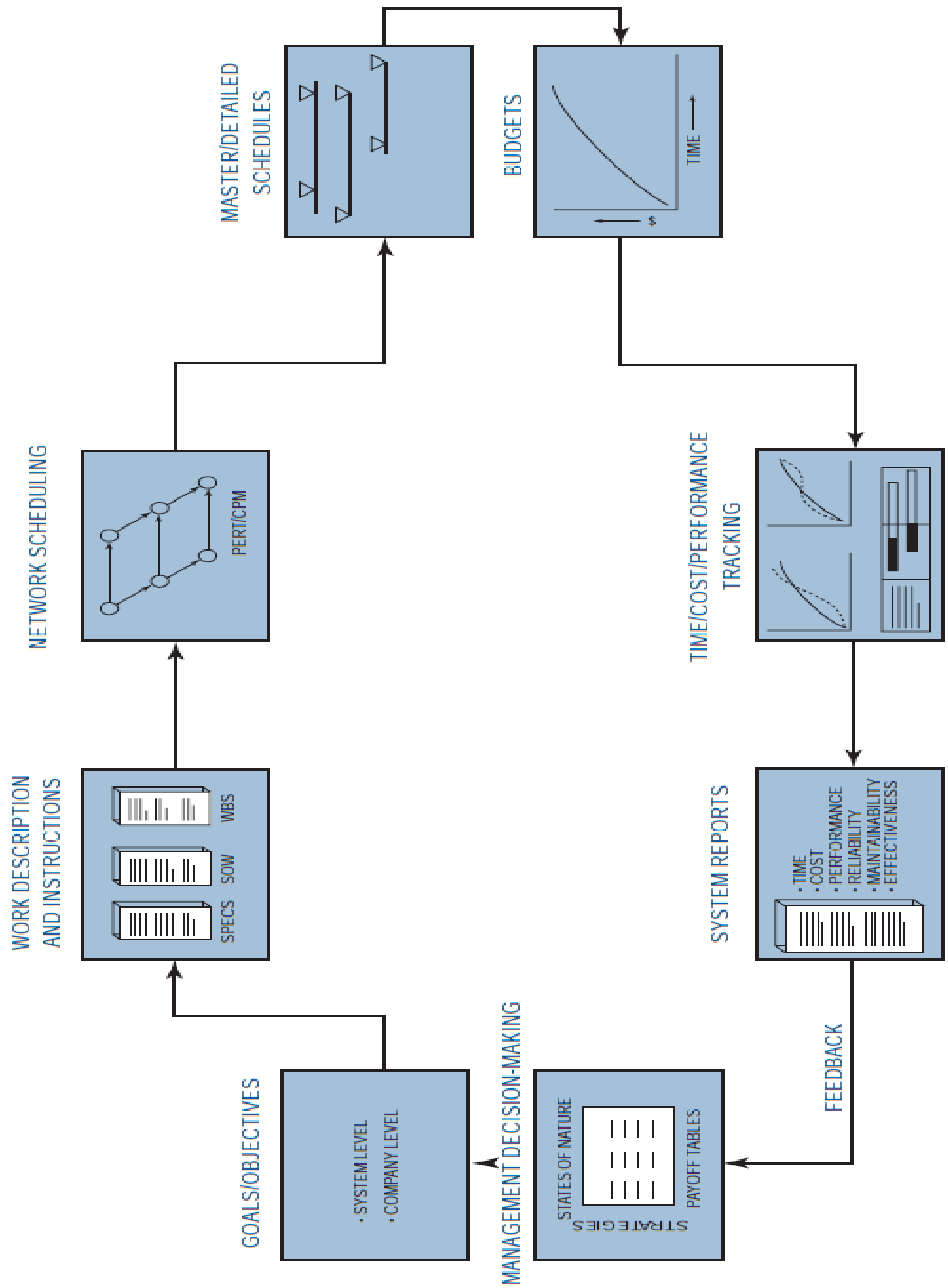
● Project initiation without defined requirements
● Wild enthusiasm
● Disillusionment
● Chaos
● Search for the guilty
● Punishment of the innocent
● Promotion of the nonparticipants

There are four basic reasons for project planning:

● To eliminate or reduce uncertainty
● To improve efficiency of the operation
● To obtain a better understanding of the objectives
● To provide a basis for monitoring and controlling work

Planning is a continuous process of making entrepreneurial decisions with an eye to the future, and methodically organizing the effort needed to carry out these decisions. Furthermore, systematic planning allows an organization of set goals. The alternative to systematic planning is decision-making based on history. This generally results in reactive management leading to crisis management, conflict management, and firefighting.

Figure 2.1 Project Planning adapted from Kerzner,(2013: 413)



2.2 Understanding and validating the assumptions

Planning begins with an understanding of the assumptions. Quite often, the assumptions are made by marketing and sales personnel and then approved by senior management as part of the project selection and approval process. The expectations for the final results are based upon the assumptions made.

Why is it that, more often than not, the final results of a project do not satisfy senior management's expectations? At the beginning of a project, it is impossible to ensure that the benefits expected by senior management will be realized at project completion. While project length is a critical factor, the real culprit is changing assumptions.

Assumptions must be documented at project initiation using the project charter as a possible means. Throughout the project, the project manager must revalidate and challenge the assumptions. Changing assumptions may mandate that the project be terminated or redirected toward a different set of objectives.

A project management plan is based upon the assumptions described in the project charter. But there are additional assumptions made by the team that are inputs to the project management plan. One of the primary reasons companies use a project charter is that project managers were most often brought on board well after the project selection process and approval process were completed. As a result, project managers were needed to know what assumptions were considered. These are assumptions about the external environmental conditions that can affect the success of the project, such as interest rates, market conditions, changing customer demands and requirements, changes in technology, and even government policies.

2.3 General Planning Concepts

Planning is determining what needs to be done, by whom, and by when, in order to fulfill one's assigned responsibility. There are nine major components of the planning phase:

1. Objective: a goal, target, or quota to be achieved by a certain time
2. Program: the strategy to be followed and major actions to be taken in order to
3. achieve or exceed objectives
4. Schedule: a plan showing when individual or group activities or accomplishments will be started and/or completed
5. Budget: planned expenditures required to achieve or exceed objectives
6. Forecast: a projection of what will happen by a certain time
7. Organization: design of the number and kinds of positions, along with corresponding duties and responsibilities, required to achieve or exceed objectives
8. Policy: a general guide for decision-making and individual actions
9. Procedure: a detailed method for carrying out a policy
10. Standard: a level of individual or group performance defined as adequate or acceptable.

An item that has become important in recent years is documenting assumptions that go into the objectives or the project/subsidiary plans. As projects progress, even for short term projects, assumptions can change because of the economy, technological advances, or market conditions. These changes can invalidate original assumptions or require that new assumptions be made. These changes could also mandate that projects be canceled.

Companies are now validating assumptions during gate review meetings. Project charters now contain sections for documenting assumptions. Several of these factors require additional comment. Forecasting what will happen may not be easy, especially if predictions of environmental reactions are required.

For example, planning is customarily defined as either strategic, tactical, or operational. Strategic planning is generally for five years or more, tactical can be for one to five years, and operational is the here and now of six months to one year. Although most projects are operational, they can be considered as strategic, especially if spin-offs or follow-up work is promising. Forecasting also requires an understanding of strengths and weaknesses as found in:

- The competitive situation
- Marketing
- Research and development
- Production
- Financing
- Personnel
- The management structure

If project planning is strictly operational, then these factors may be clearly definable. However, if strategic or long-range planning is necessary, then the future economic outlook can vary, say, from year to year, and re-planning must be done at regular intervals because the goals and objectives can change.

The last three factors, policies, procedures, and standards, can vary from project to project because of their uniqueness. Each project manager can establish project policies, provided that they fall within the broad limits set forth by top management.

Project policies must often conform closely to company policies, and are usually similar in nature from project to project. Procedures, on the other hand, can be drastically different from project to project, even if the same activity is performed. For example, the signing off of manufacturing plans may require different signatures on two selected projects even though the same end-item is being produced.

Planning varies at each level of the organization. At the individual level, planning is required so that cognitive simulation can be established before irrevocable actions are taken.

At the working group or functional level, planning must include:

- Agreement on purpose
- Assignment and acceptance of individual responsibilities
- Coordination of work activities
- Increased commitment to group goals
- Lateral communications

At the organizational or project level, planning must include:

- Recognition and resolution of group conflict on goals
- Assignment and acceptance of group responsibilities
- Increased motivation and commitment to organizational goals
- Vertical and lateral communications
- Coordination of activities between groups

The logic of planning requires answers to several questions in order for the alternatives and constraints to be fully understood.

A list of questions would include:

   ➢ Prepare environmental analysis

- Where are we?
- How and why did we get here?

   ➢ Set objectives

- Is this where we want to be?
- Where would we like to be? In a year? In five years?

   ➢ List alternative strategies

- Where will we go if we continue as before?
- Is that where we want to go?
- How could we get to where we want to go?

   ➢ List threats and opportunities

- What might prevent us from getting there?

● What might help us to get there?

- Prepare forecasts

● Where are we capable of going?

● What do we need to take us where we want to go?

- Select strategy portfolio

● What is the best course for us to take?

● What are the potential benefits?

● What are the risks?

- Prepare action programs

● What do we need to do?

● When do we need to do it?

● How will we do it?

● Who will do it?

- Monitor and control

● Are we on course? If not, why?

● What do we need to do to be on course?

● Can we do it?

One of the most difficult activities in the project environment is to keep the planning on target. These procedures can assist project managers during planning activities:

● Let functional managers do their own planning. Too often operators are operators, planners are planners, and never the twain shall meet.

● Establish goals before you plan. Otherwise short-term thinking takes over.

● Set goals for the planners. This will guard against the nonessentials and places your effort where there is payoff.

● Stay flexible. Use people-to-people contact, and stress fast response.

● Keep a balanced outlook. Don’t overreact, and position yourself for an upturn.

● Welcome top-management participation. Top management has the capability to make or break a plan, and may well be the single most important variable.

● Beware of future spending plans. This may eliminate the tendency to underestimate.

- Test the assumptions behind the forecasts. This is necessary because professionals are generally too optimistic. Do not depend solely on one set of data.

2.4 Project Planning in the Life Cycle Phases

Project planning takes place at two levels. The first level is the corporate cultural approach; the second method is the individual's approach. The corporate cultural approach breaks the project down into life-cycle phases.

The life-cycle phase approach is not an attempt to put handcuffs on the project manager but to provide a methodology for uniformity in project planning. Many companies, including government agencies, prepare checklists of activities that should be considered in each phase. These checklists are for consistency in planning. The project manager can still exercise his own planning initiatives within each phase.

A second benefit of life-cycle phases is control. At the end of each phase there is a meeting of the project manager, sponsor, senior management, and even the customer, to assess the accomplishments of this life-cycle phase and to get approval for the next phase. These meetings are often called critical design reviews, "on-off ramps," and "gates." In some companies, these meetings are used to firm up budgets and schedules for the follow -on phases. In addition to monetary considerations, life-cycle phases can be used for manpower deployment and equipment/facility utilization. Some companies go so far as to prepare project management policy and procedure manuals where all information is subdivided according to life-cycle phasing. Life-cycle phase decision points eliminate the problem where project managers do not ask for phase funding, but rather ask for funds for the whole project before the true scope of the project is known. Several companies have even gone so far as to identify the types of decisions that can be made at each end-of-phase review meeting.

They include:

- Proceed with the next phase based on an approved funding level
- Proceed to the next phase but with a new or modified set of objectives
- Postpone approval to proceed based on a need for additional information
- Terminate project

Consider a company that utilizes the following life-cycle phases:

- Conceptualization
- Feasibility
- Preliminary planning
- Detail planning
- Execution
- Testing and commissioning

The conceptualization phase includes brainstorming and common sense and involves two critical factors: (1) identify and define the problem, and (2) identify and define potential solutions.

In a brainstorming session, all ideas are recorded and none are discarded. The brainstorming session works best if there is no formal authority present and if it lasts thirty to sixty minutes. Sessions over sixty minutes will produce ideas that may resemble science fiction.

The feasibility study phase considers the technical aspects of the conceptual alternatives and provides a firmer basis on which to decide whether to undertake the project.

The purpose of the feasibility phase is to:

- Plan the project development and implementation activities.
- Estimate the probable elapsed time, staffing, and equipment requirements.
- Identify the probable costs and consequences of investing in the new project.

If practical, the feasibility study results should evaluate the alternative conceptual solutions along with associated benefits and costs.

The objective of this step is to provide management with the predictable results of implementing a specific project and to provide generalized project requirements. This, in the form of a feasibility study report, is used as the basis on which to decide whether to proceed with the costly requirements, development, and implementation phases.

User involvement during the feasibility study is critical. The user must supply much of the required effort and information, and, in addition, must be able to judge the impact of alternative approaches. Solutions must be operationally, technically, and economically feasible.

Much of the economic evaluation must be substantiated by the user. Therefore, the primary user must be highly qualified and intimately familiar with the workings of the organization and should come from the line operation.

The feasibility study also deals with the technical aspects of the proposed project and requires the development of conceptual solutions. Considerable experience and technical expertise are required to gather the proper information, analyze it, and reach practical conclusions.

Improper technical or operating decisions made during this step may go undetected or unchallenged throughout the remainder of the process. In the worst case, such an error could result in the termination of a valid project—or the continuation of a project that is not economically or technically feasible. In the feasibility study phase, it is necessary to define the project’s basic approaches and its boundaries or scope.

A typical feasibility study checklist might include:

- Summary level
- Evaluate alternatives

- Evaluate market potential
- Evaluate cost effectiveness
- Evaluate producibility
- Evaluate technical base
- Detail level
- A more specific determination of the problem
- Analysis of the state-of-the-art technology
- Assessment of in-house technical capabilities
- Test validity of alternatives
- Quantify weaknesses and unknowns
- Conduct trade-off analysis on time, cost, and performance
- Prepare initial project goals and objectives
- Prepare preliminary cost estimates and development plan

The end result of the feasibility study is a management decision on whether to terminate the project or to approve its next phase. Although management can stop the project at several later phases, the decision is especially critical at this point, because later phases require a major commitment of resources. All too often, management review committees approve the continuation of projects merely because termination at this point might cast doubt on the group's judgment in giving earlier approval.

The decision made at the end of the feasibility study should identify those projects that are to be terminated. Once a project is deemed feasible and is approved for development, it must be prioritized with previously approved projects waiting for development (given a limited availability of capital or other resources). As development gets under way, management is given a series of checkpoints to monitor the project's actual progress as compared to the plan.

The third life-cycle phase is either preliminary planning or "defining the requirements."

This is the phase where the effort is officially defined as a project. In this phase, we should consider the following:

- General scope of the work
- Objectives and related background
- Contractor’s tasks
- Contractor end-item performance requirements
- Reference to related studies, documentation, and specifications
- Data items (documentation)
- Support equipment for contract end-item
- Customer-furnished property, facilities, equipment, and services
- Customer-furnished documentation
- Schedule of performance
- Exhibits, attachments, and appendices

These elements can be condensed into four core documents. Also, it should be noted that the word “customer” can be an internal customer, such as the user group or your own executives.

The table below shows the percentage of direct labor that can be spent in each phase:

Table 2.1

Phase	Percent of Direct Labor Dollars
Conceptualization	5
Feasibility study	10
Preliminary planning	15
Detail planning	20
Execution	40
Commissioning	10

Adapted from Kerzner, (2013: 420)

From the above table it is evident that at least 50% of the direct labour hours and dollars is spent before execution.

2.5 Evaluating and constructing a proposal

A project manager writes a proposal based on future work, this takes place during the feasibility phase where the organization decides whether to bid on the job. The following four ways highlight how proposal preparation can occur:

- Project manager prepares entire proposal. This occurs frequently in small companies. In large organizations, the project manager may not have access to all available data, some of which may be company proprietary, and it may not be in the best interest of the company to have the project manager spend all of his time doing this.

● Proposal manager prepares entire proposal. This can work as long as the project manager is allowed to review the proposal before delivery to the customer and feels committed to its direction.

● Project manager prepares proposal but is assisted by a proposal manager. This is common, but again places tremendous pressure on the project manager.

● Proposal manager prepares proposal but is assisted by a project manager. This is the preferred method. The proposal manager maintains maximum authority and control until such time as the proposal is sent to the customer, at which point the project manager takes charge. The project manager is on board right from the start, although his only effort may be preparing the technical volume of the proposal and perhaps part of the management volume.

2.6 Starting the project (Kick- Off meetings)

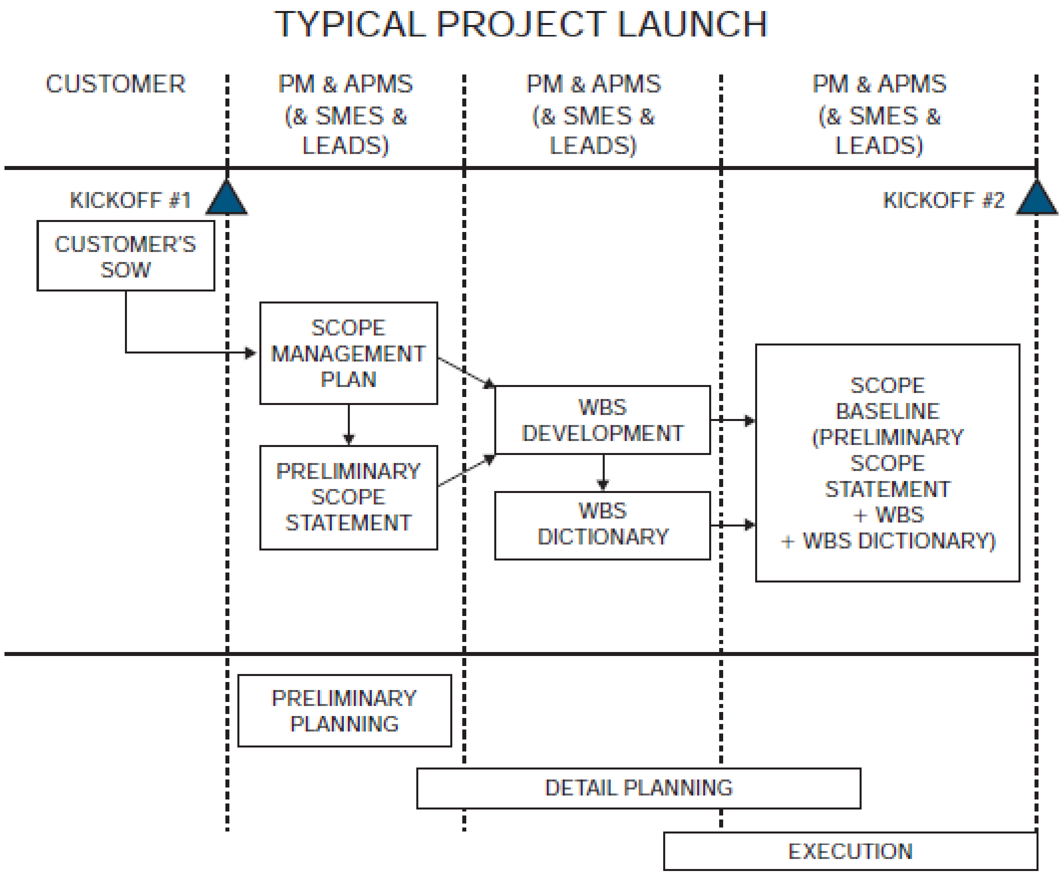
A launch of a project begins with a kick off meeting involving the major stakeholders responsible for planning, including the project manager. The typical launch of a project begins with a kickoff meeting involving the major players responsible for planning, including the project manager, assistant project managers for certain areas of knowledge, subject matter experts (SME), and functional leads. A typical sequence is shown in Figure 2.2. There can be multiple kickoff meetings based upon the size, complexity, and time requirements for the project. The major players are usually authorized by their functional areas to make decisions concerning timing, costs, and resource requirements.

Some of the items discussed in the initial kickoff meeting include:

- Wage and salary administration, if applicable
- Letting the employees know that their boss will be informed as to how well or how poorly they perform
- Initial discussion of the scope of the project including both the technical objective and the business objective
- The definition of success on this project
- The assumptions and constraints as identified in the project charter
- The project's organizational chart (if known at that time)
- The participants' roles and responsibilities

For a small or short-term project, estimates on cost and duration may be established in the kickoff meeting. In this case, there may be little need to establish a cost estimating schedule. But where the estimating cycle is expected to take several weeks, and where inputs will be required from various organizations and/or disciplines, an essential tool is an estimating schedule. In this case, there may be a need for a pre-kickoff meeting simply to determine the estimates. The minimum key milestones in a cost estimating schedule are (1) a "kick-off" meeting; (2) a "review of ground rules" meeting; (3) "resources input and review" meeting; and (4) summary meetings and presentations.

Figure 2.2



Adapted from Kerzner,(2013: 422)

2.7 Project Planning

Successful project management, whether in response to an in-house project or a customer request, must utilize effective planning techniques. The first step is understanding the project objectives. These goals may be to develop expertise in a given area, to become competitive, to modify an existing facility for later use, or simply to keep key personnel employed.

The objectives are generally not independent; they are all interrelated, both implicitly and explicitly. Many times it is not possible to satisfy all objectives. At this point, management must prioritize the objectives as to which are strategic and which are not.

Typical problems with developing objectives include:

- Project objectives/goals are not agreeable to all parties.
- Project objectives are too rigid to accommodate changing priorities.
- Insufficient time exists to define objectives well.
- Objectives are not adequately quantified.
- Objectives are not documented well enough.
- Efforts of client and project personnel are not coordinated.
- Personnel turnover is high.

Once the objectives are clearly defined, four questions must be considered:

- What are the major elements of the work required to satisfy the objectives, and how are these elements interrelated?
- Which functional divisions will assume responsibility for accomplishment of these objectives and the major-element work requirements?
- Are the required corporate and organizational resources available?
- What are the information flow requirements for the project?

If the project is large and complex, then careful planning and analysis must be accomplished by both the direct- and indirect-labor-charging organizational units. The project organizational structure must be designed to fit the project; work plans and schedules must be established so that maximum allocation of resources can be made; resource costing and accounting systems must be developed; and a management information and reporting system must be established.

Effective total program planning cannot be accomplished unless all of the necessary information becomes available at project initiation. These information requirements are:

- The statement of work (SOW)
- The project specifications
- The milestone schedule
- The work breakdown structure (WBS)

The statement of work (SOW) is a narrative description of the work to be accomplished. It includes the objectives of the project, a brief description of the work, the funding constraint if one exists, and the specifications and schedule. The schedule is a “gross” schedule and includes such things as the:

- Start date
- End date
- Major milestones
- Written reports (data items)

2.8 Statement of Work

There are four elements of scope:

- **Scope:** This is the summary of all the deliverables required for the project, such as products, services and results.
- **Project Scope:** This entails work that must be completed in order to achieve the final scope of the project such as products, services and end results.
- **Scope Statement:** This is document that provides the foundation of making future decisions such as scope changes. The purpose of the document is to ensure that all stakeholders have common knowledge of the project scope. The scope statement contains the objectives, description of deliverables, end results and justification of the project. The scope statement seeks to address seven questions: who, what, when, why, where, how and how many. The document validates the project scope against the statement of work provided by the customer.
- **Statement of work:** This is a description that narrate the end results to be provided under the contract. Kerzner, (2013: 426).

The statement of work (SOW) is a narrative description of the work required for the project. The complexity of the SOW is determined by the desires of top management, the customer, and/or the user groups.

For projects' internal to the company, the SOW is prepared by the project office with input from the user groups because the project office is usually composed of personnel with writing skills.

For projects' external to the organization, as in competitive bidding, the contractor may have to prepare the SOW for the customer because the customer may not have people trained in SOW preparation. In this case, as before, the contractor would submit the SOW to the customer for approval. It is also quite common for the project manager to rewrite a customer's SOW so that the contractor's line managers can price out the effort.

In a competitive bidding environment, there are two SOWs—the SOW used in the proposal and a contract statement of work (CSOW). There might also be a proposal WBS and a contract work breakdown structure (CWBS). Special care must be taken by contract and negotiation teams to discover all discrepancies between the SOW/WBS and CSOW/CWBS, or additional costs may be incurred. A good (or winning) proposal is no guarantee that the customer or contractor understands the SOW. For large projects, fact-finding is usually required before final negotiations because it is essential that both the customer and the contractor understand and agree on the SOW.

There are common misinterpretations of the SOW such as:

- Mixing Tasks, specifications, approvals and special instructions,
- Using imprecise language (nearly, optimum, approximately etc.)
- Lack of a pattern, structure or chronological order,
- Wide variation in size of tasks,
- Wide variation in how to describe details of the work,
- Failing to get third party review.

There have been guidelines set out by both private and public agencies in order to avoid the above misinterpretations which can result in creeping scope. The best way to control creeping scope is by stipulating a definitive set of requirements upfront.

The following guidelines deal with developing a concrete SOW:

The project manager or his designees should review the documents that authorize the project and define its objectives, and also review contracts and studies leading to the present level of development. As a convenience, a bibliography of related studies should be prepared together with samples of any similar SOWs, and compliance specifications.

● A copy of the WBS should be obtained. At this point coordination between the CWBS elements and the SOW should commence. Each task element of the preliminary CWBS should be explained in the SOW, and related coding should be used. The project manager should establish a SOW preparation team consisting of personnel he deems appropriate from the program or project office who are experts in the technical areas involved, and representatives from procurement, financial management, fabrication, test, logistics, configuration management, operations, safety, reliability, and quality assurance, plus any other area that may be involved in the contemplated procurement.

● Before the team actually starts preparation of the SOW, the project manager should brief program management as to the structure of the preliminary CWBS and the nature of the contemplated SOW. This briefing is used as a baseline from which to proceed further.

● The project manager may assign identified tasks to team members and identify compliance specifications, design criteria, and other requirements documentation that must be included in the SOW and assign them to responsible personnel for preparation. Assigned team members will identify and obtain copies of specifications and technical requirements documents, engineering drawings, and results of preliminary and/or related studies that may apply to various elements of the proposed procurement.

● The project manager should prepare a detailed checklist showing the mandatory items and the selected optional items as they apply to the main body or the appendixes of the SOW.

● The project manager should emphasize the use of preferred parts lists; standard subsystem designs, both existing and under development; available hardware in inventory; off-the-shelf equipment; component qualification data; design criteria handbooks; and other technical information available to design engineers to prevent deviations from the best design practices.

● Cost estimates (manning requirements, material costs, software requirements, etc.) developed by the cost estimating specialists should be reviewed by SOW contributors. Such reviews will permit early trade-off consideration on the desirability of requirements that are not directly related to essential technical objectives.

● The project manager should establish schedules for submission of coordinated SOW fragments from each task team member. He must assure that these schedules are compatible with the schedule for the request for proposal (RFP) issuance. The statement of work should be prepared sufficiently early to permit full project coordination and to ensure that all project requirements are included. It should be completed in advance of RFP preparation.

2.9 Project Specifications

A specification list as shown in Table 2.2 is separately identified or called out as part of the statement of work. Specifications are used for man-hour, equipment, and material estimates. Small changes in a specification can cause large cost overruns.

Another reason for identifying the specifications is to make sure that there are no surprises for the customer downstream. The specifications should be the most current revision. It is not uncommon for a customer to hire outside agencies to evaluate the technical proposal and to make sure that the proper specifications are being used.

Specifications are, in fact, standards for pricing out a proposal. If specifications do not exist or are not necessary, then work standards should be included in the proposal.

The work standards can also appear in the cost volume of the proposal. Labor justification backup sheets may or may not be included in the proposal, depending on RFP/RFQ (request for quotation) requirements.

Several years ago, a government agency queried contractors as to why some government programs were costing so much money. The main culprit turned out to be the specifications.

Typical specifications contain twice as many pages as necessary, do not stress quality enough, are loaded with unnecessary designs and schematics, are difficult to read and update, and are obsolete before they are published. Streamlining existing specifications is a costly and time-consuming effort. The better alternative is to educate those people involved in specification preparation so that future specifications will be reasonably correct.

Table 2.2: Example of specification for statement of work

Description	Specification No:
Civil	100 (index)
Concrete	101
Field Equipment	102
Piling	103
Roofing	104
Structural design	124

Adapted from Kerzner, (2013:433)

2.10 Developing Milestone Schedules

All project milestone schedules must contain information such as:

- Project Start Date
- Project End Date
- Data items (deliverables or reports)

Project start and end dates, if known, must be included. Other major milestones, such as review meetings, prototype available, procurement, testing, and so on, should also be identified. Data items, are often overlooked. There are two good reasons for preparing a separate schedule for data items. First, the separate schedule will indicate to line managers that personnel with writing skills may have to be assigned. Second, data items require direct-labor man-hours for writing, typing, editing, retyping, proofing, graphic arts, and reproduction. Many companies identify on the data item schedules the approximate number of pages per data item, and each data item is priced out at a cost per page, say $500/page. Pricing out data items separately often induces customers to require fewer reports.

The steps required to prepare a report, after the initial discovery work or collection of information, include:

- Organizing the report
- Writing
- Typing
- Editing
- Retyping
- Proofing
- Graphic arts
- Submittal for approvals
- Reproduction and distribution

2.11 Work Break Down Structure

The successful accomplishment of both contract and corporate objectives requires a plan that defines all effort to be expended, assigns responsibility to a specially identified organizational element, and establishes schedules and budgets for the accomplishment of the work. The preparation of this plan is the responsibility of the program manager, who is assisted by the program team assigned in accordance with program management system directives.

The detailed planning is also established in accordance with company budgeting policy before contractual efforts are initiated. In planning a project, the project manager must structure the work into small elements
that are:

● Manageable, in that specific authority and responsibility can be assigned

● Independent, or with minimum interfacing with and dependence on other ongoing elements

● Integratable so that the total package can be seen

● Measurable in terms of progress

The first major step in the planning process after project requirements definition is the development of the work breakdown structure (WBS). A WBS is a product-oriented family tree subdivision of the hardware, services, and data required to produce the end product. The WBS is structured in accordance with the way the work will be performed and reflects the way in which project costs and data will be summarized and eventually reported. Preparation of the WBS also considers other areas that require structured data, such as scheduling, configuration management, contract funding, and technical performance parameters.

The WBS is the single most important element because it provides a common framework from which:

● The total program can be described as a summation of subdivided elements.

● Planning can be performed.

● Costs and budgets can be established.

● Time, cost, and performance can be tracked.

● Objectives can be linked to company resources in a logical manner.

● Schedules and status-reporting procedures can be established.

● Network construction and control planning can be initiated.

● The responsibility assignments for each element can be established.

The work breakdown structure acts as a vehicle for breaking the work down into smaller elements, thus providing a greater probability that every major and minor activity will be accounted for. Although a variety of work breakdown structures exist, the most common is the six-level indented structure shown below:

Figure 2.3 Six Level indented work break down structure

	Level	*Description*
Managerial levels	1	Total program
	2	Project
	3	Task
Technical levels	4	Subtask
	5	Work package
	6	Level of effort

Adapted from Kerzner, (2013: 435)

Level 1 is the total program and is composed of a set of projects. The summation of the activities and costs associated with each project must equal the total program. Each project, however, can be broken down into tasks, where the summation of all tasks equals the summation of all projects, which, in turn, comprises the total program. The reason for this subdivision of effort is simply ease of control. Program management therefore becomes synonymous with the integration of activities, and the project manager acts as the integrator, using the work breakdown structure as the common framework. Careful consideration must be given to the design and development of the WBS. From Figure 2.3, the work breakdown structure can be used to provide the basis for:

- The responsibility matrix
- Network scheduling
- Costing
- Risk analysis
- Organizational structure

● Coordination of objectives

● Control (including contract administration)

The upper three levels of the WBS are normally specified by the customer (if part of an RFP/RFQ) as the summary levels for reporting purposes. The lower levels are generated by the contractor for in-house control. Each level serves a vital purpose: Level 1 is generally used for the authorization and release of all work, budgets are prepared at level 2, and schedules are prepared at level 3. Certain characteristics can now be generalized for these levels:

● The top three levels of the WBS reflect integrated efforts and should not be related to one specific department. Effort required by departments or sections should be defined in subtasks and work packages.

● The summation of all elements in one level must be the sum of all work in the next lower level.

● Each element of work should be assigned to one and only one level of effort. For example, the construction of the foundation of a house should be included in one project (or task), not extended over two or three. (At level 5, the work packages should be identifiable and homogeneous.)

2.12 Work Break Down Structure Decomposition Problems

There is a common misconception that WBS decomposition is an easy task to perform. In the development of the WBS, the top three levels or management levels are usually rollup levels. Preparing templates at these levels is becoming common practice. However, at levels 4–6 of the WBS, templates may not be appropriate. There are reasons for this.

● Breaking the work down to extremely small and detailed work packages may require the creation of hundreds or even thousands of cost accounts and charge numbers. This could increase the management, control, and reporting costs of these small packages to a point where the costs exceed the benefits. Although a typical work package may be 200–300 hours and approximately two weeks in duration, consider the impact on a large project, which may have more than one million direct labor hours.

● Breaking the work down to small work packages can provide accurate cost control if, and only if, the line managers can determine the costs at this level of detail. Line managers must be given the right to tell project managers that costs cannot be determined at the requested level of detail.

● The work breakdown structure is the basis for scheduling techniques such as the Arrow Diagramming Method and the Precedence Diagramming Method. At low levels of the WBS, the interdependencies between activities can become so complex that meaningful networks cannot be constructed.

One solution to the above problems is to create “hammock” activities, which encompass several activities where exact cost identification cannot or may not be accurately determined. Some projects identify a “hammock” activity called management support (or project office), which includes overall project management, data items, management reserve, and possibly procurement. The advantage of this type of hammock activity is that the charge numbers are under the direct control of the project manager.

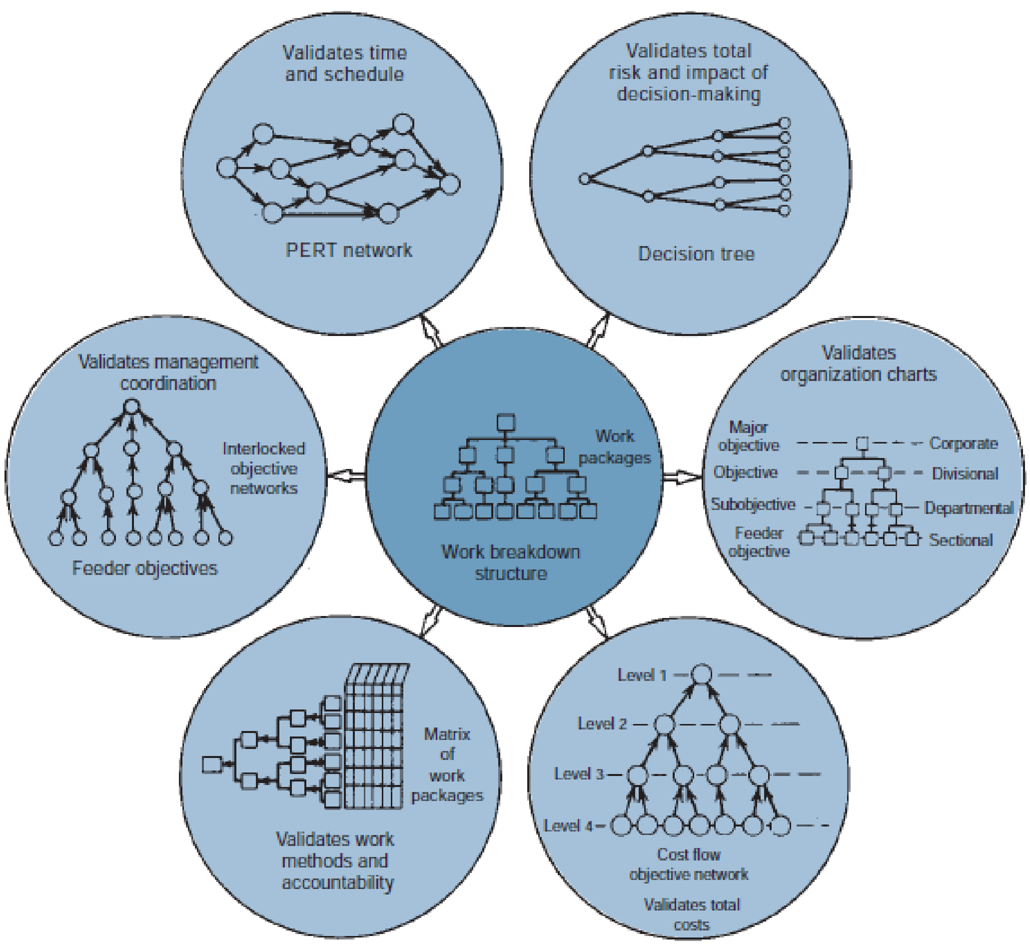
There is a common misconception that the typical dimensions of a work package are approximately 80 hours and less than two weeks to a month. Although this may be true on small projects, this would necessitate millions of work packages on large jobs and this may be impractical, even if line managers could control work packages of this size.

From a cost control point of view, cost analysis down to the fifth level is advantageous. However, it should be noted that the cost required to prepare cost analysis data to each lower level may increase exponentially, especially if the customer requires data to be presented in a specified format that is not part of the company’s standard operating procedures.

The level-5 work packages are normally for in-house control only. Some companies bill customers separately for each level of cost reporting below level 3.

The WBS can be subdivided into sub objectives with finer divisions of effort as we go lower into the WBS. By defining sub objectives, we add greater understanding and, it is hoped, clarity of action for those individuals who will be required to complete the objectives. Whenever work is structured, understood, easily identifiable, and within the capabilities of the individuals, there will almost always exist a high degree of confidence that
the objective can be reached.

Figure 2.4 Work Breakdown Structure For Objective, Control and Evaluation



Adapted from Kerzner, (2013: 436)

The level at which the project is managed is generally called the work package level. Actually, the work package can exist at any level below level one.

● The WBS must be accompanied by a description of the scope of effort required, or else only those individuals who issue the WBS will have a complete understanding of what work has to be accomplished. It is common practice to reproduce the customer's statement of work as the description for the WBS.

● It is often the best policy for the project manager, regardless of his technical expertise, to allow all of the line managers to assess the risks in the SOW. After all, the line managers are usually the recognized experts in the organization.

Project managers normally manage at the top three levels of the WBS and prefer to provide status reports to management at these levels also. Some companies are trying to standardize reporting to management by requiring the top three levels of the WBS to be the same for every project, the only differences being in levels 4–6. For companies with a great deal of similarity among projects, this approach has merit. For most companies, however, the differences between projects make it almost impossible to standardize the top levels of the WBS.

2.13 Planning Cycle

Previously, we stated that perhaps the most important reason for structuring projects into life-cycle phases is to provide management with control of the critical decision points in order to:

● Avoid commitment of major resources too early

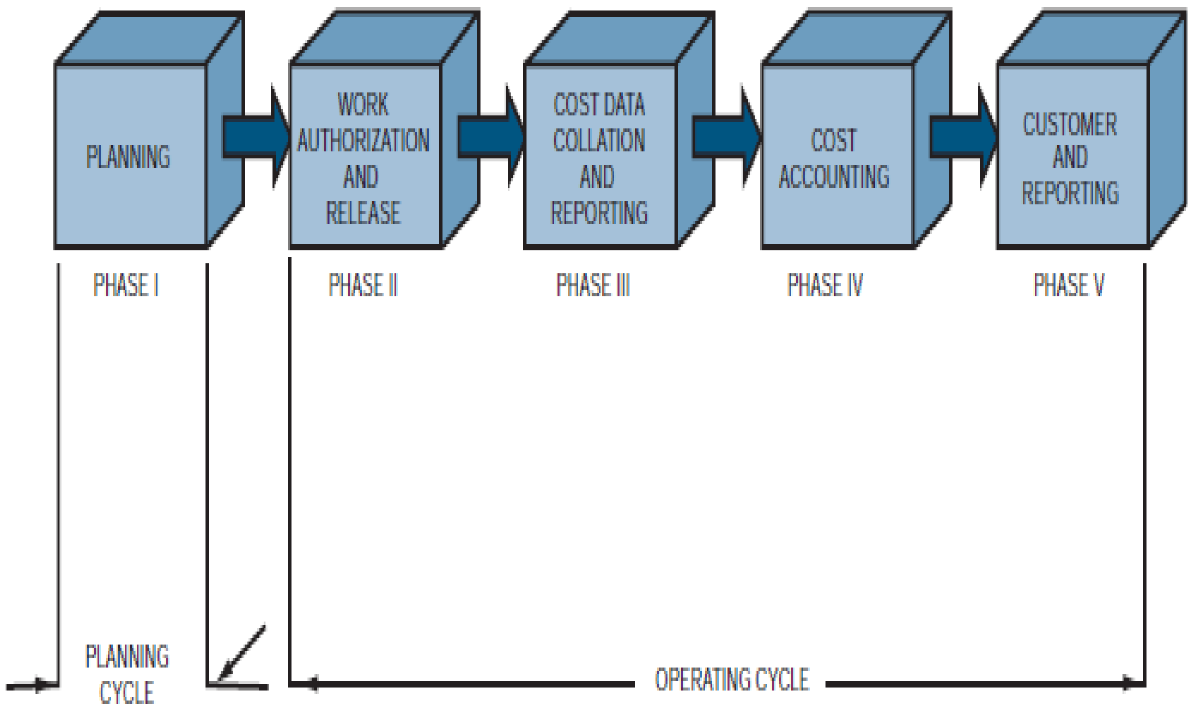
● Preserve future options

● Maximize benefits of each project in relation to all other projects

● Assess risks

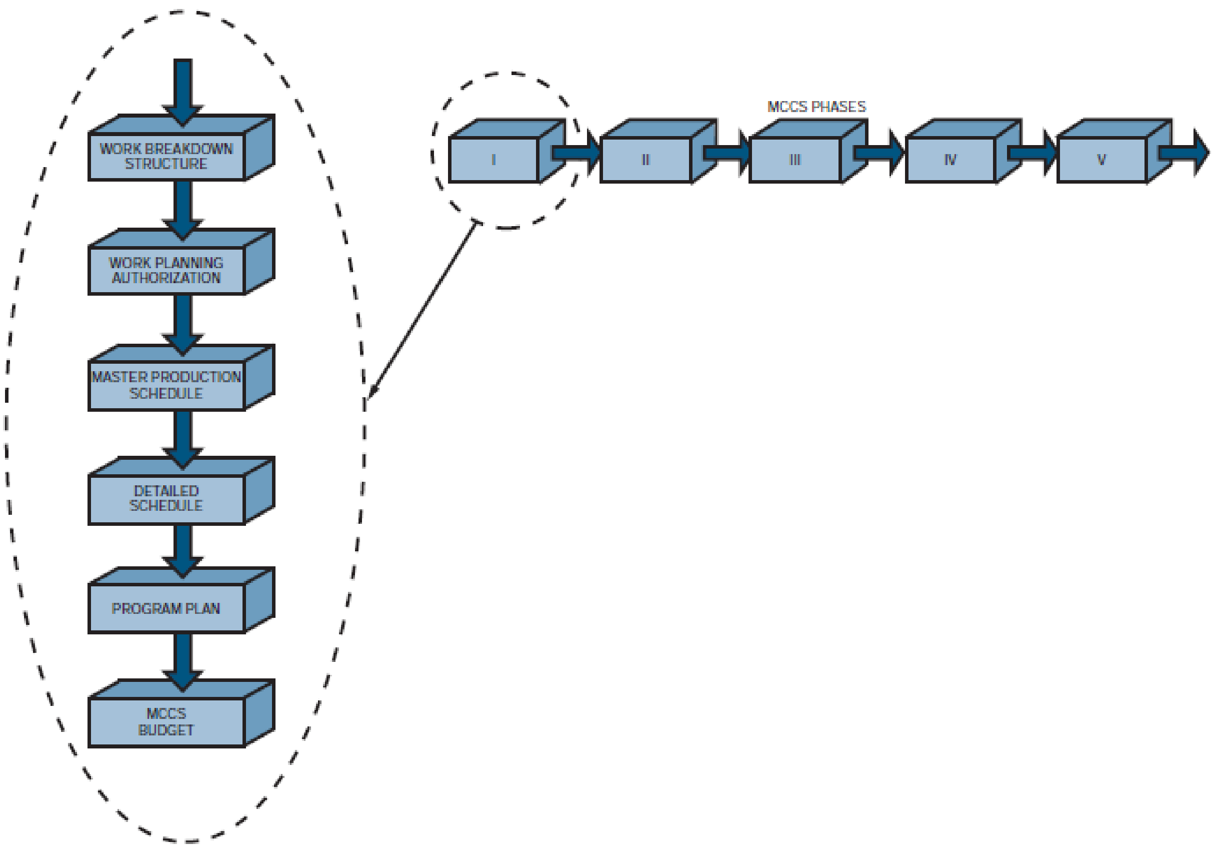
On long-term projects, phasing can be overdone, resulting in extra costs and delays. To prevent this, many project-driven companies resort to other types of systems, such as a management cost and control system (MCCS). No program or project can be efficiently organized and managed without some form of management cost and control system. Figure 2.5 shows the five phases of a management cost and control system. The first phase constitutes the planning cycle, and the next four phases identify the operating cycle. Figure 2.6 shows the activities included in the planning cycle. The work breakdown structure serves as the initial control from which all planning emanates. The WBS acts as a vital artery for communications and operations in all phases.

Figure 2.5 Phases of Management cost and control system



Adapted from Kerzner, (2013: 450)

Figure 2.6 The planning cycle of a management cost and control system



Adapted from Kerzner, (2013: 450)

2.14 Work Planning Authorization

After receipt of a contract, some form of authorization is needed before work can begin, even in the planning stage. Both work authorization and work planning authorization are used to release funds, but for different purposes.

Work planning authorization releases funds (primarily for functional management) so that scheduling, costs, budgets, and all other types of plans can be prepared prior to the release of operational cycle funds, which hereafter shall be referred to simply as work authorization. Both forms of authorization require the same paperwork. In many companies this work authorization is identified as a subdivided work description (SWD), which is a narrative description of the effort to be performed by the cost center (division-level minimum).

This package establishes the work to be performed, the period of performance, and possibly the maximum number of hours available. The SWD is multipurpose in that it can be used to release contract funds, authorize planning, describe activities as identified in the WBS, and, last but not least, release work. The SWD is one of the key elements in the planning of a program as shown in Figure 2.6. Contract control and administration releases the contract funds by issuing a SWD, which sets forth general contractual requirements and authorizes program management to proceed. Program management issues the SWD to set forth the contractual guidelines and requirements for the functional units. The SWD specifies how the work will be performed, which functional organizations will be involved, and who has what specific responsibilities, and authorizes the utilization of resources within a given time period.

The SWD authorizes both the program team and functional management to begin work. As shown in Figure 2.6, the SWD provides direct input to Phase II of the MCCS. Phase I and Phase II can and do operate simultaneously because it is generally impossible for program office personnel to establish plans, procedures, and schedules without input from the functional units.

The subdivided work description package is used by the operating organizations to further subdivide the effort defined by the WBS into small segments or work packages. Many people contend that if the data in the work authorization document are different from what was originally defined in the proposal, the project is in trouble right at the start. This may not be the case, because most projects are priced out assuming “unlimited” resources, whereas the hours and dollars in the work authorization document are based upon “limited” resources. This situation is common for companies that thrive on competitive bidding.

2.15 Common Causes of Planning Failure

No matter how hard we try, planning is not perfect, and sometimes plans fail. Typical reasons include:

● Corporate goals are not understood at the lower organizational levels.

● Plans encompass too much in too little time.

● Financial estimates are poor.

● Plans are based on insufficient data.

● No attempt is being made to systematize the planning process.

● Planning is performed by a planning group.

● No one knows the ultimate objective.

● No one knows the staffing requirements.

● No one knows the major milestone dates, including written reports.

● Project estimates are best guesses, and are not based on standards or history.

● Not enough time has been given for proper estimating.

● People are not working toward the same specifications.

● People are consistently shuffled in and out of the project with little regard for schedule.

Why do these situations occur? If corporate goals are not understood, it is because corporate executives have been negligent in providing the necessary strategic information and feedback. If a plan fails because of extreme optimism, then the responsibility lies with both the project and line managers for not assessing risk. Project managers should ask the line managers if the estimates are optimistic or pessimistic, and expect an honest answer. Erroneous financial estimates are the responsibility of the line manager. If the project fails because of a poor definition of the requirements, then the project manager is totally at fault. Sometimes project plans fail because simple details are forgotten or overlooked.

Examples of this might be:

● Neglecting to tell a line manager early enough that the prototype is not ready and that rescheduling is necessary.

● Neglecting to see if the line manager can still provide additional employees for the next two weeks because it was possible to do so six months ago.

Sometimes plans fail because the project manager “bites off more than he can chew,” and then something happens, such as his becoming ill. Many projects have failed because the project manager was the only one who knew what was going on and then got sick.

2.16 Reasons for pausing Projects

There are always situations in which projects have to be stopped. Nine reasons for stopping are:

● Final achievement of the objectives
● Poor initial planning and market prognosis
● A better alternative is found
● A change in the company interest and strategy
● Allocated time is exceeded
● Budgeted costs are exceeded
● Key people leave the organization
● Personal whims of management
● Problem too complex for the resources available

Today most of the reasons why projects are not completed on time and within cost are behavioral rather than quantitative. They include:

● Poor morale
● Poor human relations
● Poor labor productivity
● No commitment by those involved in the project

The last item appears to be the cause of the first three items in many situations.

Once the reasons for cancellation are defined, the next problem concerns how to stop the project. Some of the ways are:

● Orderly planned termination
● The “hatchet” (withdrawal of funds and removal of personnel)

Reassignment of people to higher priority tasks

● Redirection of efforts toward different objectives

● Burying it or letting it die on the vine (i.e., not taking any official action)

There are three major problem areas to be considered in stopping projects:

● Worker morale

● Reassignment of personnel

● Adequate documentation and wrap-up

2.17 Project Phase outs and transfers

By definition, projects (and even life cycle phases) have an end point.
Closing out is a very important phase in the project life cycle, which
should follow particular disciplines and procedures with the objective of:

● Effectively bringing the project to closure according to agreed-on contractual requirements

● Preparing for the transition of the project into the next operational phase, such as from production to field installation, field operation, or training

● Analyzing overall project performance with regard to financial data, schedules, and technical efforts

● Closing the project office, and transferring or selling off all resources originally assigned to the project, including personnel

● Identifying and pursuing follow-on business

Although most project managers are completely cognizant of the necessity for proper planning for project start-up, many project managers neglect planning for project termination.

Planning for project termination includes:

● Transferring responsibility

● Completion of project records

● Historic reports

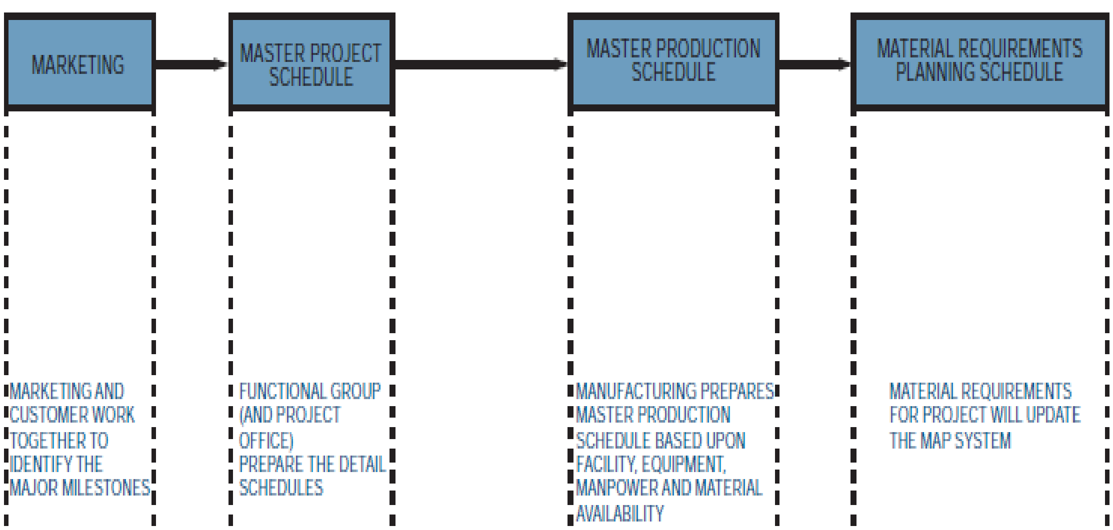
● Post project analysis

- Documenting results to reflect "as built" product or installation
- Acceptance by sponsor/user
- Satisfying contractual requirements
- Releasing resources
- Reassignment of project office team members
- Disposition of functional personnel
- Disposition of materials
- Closing out work orders (financial closeout)
- Preparing for financial payments

2.18 Master Production Scheduling

Master production scheduling is not a new concept. Earliest material control systems used a "quarterly ordering system" to produce a master production schedule (MPS) for plant production. This system uses customer order backlogs to develop a production plan over a three-month period. The production plan is then exploded manually to determine what parts must be purchased or manufactured at the proper time. However, rapidly changing customer requirements and fluctuating lead times, combined with a slow response to these changes, can result in the disruption of master production scheduling.

Figure 2.7 Material requirements planning interrelationships



Adapted from Kerzner, (2013: 458)

A master production schedule is a statement of what will be made, how many units will be made, and when they will be made. It is a production plan, not a sales plan. The MPS considers the total demand on a plant's resources, including finished product sales, spare (repair) part needs, and interplant needs. The MPS must also consider the capacity of the plant and the requirements imposed on vendors. Provisions are made in the overall plan for each manufacturing facility's operation. All planning for materials, manpower, plant, equipment, and financing for the facility is driven by the master production schedule.

Objectives of master production scheduling are:

- To provide top management with a means to authorize and control manpower levels, inventory investment, and cash flow
- To coordinate marketing, manufacturing, engineering, and finance activities by a common performance objective
- To reconcile marketing and manufacturing needs
- To provide an overall measure of performance
- To provide data for material and capacity planning

2.19 Project Plan

A project plan is fundamental to the success of any project. For large and often complex projects, customers may require a project plan that documents all activities within the program. The project plan then serves as a guideline for the lifetime of the project and may be revised as often as once a month, depending on the circumstances and the type of project (i.e., research and development projects require more revisions to the project plan than manufacturing or construction projects). The project plan provides the following framework:

- Eliminates conflicts between functional managers
- Eliminates conflicts between functional management and program management

● Provides a standard communications tool throughout the lifetime of the project

● Provides verification that the contractor understands the customer's objectives and requirements

● Provides a means for identifying inconsistencies in the planning phase

● Provides a means for early identification of problem areas and risks so that no surprises occur downstream

● Contains all of the schedules defined in Section 11.18 as a basis for progress analysis and reporting Development of a project plan can be time-consuming and costly.

All levels of the organization participate. The upper levels provide summary information, and the lower levels provide the details. The project plan, like activity schedules, does not preclude departments from developing their own plans.

2.20 Project Charter

The original concept behind the project charter was to document the project manager's authority and responsibility, especially for projects implemented away from the home office. Today, the project charter is more of an internal legal document identifying to the line managers and their personnel the project manager's authority and responsibility and the management- and/or customer-approved scope of the project.

Theoretically, the sponsor prepares the charter and affixes his/her signature, but in reality, the project manager may prepare it for the sponsor's signature. At a minimum, the charter should include:

● Identification of the project manager and his/her authority to apply resources to the project

● The business purpose that the project was undertaken to address, including all assumptions and constraints

● Summary of the conditions defining the project

● Description of the project

● Objectives and constraints on the project

- Project scope (inclusions and exclusions)
- Key stakeholders and their roles
- Risks
- Involvement by certain stakeholders

The charter is a “legal” agreement between the project manager and the company. Some companies supplement the charter with a “contract” that functions as an agreement between the project and the line organizations.

Some companies have converted the charter into a highly detailed document containing:

- The scope baseline/scope statement
- Scope and objectives of the project (SOW)
- Specifications
- WBS (template levels)
- Timing
- Spending plan (S-curve)
- The management plan
- Resource requirements and man loading (if known)
- Resumés of key personnel
- Organizational relationships and structure
- Responsibility assignment matrix
- Support required from other organizations
- Project policies and procedures
- Change management plan
- Management approval of above

When the project charter contains a scope baseline and management plan, the project charter may function as the project plan. This is not really an effective use of the charter, but it may be acceptable on certain types of projects for internal customers.

2.21 Project Audits

In recent years, the necessity for a structured independent review of various parts of a business, including projects, has taken on a more important role. Part of this can be attributed to the Sarbanes–Oxley law compliance requirements. These independent reviews are audits that focus on either discovery or decision-making. The audits can be scheduled or random and can be performed by in-house personnel or external examiners.

There are several types of audits. Some common types include:

● Performance Audits: These audits are used to appraise the progress and performance of a given project. The project manager, project sponsor, or an executive steering committee can conduct this audit.

● Compliance Audits: These audits are usually performed by the project management office (PMO) to validate that the project is using the project management methodology properly. Usually the PMO has the authority to perform the audit but may not have the authority to enforce compliance.

● Quality Audits: These audits ensure that the planned project quality is being met and that all laws and regulations are being followed. The quality assurance group performs this audit.

● Exit Audits: These audits are usually for projects that are in trouble and may need to be terminated. Personnel external to the project, such as an exit champion or an executive steering committee, conduct the audits.

● Best Practices Audits: These audits can be conducted at the end of each life-cycle phase or at the end of the project. Some companies have found that project managers may not be the best individuals to perform the audit. In such situations, the company may have professional facilitators trained in conducting best practices reviews.

REFLECTION QUESTIONS

2.1 Under what conditions would each of the following either not be available or not be necessary for initial planning?

2.2 a. Work breakdown structure

2.3 b. Statement of work

2.4 c. Specifications

2.5 d. Milestone schedules

2.6 What planning steps should precede total program scheduling? What steps are necessary?

2.7 How does a project manager determine how complex to make a program plan or how many schedules to include? Can objectives always be identified and scheduled?

2.8 Can a WBS always be established for attaining an objective?

2.9 Who determines the work necessary to accomplish an objective?

2.10 What roles does a functional manager play in establishing the first three levels of the WBS?

2.11 Should the length of a program have an impact on whether to set up a separate project or

2.12 task for administrative support? How about for raw materials?

2.13 Is it possible for the WBS to be designed so that resource allocation is easier to identify?

2.14 If the scope of effort of a project changes during execution of activities, what should be the role of the functional manager?

2.15 What types of conflicts can occur during the planning cycle, and what modes should be used for their resolution?

2.16 What would be the effectiveness of Figure 11–3 if the work packages were replaced by tasks?

CHAPTER 3

Developing the Project Schedule

Chapter 3 Developing the Project Schedule

CHAPTER OUTCOMES

Upon completion of this Chapter, students should be able to:

- Develop precedence networks
- Critically analyse the relationship between cost and scheduled performance
- Distinguish between the three types of dependencies
- Identify and calculate slack time
- Estimate activity times using project management tools
- Contrast the effectiveness of resource levelling and resource allocations in network re-planning
- Utilise project management equations to calculate the probability of completing the project on time, the standard deviations of each activity
- Appraise alternate project evaluation and review techniques

Essential Reading

Textbooks:

- Kerzner, H (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Wiley & Sons, Inc., Hoboken, New Jersey, Chapter Twelve

3.1 Introduction

Management is continually seeking new and better control techniques to cope with the complexities, masses of data, and tight deadlines that are characteristic of highly competitive industries. Managers also want better methods for presenting technical and cost data to customers. Scheduling techniques help achieve these goals. The most common techniques are:

● Gantt or bar charts
● Milestone charts
● Line of balance1
● Networks
● Program Evaluation and Review Technique (PERT)
● Arrow Diagram Method (ADM) [Sometimes called the Critical Path Method (CPM)
● Precedence Diagram Method (PDM)
● Graphical Evaluation and Review Technique (GERT)

Advantages of network scheduling techniques include:

● They form the basis for all planning and predicting and help management decide how to use its resources to achieve time and cost goals.
● They provide visibility and enable management to control “one-of-a-kind” programs.
● They help management evaluate alternatives by answering such questions as how time delays will influence project completion, where slack exists between elements, and what elements are crucial to meet the completion date.
● They provide a basis for obtaining facts for decision-making.
● They utilize a so-called time network analysis as the basic method to determine manpower, material,
and capital requirements, as well as to provide a means for checking progress.
● They provide the basic structure for reporting information.
● They reveal interdependencies of activities.

- They facilitate “what if ” exercises.
- They identify the longest path or critical paths.
- They aid in scheduling risk analysis.

PERT was originally developed in 1958 and 1959 to meet the needs of the “age of massive engineering” where the techniques of Taylor and Gantt were inapplicable. The Special Projects Office of the U.S. Navy, concerned with performance trends on large military development programs, introduced PERT on its Polaris Weapon System in 1958, after the technique had been developed with the aid of the management consulting firm of Booz, Allen, and Hamilton. Since that time, PERT has spread rapidly throughout almost all industries. At about the same time, the DuPont Company initiated a similar technique known as the critical path method (CPM), which also has spread widely, and is particularly concentrated in the construction and process industries. In the early 1960s, the basic requirements of PERT/time as established by the Navy were as follows:

- All of the individual tasks to complete a program must be clear enough to be put down in a network, which comprises events and activities; i.e., follow the work breakdown structure.
- Events and activities must be sequenced on the network under a highly logical set of ground rules that allow the determination of critical and subcritical paths. Networks may have more than one hundred events, but not fewer than ten. Time estimates must be made for each activity on a three-way basis. Optimistic, most likely, and pessimistic elapsed-time figures are estimated by the person(s) most familiar with the activity.
- Critical path and slack times are computed. The critical path is that sequence of activities and events whose accomplishment will require the greatest time.

A big advantage of PERT lies in its extensive planning. Network development and critical path analysis reveal interdependencies and problems that are not obvious with other planning methods.

PERT therefore determines where the greatest effort should be made to keep a project on schedule. The second advantage of PERT is that one can determine the probability of meeting deadlines by development of alternative plans. If the decision maker is statistically sophisticated, he can examine the standard deviations and the probability of accomplishment data. If there exists a minimum of uncertainty, one may use the single-time approach, of course, while retaining the advantage of network analysis. A third advantage is the ability to evaluate the effect of changes in the program. For example, PERT can evaluate the effect of a contemplated shift of resources from the less critical activities to the activities identified as probable bottlenecks. PERT can also evaluate the effect of a deviation in the actual time required for an activity from what had been predicted. Finally, PERT allows a large amount of sophisticated data to be presented in a well-organized diagram from which contractors and customers can make joint decisions.

PERT, unfortunately, is not without disadvantages. The complexity of PERT adds to implementation problems. There exist more data requirements for a PERT-organized reporting system than for most others. PERT, therefore, becomes expensive to maintain and is utilized most often on large, complex programs. Many companies have taken a hard look at the usefulness of PERT on small projects. The result has been the development of PERT/LOB procedures, which can do the following:

- Cut project costs and time
- Coordinate and expedite planning
- Eliminate idle time
- Provide better scheduling and control of subcontractor activities
- Develop better troubleshooting procedures
- Cut the time required for routine decisions, but allow more time for decision-making.

Even with these advantages, many companies should ask whether they actually need PERT because incorporating it may be difficult and costly, even with canned software packages. Criticism of PERT includes:

- Time and labor intensive
- Decision-making ability reduced
- Lacks functional ownership in estimates
- Lacks historical data for time–cost estimates
- Assumes unlimited resources
- Requires too much detail

3.2 Network Foundations

The major discrepancy with Gantt, milestone, or bubble charts is the inability to show the interdependencies between events and activities.

These interdependencies must be identified so that a master plan can be developed that provides an up-to-date picture of operations at all times. Interdependencies are shown through the construction of networks. Network analysis can provide valuable information for planning, integration of plans, time studies, scheduling, and resource management. The primary purpose of network planning is to eliminate the need for crisis management by providing a pictorial representation of the total program. The following management information can be obtained from such a representation:

- Interdependencies of activities
- Project completion time
- Impact of late starts
- Impact of early starts
- Trade-offs between resources and time
- “What if” exercises
- Cost of a crash program
- Slippages in planning/performance
- Evaluation of performance

Networks are composed of events and activities. The following terms are helpful in understanding networks:

● Event: Equivalent to a milestone indicating when an activity starts or finishes.

● Activity: The element of work that must be accomplished.

● Duration: The total time required to complete the activity.

● Effort: The amount of work that is actually performed within the duration. For example, the duration of an activity could be one month but the effort could be just a two-week period within the duration.

● Critical Path: This is the longest path through the network and determines the duration of the project. It is also the shortest amount of time necessary to accomplish the project.

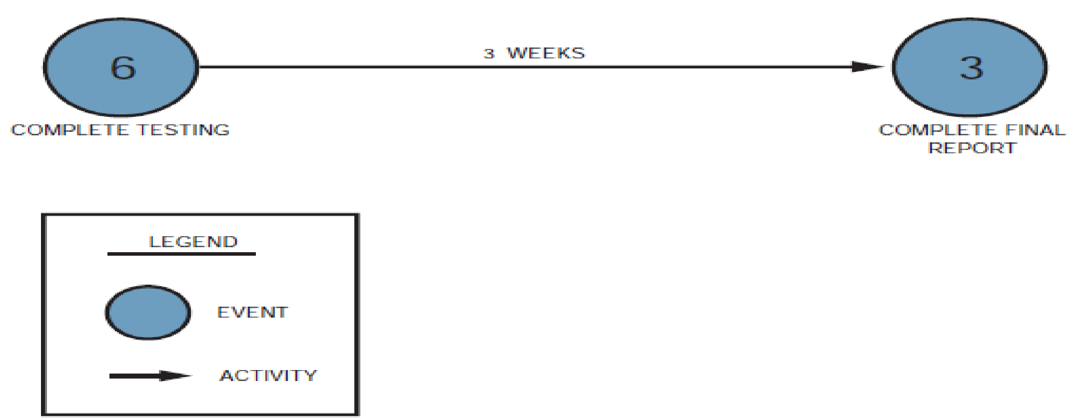
Figure 3.1 shows the standard nomenclature for PERT networks. The circles represent events, and arrows represent activities. The numbers in the circles signify the specific events or accomplishments. The number over the arrow specifies the time needed (hours, days, months), to go from event 6 to event 3. The events need not be numbered in any specific order. However, event 6 must take place before event 3 can be completed (or begun).

In Figure 3.2 A, event 26 must take place prior to events 7, 18, and 31.

In Figure 3.2 B, the opposite holds true, and events 7, 18, and 31 must take place prior to event 26.

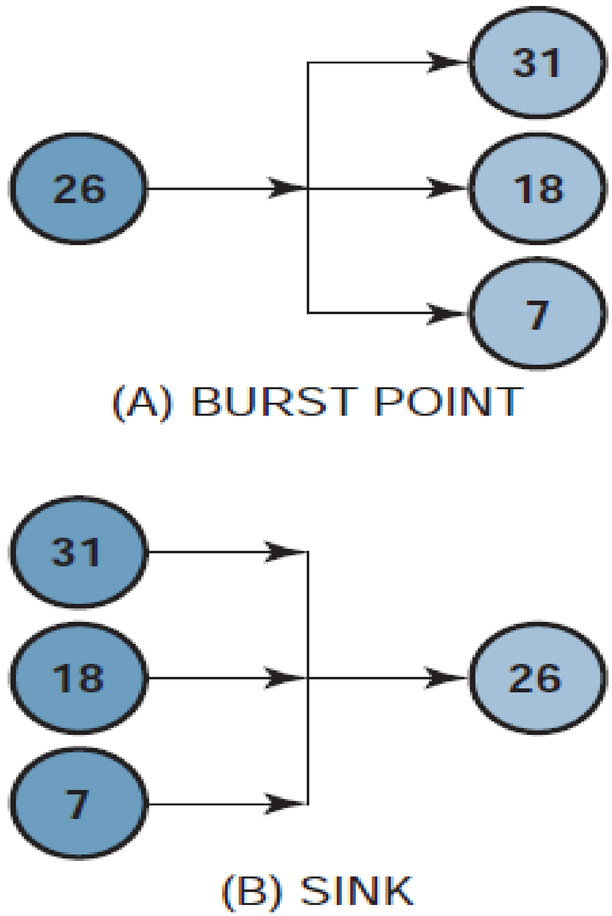
Figure 3.2 B is similar to “and gates” used in logic diagrams.

Figure 3.1 Standard Pert Terminology



Adapted from Kerzner, (2013: 497)

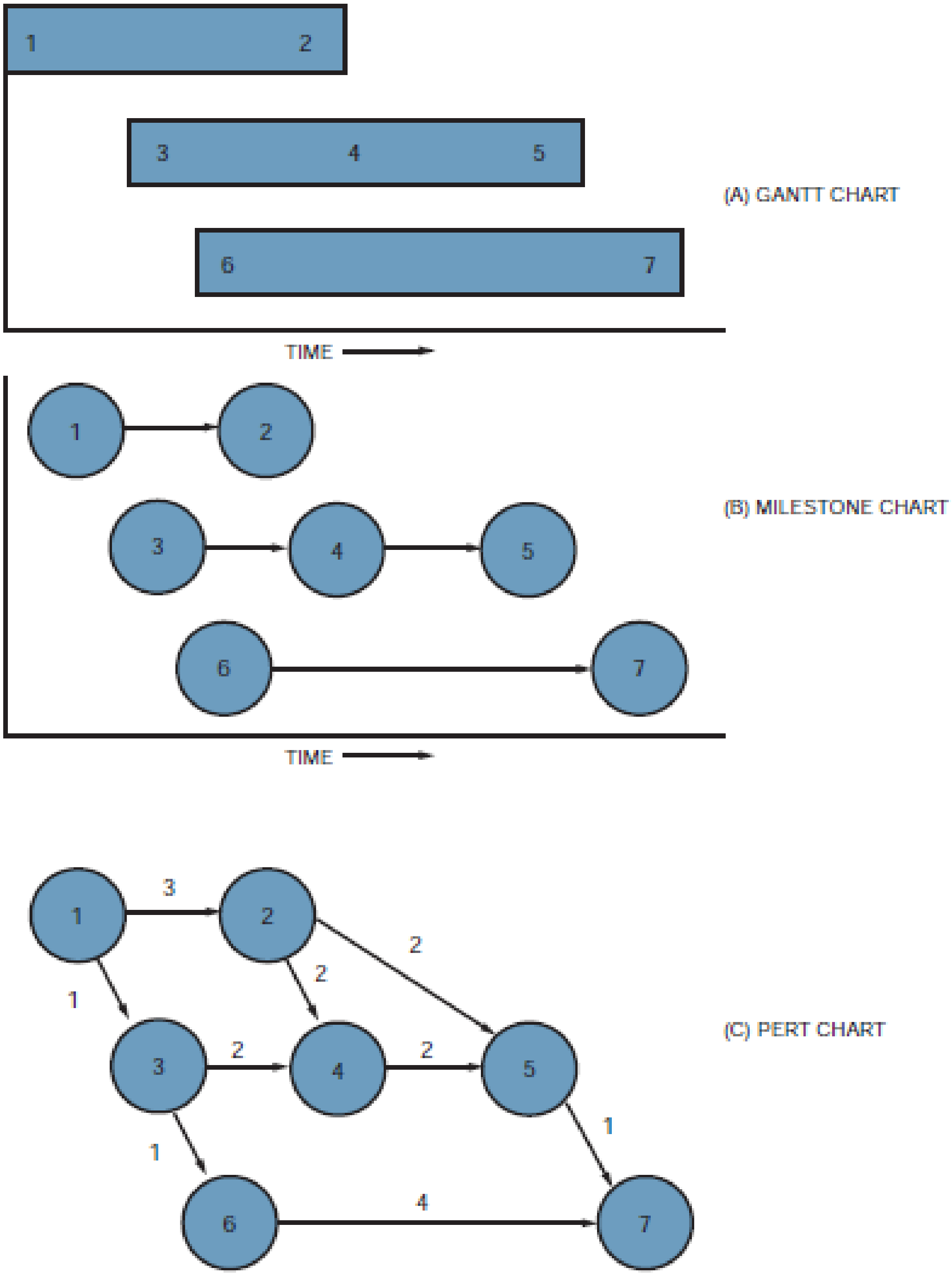
Figure 3.2 Pert Sources, Burst points and sinks



Adapted from Kerzner, (2013: 497)

Gantt and milestone charts can be used to develop the PERT network, as shown in Figure 3.3. The bar chart in Figure 3.3A can be converted to the milestone chart in Figure 3.3B. By then defining the relationship between the events on different bars in the milestone chart, we can construct the PERT chart in Figure 3.3C. PERT is basically a management planning and control tool. It can be considered as a road map for a particular program or project in which all of the major elements (events).

Figure 3.3 Conversion from Bar charts to PERT Chart



Ada[ted from Kerzner, (2013: 498)

One of the purposes of constructing the PERT chart is to determine how much time is needed to complete the project. PERT, therefore, uses time as a common denominator to analyze those elements that directly influence the success of the project, namely, time, cost, and performance. The construction of the network requires two inputs. First, do events represent the start or the completion of an activity? Event completions are generally preferred. The next step is to define the sequence of events, as shown in Table 3.1.

Table 3.1: Sequence of Events

Activity	Title	Immediate Predecessors	Activity Time, Weeks
1–2	A	—	1
2–3	B	A	5
2–4	C	A	2
3–5	D	B	2
3–7	E	B	2
4–5	F	C	2
4–8	G	C	3
5–6	H	D,F	2
6–7	I	H	3
7–8	J	E,I	3
8–9	K	G,J	2

Adapted from Kerzner, (2013: 499)

The sequence of events table relates each event to its immediate predecessor. Large projects can easily be converted into PERT networks once the following questions are answered:

- What job immediately precedes this job?
- What job immediately follows this job?
- What jobs can be run concurrently?

Figure 3.4 shows a typical PERT network. The bold line in Figure 3.4 represents the critical path, which is established by the longest time span through the total system of events. The critical path is composed of events 1–2–3–5–6–7–8–9. The critical path is vital for successful control of the project because it tells management two things:

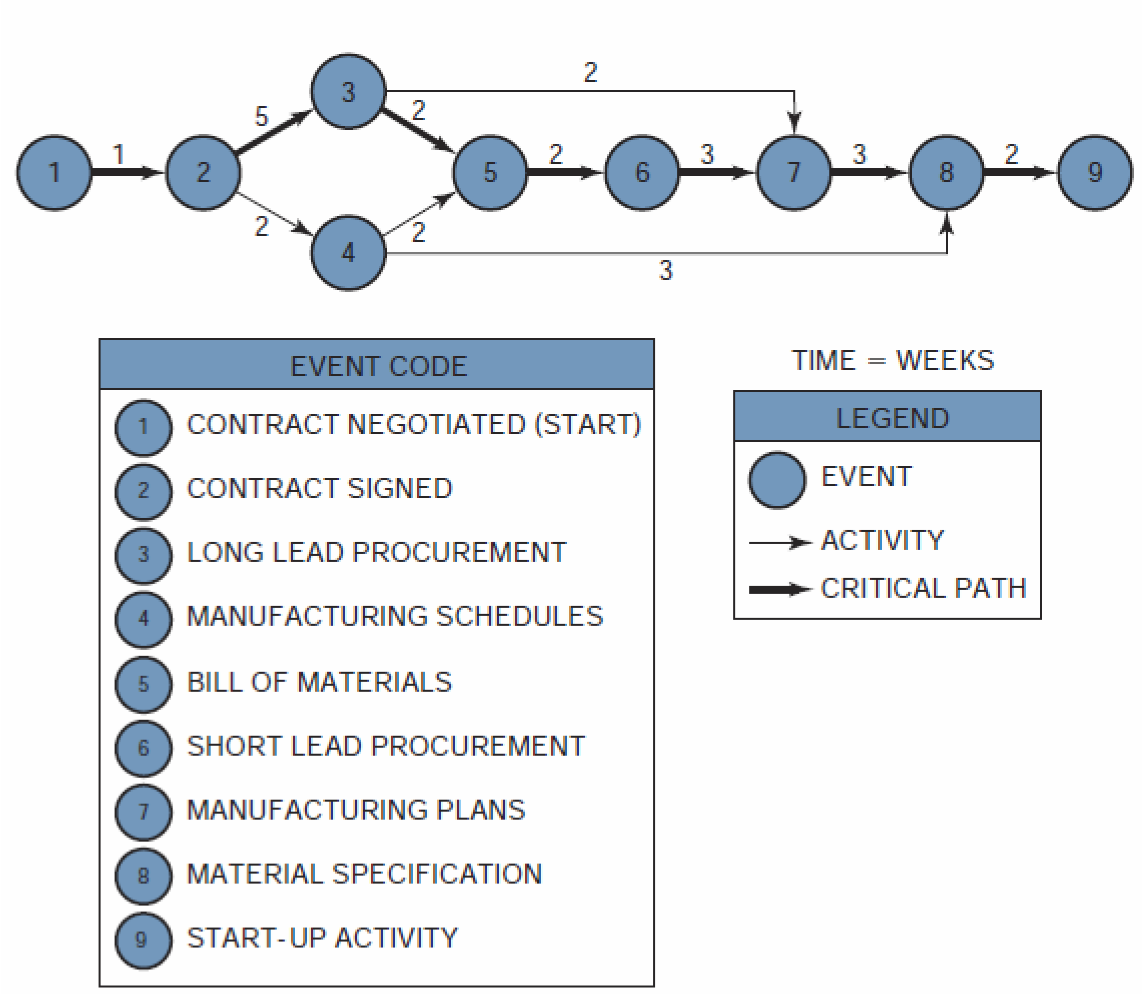
● Because there is no slack time in any of the events on this path, any slippage will cause a corresponding slippage in the end date of the program unless this slippage can be recovered during any of the downstream events (on the critical path).

● Because the events on this path are the most critical for the success of the project, management must take a hard look at these events in order to improve the total program.

Using PERT we can now identify the earliest possible dates on which we can expect an event to occur, or an activity to start or end. There is nothing overly mysterious about this type of calculation, but without a network analysis the information might be hard to obtain. PERT charts can be managed from either the events or the activities. For levels 1–3 of the Work Breakdown Structure (WBS), the project manager's prime concerns are the milestones, and therefore, the events are of prime importance. For levels 4–6 of the WBS, the project manager's concerns are the activities. The principles that we have discussed thus far also apply to CPM. The nomenclature is the same and both techniques are often referred to as arrow diagramming methods, or activity-on-arrow networks. The differences between PERT and CPM are:

● PERT uses three time estimates (optimistic, most likely, and pessimistic to derive an expected time. CPM uses one time estimate that represents the normal time (i.e., better estimate accuracy with CPM).

Figure 3.4: Simplified PERT network diagram



Adapted from Kerzner, (2013: 500)

PERT is probabilistic in nature, based on a beta distribution for each activity time and a normal distribution for expected time duration. This allows us to calculate the “risk” in completing a project. CPM is based on a single time estimate and is deterministic in nature.

● Both PERT and CPM permit the use of dummy activities in order to develop the logic.

● PERT is used for R&D projects where the risks in calculating time durations have a high variability. CPM is used for construction projects that are resource dependent and based on accurate time estimates.

● PERT is used on those projects, such as R&D, where percent complete is almost impossible to determine except at completed milestones. CPM is used for those projects, such as construction, where percent complete can be determined with reasonable accuracy and customer billing can be accomplished based on percent complete.

3.3 Dependencies

There are three basic types of interrelationships or dependencies:

● Mandatory dependencies (i.e., hard logic): These are dependencies that cannot change, such as erecting the walls of a house before putting up the roof.

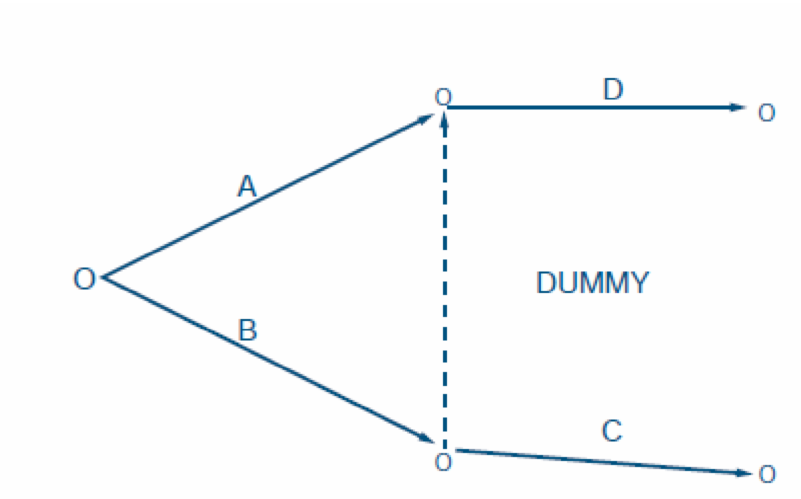
● Discretionary dependencies (i.e., soft logic): These are dependencies that may be at the discretion of the project manager or may simply change from project to project. As an example, one does not need to complete the entire bill of materials prior to beginning procurement.

● External dependencies: These are dependencies that may be beyond the control of the project manager such as having contractors sit on your critical path.

Sometimes, it is impossible to draw network dependencies without including dummy activities. Dummy activities are artificial activities, represented by a dotted line, and do not consume resources or require time. They are added into the network simply to complete the logic.

In Figure 3.5, activity C is preceded by activity B only. Now, let's assume that there exists an activity D that is preceded by both activities A and B. Without drawing a dummy activity (i.e., the dashed line), there is no way to show that activity D is preceded by both activities A and B. Using two dummy activities, one from activity A to activity D and another one from activity B to activity D, could also accomplish this representation. Software programs insert the minimum number of dummy activities, and the direction of the arrowhead is important. In Figure 3.5, the arrowhead must be pointed upward.

Figure 3.5 Arrow Diagramming Method



Adapted from Kerzner, (2013: 501)

3.4 Slack Time

Since there exists only one path through the network that is the longest, the other paths must be either equal in length to or shorter than that path. Therefore, there must exist events and activities that can be completed before the time when they are actually needed. The time differential between the scheduled completion date and the required date to meet critical path is referred to as the slack time. In Figure 3.4, event 4 is not on the crucial path. To go from event 2 to event 5 on the critical path requires seven weeks taking the route 2–3–5. If route 2–4–5 is taken, only four weeks are required. Therefore, event 4, which requires two weeks for completion, should begin anywhere from zero to three weeks after event 2 is complete. During these three weeks, management might find another use for the resources of people, money, equipment, and facilities required to complete event 4.

The critical path is vital for resource scheduling and allocation because the project manager, with coordination from the functional manager, can reschedule those events not on the critical path for accomplishment during other time periods when maximum utilization of resources can be achieved, provided that the critical path time is not extended.

This type of rescheduling through the use of slack times provides for a better balance of resources throughout the company, and may possibly reduce project costs by eliminating idle or waiting time. Slack can be defined as the difference between the latest allowable date and the earliest expected date based on the nomenclature below:

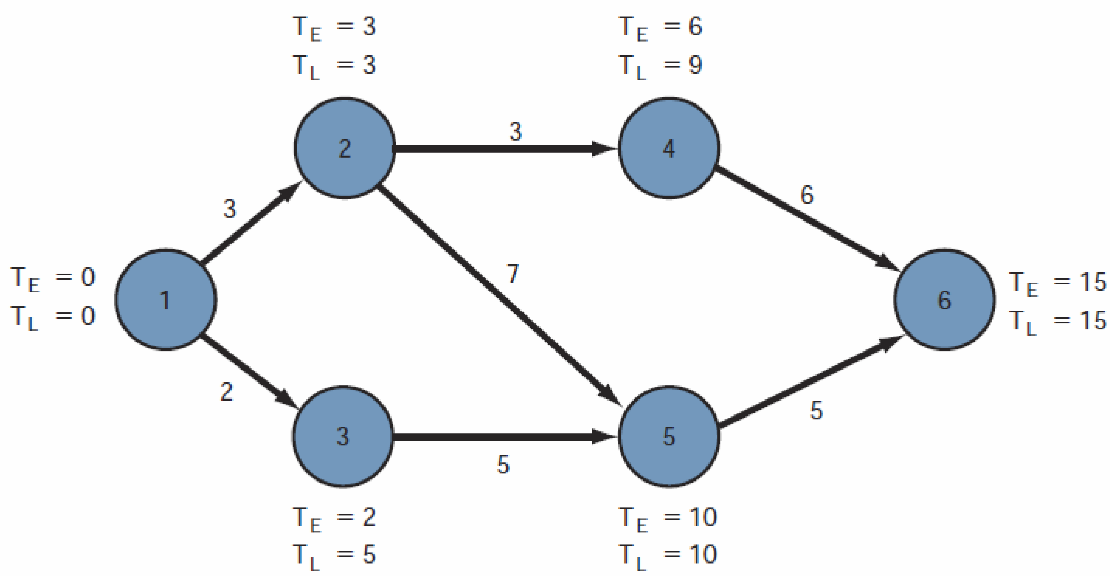
- TE = the earliest time (date) on which an event can be expected to take place
- TL= the latest date on which an event can take place without extending the completion date of the project
- Slack time = TL -TE

The calculation for slack time is performed for each event in the network, as shown in Figure 3.6, by identifying the earliest expected date and the latest starting date. For event 1, TL- TE 0.

Event 1 serves as the reference point for the network and could just as easily have been defined as a calendar date. As before, the critical path is represented as a bold line. The events on the critical path have no slack (i.e., TL =TE) and provide the boundaries for the noncritical path events.5 Since event 2 is critical, TL = TE 3 + 7= 10 for event 5. Event 6 terminates the critical path with a completion time of fifteen weeks.

The earliest time for event 3, which is not on the critical path, would be two weeks (TE 0 + 2= 2), assuming that it started as early as possible. The latest allowable date is obtained by subtracting the time required to complete the activity from events 3 to 5 from the latest starting date of event 5. Therefore, TL (for event 3) =10 - 5 = 5 weeks. Event 3 can now occur anywhere between weeks 2 and 5 without interfering with the scheduled completion date of the project. This same procedure can be applied to event 4, in which case TE 6 and TL 9.

Figure 3.6 Network with slack time



Adapted from Kerzner, (2013:503)

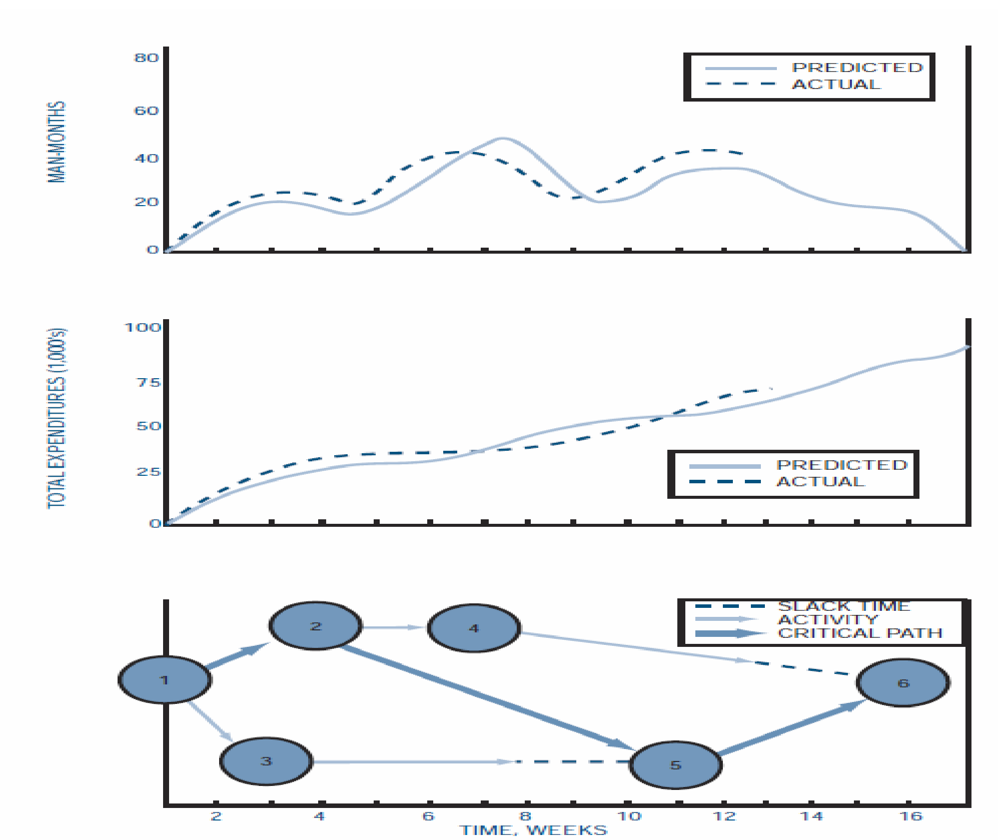
Figure 3.6 contains a simple PERT network, and therefore the calculation of slack time is not too difficult. For complex networks containing multiple paths, the earliest starting dates must be found by proceeding from start to finish through the network, while the latest allowable starting date must be calculated by working backward from finish to start. The importance of knowing exactly where the slack exists cannot be overstated. Proper use of slack time permits better technical performance. Donald Marquis has observed that those companies making proper use of slack time were 30 percent more successful than the average in completing technical requirements. Because of these slack times, PERT networks are often not plotted with a time scale. Planning requirements, however, can require that PERT charts be reconstructed with time scales, in which case a decision must be made as to whether we wish early or late time requirements for slack variables.

This is shown in Figure 3.7 for comparison with total program costs and manpower planning.

Early time requirements for slack variables are utilized in this figure. The earliest times and late times can be combined to determine the probability of successfully meeting the schedule. A sample of the required information is shown in Table 3.2. The earliest and latest times are considered as random variables. The original schedule refers to the schedule for event occurrences that were established at the beginning of the project. The last column in Table 3.2 gives the probability that the earliest time will not be greater than the original schedule time for this event. The exact method for determining this probability, as well as the variances.

In the example shown in Figure 3.6, the earliest and latest times were calculated for each event. Some people prefer to calculate the earliest and latest times for each activity instead. Also, the earliest and latest times were identified simply as the time or date when an event can be expected to take place.

Figure 3.7 Comparison models for a time-phase PERT chart.



Adapted from Kerzner, (2013:504)

To make full use of the capabilities of PERT/CPM, we could identify four values:

- The earliest time when an activity can start (ES)
- The earliest time when an activity can finish (EF)
- The latest time when an activity can start (LS)
- The latest time when an activity can finish (LF).

To calculate the earliest starting times, we must make a forward pass through the network (i.e., left to right). The earliest starting time of a successor activity is the latest of the earliest finish dates of the predecessors. The earliest finishing time is the total of the earliest starting time and the activity duration.

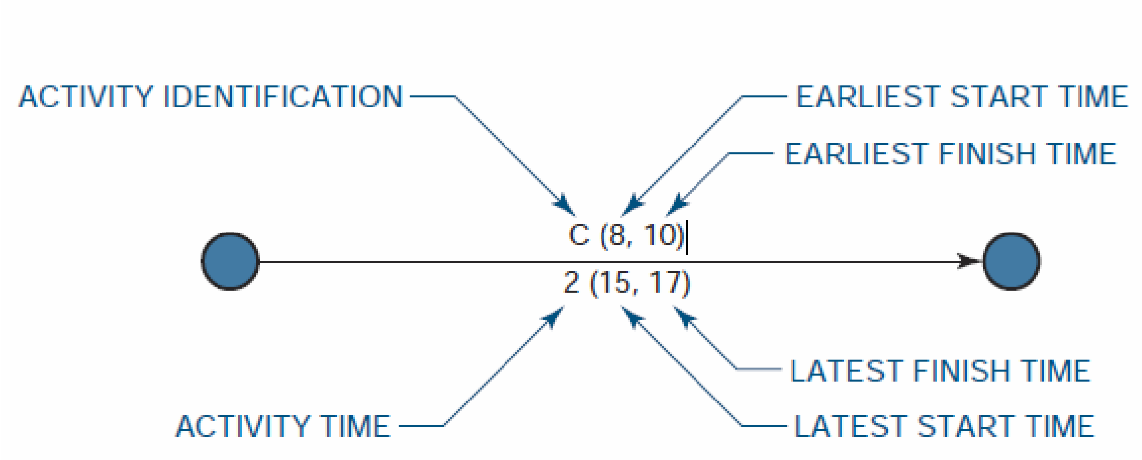
Table 3.2 PERT Control output information

Event Number	Earliest Time		Latest Time		Slack	Original Schedule	Probability of Meeting Schedule
	Expected	Variance	Expected	Variance			

.

Adapted from Kerzner, (2013: 505)

Figure 3.8 Slack identification



Adapted from Kerzner, (2013: 506)

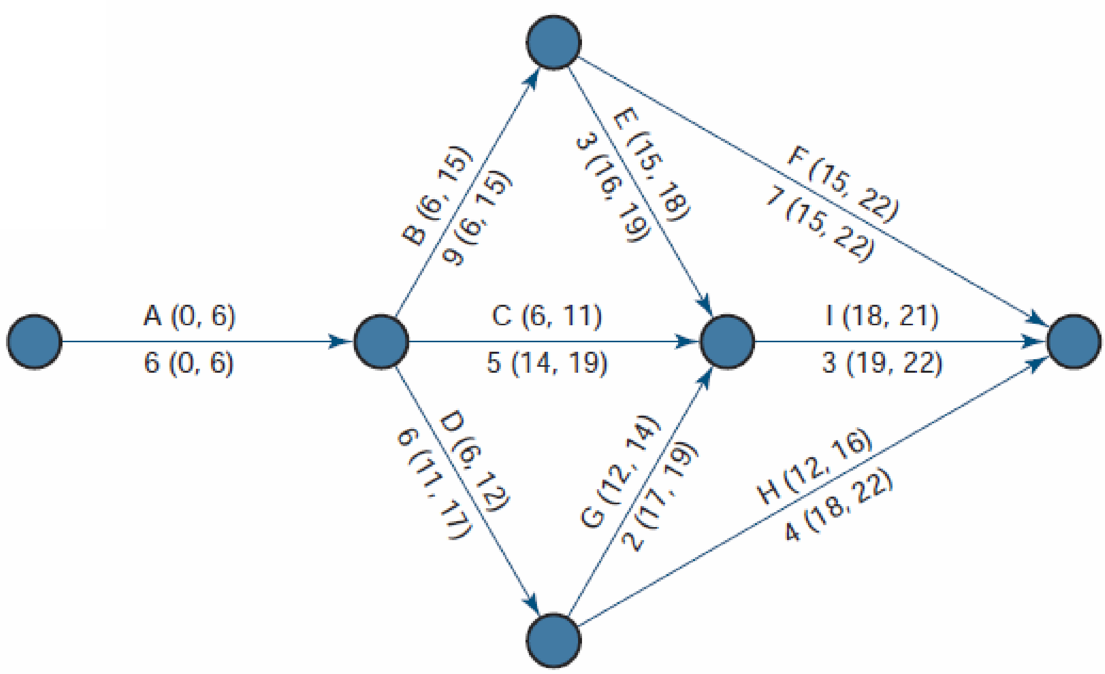
To calculate the latest times, we must make a backward pass through the network by calculating the latest finish time. Since the activity time is known, the latest starting time can be calculated by subtracting the activity time from the latest finishing time. The latest finishing time for an activity entering a node is the earliest starting time of the activities exiting the node.

Figure 3.9 shows the earliest and latest starting and finishing times for a typical network.

The identification of slack time can function as an early warning system for the project manager. As an example, if the total slack time available begins to decrease from one reporting period to the next, that could indicate that work is taking longer than anticipated or that more highly skilled labor is needed. A new critical path could be forming. Looking at the earliest and latest start and finish times can identify slack. As an example, look at the two situations below:

Situation a	Situation b
$\frac{[20, 26]}{[24, 30]}$	$\frac{[30, 36]}{[25, 31]}$

Figure 3.9 PERT CHART with slack times



Adapted from Kerzner, (2013: 506)

In Situation 'a', the slack is easily identified as four work units, where the work units can be expressed in hours, days, weeks, or even months. In Situation 'b', the slack is negative five units of work. This is referred to as negative slack or negative float. What can cause the slack to be negative?

Look at Figure 3.10. When performing a forward pass through a network, we work from left to right beginning at the customer's starting milestone (position 1). The backward pass, however, begins at the customer's end date milestone (position 2), not (as is often taught in the classroom) where the forward pass ends. If the forward pass ends at position 3, which is before the customer's end date, it is possible to have slack on the critical path. This slack is often called reserve time and may be added to other activities or filled with activities such as report writing so that the forward pass will extend to the customer's completion date.

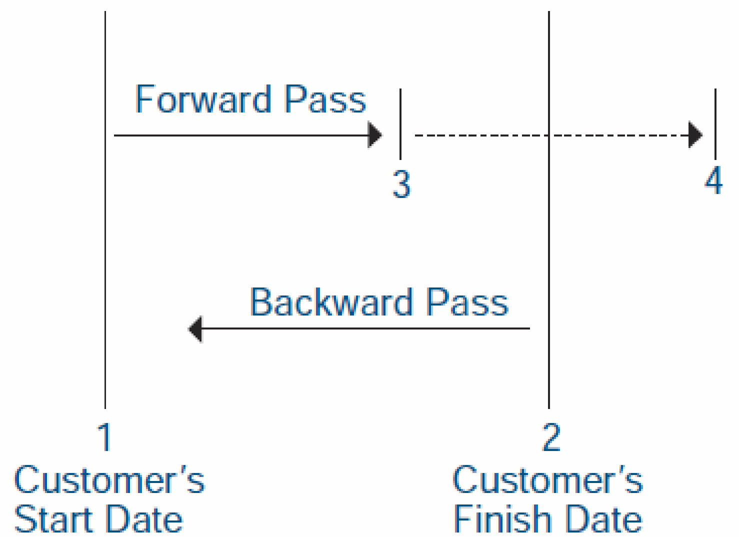
Negative slack usually occurs when the forward pass extends beyond the customer’s end date, as shown by position 4 in the figure. However, the backward pass is still measured from the customer’s completion date, thus creating negative slack. This is most likely to result when:

- The original plan was highly optimistic, but unrealistic
- The customer’s end date was unrealistic
- One or more activities slipped during project execution
- The assigned resources did not possess the correct skill levels
- The required resources would not be available until a later date

In any event, negative slack is an early warning indicator that corrective action is needed to maintain the customer’s end date.

At this point, it is important to understand the physical meaning of slack. Slack measures how early or how late an event can start or finish.

Figure 3.10 Slack Time



Adapted from Kerzner, (2013: 507)

Most networks today, however, focus on the activity rather than the event, as shown in Figure 3.9. When slack is calculated on the activity, it is usually referred to as float rather than slack, but most project managers use the terms interchangeably. For activity C in Figure 3.9, the float is eight units. If the float in an activity is zero, then it is a critical path activity, such as seen in activity F. If the slack in an event is zero, then the event is a critical path event. Another term is maximum float. The equation for maximum float is:

Maximum float = latest finish - earliest start - duration

For activity H in Figure 3.9, the maximum float is six units.

3.5 Network Re-planning

Once constructed, the PERT/CPM charts provide the framework from which detailed planning can be initiated and costs can be controlled and tracked. Many iterations, however, are normally made during the planning phase before the PERT/CPM chart is finished. Figure 3.11 shows this iteration process. The slack times form the basis from which additional iterations, or network re-planning, can be performed. Network re-planning is performed either at the conception of the program in order to reduce the length of the critical path, or during the program, should the unexpected occur. If all were to go according to schedule, then the original PERT/CPM chart would be unchanged for the duration of the project. But, how many programs or projects follow an exact schedule from start to finish?

Suppose that activities 1–2 and 1–3 in Figure 3.6 require manpower from the same functional unit. Upon inquiry by the project manager, the functional manager asserts that he can reduce activity 1–2 by one week if he shifts resources from activity 1–3 to activity 1–2. Should this happen, however, activity 1–3 will increase in length by one week.

Reconstructing the PERT/CPM network as shown in Figure 3.12, the length of the critical path is reduced by one week, and the corresponding slack events are likewise changed.

There are two network re-planning techniques based almost entirely upon resources: resource leveling and resource allocation.

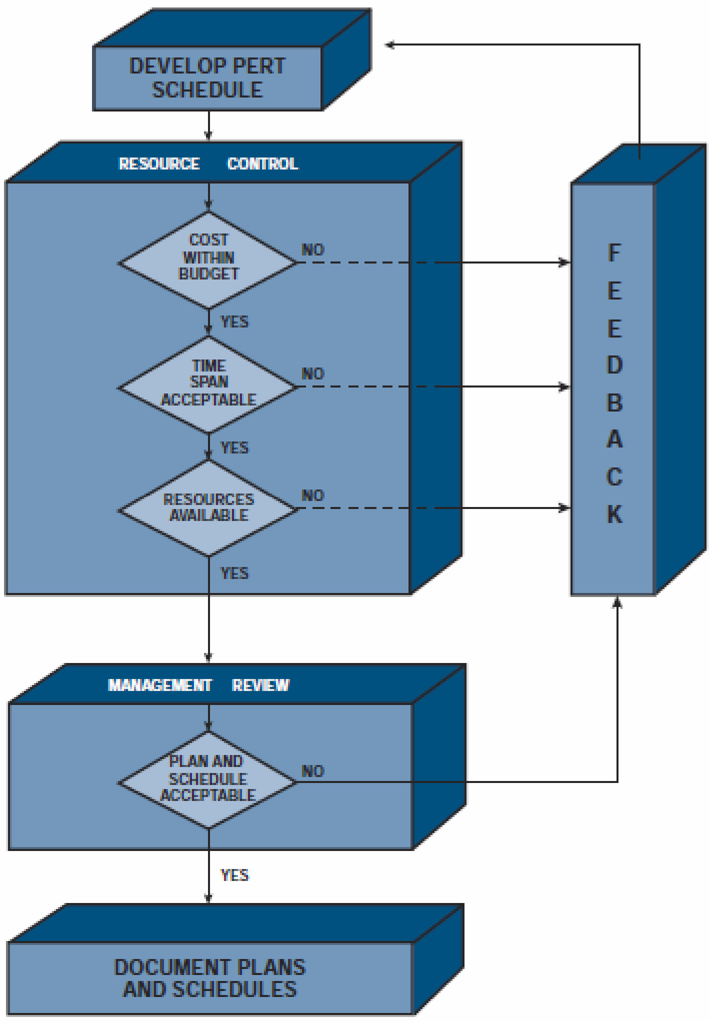
● Resource leveling is an attempt to eliminate the manpower peaks and valleys by smoothing out the period-to-period resource requirements. The ideal situation is to do this without changing

● the end date. However, in reality, the end date moves out and additional costs are incurred.

● Resource allocation (also called resource-limited planning) is an attempt to find the shortest possible critical path based upon the available or fixed resources. The problem with this approach is that the employees may not be qualified technically to perform on more than one activity in a network.

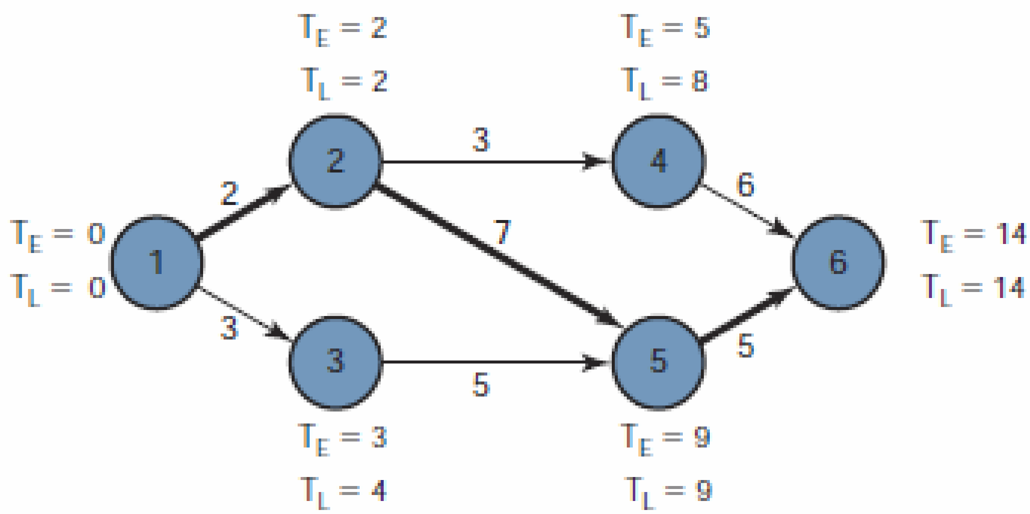
Unfortunately, not all PERT/CPM networks permit such easy rescheduling of resources. Project managers should make every attempt to reallocate resources to reduce the critical path, provided that the slack was not intentionally planned as a safety valve.

Figure 3.11: Iteration process for PERT schedule development



Adapted from Kerzner, (2013, 509)

Figure 3.12: Network Re- Planning of figure 3.6



Adapted from Kerzner, (2013, 509)

Transferring resources from slack paths to more critical paths is only one method for reducing expected project time. Several other methods are available:

- Elimination of some parts of the project
- Addition of more resources (i.e., crashing)
- Substitution of less time-consuming components or activities
- Parallelization of activities
- Shortening critical path activities
- Shortening early activities
- Shortening longest activities
- Shortening easiest activities
- Shortening activities that are least costly to speed up
- Shortening activities for which you have more resources
- Increasing the number of work hours per day

Under the ideal situation, the project start and end dates are fixed, and performance within this time scale must be completed within the guidelines described by the statement of work.

Should the scope of effort have to be reduced in order to meet other requirements, the contractor incurs a serious risk that the project may be canceled, or performance expectations may no longer be possible. Adding resources is not always possible. If the activities requiring these added resources also call for certain expertise, then the contractor may not have qualified or experienced employees, and may avoid the risk. The contractor might still reject this idea, even if time and money were available for training new employees, because on project termination he might not have any other projects for these additional people. However, if the project is the construction of a new facility, then the labor-union pool may be able to provide additional experienced manpower.

3.6 Estimating Activity Time

Determining the elapsed time between events requires that responsible functional managers evaluate the situation and submit their best estimates. The calculations for critical paths and slack times in the previous sections were based on these best estimates. In this ideal situation, the functional manager would have at his disposal a large volume of historical data from which to make his estimates. Obviously, the more historical data available, the more reliable the estimate. Many programs, however, include events and activities that are non-repetitive. In this case, the functional managers must submit their estimates using three possible completion assumptions:

● Optimistic completion time. This time assumes that everything will go according to plan and with minimal difficulties. This should occur approximately 1 percent of the time.

● Pessimistic completion time. This time assumes that everything will not go according to plan and maximum difficulties will develop. This should also occur approximately 1 percent of the time.

● Most likely completion time. This is the time that, in the mind of the functional manager, would most often occur should this effort be reported over and over again.

Before these three times can be combined into a single expression for expected time, two assumptions must be made. The first assumption is that the standard deviation, σ , is one-sixth of the time requirement range. This assumption stems from probability theory, where the end points of a curve are three standard deviations from the mean. The second assumption requires that the probability distribution of time required for an activity be expressible as a beta distribution.

The expected time between events can be found from the expression:

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

where *te* = expected time, a most optimistic time, b most pessimistic time, and *m* = most likely time. As an example, if *a* = 3, *b* = 7, and *m* = 5 weeks, then the expected time, *te*, would be 5 weeks. This value for *te* would then be used as the activity time between two events in the construction of a PERT chart. This method for obtaining best estimates contains a large degree of uncertainty. If we change the variable times to *a* = 2, *b* = 12, and *m* = 4 weeks, then *te* will still be 5 weeks. The latter case, however, has a much higher degree of uncertainty because of the wider spread between the optimistic and pessimistic times. Care must be taken in the evaluation of risks in the expected times.

3.7 Estimating Total Project Time

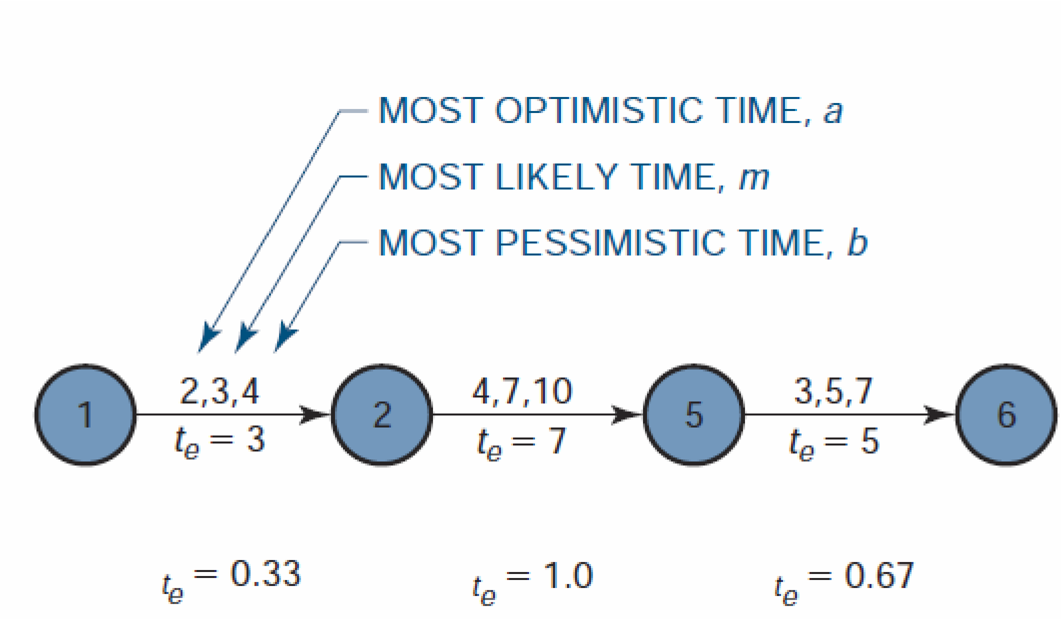
In order to calculate the probability of completing the project on time, the standard deviations of each activity must be known. This can be found from the expression:

$$\sigma te = \frac{b - a}{6}$$

Where σte is the standard deviation of the expected time, *te.* Another useful expression is the variance, v, which is the square of the standard deviation. The variance is primarily useful for comparison to the expected values. However, the standard deviation can be used just as easily, except that we must identify whether it is a one, two, or three sigma limit deviation.

Figure 3.13 shows the critical path of Figure 3.6, together with the corresponding values from which the expected times were calculated, as well as the standard deviations.

Figure 3.13: Expected time analysis for critical path events shown in Figure 3.6



Adapted from Kerzner, (2013, 513).

The total path standard deviation is calculated by the square root of the sum of the squares of the activity standard deviations using the following expression:

$$\begin{aligned}\sigma_{\text{total}} &= \sqrt{\sigma_{1-2}^2 + \sigma_{2-5}^2 + \sigma_{5-6}^2} \\ &= \sqrt{(0.33)^2 + (1.0)^2 + (0.67)^2} \\ &= 1.25\end{aligned}$$

The purpose of calculating σ is that it allows us to establish a confidence interval for each activity and the critical path.

From statistics, using a normal distribution, we know that there is a 68 percent chance of completing the project within one standard deviation, a 95 percent chance within two standard deviations, and a 99.73 percent chance within three standard deviations.

This type of analysis can be used to measure the risks in the estimates, the risks in completing each activity, and the risks in completing the entire project. In other words, the standard deviation, σ, serves as a measurement of the risk. This analysis, however, assumes that normal distribution applies, which is not always the case. As an example of measuring risk, consider a network that has only three activities on the critical path as shown below (all times in weeks):

Table 3.3

Activity	Optimistic Time	Most Likely Time	Pessimistic Time	T_{ex}	σ	σ^2
A	3	4	5	4	$2/6$	$4/36$
B	4	4.5	8	5	$4/6$	$16/36$
C	4	6	8	6	$2/6$	$16/36$
				15		1.0

Adapted from Kerzner, (2013, 514)

From the above table, the length of the critical path is 15 weeks. Since the variance (i.e., σ 2) is 1.0, then σ path, which is the square root of the variance, must be 1 week. We can now calculate the probability of completing the project within certain time limits:

- The probability of getting the job done within 16 weeks is
- 50% + (1⁄2) x(68%), or 84%.
- Within 17 weeks, we have 50% + (1⁄2) x (95%), or 97.5%.
- Within 14 weeks, we have 50% - (1⁄2) x (68%), or 16%.
- Within 13 weeks, we have 50% - (1⁄2) x (95%), or 2.5%.

3.8 Total PERT/ CPM Planning

It is necessary to discuss the methodology for preparing PERT schedules. PERT scheduling is a six-step process. Steps one and two begin with the project manager laying out a list of activities to be performed and then placing these activities in order of precedence, thus identifying the interrelationships. These charts drawn by the project manager are called either logic charts, arrow diagrams, work flow, or simply networks. The arrow diagrams will look like Figure 3.6 with two exceptions: The activity time is not identified, and neither is the critical path. Step three is reviewing the arrow diagrams with the line managers (i.e., the true experts) in order to obtain their assurance that neither too many nor too few activities are identified, and that the interrelationships are correct.

In step four the functional manager converts the arrow diagram to a PERT chart by identifying the time duration for each activity. It should be noted here that the time estimates that the line managers provide are based on the assumption of unlimited resources because the calendar dates have not yet been defined.

Step five is the first iteration on the critical path. It is here that the project manager looks at the critical calendar dates in the definition of the project's requirements. If the critical path does not satisfy the calendar requirements, then the project manager must try to shorten the critical path or ask the line managers to take the "fat" out of their estimates. Step six is often the most overlooked step. Here the project manager places calendar dates on each event in the PERT chart, thus converting from planning under unlimited resources to planning with limited resources. Even though the line manager has given you a time estimate, there is no guarantee that the correct resources will be available when needed. That is why this step is crucial. If the line manager cannot commit to the calendar dates, then re- planning will be necessary. Most companies that survive on competitive bidding lay out proposal schedules based on unlimited resources. After contract award, the schedules are analyzed again because the company now has limited resources.

After all, how can a company bid on three contracts simultaneously and put a detailed schedule into each proposal if it is not sure how many contracts, if any, it will win? For this reason, customers require that formal project plans and schedules be provided thirty to ninety days after contract award.

Finally, PERT re-planning should be an ongoing function during project execution. The best project managers continually try to assess what can go wrong and perform perturbation analysis on the schedule. (This should be obvious because the constraints and objectives of the project can change during execution.) Primary objectives on a schedule are:

- Best time
- Least cost
- Least risk

Secondary objectives include:

- Studying alternatives
- Optimum schedules
- Effective use of resources
- Communications
- Refinement of the estimating process
- Ease of project control
- Ease of time or cost revisions

Obviously, these objectives are limited by such constraints as:

- Calendar completion
- Cash or cash flow restrictions
- Limited resources
- Management approvals

3.9 Alternative PERT/ CPM Models

Because of the many advantages of PERT/time, numerous industries have found applications for this form of network.

A partial list of these advantages includes capabilities for:

● Trade-off studies for resource control

● Providing contingency planning in the early stages of the project

● Visually tracking up-to-date performance

● Demonstrating integrated planning

● Providing visibility down through the lowest levels of the work breakdown structure

● Providing a regimented structure for control purposes to ensure compliance with

the work breakdown structure and the statement of work

● Increasing functional members' ability to relate to the total program, thus providing participants with a sense of belonging Even with these advantages, in many situations PERT/time has proved ineffective in controlling resources. In the beginning of this chapter we defined three parameters necessary for the control of resources: time, cost, and performance. With these factors in mind, companies began reconstructing PERT/time into PERT/cost and PERT/performance models. PERT/cost is an extension of PERT/time and attempts to overcome the problems associated with the use of the most optimistic and most pessimistic time for estimating completion.

PERT/cost can be regarded as a cost accounting network model based on the work breakdown structure and capable of being subdivided down to the lowest elements, or work packages. The advantages of PERT/cost are that it:

● Contains all the features of PERT/time

● Permits cost control at any WBS level

The primary reason for the development of PERT/cost was so that project managers could identify critical schedule slippages and cost overruns in time to correct them.

3.10 Precedence Networks

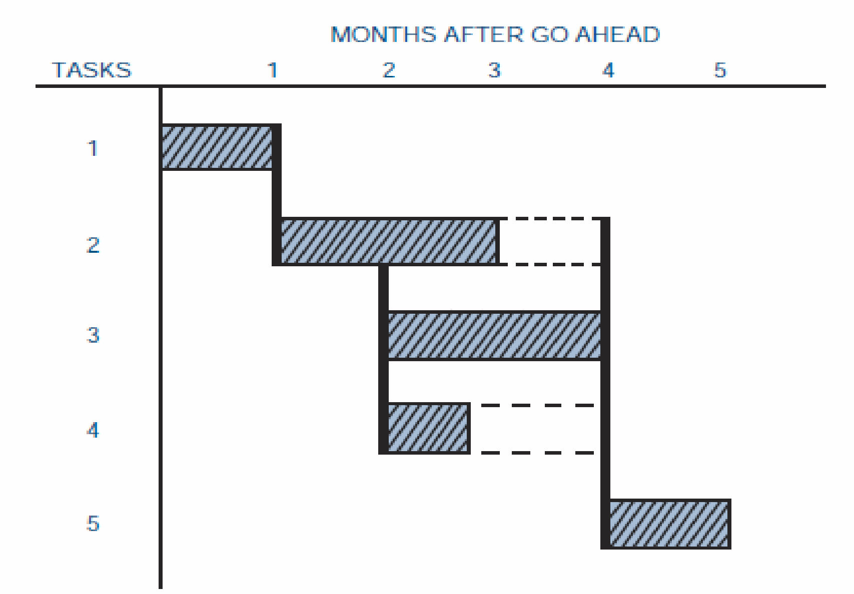
In recent years, there has been an explosion in project management software packages. Small packages may sell for a few thousand dollars, whereas the price for larger packages may be tens of thousands of dollars. Computerized project management can provide answers to such questions as:

- How will the project be affected by limited resources?
- How will the project be affected by a change in the requirements?
- What is the cash flow for the project (and for each WBS element)?
- What is the impact of overtime?
- What additional resources are needed to meet the constraints of the project?
- How will a change in the priority of a certain WBS element affect the total project?

The more sophisticated packages can provide answers to schedule and cost based on:

- Adverse weather conditions
- Weekend activities
- Unleveled manpower requirements

Figure 3.14: Precedence Network



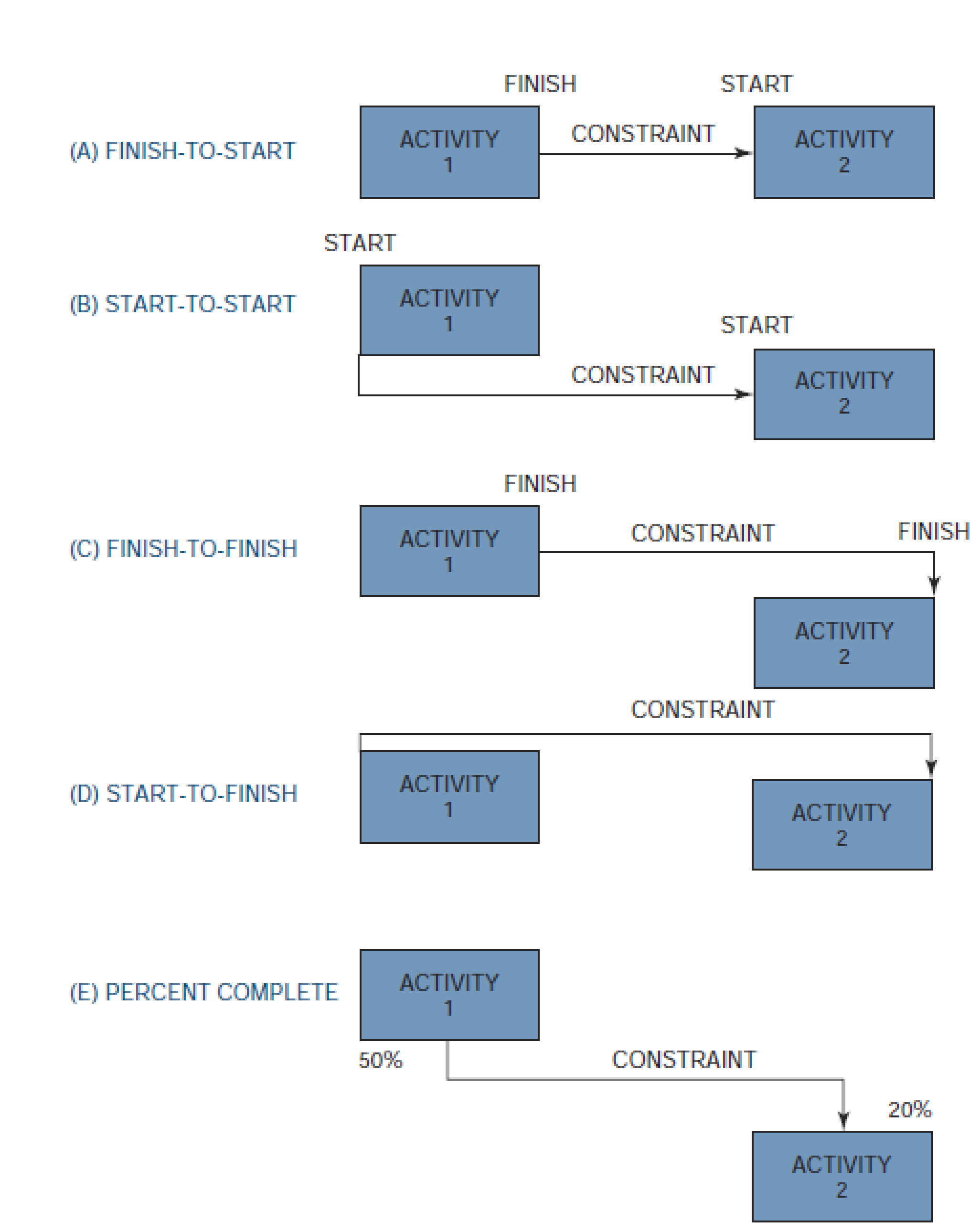
Adapted from Kerzner, (2013, 524)

- Variable crew size
- Splitting of activities
- Assignment of unused resources

Regardless of the sophistication of computer systems, printers and plotters prefer to draw straight lines rather than circles. Most software systems today use precedence networks, as shown in Figure 3.14, which attempt to show interrelationships on bar charts. In Figure 3.14, task 1 and task 2 are related because of the solid line between them. Task 3 and task 4 can begin when task 2 is half finished. (This cannot be shown easily on PERT without splitting activities.) The dotted lines indicate slack. The critical path can be identified by putting an asterisk (*) beside the critical elements, or by putting the critical connections in a different color or boldface. The more sophisticated software packages display precedence networks in the format shown in Figure 3.15. In each of these figures, work is accomplished during the activity.

This is sometimes referred to as the activity-on-node method. The arrow represents the relationship or constraint between activities. Figure 3.15 A illustrates a finish-to-start constraint. In this figure, activity 2 can start no earlier than the completion of activity 1. All PERT charts are finish-to-start constraints. Figure 3.15 B illustrates a start-to-start constraint. Activity 2 cannot start prior to the start of activity 1. Figure 3.15 C illustrates a finish-to-finish constraint. In this figure, activity 2 cannot finish until activity 1 finishes. Figure 3.15 D illustrates a start-to-finish constraint.

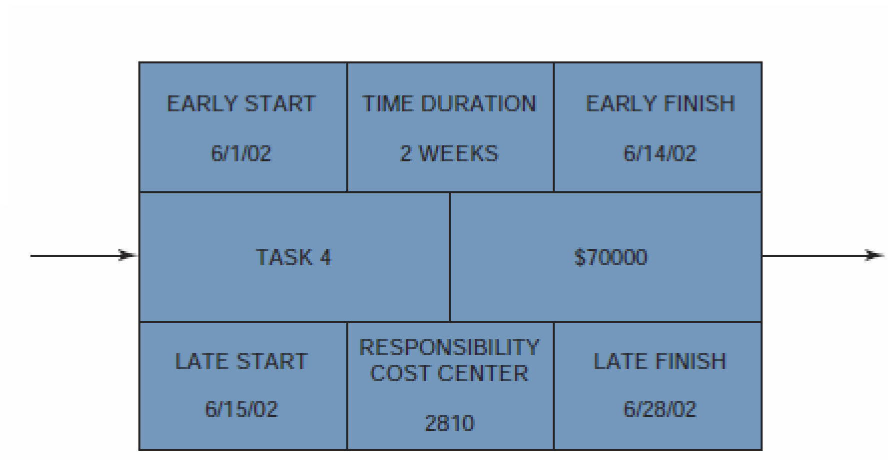
Figure 3.15 Precedence Relationships



An example might be that you must start studying for an exam some time prior to the completion of the exam. This is the least common type of precedence chart. Figure 3.15E illustrates a percent complete constraint.

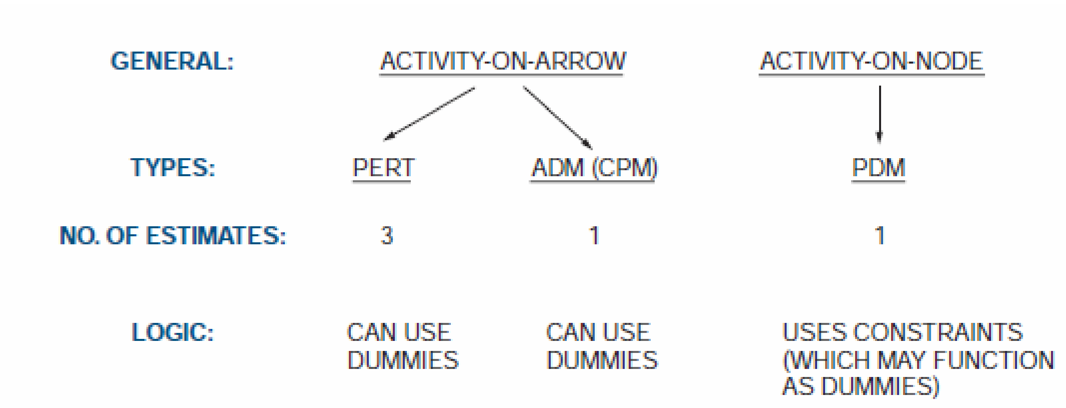
In this figure, the last 20 percent of activity 2 cannot be started until 50 percent of activity 1 has been completed.

Figure 3.16 Computerized Information Flow



Adapted from Kerzner, (2013, 526)

Figure 3.17 Comparison of networks



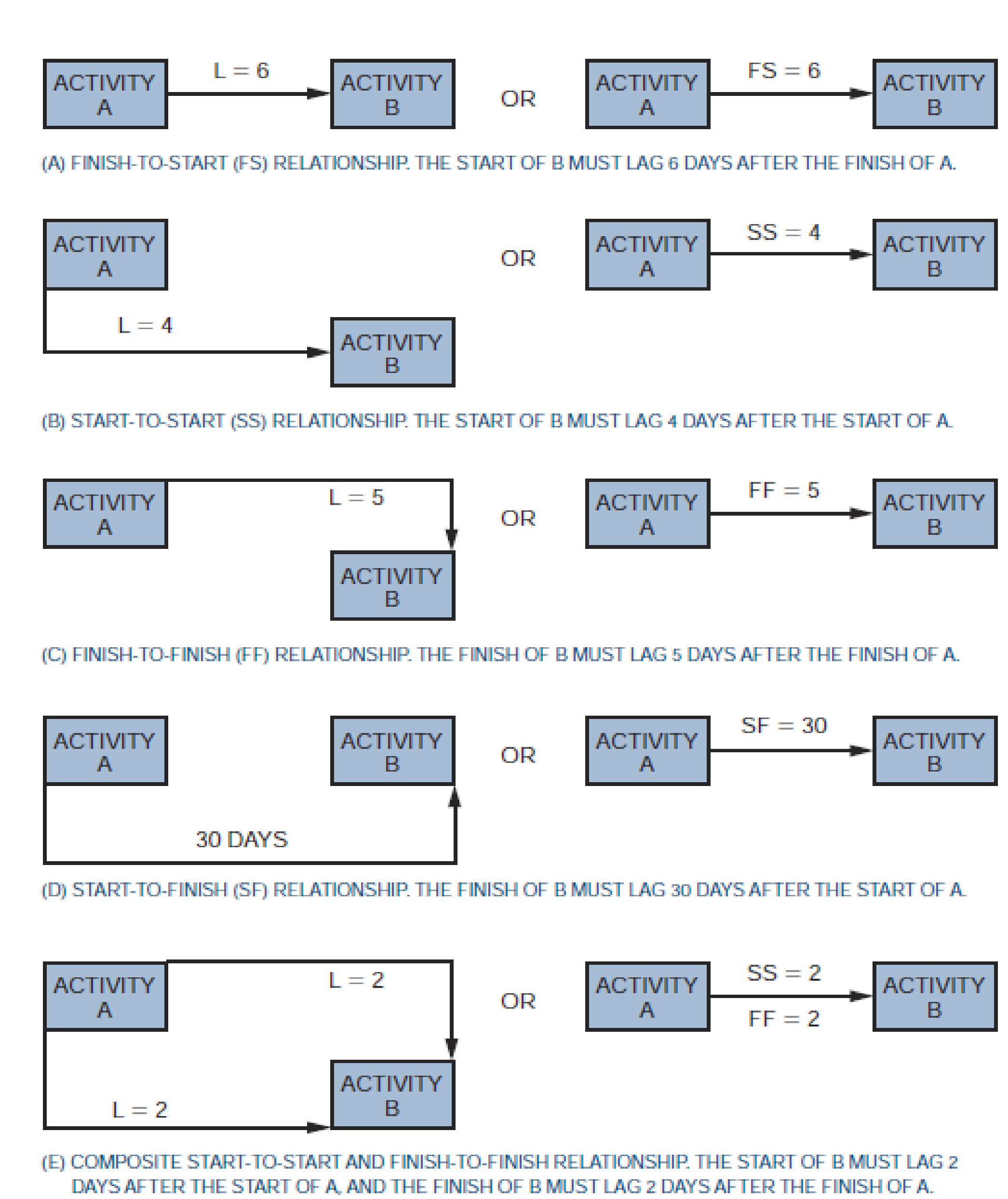
Adapted from Kerzner, (2013, 526)

Figure 3.16 shows the typical information that appears in each of the activity boxes shown in Figure 3.15. The box identified as "responsibility cost center" could also have been identified as the name, initials, or badge number of the person responsible for this activity. Figure 3.17 shows the comparison of three of the network techniques.

3.11 LAG

The time period between the early start or finish of one activity and the early start or finish of another activity in the sequential chain is called lag. Lag is most commonly used in conjunction with precedence networks. Figure 3.18 shows five different ways to identify lag on the constraints.

Figure 3.18 Precedence Charts with lag



Adapted from Kerzner, (2013, 527)

Slack is measured **within** activities whereas lag is measured **between** activities. As an example, look at Figure 3.18 A. Suppose that activity A ends at the end of the first week of March. Since it is a finish-to-start precedence chart, one would expect the start of activity B to be the beginning of the second week in March. But if activity B cannot start until the beginning of the third week of March, that would indicate a week of lag between activity A and activity B even though both activities can have slack within the activity. Simply stated, slack is measured within the activities whereas lag is measured between the activities. The lag may be the result of resource constraints. Any common term is lead. Again looking at Figure 3.18 A, suppose that activity A finishes on March 15 but the precedence chart shows activity B starting on March 8, seven days prior to the completion of activity A. In this case, L= -7, a negative value, indicating that the start of activity B leads the completion of activity A by seven days. To illustrate how this can happen, consider the following example: The line manager responsible for activity B promised you that his resources would be available on March 16, the day after activity A was scheduled to end. The line manager then informs you that these resources will be available on March 8, and if you do not pick them up on your charge number at that time, they may be assigned elsewhere and not be available on the 16th. Most project managers would take the resources on the 8th and find some work for them to do even though logic says that the work cannot begin until after activity A has finished.

3.12 Scheduling Problems

Every scheduling technique has advantages and disadvantages. Some scheduling problems are the result of organizational indecisiveness, such as having a project sponsor that refuses to provide the project manager guidance on whether the schedule should be based upon a least time, least cost, or least risk scheduling objective. As a result, precious time is wasted in having to redo the schedules. However, there are some scheduling problems that can impact all scheduling techniques.

These include:

- Using unrealistic estimates for effort and duration
- Inability to handle employee workload imbalances
- Having to share critical resources across several projects
- Overcommitted resources
- Continuous readjustments to the WBS primarily from scope changes
- Unforeseen bottlenecks

REFLECTION QUESTIONS

3.1 Should a PERT/CPM network become a means of understanding reports and schedules,
or should it be vice versa?

3.2 Before PERT diagrams are prepared, should the person performing the work have a clear
definition of the requirements and objectives, both prime and supporting? Is it an absolute
necessity?

3.3 Who prepares the PERT diagrams? Who is responsible for their integration?

3.4 Should PERT networks follow the work breakdown structure?

3.5 How can a PERT network be used to increase functional ability to relate to the total
program?

3.6 What problems are associated with applying PERT to small programs?

3.7 Should PERT network design be dependent on the number of elements in the work
breakdown structure?

3.8 Can bar charts and PERT diagrams be used to smooth out departmental manpower
requirements?

3.9 Should key milestones be established at points where trade-offs are most likely to occur?

3.10 Would you agree or disagree that the cost of accelerating a project rises exponentially,
especially as the project nears completion?

3.11 What are the major difficulties with PERT, and how can they be overcome?

3.12 Is PERT/cost designed to identify critical schedule slippages and cost overruns early
enough that corrective action can be taken?

3.13 Draw the network and identify the critical path. Also calculate the earliest–latest starting and finishing times for each activity:

Activity	Preceding Activity	Time (Weeks)
A	—	7
B	—	8
C	—	6
D	A	6
E	B	6
F	B	8
G	C	4
H	D, E	7
I	F, G, H	3

CHAPTER 4

Project Graphics

Chapter 4 Monitoring, Evaluation and Reporting

CHAPTER OUTCOMES

Upon completion of this Chapter, students should be able to:

- Develop BAR (Gannt) charts
- Critically analyse other conventional presentation techniques in project management
- Distinguish between various types of customer reporting methods
- Construct logic diagrams

Essential Reading

Textbooks:

- Kerzner. (2013). Project management A Systems Approach. 10 th Edition. Wiley & Sons, Chapter 13.

4.1 Introduction

In Chapter 2, we defined the steps involved in establishing a formal program plan with detailed schedules to manage the total program. Any plan, schedule, drawing, or specification that will be read by more than one person must be expressed in a language that is understood by all recipients. The ideal situation is to construct charts and schedules in suitable notation that can be used for both in-house control and out-of-house customer status reporting. Unfortunately, this is easier said than done. Customers and contractors are interested mainly in the three vital control parameters:

- Time
- Cost
- Performance

All schedules and charts should consider these three parameters and their relationship to corporate resources.

Information to ensure proper project evaluation is usually obtained through four methods:

- Firsthand observation
- Oral and written reports
- Review and technical interchange meetings
- Graphical displays

Firsthand observations are an excellent tool for obtaining unfiltered information, but they may not be possible on large projects. Although oral and written reports are a way of life, they often contain either too much or not enough detail, and significant information may be disguised. Review and technical interchange meetings provide face-to-face communications and can result in immediate agreement on problem definitions or solutions, such as changing a schedule. The difficulty is in the selection of attendees from the customer's and the contractor's organizations.

Good graphical displays make the information easy to identify and are the prime means for tracking cost, schedule, and performance. Proper graphical displays can result in:

- Cutting project costs and reducing the time scale
- Coordinating and expediting planning
- Eliminating idle time
- Obtaining better scheduling and control of subcontractor activities
- Developing better troubleshooting procedures
- Cutting time for routine decisions, but allowing more time for decision-making

4.2 Customer Reporting

There are more than thirty visual methods for representing activities. The method chosen should depend on the intended audience. For example, upper-level management may be interested in costs and integration of activities, with very little detail. Summary-type charts normally suffice for this purpose. Daily practitioners, on the other hand, may require considerable detail. For customers, the presentation should include cost and performance data.

When presenting cost and performance data, figures and graphs should be easily understood and diagrams should quickly convey the intended message or objective. In many organizations, each department or division may have its own method of showing scheduling activities. Research and development organizations prefer to show the logic of activities rather than the integration of activities that would normally be representative of a manufacturing plant. The ability to communicate is a prerequisite for successful management of a program. Program review meetings, technical interchange meetings, customer summary meetings, and in-house management control meetings all require different representative forms of current program performance status. The final form of the schedule may be bar charts, graphs, tables, bubble charts, or logic diagrams. These are described in the sections that follow.

4.3 BAR (GANTT) Chart

The most common type of display is the bar or Gantt chart, named for Henry Gantt, who first utilized this procedure in the early 1900s. The bar chart is a means of displaying simple activities or events plotted against time or dollars. An activity represents the amount of work required to proceed from one point in time to another. Events are described as either the starting or ending point for either one or several activities.

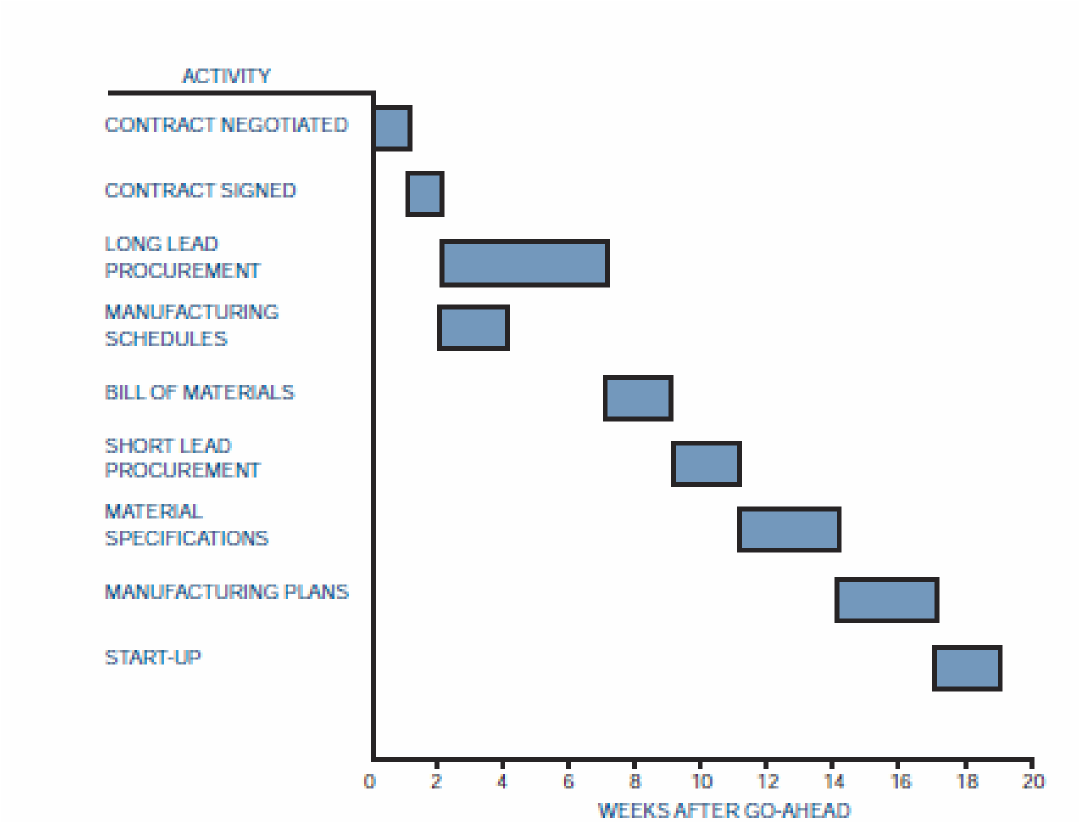
Bar charts are most commonly used for exhibiting program progress or defining specific work required to accomplish an objective. Bar charts often include such items as listings of activities, activity duration, schedule dates, and progress-to-date.

Figure 4.1 shows nine activities required to start up a production line for a new product. Each bar in the figure represents a single activity. Figure 4.1 is a typical bar chart that would be developed by the program office at program inception.

Bar charts are advantageous in that they are simple to understand and easy to change. They are the simplest and least complex means of portraying progress (or the lack of it) and can easily be expanded to identify specific elements that may be either behind or ahead of schedule.

Bar charts provide only a vague description of how the entire program or project reacts as a system, and have three major limitations. First, bar charts do not show the interdependencies of the activities, and therefore do not represent a "network" of activities. This relationship between activities is crucial for controlling program costs. Without this relationship, bar charts have little predictive value. For example, does the long-lead procurement activity in Figure 4.1 require that the contract be signed before procurement can begin?

Figure 4.1 Single Activity BAR Chart



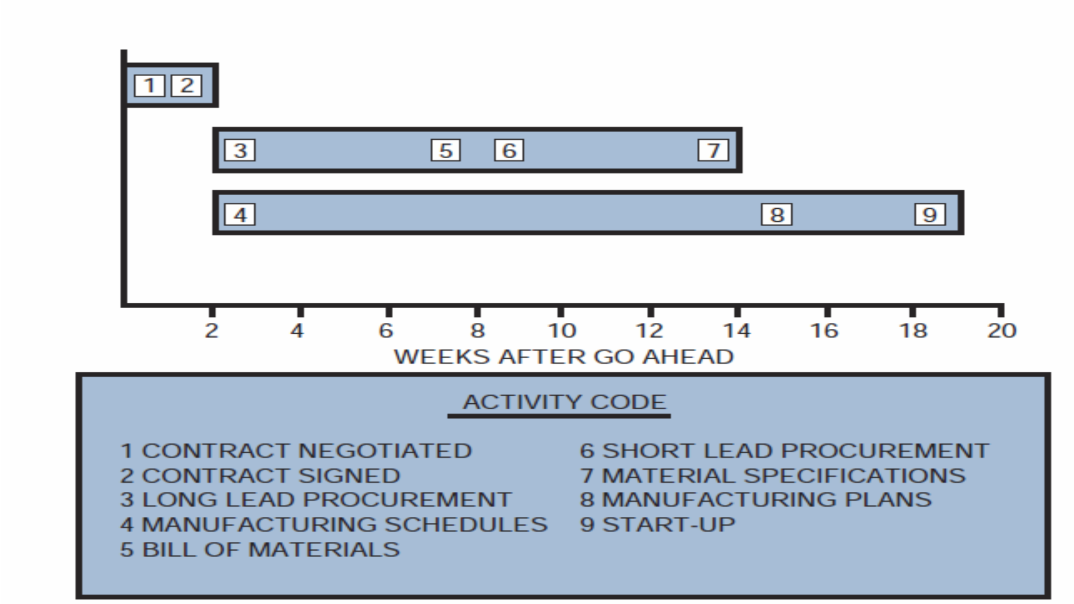
Adapted from Kerzner, (2013, 558)

Can the manufacturing plans be written without the material specifications activity being completed? The second major discrepancy is that the bar chart cannot show the results of either an early or a late start in activities. How will a slippage of the manufacturing schedules activity in Figure 4.1 affect the completion date of the program? Can the manufacturing schedules activity begin two weeks later than shown and still serve as an input to the bill of materials activity? What will be the result of a crash program to complete activities in sixteen weeks after go-ahead instead of the originally planned nineteen weeks? Bar charts do not reflect true project status because elements behind schedule do not mean that the program or project is behind schedule. The third limitation is that the bar chart does not show the uncertainty involved in performing the activity and, therefore, does not readily admit itself to sensitivity analysis.

For instance, what is the shortest time that an activity might take? What is the longest time? What is the average or expected time to activity completion?

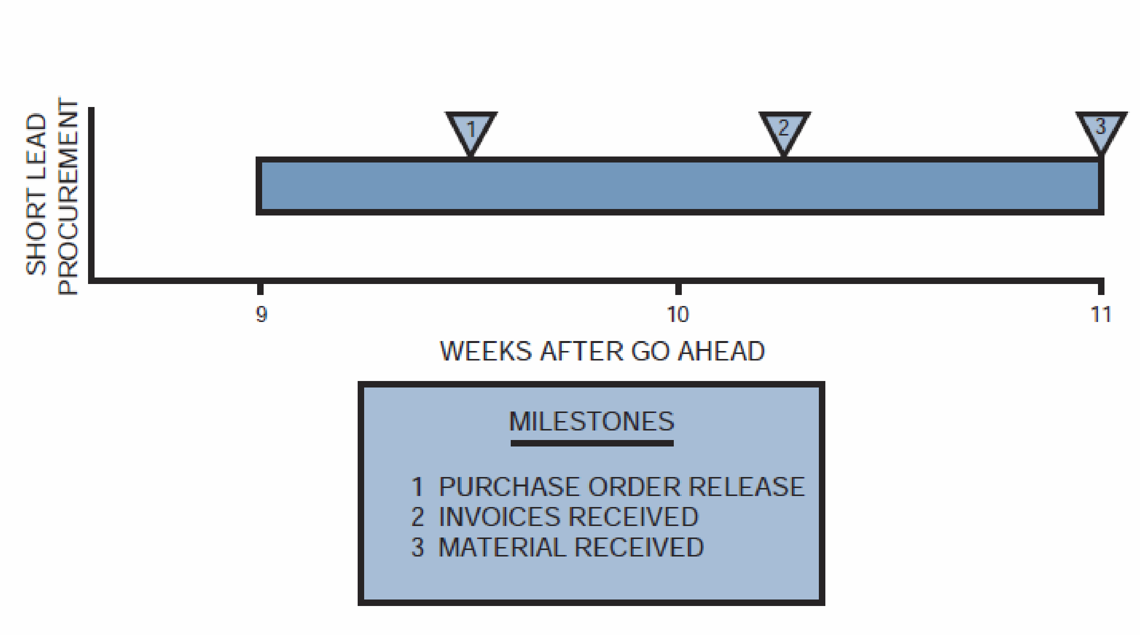
Even with these limitations, bar charts do, in fact, serve as useful tools for program analysis. Some of the limitations of bar charts can be overcome by combining single activities, as shown in Figure 4.2. The weakness in this method is that the numbers representing each of the activities do not indicate whether this is the beginning or the end of the activity. Therefore, the numbers should represent events rather than activities, together with proper identification. As before, no distinction is made as to whether event 2 must be completed prior to the start of event 3 or event 4. The chart also fails to define clearly the relationship between the multiple activities on a single bar. For example, must event 3 be completed prior to event 5? Often, combined activity bar charts can be converted to milestone bar charts by placing small triangles at strategic locations in the bars to indicate completion of certain milestones within each activity or grouping of activities, as shown in Figure 4.3. The exact definition of a milestone differs from company to company, but usually implies some point where major activity either begins or ends, or cost data become critical.

Figure 4.2 BAR Chart showing Combined Activities



Adapted from Kerzner, (2013, 558)

Figure 4.3 BAR/ Milestones Chart

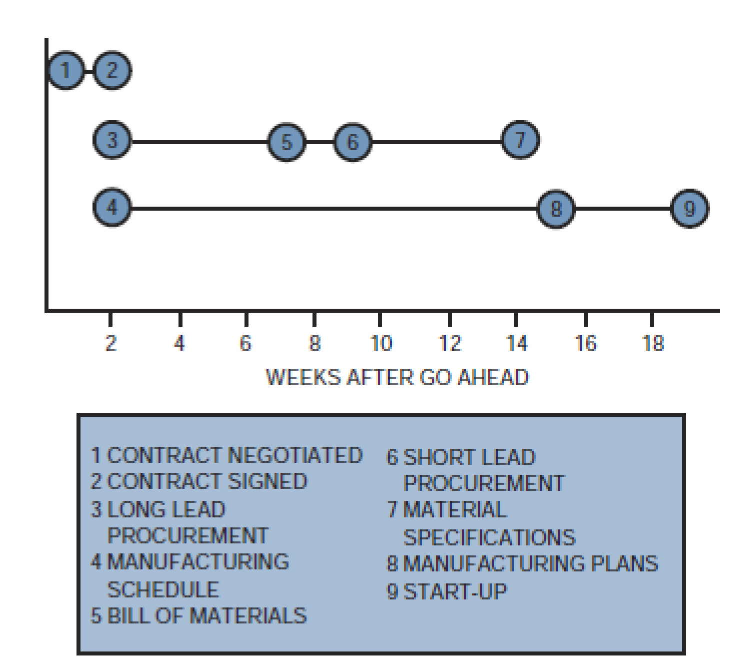


Adapted from Kerzner, (2013, 559)

Bar charts can be converted to partial interrelationship charts by indicating (with arrows) the order in which activities must be performed. Figure 4.4 represents the partial interrelationship of the activities in Figures 4.1 and 4.2. A full interrelationship schedule is included under the discussion of PERT networks in the previous chapter. The most common method of presenting data to both in-house management and the customer is through the use of bar charts. Care must be taken not to make the figures overly complex so that more than one interpretation can exist. A great deal of information and color can be included in bar charts.

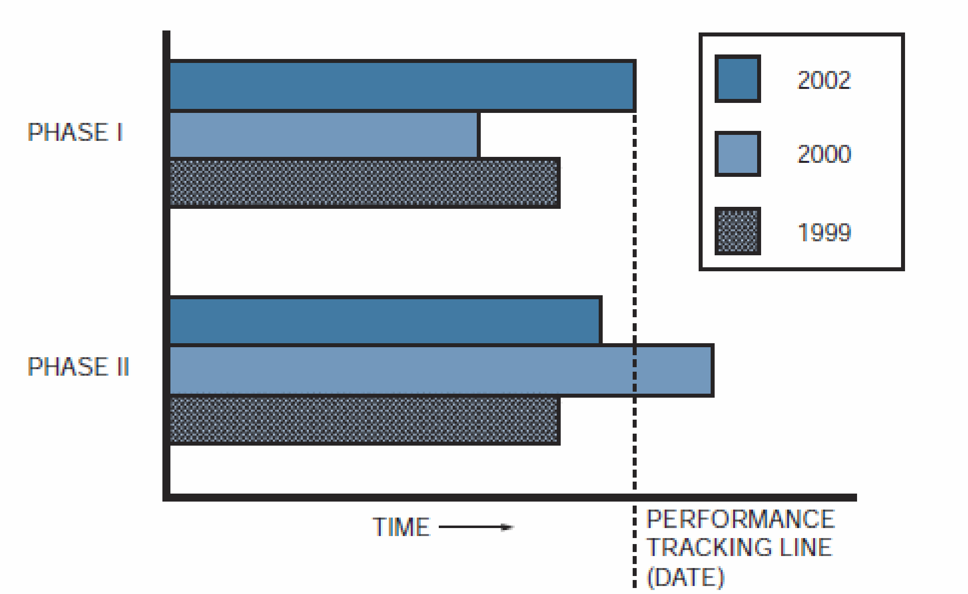
Figure 4.5 shows a grouped bar chart for comparison of three projects performed during different years. When using different shading techniques, each area must be easily definable and no major contrast should exist between shaded areas, except for possibly the current project. When grouped, bars appear on one chart, non-shaded bars should be avoided. Each bar should have some sort of shading, whether it be cross-hatched or color-coded.

Figure 4.4: Partial Inter- relationship chart



Adapted from Kerzner, (2013, 559)

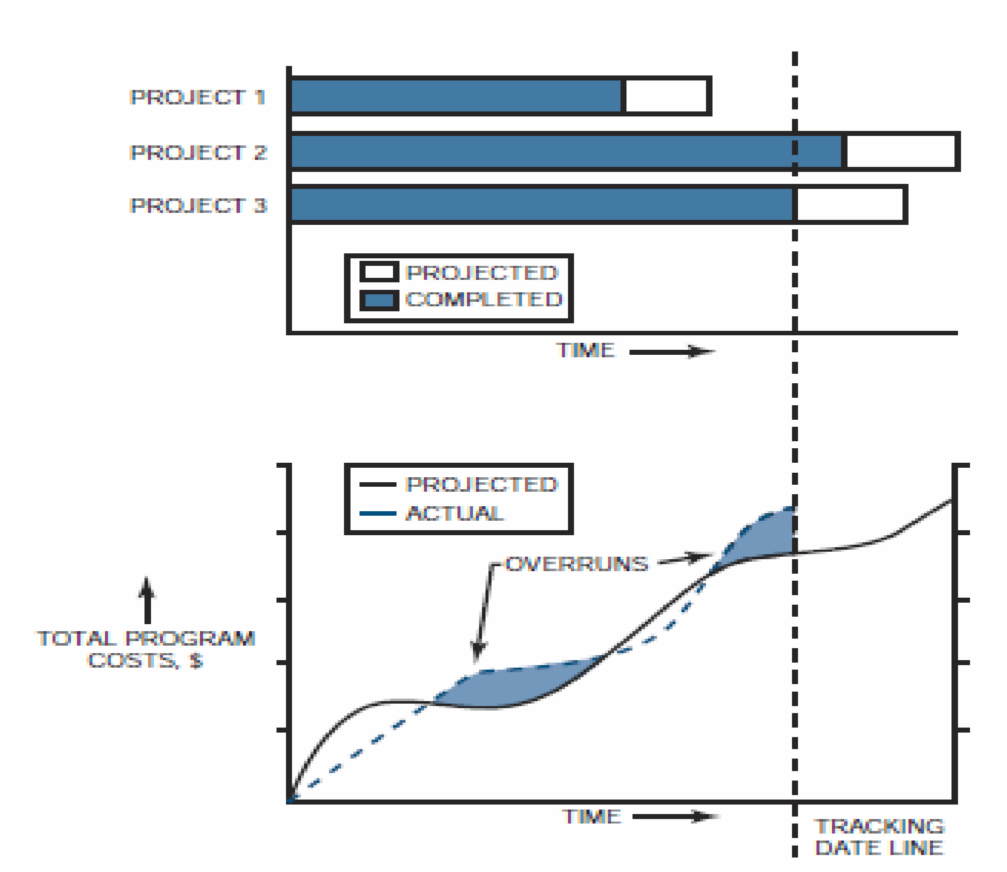
Figure 4.5: Grouped bar chart for performance comparison



Adapted from Kerzner, (2013, 560)

Contrasting shaded to non-shaded areas is normally used for comparing projected progress to actual progress, as shown in Figure 4.6. The tracking date line indicates the time when the cost data/performance data were analyzed. Project 1 is behind schedule, project 2 is ahead of schedule, and project 3 is on target. Unfortunately, the upper portion of Figure 4.6 does not indicate the costs attributed to the status of the three projects.

Figure 4.6: Cost performance and tracking schedule



Adapted from Kerzner, (2013, 560)

By plotting the total program costs against the same time axis (as shown in Figure 4.6), a comparison between cost and performance can be made. From the upper section of Figure 4.6 it is impossible to tell the current program cost position. From the lower section, however, it becomes evident that the program is heading for a cost overrun, possibly due to project 1. It is generally acceptable to have the same shading technique represent different situations, provided that clear separation between the shaded regions appears, as in Figure 4.6.

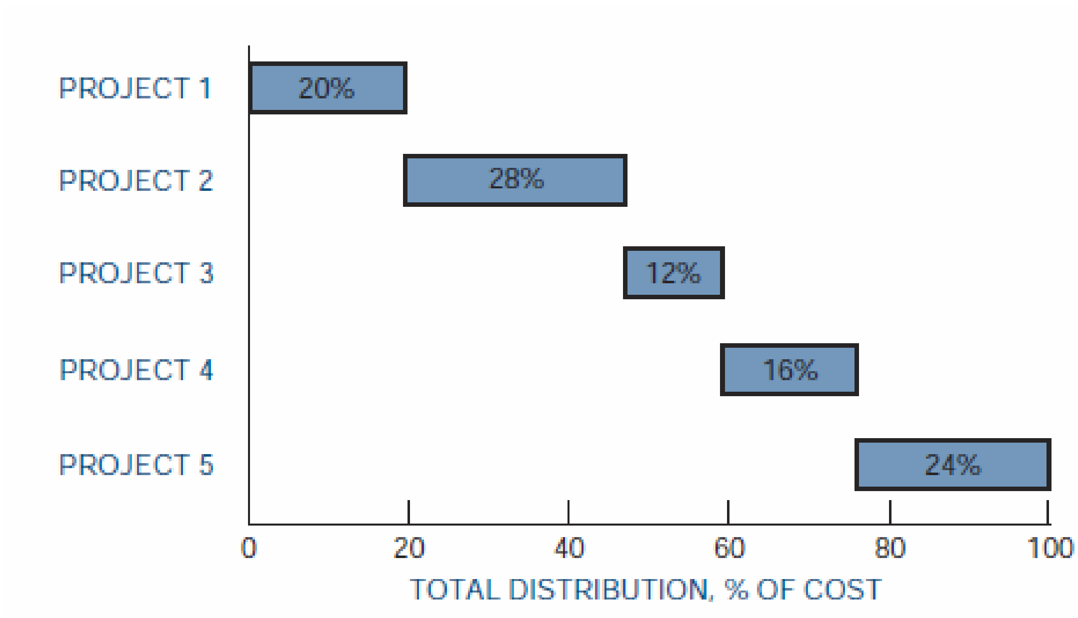
Another common means for comparing activities or projects is through the use of step arrangement bar charts. Figure 4.7 shows a step arrangement bar chart for a cost percentage breakdown of the five projects included within a program. Figure 4.7 can also be used for tracking, by shading certain portions of the steps that identify each project.

This is not normally done, however, since this type of step arrangement tends to indicate that each step must be completed before the next step can begin.
Bar charts need not be represented horizontally. Figure 4.8 indicates the comparison between the 2000 and 2002 costs for the total program and raw materials. Three- dimensional vertical bar charts are often beautiful to behold.

Figure 4.9 shows a typical three-dimensional bar chart for direct and indirect labor and material cost breakdowns.
Bar charts can be made colorful and appealing by combining them with other graphic techniques. Figure 4.10 shows a quantitative-pictorial bar chart for the distribution of total program costs. Figure 4.11 shows the same cost distribution as in Figure 4.10, but represented with the commonly used pie technique. Figure 4.12 illustrates how two quantitative bar charts can be used side by side to create a quick comparison. The right- hand side shows the labor hour percentages.
Figure 4.12 works best if the scale of each axis is the same; otherwise the comparisons may appear distorted when, in fact, they are not.

The figures shown in this section do not, by any means, represent the only methods of presenting data in bar chart format. Several other methods are shown in the sections that follow.

Figure 4.7: Step arrangement bar chart for total cost as a percentage of the five programme projects.



Adapted from Kerzner, (2013, 561)

Figure 4.8: Cost Comparison 2000 versus 2002

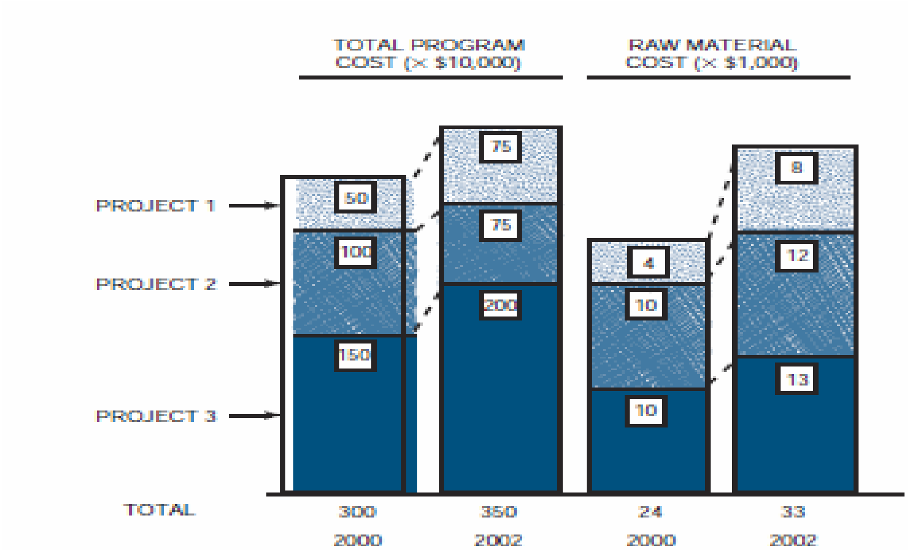
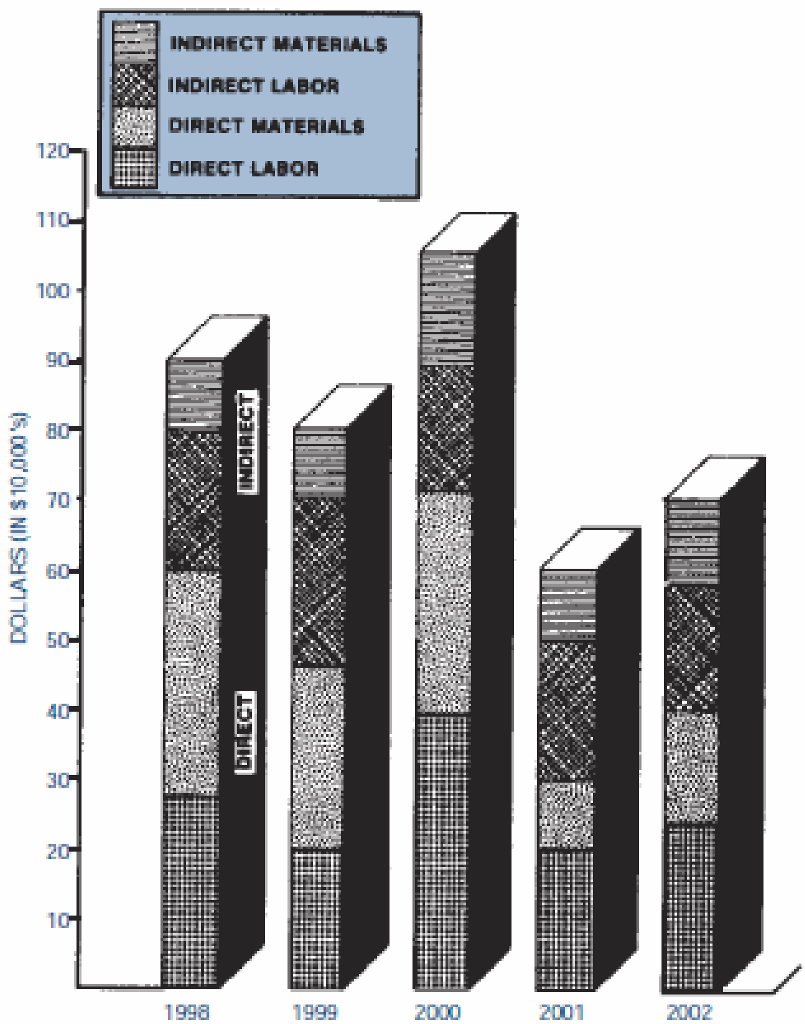
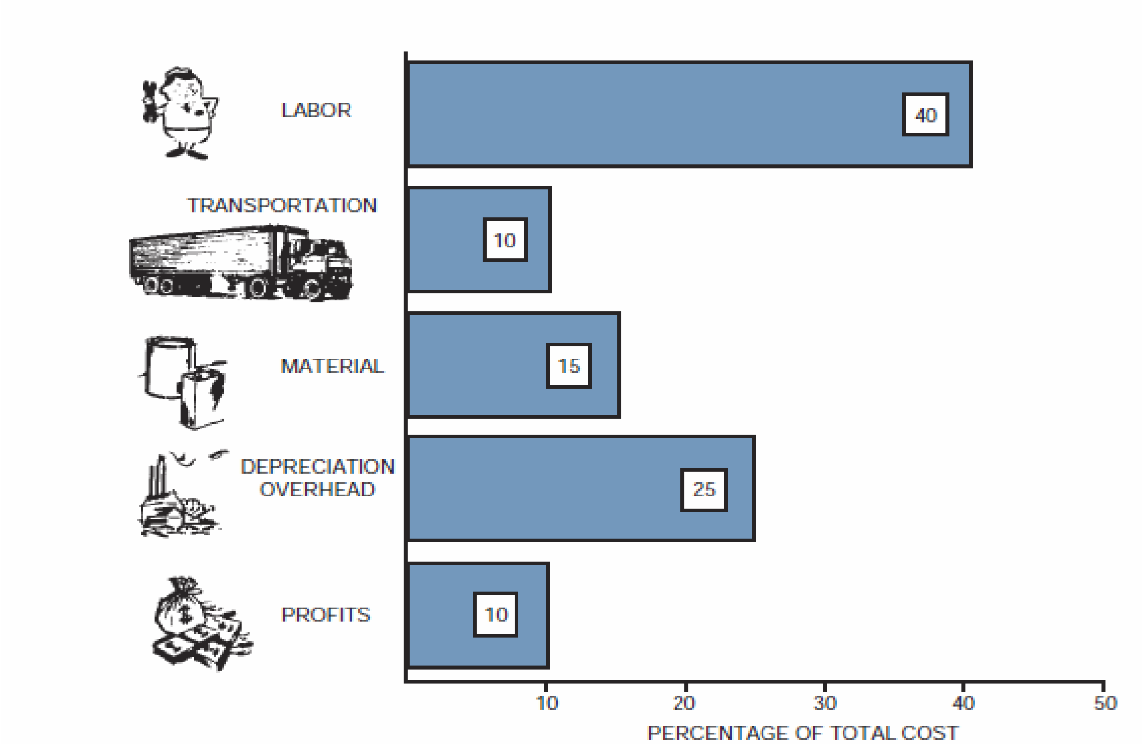


Figure 4.9 Direct and indirect materiel labor cost breakdowns for all programmes per year



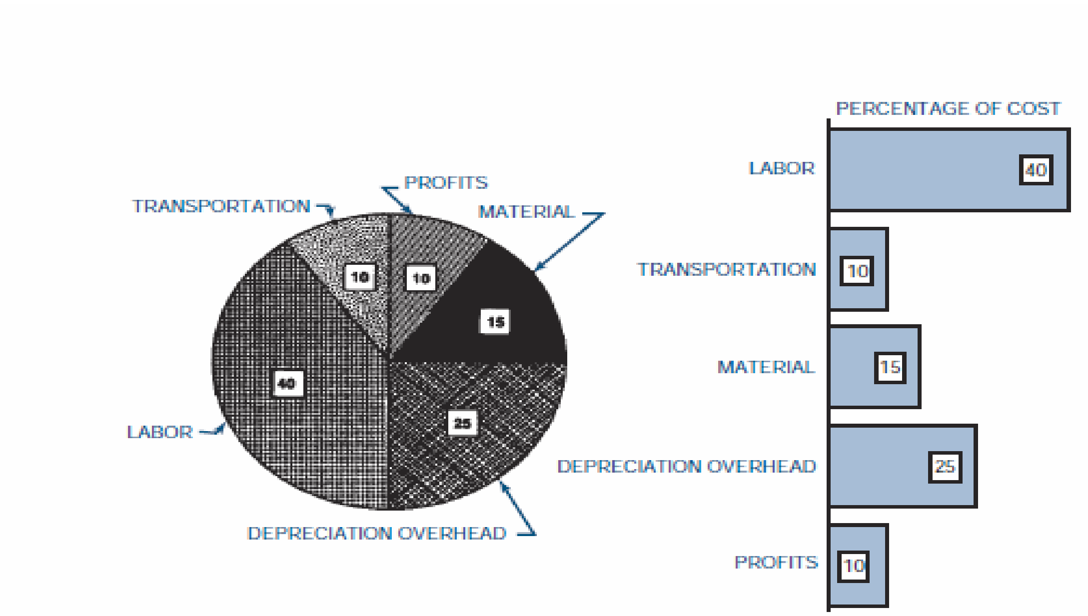
Adapted from Kerzner, (2013, 562)

Figure 4.10: BAR (GANTT) Chart: Total programme cost distribution (quantitative pictorial bar chart)



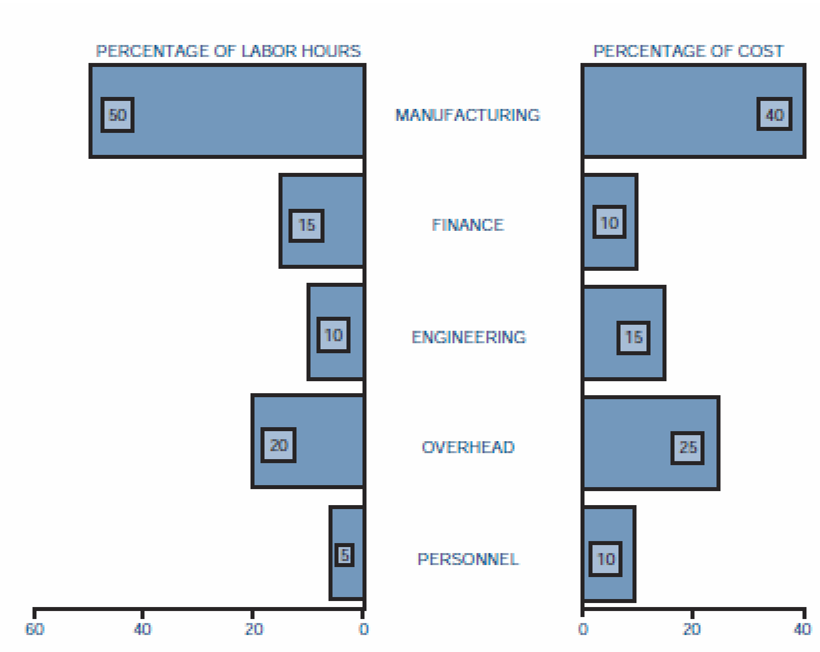
Adapted from Kerzner, (2013, 563)

Figure 4.11 Distribution of the programme dollar



Adapted from Kerzner, (2013, 563)

Figure 4.12: Divisional breakdown of costs and labour hours



Adapted from Kerzner, (2013, 564)

4.4 Further Conventional Presentation Techniques

Bar charts serve as a useful tool for presenting data at technical meetings. Unfortunately, programs must be won competitively or organized in-house before technical meeting presentations can be made. Competitive proposals or in-house project requests should contain descriptive figures and charts, not necessarily representing activities, but showing either planning, organizing, tracking, or technical procedures designed for the current program or used previously on other programs. Proposals generally contain figures that require either some interpolation or extrapolation.

Figure 4.13 shows the breakdown of total program costs. Although this figure would also normally require interpretation, a monthly cost table accompanies it. If the table is not too extensive, then it can be included with the figure. This is shown in Figure 4.14. During proposal activities, the actual and cumulative delivery columns, as well as the dotted line in Figure 4.14, would be omitted, but would be included after updating for use in technical interchange meetings.

It is normally a good practice to use previous figures and tables whenever possible because management becomes accustomed to the manner in which data are presented. Another commonly used technique is schematic models. Organizational charts are schematic models that depict the interrelationships between individuals, organizations, or functions within an organization. One organizational chart normally cannot suffice for describing total program interrelationships.

Figure 4.8 identified the Midas Program in relation to other programs within Dalton Corporation. The Midas Program is indicated by the bold lines. The program manager for the Midas Program was placed at the top of the column, even though his program may have the lowest priority. Each major unit of management for the Midas Program should be placed as close as possible to top-level management to indicate to the customer the “implied” relative importance of the program.

Another type of schematic representation is the work flowchart, synonymous with the application of flowcharting for computer programming. Flowcharts are designed to describe, either symbolically or pictorially, the sequence of events required to complete an activity.

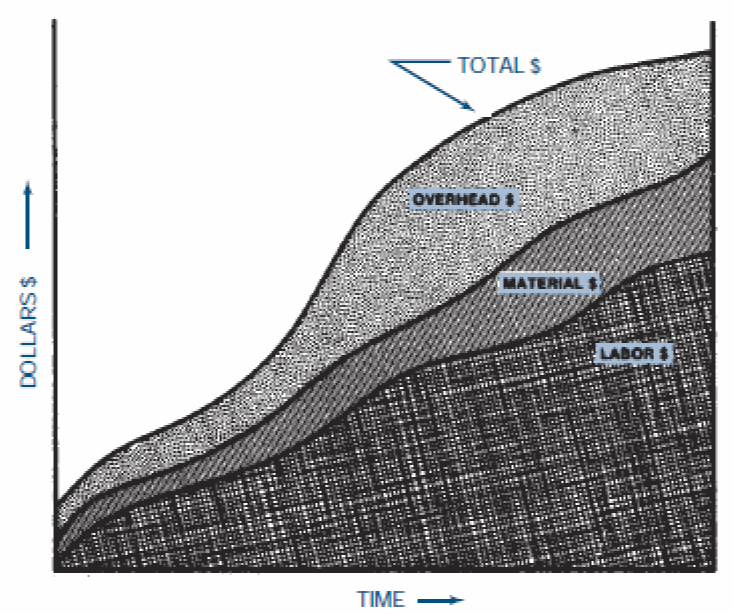
Figure 4.15 shows the logic flow for production of molding VZ-3. The symbols shown in Figure 4.15 are universally accepted by several industries.
Pictorial representation, although often a costly procedure, can add color and quality to any proposal, and they are easier to understand than a logic or bubble chart. Because customers may request tours during activities to relate to the pictorial figures, program management should avoid pictorial representation of activities that may be closed off to customer viewing, possibly due to security or safety.

Block diagrams can also be used to describe the flow of activities. Figures 4.8 and 4.9 are examples of block diagrams. Block diagrams can be used to show how information is distributed throughout an organization or how a process or activity is assembled. Figure 4.16 shows the testing matrix for propellant samples. Figures similar to this are developed when tours are scheduled during the production or testing phase of a program.

Figure 4.16 shows the customer not only where the testing will take place, but what tests will be conducted.

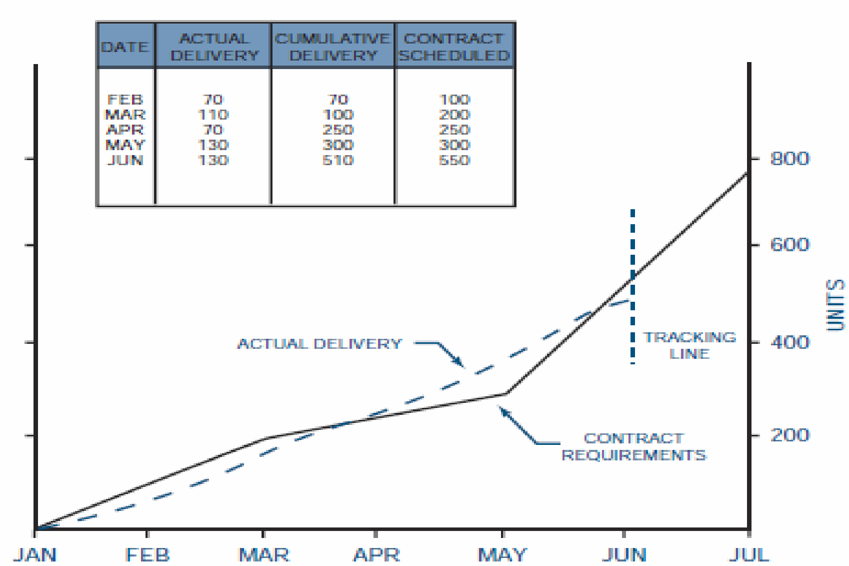
Block diagrams, schematics, pictorials, and logic flows all fulfill a necessary need for describing the wide variety of activities within a company. The figures and charts are more than descriptive techniques. They can also provide management with the necessary tools for decision-making.

Figure 4.13: Total programme cost breakdown



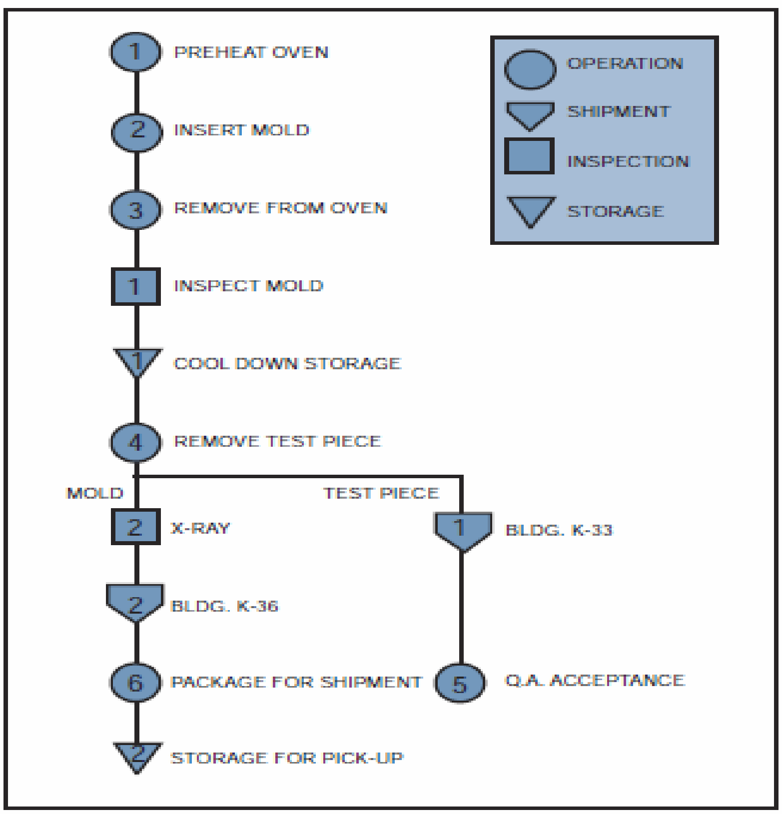
Adapted from Kerzner, (2013, 565)

Figure 4.14: Delivery schedule tracking (line of balance)



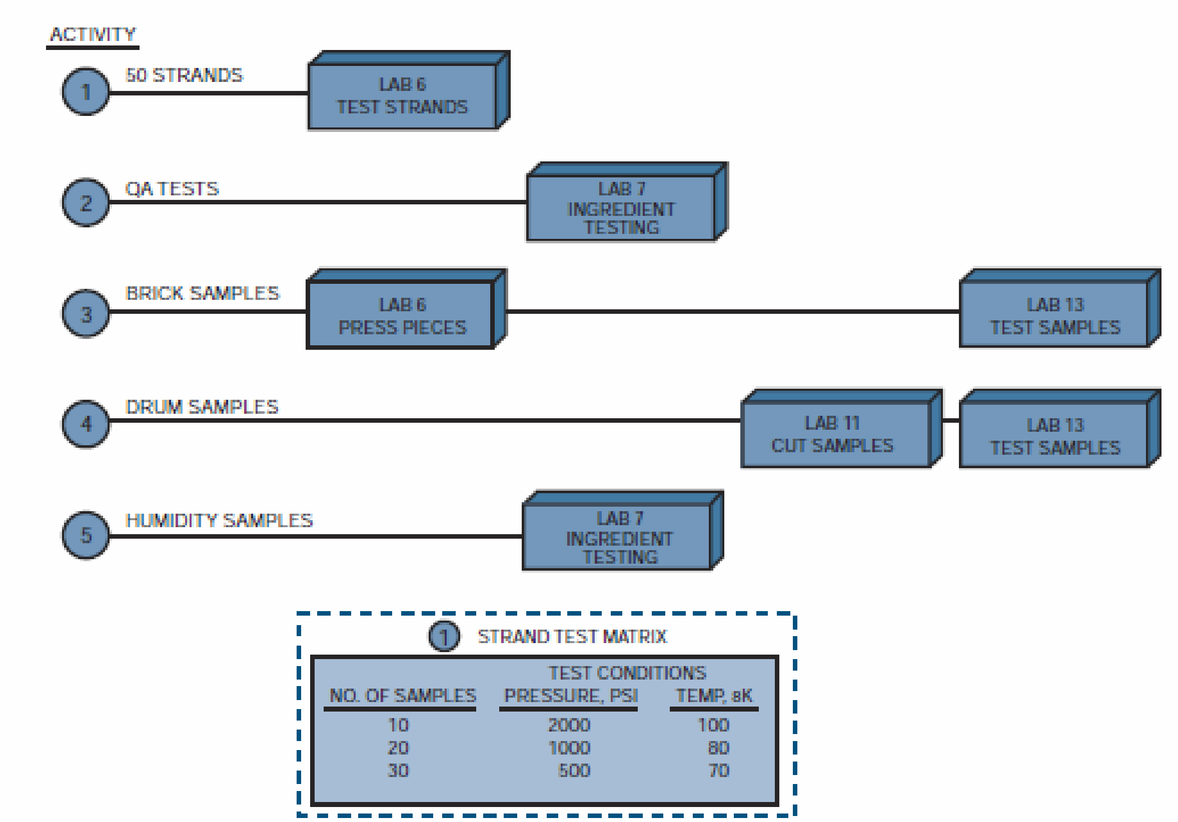
Adapted from Kerzner, (2013, 565)

Figure 4.15: Logic Flow for production of molding VZ-3



Adapted from Kerzner, (2013, 566)

Figure 4.16: Propellant Testing Matrix



Adapted from Kerzner, (2013, 567)

4.5 Logic Diagrams/ Networks

Probably the most difficult figure to construct is the logic diagram. Logic diagrams are developed to illustrate the inductive and deductive reasoning necessary to achieve some objective within a given time frame. The major difficulty in developing logic diagrams is the inability to answer such key questions as: What happens if something goes wrong? Can I quantify any part of the diagram's major elements? Logic diagrams are constructed similarly to bar charts on the supposition that nothing will go wrong and are usually accompanied by detailed questions, possibly in a checklist format, that require answering.

The following questions would be representative of those asked for an R&D project:

● What documentation is released to start the described activity and possibly the elements within each activity?

● What information is required before this documentation can be released? (What prior activities must be completed, work designed, studies finalized, etc?)

● What are the completion, or success, criteria for the activity?

● What are the alternatives for each phase of the program if success is not achieved?

● What other activities are directly dependent on the result of this activity?

● What other activities or inputs are required to perform this activity?

● What are the key decision points, if any, during the activity?

● What documentation signifies completion of the activity (i.e., report, drawing, etc.)?

● What management approval is required for final documentation?

These types of questions are applicable to many other forms of data presentation, not only logic diagrams.

REFLECTION QUESTIONS

4.1 For each type of schedule defined in this chapter answer the following questions:

a. Who prepares the schedule?

b. Who updates the schedule?

c. Who should present the data to the customers?

4.2 Should the customers have the right to dictate to the contractor how the schedule should

be prepared and presented?

4.3 What if this request contradicts company policies and procedures?

4.4 Should a different set of schedules and charts be maintained for out-of-house as well as in-house reporting?

4.5 Should separate schedules be made for each level of management?

4.6 Is there a more effective way to ease these types of problems?

CHAPTER 5

PROJECT COST MANAGEMENT

Chapter 5 Project Cost Management

CHAPTER OUTCOMES

Upon completion of this Chapter, students should be able to:

- Comprehend the different types of pricing estimates
- Critically analyse the pricing process
- Distinguish between the different organizational process requirements
- Identify the different labour distributions
- Identify and calculate overhead rates
- Explain how logical pricing techniques can help an organisation control limited resources
- Comprehend different project costs
- Critically analyse different cost estimating techniques
- Distinguish and apply project budgeting techniques
- Determine the significance and process of earned value management
- Explain the meaning of each of the earned value management terms

Essential Reading

Textbooks:

- Kerzner. (2013). Project management: A Systems Approach, 10th edition. Wiley & Sons, Chapter 14 and Chapter 15.

5.1 Introduction

With the complexities involved, it is not surprising that many business managers consider pricing an art. Having information on customer cost budgets and competitive pricing would certainly help. However, the reality is that whatever information is available to one bidder is generally available to the others. A disciplined approach helps in developing all the input for a rational pricing recommendation. A side benefit of using a disciplined management process is that it leads to the documentation of the many factors and assumptions involved at a later time. These can be compared and analyzed, contributing to the learning experiences that make up the managerial skills needed for effective business decisions.

Estimates are not blind luck. They are well-thought-out decisions based on either the best available information, some type of cost estimating relationship, or some type of cost model. Cost estimating relationships
(CERs) are generally the output of cost models. Typical CERs might be:

- Mathematical equations based on regression analysis
- Cost–quantity relationships such as learning curves
- Cost–cost relationships
- Cost–non-cost relationships based on physical characteristics, technical parameters, or performance characteristics.

5.2 Global pricing Strategies

Specific pricing strategies must be developed for each individual situation. Frequently, however, one of two situations prevail when one is pursuing project acquisitions competitively. First, the new business opportunity may be a one-of-a-kind program with little or no follow-on potential, a situation classified as type I acquisition. Second, the new business opportunity may be an entry point to a larger follow-on or repeat business, or may represent a planned penetration into a new market. This acquisition is classified as type II. Clearly, in each case, we have specific but different business objectives.

The objective for type I acquisition is to win the program and execute it profitably and satisfactorily according to contractual agreements. The type II objective is often to win the program and perform well, thereby gaining a foothold in a new market segment or a new customer community in place of making a profit. Accordingly, each acquisition type has its own, unique pricing strategy, as summarized in Table 5.1.

Comparing the two pricing strategies for the two global situations (as shown in Table 5.1) reveals a great deal of similarity for the first five points. The fundamental difference is that for a profitable new business acquisition the bid price is determined according to actual cost, whereas in a “must-win” situation the price is determined by the market forces.

It should be emphasized that one of the most crucial inputs in the pricing decision is the cost estimate of the proposed baseline. The design of this baseline to the minimum requirements should be started early, in accordance with well-defined ground rules, cost models, and established cost targets. Too often the baseline design is performed in parallel with the proposal development. At the proposal stage, it is too late to review and fine tune the baseline for minimum cost. Also, such a late start does not allow much of an option for a final bid decision. Even if the price appears outside the competitive range, it makes little sense to terminate the proposal development. As all resources have been sent anyway, one might as well submit a bid in spite of the remote chance of winning.

Clearly, effective pricing begins a long time before proposal development. It starts with preliminary customer requirements, well-understood subtasks, and a top-down estimate with should-cost targets. This allows the functional organization to design a baseline to meet the customer requirements and cost targets, and gives management the time to review and redirect the design before the proposal is submitted.

Furthermore, it gives management an early opportunity to assess the chances of winning during the acquisition cycle, at a point when additional resources can be allocated or the acquisition effort can be terminated before too many resources are committed to a hopeless effort.

The final pricing review session should be an integration and review of information already well known in its basic context. The process and management tools outlined here should help to provide the framework and discipline for deriving pricing decisions in an orderly and effective way.

Table 5.1 Global Pricing Strategies

Type I Acquisition: One-of-a-Kind Program with Little or No Follow-On Business	Type II Acquisition: New Program with Potential for Large Follow-On Business or Representing a Desired Penetration into New Markets
1. Develop cost model and estimating guidelines; design proposed project/program baseline for minimum cost, to minimum customer requirements. 2. Estimate cost realistically for minimum requirements. 3. Scrub the baseline. Squeeze out unnecessary costs. 4. Determine realistic minimum cost. Obtain commitment from performing organizations. 5. Adjust cost estimate for risks. 6. Add desired margins. Determine the price. 7. Compare price to customer budget and competitive cost information. 8. Bid only if price is within competitive range.	1. Design proposed project/program baseline compliant with customer requirements, with innovative features but minimum risks. 2. Estimate cost realistically. 3. Scrub baseline. Squeeze out unnecessary costs. 4. Determine realistic minimum cost. Obtain commitment from performing organizations. 5. Determine "should-cost" including risk adjustments. 6. Compare your final cost estimate to customer budget and the "most likely" winning price. 7. Determine the gross profit margin necessary for your winning proposal. This margin could be negative! 8. Decide whether the gross margin is acceptable according to the must-win desire. 9. Depending on the strength of your desire to win, bid the "most likely" winning price or lower. 10. If the bid price is below cost, it is often necessary to provide a detailed explanation to the customer of where the additional funding is coming from. The source could be company profits or sharing of related activities. In any case, a clear resource picture should be given to the customer to ensure cost credibility.

Adapted from Kerzner, (2013, 573)

5.3 Types of Estimates

Any company or corporation that wants to remain profitable must continuously improve its estimating and pricing methodologies.

While it is true that some companies have been successful without good cost estimating and pricing, very few remain successful without them. Good estimating requires that information be collected prior to the initiation of the estimating process. Typical information includes:

- Recent experience in similar work
- Professional and reference material
- Market and industry surveys
- Knowledge of the operations and processes
- Estimating software and databases if available
- Interviews with subject matter experts

Projects can range from a feasibility study, through modification of existing facilities, to complete design, procurement, and construction of a large complex. Whatever the project may be, whether large or small, the estimate and type of information desired may differ radically.

The first type of estimate is an order-of-magnitude analysis, which is made without any detailed engineering data. The order-of-magnitude analysis may have an accuracy of +-35 percent within the scope of the project. This type of estimate may use past experience (not necessarily similar), scale factors, parametric curves, or capacity estimates (i.e., $/# of product or $/kW electricity).

Order-of-magnitude estimates are top-down estimates usually applied to level 1 of the WBS, and in some industries, use of parametric estimates are included. A parametric estimate is based upon statistical data. For example, assume that you live in a Chicago suburb and wish to build the home of your dreams. You contact a construction contractor who informs you that the parametric or statistical cost for a home in this suburb is $120 per square foot. In Los Angeles, the cost may be $4150 per square foot.

Next, there is the approximate estimate (or top-down estimate), which is also made without detailed engineering data, and may be accurate to +-15 percent. This type of estimate is prorated from previous projects that are similar in scope and capacity, and may be titled as estimating by analogy, parametric curves, rule of thumb, and indexed cost of similar activities adjusted for capacity and technology.

In such a case, the estimator may say that this activity is 50 percent more difficult than a previous (i.e., reference) activity and requires 50 percent more time, man-hours, dollars, materials, and so on.

The definitive estimate, or grassroots buildup estimate, is prepared from well-defined engineering data including (as a minimum) vendor quotes, fairly complete plans, specifications, unit prices, and estimate to complete. The definitive estimate, also referred to as detailed estimating, has an accuracy of +-5 percent. Another method for estimating is the use of learning curves. Learning curves are graphical representations of repetitive functions in which continuous operations will lead to a reduction in time, resources, and money. The theory behind learning curves is usually applied to manufacturing operations.

Each company may have a unique approach to estimating. However, for normal project management practices, Table 5.2 would suffice as a starting point.
Many companies try to standardize their estimating procedures by developing an estimating manual. The estimating manual is then used to price out the effort, perhaps as much as 90 percent. Estimating manuals usually give better estimates than industrial engineering standards because they include groups of tasks and take into consideration such items as downtime, cleanup time, lunch, and breaks. Table 5.3 shows the table of contents for a construction estimating manual.

Table 5.2: Standard Project Estimating

Estimating Method	Generic Type	WBS Relationship	Accuracy	Time to Prepare
Parametric	ROM*	Top down	−25% to +75%	Days
Analogy	Budget	Top down	−10% to +25%	Weeks
Engineering (grass roots)	Definitive	Bottom up	−5% to +10%	Months

*ROM = Rough order of magnitude.

Table 5.3: Estimating Manual Table of Contents

Introduction
- Purpose and types of estimates

Major Estimating Tools
- Cataloged equipment costs
- Automated investment data system
- Automated estimate system
- Computerized methods and procedures

Classes of Estimates
- Definitive estimate
- Capital cost estimate
- Appropriation estimate
- Feasibility estimate
- Order of magnitude
- Charts—estimate specifications quantity and pricing guidelines

Data Required
- Chart—comparing data required for preparation of classes of estimates

Presentation Specifications
- Estimate procedure—general
- Estimate procedure for definitive estimate
- Estimate procedure for capital cost estimate
- Estimate procedure for appropriation estimate
- Estimate procedure for feasibility estimate

Adapted from Kerzner, (2013, 575)

Estimating manuals, as the name implies, provide estimates. The question, of course, is "How good are the estimates?" Most estimating manuals provide accuracy limitations by defining the type of estimates (shown in Table 5.3). Using Table 5.3, we can create Tables 5.4, 5.5, and 5.6, which illustrate the use of the estimating manual.

Not all companies can use estimating manuals. Estimating manuals work best for repetitive tasks or similar tasks that can use a previous estimate adjusted by a degree-of difficulty factor. Activities such as R&D do not lend themselves to the use of estimating manuals other than for benchmark, repetitive laboratory tests.

Proposal managers must carefully consider whether the estimating manual is a viable approach. The literature abounds with examples of companies that have spent millions trying to develop estimating manuals for situations that just do not lend themselves to the approach.

During competitive bidding, it is important that the type of estimate be consistent with the customer's requirements. For in-house projects, the type of estimate can vary over the life cycle of a project:

● Conceptual stage: Venture guidance or feasibility studies for the evaluation of future work. This estimating is often based on minimum-scope information.
● Planning stage: Estimating for authorization of partial or full funds. These estimates are based on preliminary design and scope.
● Main stage: Estimating for detailed work.
● Termination stage: Re-estimation for major scope changes or variances beyond the authorization range.

Table 5.5: Checklist for work normally required for the various classes (1-VI) of estimates.

Item	I	II	III	IV	V	VI
1. Inquiry	X	X	X	X	X	X
2. Legibility	X	X	X			
3. Copies	X	X				
4. Schedule	X	X	X	X		
5. Vendor inquiries	X	X	X			
6. Subcontract packages	X	X				
7. Listing	X	X	X	X	X	
8. Site visit	X	X	X	X		
9. Estimate bulks	X	X	X	X	X	
10. Labor rates	X	X	X	X	X	
11. Equipment and subcontract selection	X	X	X	X	X	
12. Taxes, insurance, and royalties	X	X	X	X	X	
13. Home office costs	X	X	X	X	X	
14. Construction indirects	X	X	X	X	X	
15. Basis of estimate	X	X	X	X	X	X
16. Equipment list	X					
17. Summary sheet	X	X	X	X	X	
18. Management review	X	X	X	X	X	X
19. Final cost	X	X	X	X	X	X
20. Management approval	X	X	X	X	X	X
21. Computer estimate	X	X	X	X		

Adapted from Kerzner, (2013, 576)

5.4 Pricing Process

This activity schedules the development of the work breakdown structure and provides management with two of the three operational tools necessary for the control of a system or project. The development of these two tools is normally the responsibility of the program office with input from the functional units.

The integration of the functional unit into the project environment or system occurs through the pricing-out of the work breakdown structure. The total program costs obtained by pricing out the activities over the scheduled period of performance provide management with the third tool necessary to successfully manage the project.

During the pricing activities, the functional units have the option of consulting program management about possible changes in the activity schedules and work breakdown structure. The work breakdown structure and activity schedules are priced out through the lowest pricing units of the company. It is the responsibility of these pricing units, whether they be sections, departments, or divisions, to provide accurate and meaningful cost data (based on historical standards, if possible). All information is priced out at the lowest level of performance required, which, from the assumption of Chapter 3, will be the task level.

Table 5.6 Data required for preparation of estimates

	Classes of Estimates					
	I	II	III	IV	V	VI
General						
Product	X	X	X	X	X	X
Process description	X	X	X	X	X	X
Capacity	X	X	X	X	X	X
Location—general					X	X
Location—specific	X	X	X	X		
Basic design criteria	X	X	X	X		
General design specifications	X	X	X	X		
Process						
Process block flow diagram						X
Process flow diagram (with equipment size and material)				X	X	
Mechanical P&Is	X	X	X			
Equipment list	X	X	X	X	X	
Catalyst/chemical specifications	X	X	X	X	X	
Site						
Soil conditions	X	X	X	X		
Site clearance	X	X	X			
Geological and meteorological data	X	X	X			
Roads, paving, and landscaping	X	X	X			
Property protection	X	X	X			
Accessibility to site	X	X	X			
Shipping and delivery conditions	X	X	X			
Major cost is factored					X	X
Major Equipment						
Preliminary sizes and materials			X	X	X	
Finalized sizes, materials, and appurtenances	X	X				
Bulk Material Quantities						
Finalized design quantity take-off		X				
Preliminary design quantity take-off	X	X	X	X		
Engineering						
Plot plan and elevations	X	X	X	X		
Routing diagrams	X	X	X			
Piping line index	X	X				
Electrical single line	X	X	X	X		
Fire protection	X	X	X			
Sewer systems	X	X	X			
Pro-services—detailed estimate	X	X				
Pro-services—ratioed estimate			X	X	X	
Catalyst/chemicals quantities	X	X	X	X	X	
Construction						
Labor wage, F/B, travel rates	X	X	X	X	X	
Labor productivity and area practices	X	X				
Detailed construction execution plan	X	X				
Field indirects—detailed estimate	X	X				
Field indirects—ratioed estimate			X	X	X	
Schedule						
Overall timing of execution				X	X	
Detailed schedule of execution	X	X	X			
Estimating preparation schedule	X	X	X			

Adapted from Kerzner, (2013, 577)

Costing information is rolled up to the project level and then one step further to the total program level. Under ideal conditions, the work required (i.e., man-hours) to complete a given task can be based on historical standards. Unfortunately, for many industries, projects and programs are so diversified that realistic comparison between previous activities may not be possible. The costing information obtained from each pricing unit, whether or not it is based on historical standards, should be regarded only as an estimate. How can a company predict the salary structure three years from now? What will be the cost of raw materials two years from now? Will the business base (and therefore overhead rates) change over the duration of the program? The final response to these questions shows that costing data are explicitly related to an environment that cannot be predicted with any high degree of certainty. The systems approach to management, however, provides for a more rapid response to the environment than less structured approaches permit.

Once the cost data are assembled, they must be analyzed for their potential impact on the company resources of people, money, equipment, and facilities. It is only through a total program cost analysis that resource allocations can be analyzed. The resource allocation analysis is performed at all levels of management, ranging from the section supervisor to the vice president and general manager. For most programs, the chief executive must approve final cost data and the allocation of resources.

Proper analysis of the total program costs can provide management (both program and corporate) with a strategic planning model for integration of the current program with other programs in order to obtain a total corporate strategy. Meaningful planning and pricing models include analyses for monthly man loading schedules per department, monthly costs per department, monthly and yearly total program costs, monthly material expenditures, and total program cash-flow and man-hour requirements per month.

Previously we identified several of the problems that occur at the nodes where the horizontal hierarchy of program management interfaces with the vertical hierarchy of functional management. The pricing-out of the work breakdown structure provides the basis for effective and open communication between functional and program management where both parties have one common goal. This is shown in Figure 5.1. After the pricing effort is completed, and the program is initiated, the work breakdown structure still forms the basis of a communications tool by documenting the performance agreed on in the pricing effort, as well as establishing the criteria against which performance costs will be measured.

5.5 Organizational Input Requirements

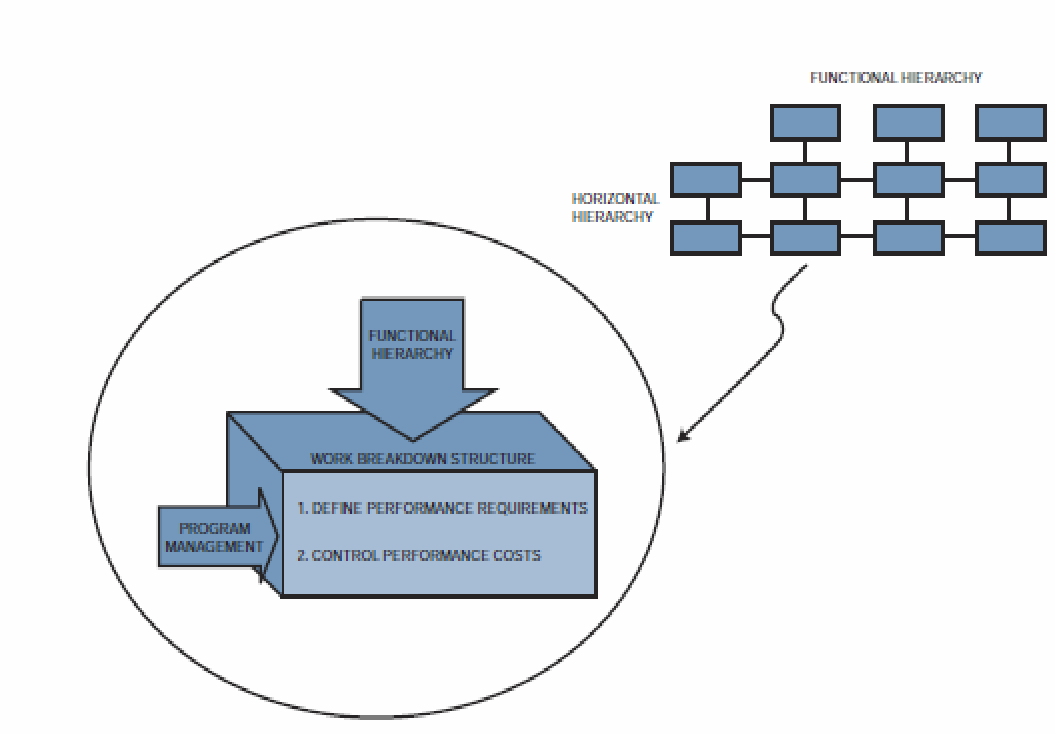
Once the work breakdown structure and activity schedules are established, the program manager calls a meeting for all organizations that will submit pricing information. It is imperative that all pricing or labor-costing representatives be present for the first meeting.

During this “kickoff” meeting, the work breakdown structure is described in depth so that each pricing unit manager will know exactly what his responsibilities are during the program.

The kickoff meeting also resolves the struggle for power among functional managers whose responsibilities may be similar. An example of this would be quality control activities. During the research and development phase of a program, research personnel may be permitted to perform their own quality control efforts, whereas during production activities the quality control department or division would have overall responsibility. Unfortunately, one meeting is not always sufficient to clarify all problems. Follow-up or status meetings are held, normally with only those parties concerned with the problems that have arisen. Some companies prefer to have all members attend the status meetings so that all personnel will be familiar with the total effort and the associated problems. The advantage of not having all program-related personnel attend is that time is of the essence when pricing out activities.

Many functional divisions carry this policy one step further by having a divisional representative together with possibly key department managers or section supervisors as the only attendees at the kickoff meeting. The divisional representative then assumes all responsibility for assuring that all costing data are submitted on time.

Figure 5.1 Vertical- Horizontal Interface



Adapted from Kerzner, 92013, 579)

This arrangement may be beneficial in that the program office need contact only one individual in the division to learn of the activity status, but it may become a bottleneck if the representative fails to maintain proper communication between the functional units and the program office, or if the individual simply is unfamiliar with the pricing requirements of the work breakdown structure. During proposal activities, time may be extremely important. There are many situations in which a request for proposal (RFP) requires that all responders submit their bids by a specific date.

Under a proposal environment, the activities of the program office, as well as those of the functional units, are under a schedule set forth by the proposal manager. The proposal manager's schedule has very little, if any, flexibility and is normally under tight time constraints so that the proposal may be typed, edited, and published prior to the date of submittal. In this case, the RFP will indirectly define how much time the pricing units have to identify and justify labor costs. The justification of the labor costs may take longer than the original cost estimates, especially if historical standards are not available. Many proposals often require that comprehensive labor justification be submitted. Other proposals, especially those that request an almost immediate response, may permit vendors to submit labor justification at a later date. In the final analysis, it is the responsibility of the lowest pricing unit supervisors to maintain adequate standards, so that an almost immediate response can be given to a pricing request from a program office.

5.6 Labour Distributions

The development of the labor rates to be used in the projection is based on historical costs in business base hours and dollars for the most recent month or quarter. Average hourly rates are determined for each labor unit by direct effort within the operations at the department level. The rates are only averages, and include both the highest-paid employees and lowest-paid employees, together with the department manager and the clerical support. These base rates are then escalated as a percentage factor based on past experience, budget as approved by management, and the local outlook and similar industries. If the company has a predominant aerospace or defense industry business base, then these salaries are negotiated with local government agencies prior to submittal for proposals.

The labor hours submitted by the functional units are quite often overestimated for fear that management will "massage" and reduce the labor hours while attempting to maintain the same scope of effort.

Many times, management is forced to reduce man-hours either because of insufficient funding or just to remain competitive in the environment. The most common solution to this conflict rests with the program manager. If the program manager selects members for the program team who are knowledgeable in man-hour standards for each of the departments, then an atmosphere of trust can develop between the program office and the functional department so that man-hours can be reduced in a manner that represents the best interests of the company. This is one of the reasons why program team members are often promoted from within the functional ranks.

Consider the example below:

On May 15, Apex Manufacturing decided to enter into competitive bidding for the modification and updating of an assembly line program. A work breakdown structure was developed as shown below:

PROGRAM (01-00-00): Assembly Line Modification

PROJECT 1 (01-01-00): Initial Planning

Task 1 (01-01-01): Engineering Control

Task 2 (01-01-02): Engineering Development

PROJECT 2 (01-02-00): Assembly

Task 1 (01-02-01): Modification

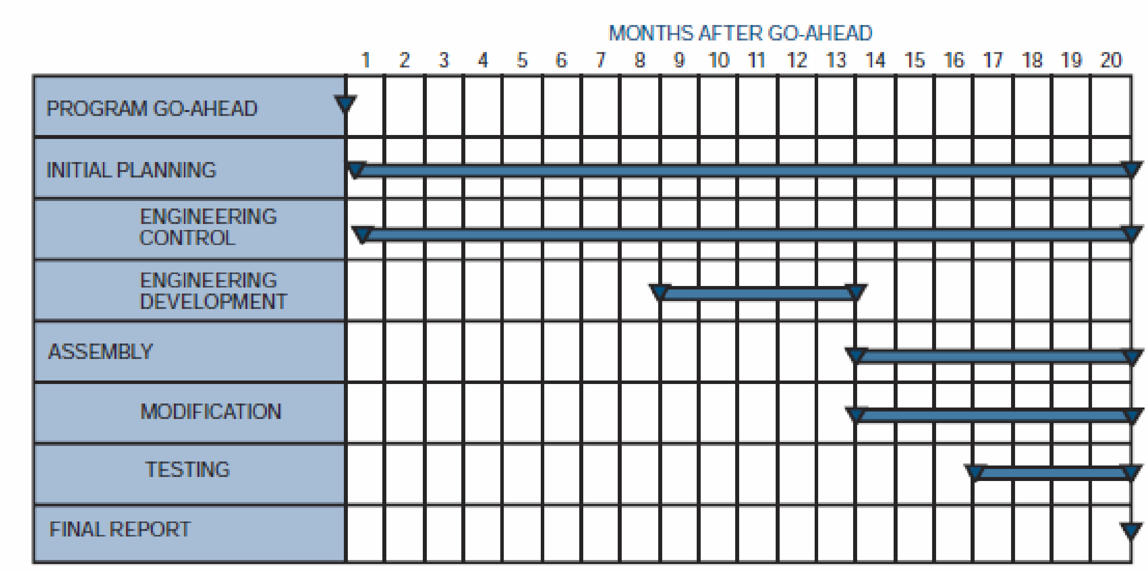
Task 2 (01-02-02): Testing

On June 1, each pricing unit was given the work breakdown structure together with the schedule shown in Figure 5.2. According to the schedule developed by the proposal manager for this project, all labor data must be submitted to the program office for review no later than June 15. It should be noted here that, in many companies, labor hours are submitted directly to the pricing department for submittal into the base case computer run. In this case, the program office would “massage” the labor hours only after the base case figures are available. This procedure assumes that sufficient time exists for analysis and modification of the base case.

If the program office has sufficient personnel capable of critiquing the labor input prior to submittal to the base case, then valuable time can be saved, especially if two or three days are required to obtain computer output for the base case.

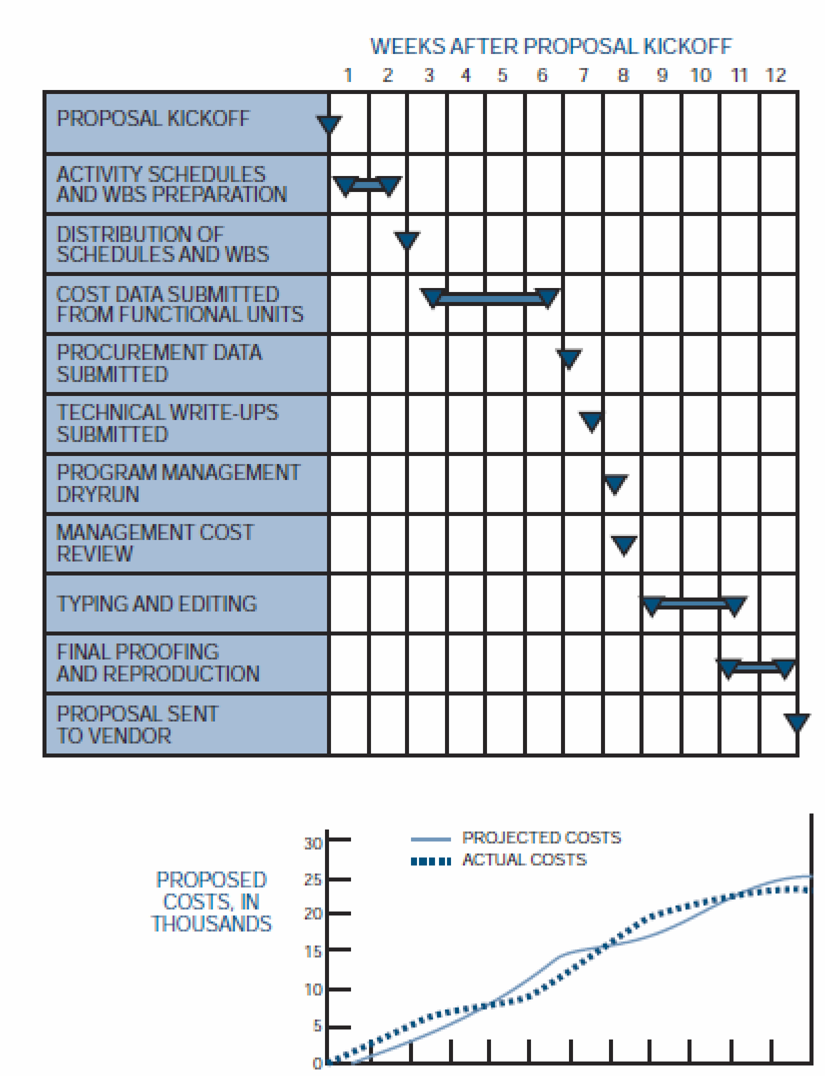
During proposal activities, the proposal manager, pricing manager, and program manager must all work together, although the program manager has the final say. The primary responsibility of the proposal manager is to integrate the proposal activities into the operational system so that the proposal will be submitted to the requestor on time. A typical schedule developed by the proposal manager is shown in Figure 5.3. The schedule includes all activities necessary to "get the proposal out of the house," with the first major step being the submittal of man-hours by the pricing organizations. Figure 5.3 also indicates the tracking of proposal costs. The proposal activity schedule is usually accompanied by a time schedule with a detailed estimates checklist if the complexity of the proposal warrants one. The checklist generally provides detailed explanations for the proposal activity schedule.

Figure 5.2 Activity schedule for assembly line updating



Adapted from Kerzner, (2013, 582)

Figure 5.3 Proposal Activity Schedule

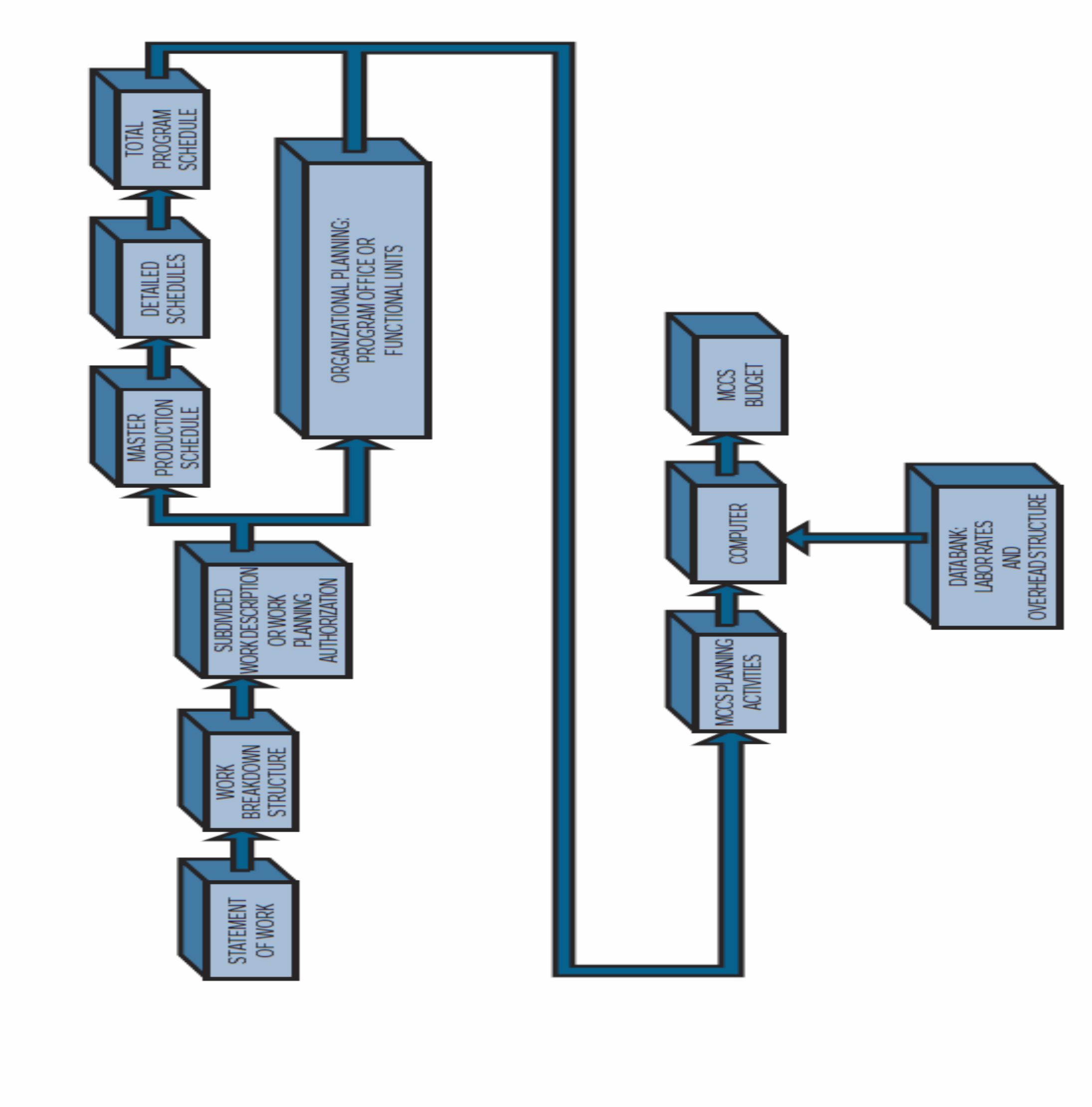


Adapted from Kerzner, (2013, 583)

After the planning and pricing charts are approved by program team members and program managers, they are entered into an electronic data processing (EDP) system as shown in Figure 5.4. The computer then prices the hours on the planning charts using the applicable department rates for preparation of the direct budget time plan and estimate- at-completion reports. The direct budget time plan reports, once established, remain the same for the life of the contract except for customer-directed or approved changes or when contractor management determines that a reduction in budget is advisable.

However, if a budget is reduced by management, it cannot be increased without customer approval. The time plan is normally a monthly mechanical printout of all planned effort by work package and organizational element over the life of the contract, and serves as the data bank for preparing the status completion reports. Initially, the estimate-at-completion report is identical to the budget report, but it changes throughout the life of a program to reflect degradation or improvement in performance or any other events that will change the program cost or schedule.

Figure 5.4: Labour Planning Flowchart



Adapted from Kerzner, (2013, 584)

5.7 Overhead Rates

The ability to control program costs involves more than tracking labor dollars and labor hours; overhead dollars, one of the biggest headaches, must also be tracked. Although most programs have an assistant program manager for cost whose responsibilities include monthly overhead rate analysis, the program manager can drastically increase the success of his program by insisting that each program team member understand overhead rates. For example, if overhead rates apply only to the first forty hours of work, then, depending on the overhead rate, program dollars can be saved by performing work on overtime where the increased salary is at a lower burden. This can be seen in the example below:

Assume that Apex Manufacturing must write an interim report for task 1 of project 1 during regular shift or on overtime. The project will require 500 man-hours at $15.00 per hour. The overhead burden is 75 percent on regular shift but only 5 percent on overtime. Overtime, however, is paid at a rate of time and a half. Assuming that the report can be written on either time, which is cost-effective—regular time or overtime?

- On regular time the total cost is:
  (500 hours) X ($15.00/hour) X (100% + 75% burden) = $13,125.00
- On overtime, the total cost is:
  (500 hours) X ($15.00/hour X 1.5 overtime) X (100% + 5% burden)
  = $11,812.50

Therefore, the company can save $1,312.50 ($13,125.00 - $11,812.50) by performing the work on overtime.

Scheduling overtime can produce increased profits if the overtime overhead rate burden is much less than the regular time burden. This difference can be very large in manufacturing divisions, where overhead rates between 300 and 450 percent are common.

The development of the overhead rates is a function of three separate elements: direct labor rates, direct business base projections, and projection of overhead expenses. Direct labor rates have already been discussed. The direct business base projection involves the determination of the anticipated direct labor hours and dollars along with the necessary direct materials and other direct costs required to perform and complete the program efforts included in the business base. Those items utilized in the business base projection include all contracted programs as well as the proposed or anticipated efforts.

The foundation for determination of the business base required for each program can be one or more of the following:

- Actual costs to date and estimates to completion
- Proposal data
- Marketing intelligence
- Management goals
- Past performance and trends

The projection of the overhead expenses is made by an analysis of each of the elements that constitute the overhead expense.

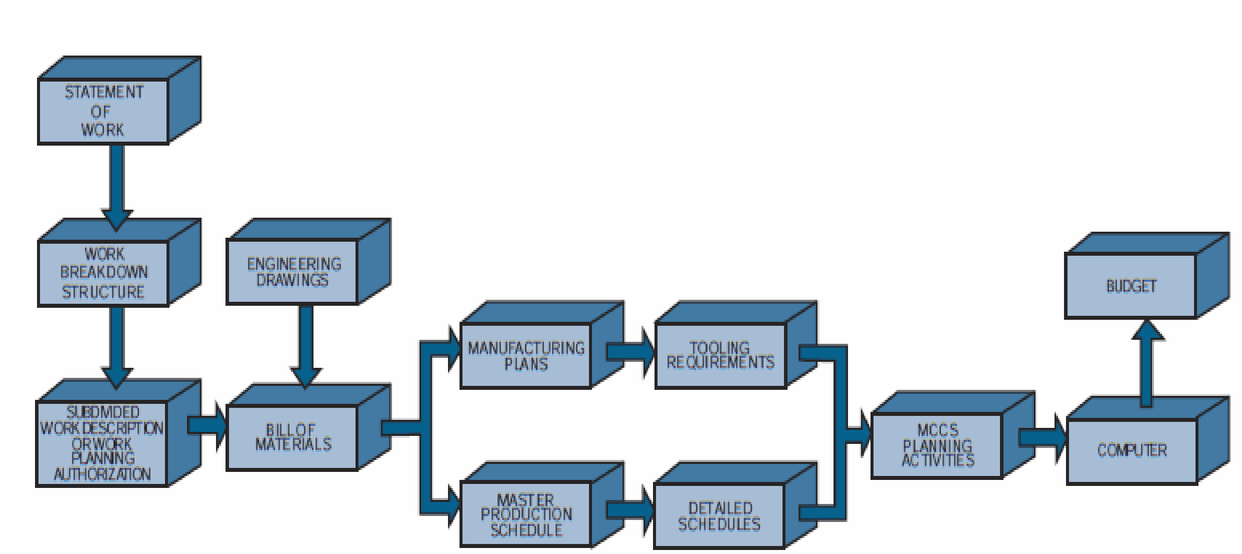
Projection of expenses within the individual elements is then made based on one or more of the following:

- Historical direct/indirect labor ratios
- Regression and correlation analysis
- Manpower requirements and turnover rates
- Changes in public laws
- Anticipated changes in company benefits
- Fixed costs in relation to capital asset requirements
- Changes in business base
- Bid and proposal (B&P) tri-service agreements
- Internal research and development (IR&D) tri-service agreements

5.8 Materials/ Support Costs

The salary structure, overhead structure, and labor hours fulfill three of four major pricing input requirements. The fourth major input is the cost for materials and support. Six subtopics are included under materials/support: materials, purchased parts, subcontracts, freight, travel, and other. Freight and travel can be handled in one of two ways, both normally dependent on the size of the program. For small-dollar-volume programs, estimates are made for travel and freight. For large dollar- volume programs, travel is normally expressed as between 3 and 5 percent of the direct labor costs, and freight is likewise between 3 and 5 percent of all costs for material, purchased parts, and subcontracts. The category labeled “other support costs” may include such topics as computer hours or special consultants.

Figure 5.5: Materiel Planning Flowchart



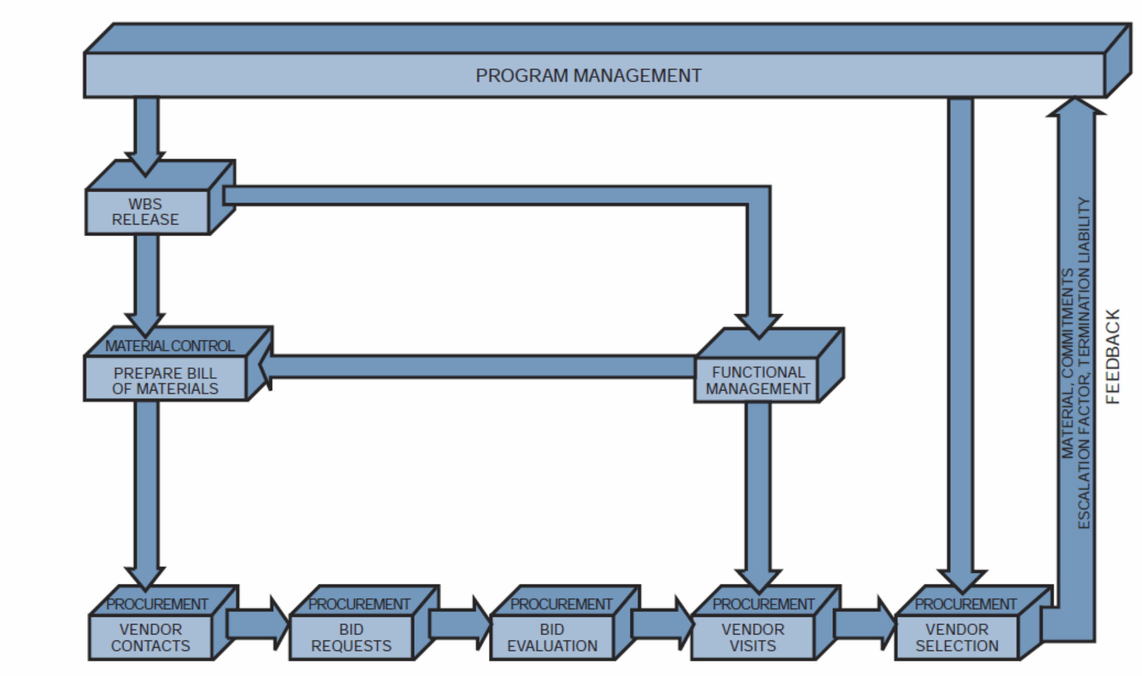
Adapted from Kerzner, (2013, 587)

Determination of the material costs is very time-consuming, more so than cost determination for labor hours. Material costs are submitted via a bill of materials that includes all vendors from whom purchases will be made, projected costs throughout the program, scrap factors, and shelf lifetime for those products that may be perishable.

Upon release of the work statement, work breakdown structure, and subdivided work description, the end-item bill of materials and manufacturing plans are prepared as shown in Figure 5.5. End-item materials are those items identified as an integral part of the production end-item. Support materials consist of those materials required by engineering and operations to support the manufacture of end-items, and are identified on the manufacturing plan. A procurement plan/purchase requisition is prepared as soon as possible after contract negotiations (using a methodology as shown in Figure 15.6). This plan is used to monitor material acquisitions, forecast inventory levels, and identify material price variances.

Manufacturing plans prepared upon release of the subdivided work descriptions are used to prepare tool lists for manufacturing, quality assurance, and engineering. From these plans a special tooling breakdown is prepared by tool engineering, which defines those tools to be procured and the material requirements of tools to be fabricated in-house. These items are priced by cost element for input on the planning charts. The materials/support costs are submitted by month for each month of the program. If long-lead funding of materials is anticipated, then they should be assigned to the first month of the program. In addition, an escalation factor for costs of materials/support items must be applied to all materials/support costs. Some vendors may provide fixed prices over time periods in excess of a twelve-month period. As an example, vendor Z may quote a firm-fixed price of $130.50 per unit for 650 units to be delivered over the next eighteen months if the order is placed within sixty days. There are additional factors that influence the cost of materials.

Figure 5.6: Procurement Activity



Adapted from Kerzner, (2013, 588)

5.9 Determining Prices for the work

Using logical pricing techniques will help in obtaining detailed estimates. The following thirteen steps provide a logical sequence to help a company control its limited resources. These steps may vary from company to company.

Step 1: Provide a complete definition of the work requirements.

Step 2: Establish a logic network with checkpoints.

Step 3: Develop the work breakdown structure.

Step 4: Price out the work breakdown structure.

Step 5: Review WBS costs with each functional manager.

Step 6: Decide on the basic course of action.

Step 7: Establish reasonable costs for each WBS element.

Step 8: Review the base case costs with upper-level management.

Step 9: Negotiate with functional managers for qualified personnel.

Step 10: Develop the linear responsibility chart.

Step 11: Develop the final detailed and PERT/CPM schedules.

Step 12: Establish pricing cost summary reports.

Step 13: Document the result in a program plan.

Although the pricing of a project is an iterative process, the project manager must still develop cost summary reports at each iteration point so that key project decisions can be made during the planning. Detailed pricing summaries are needed at least twice: in preparation for the pricing review meeting with management and at pricing termination. At all other times, it is possible that "simple cosmetic surgery" can be performed on previous cost summaries, such as perturbations in escalation factors and procurement cost of raw materials.

The list below shows the typical pricing reports:

● *A detailed cost breakdown for each WBS element.* If the work is priced out at the task level, then there should be a cost summary sheet for each task, as well as rollup sheets for each project and the total program.

● *A total program manpower curve for each department.* These manpower curves show how each department has contracted with the project office to supply functional resources. If the departmental manpower curves contain several "peaks and valleys," then the project manager may have to alter some of his schedules to obtain some degree of manpower smoothing. Functional managers always prefer manpower-smoothed resource allocations.

● A monthly equivalent manpower cost summary. This table normally shows the fully burdened cost for the average departmental employee carried out over the entire period of project performance. If project costs have to be reduced, the project manager performs a parametric study between this table and the manpower curve tables.

● A yearly cost distribution table. This table is broken down by WBS element and shows the yearly (or quarterly) costs that will be required. This table, in essence, is a project cash-flow summary per activity.

● A functional cost and hour summary.

This table provides top management with an overall description of how many hours and dollars will be spent by each major functional unit, such as a division. Top management would use this as part of the forward planning process to make sure that there are sufficient resources available for all projects. This also includes indirect hours and dollars.

● A monthly labor hour and dollar expenditure forecast. This table can be combined with the yearly cost distribution, except that it is broken down by month, not activity or department. In addition, this table normally includes manpower termination liability information for premature cancellation of the project by outside customers.

● A raw material and expenditure forecast. This shows the cash flow for raw materials based on vendor lead times, payment schedules, commitments, and termination liability.

● Total program termination liability per month. This table shows the customer the monthly costs for the entire program. This is the customer's cash flow, not the contractor's. The difference is that each monthly cost contains the termination liability for man-hours and dollars, on labor and raw materials. This table is actually the monthly costs attributed to premature project termination.

5.10 Low Bidder Dilemma

There is little argument about the importance of the price tag to the proposal.

The question is, what price will win the job? The decision process that leads to the final price of your proposal is highly complex with many uncertainties. Yet proposal managers, driven by the desire to win the job, may think that a very low-priced proposal will help. But winning is only the beginning. Companies have short- and long-range objectives on profit, market penetration, new product development, and so on. These objectives may be incompatible with or irrelevant to a low-price strategy.

For example:

● A suspiciously low price, particularly on cost-plus type proposals, might be perceived by the customer as unrealistic, thus affecting the bidder's cost credibility or even the technical ability to perform.

● The bid price may be unnecessarily low, relative to the competition and customer budget, thus eroding profits.

● The price may be irrelevant to the bid objective, such as entering a new market. Therefore, the contractor has to sell the proposal in a credible way, e.g., using cost sharing.

● Low pricing without market information is meaningless. The price level is always relative to (1) the competitive prices, (2) the customer budget, and (3) the bidder's cost estimate.

● The bid proposal and its price may cover only part of the total program. The ability to win phase II or follow-on business depends on phase I performance and phase II price.

● The financial objectives of the customer may be more complex than just finding the lowest bidder. They may include cost objectives for total system life-cycle cost (LCC), for design to unit production cost (DTUPC), or for specific logistic support items. Presenting sound approaches for attaining these system cost–performance parameters and targets may be just as important as, if not more important than, a low bid for the system's development. Further, it is refreshing to note that in spite of customer pressures toward low cost and fixed price, the lowest bidder is certainly not an automatic winner. Both commercial and governmental customers are increasingly concerned about cost realism and the ability to perform under contract. A compliant, sound, technical and management proposal, based on past experience with realistic, well-documented cost figures, is often chosen over the lowest bidder, who may project a risky image regarding technical performance, cost, or schedule.

5.11 Project Risks

Project plans are "living documents" and are therefore subject to change.

Changes are needed in order to prevent or rectify unfortunate situations.

These unfortunate situations can be called project risks.

Risk refers to those dangerous activities or factors that, if they occur, will *increase* the probability that the project's goals of time, cost, and performance will not be met. Many risks can be anticipated and controlled. Furthermore, risk management must be an integral part of project management throughout the entire life cycle of the project.

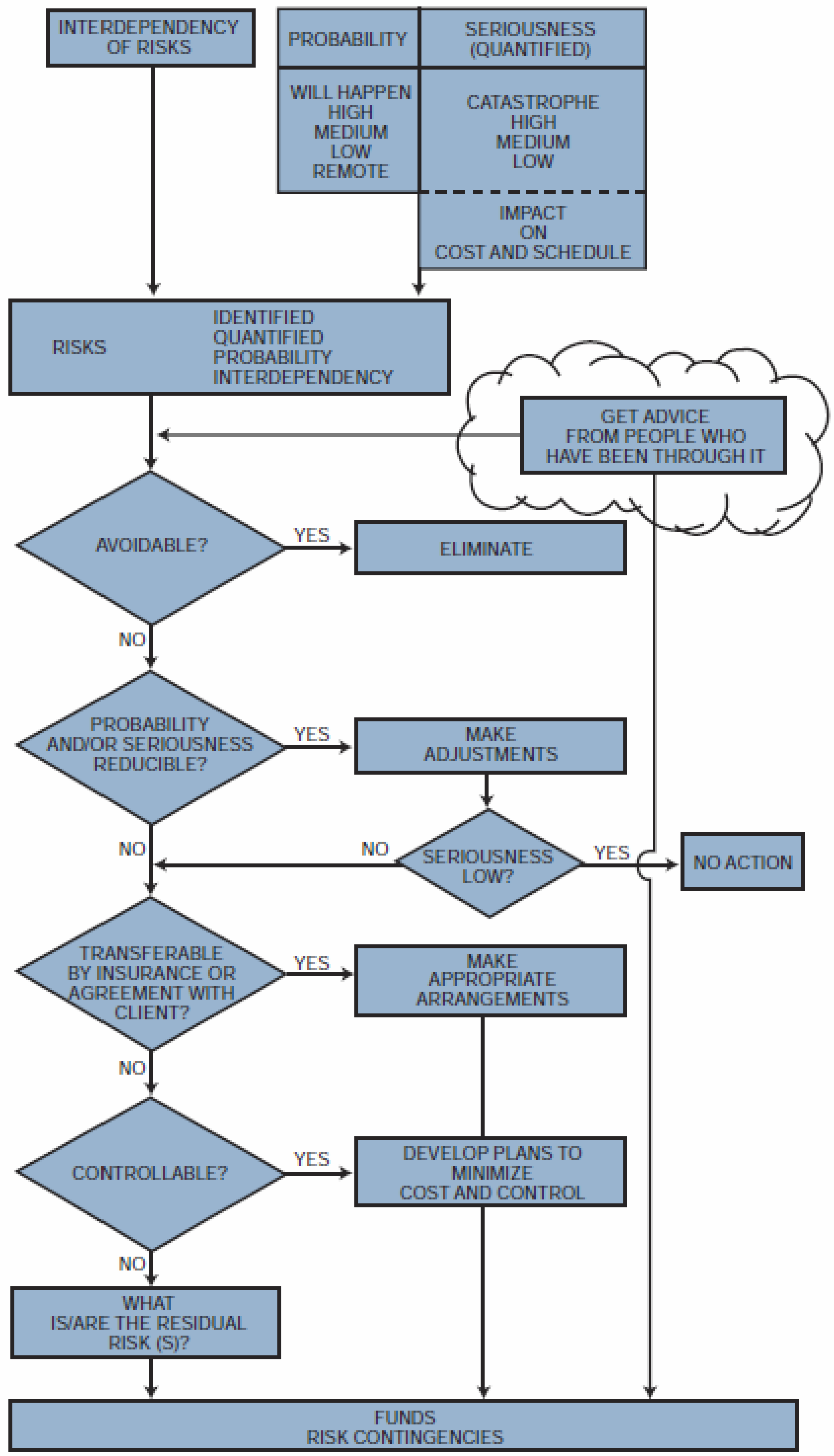
Some common risks include:

- Poorly defined requirements
- Lack of qualified resources
- Lack of management support
- Poor estimating
- Inexperienced project manager

Risk identification is an art. It requires the project manager to probe, penetrate, and analyse all data. Tools that can be used by the project manager include:

- Decision support systems
- Expected value measures
- Trend analysis/projections
- Independent reviews and audits

Figure 5.7: Decision Elements for risk contingencies



Adapted from Kerzner, (2013, 603)

Managing project risks is not as difficult as it may seem. There are six steps in the risk management process:

● Identification of the risk

● Quantifying the risk

● Prioritizing the risk

● Developing a strategy for managing the risk

● Project sponsor/executive review

● Taking action

5.12 Project Financing Methods

It is not the objective of this module to cover the different financing and economic criteria in depth as these aspects would be covered in the financial component of the MBA. The financing methodologies presented below are intended only for an overview and to establish the link between project management and financial management. Project managers are often called upon to be active participants during the benefit-to-cost analysis of project selection. It is highly unlikely that companies will approve a project where the costs exceed the benefits. Benefits can be measured in either financial or nonfinancial terms. The process of identifying the financial benefits is called capital budgeting, which may be defined as the decision-making process by which organizations evaluate projects that include the purchase of major fixed assets such as buildings, machinery, and equipment.

Sophisticated capital budgeting techniques take into consideration depreciation schedules, tax information, and cash flow. Since only the principles of capital budgeting will be discussed in this text, we will restrict ourselves to the following topics:

● Payback Period

● Discounted Cash Flow (DCF)

● Net Present Value (NPV)

● Internal Rate of Return (IRR)

5.11.1 Pay Back Period

The payback period is the exact length of time needed for a firm to recover its initial investment as calculated from cash inflows. Payback period is the *least* precise of all capital budgeting methods because the calculations are in dollars and not adjusted for the time value of money. Table 5.7 shows the cash flow stream for Project A.

Table 5.7: Capital expenditure data for project A

Initial Investment	Expected Cash Inflows				
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
$10,000	$1,000	$2,000	$2,000	$5,000	$2,000

From Table 5.7, Project A will last for exactly five years with the cash inflows shown. The payback period will be exactly four years. If the cash inflow in Year 4 were $6,000 instead of $5,000, then the payback period would be three years and 10 months. The problem with the payback method is that $5,000 received in Year 4 is not worth $5,000 today. This unsophisticated approach mandates that the payback method be used as a supplemental tool to accompany other methods.

5.11.2 Time Value of money

Everyone knows that a dollar today is worth more than a dollar a year from now. The reason for this is because of the time value of money. To illustrate the time value of money, let us look at the following equation:

FV = PV(1 _ *k*)*n*

where FV _ Future value of an investment

PV = Present value

k = Investment interest rate (or cost of capital)

n = Number of years

Using this formula, we can see that an investment of $1,000 today (i.e., PV) invested at 10% (i.e., *k*) for one year (i.e., *n*) will give us a future value of $1,100. If the investment is for two years, then the future value would be worth $1,210. Now, let us look at the formula from a different perspective. If an investment yields $1,000 a year from now, then how much is it worth *today* if the cost of money is 10%?

To solve the problem, we must discount future values to the present for comparison purposes. This is referred to as "discounted cash flows."
The previous equation can be written as:

$$PV = \frac{FV}{(1 + k)^n}$$

Using the data given:

$$PV = \frac{\$1{,}000}{(1 + 0.1)^1} = \$909$$

Therefore, $1,000 a year from now is worth only $909 today. If the interest rate, *k*, is known to be 10%, then you should *not* invest more than $909 to get the $1,000 return a year from now. However, if you could purchase this investment for $875, your interest rate would be more than 10%.

Discounting cash flows to the present for comparison purposes is a viable way to assess the value of an investment. As an example, you have a choice between two investments. Investment A will generate $100,000 two years from now and investment B will generate $110,000 three years from now. If the cost of capital is 15%, which investment is better? Using the formula for discounted cash flow, we find that:

PVA = $75,614

PVB = $72,327

This implies that a return of $100,000 in two years is worth more to the firm than a $110,000 return three years from now.

5.11.3 Net Present Value (NPV)

The net present value (NPV) method is a sophisticated capital budgeting technique that equates the discounted cash flows against the initial investment. Mathematically,

$$\text{NPV} = \sum_{t=1}^{n} \left[\frac{\text{FV}_t}{(1+k)^t} \right] - \text{II}$$

where FV is the future value of the cash inflows, II represents the initial investment, and *k* is the discount rate equal to the firm's cost of capital. Table 14–16 calculates the NPV for the data provided previously in Table 5.7 using a discount rate of 10%.

Table 5.8: NPV Calculation: Project A

Year	Cash Inflows	Present Value
1	$1,000	$ 909
2	2,000	1,653
3	2,000	1,503
4	5,000	3,415
5	2,000	1,242
	Present value of cash inflows	$ 8,722
	Less investment	10,000
	Net Present Value	<1,278>

Adapted from Kerzner, (2013, 616)

This indicates that the cash inflows discounted to the present will *not* recover the initial investment. This, in fact, is a bad investment to consider. Previously, we stated that the cash flow stream yielded a payback period of four years.

However, using discounted cash flow, the actual payback is greater than five years, assuming that there will be cash inflow in years 6 and 7.

If in Table 5.8 the initial investment was $5,000, then the net present value would be $3,722. The decision-making criteria using NPV are as follows:

- If the NPV is greater than or equal to zero dollars, accept the project.
- If the NPV is less than zero dollars, reject the project.

A positive value of NPV indicates that the firm will earn a return equal to or greater than its cost of capital.

5.11.4 Internal Rate of Return

The internal rate of return (IRR) is perhaps the most sophisticated capital budgeting technique and also more difficult to calculate than NPV. The internal rate of return is the discount rate where the present value of the cash inflows exactly equals the initial investment. In other words, IRR is the discount rate when NPV _ 0. Mathematically

$$\sum_{t=1}^{n}\left[\frac{FV_t}{(1+IRR)^t}\right] - II = 0$$

The solution to problems involving IRR is basically a trial-and-error solution. Table 5.9 shows that with the cash inflows provided, and with a $5,000 initial investment, an IRR of 10% yielded a value of $3,722 for NPV. Therefore, as a second guess, we should try a value greater than 10% for IRR to generate a zero value for NPV. Table 5.9 shows the final calculation.

The table implies that the cash inflows are equivalent to a 31% return on investment. Therefore, if the cost of capital were 10%, this would be an excellent investment. Also, this project is “probably” superior to other projects with a lower value for IRR.

Table 5.9: IRR Calculation for Project A Cash Inflows

IRR	NPV
10%	$3,722
20%	1,593
25%	807
30%	152
31%	34
32%	<78>

Adapted from Kerzner, (2013, 617)

5.11.5 Comparing IRR, NPV and Payback

For most projects, both IRR and NPV will generate the same accept /reject decision. However, there are differences that can exist in the underlying assumptions that can cause the projects to be ranked differently. The major problem is the differences in the magnitude and timing of the cash inflows. NPV assumes that the cash inflows are reinvested at the cost of capital, whereas IRR assumes reinvestment at the project's IRR. NPV tends to be a more conservative approach.

The timing of the cash flows is also important. Early year cash inflows tend to be at a lower cost of capital and are more predictable than later year cash inflows. Because of the downstream uncertainty, companies prefer larger cash inflows in the early years rather than the later years. Magnitude and timing are important in the selection of capital projects.

5.12 Project Costing

During the project execution, the actual costs must be monitored against the budget, and the earned value of the work performed must be determined. Clements and Gido (2012) state that the following cost-related parameters should be monitored during the project:

- Cumulative actual amount spent since the start of the project;
- Cumulative earned value of the work performed since the start of the project;
- Cumulative budgeted amount planned to be spent, based on the project schedule, from the start of the project.

Some important financial concepts that students will also become familiar with are: estimating costs of activities; determining a time-phased baseline budget and earned value of work performed; analysing, forecasting and controlling project costs; and managing cash flow.

5.13 Estimating activity costs

Cost estimating involves approximating or estimating the costs of resources required to complete a project. Cost budgeting involves the allocation of the overall cost estimate to individual tasks over time to establish a baseline for measuring performance. If a project manager wants to effectively plan and control a project, accurate estimating is vital. According to Burke (2009:84), the quality and accuracy of the estimate can be continually improved as the project is progressively executed, and more accurate and detailed information comes to the fore. However, the project manager is often forced to do a cost estimate at the tender or quotation stage when the amount of data and information is usually limited. Burke (2009:88) subdivides project cost estimates as follows:

- Direct and indirect costs
- Fixed and variable costs
- Time-related costs
- Labour, material and equipment costs
- Transport costs
- Preliminary and general (P&G) costs
- Project office costs
- Project team costs

Similarly, Clements and Gido (2012:245) describe the following costs:

- Labour costs
- Material costs
- Equipment costs
- Facilities costs
- Subcontractors and consultant's costs
- Travel costs
- Contingency costs

According to Burke (2009:96), various estimating techniques may be used to predict the project's parameters and resource requirements quickly and accurately. These include:

- Jobbing
- Factoring
- Inflation
- Economies of scale
- Unit rates

Burke (2009:96) elaborates on the five estimating techniques (listed above) as follows:

5.14 Jobbing (operational costing)

It is the process of including all the operations that are required for an activity or task. Table 5.10 below provides an example of a job that is subdivided into its component parts:

Table 5.10: Example of estimating costs using jobbing.

Task	Description	Labour	Materials	Plant hire	Transport	Total
100	Mark-out foundations	R2 000	R1 000			R3 000
200	Dig foundations	R10 000	R1 000	R2 000	R1 000	R14 000
300	Lay foundations	R6 000	R20 000	R6 000	R4 000	R36 000

Once the activity has commenced, job costing enables the progress to be quantified:

- It provides a cost estimate for all WBS packages and activities.
- Progress can be measured in terms of percentage complete or duration remaining.
- The profit or loss can be calculated when the activity is complete.

During the tender stage, there may not be sufficient time or need to produce an estimate with this level of detail. We therefore need to examine other estimating techniques that are quicker to produce a reasonably accurate estimate.

5.15 Factoring (Component Ratio/ Parametric method)

This technique can be used when data stored from previous projects indicates than an item of the project may be expressed as a percentage of a known or calculated core cost. Table 5.11 below provides an example:

Table 5.11: Example of estimating costs using factoring.

Management fee	6% of contract price
Quality assurance	2% of contract price
Engine beds	3% of engine costs
Pipe work	18% of generator costs
Consumables	12% of material costs
Profit	25% of construction price

5.16 Inflation (Time Based Indices)

One cannot ignore the effects of inflation on project costs. If a current project is similar to one done a few years ago, the financial figures for the previous project may be used as the basis for the current estimate. Table 5.12 illustrates an example of this:

Table 5.12: Example of estimating costs using inflation.

	2010	2011		2012	
	Base cost	Inflation rate	New price	Inflation rate	New price
Labour	R250 000	10%	R275 000	8%	R297 000
Material	R200 000	15%	R230 000	5%	R241 500
Total	R450 000	12.22% average	R505 000	6.63% average	R538 500

One of the problems with this method is that different commodities escalate at different rates. This problem can be addressed by using a separate escalation factor for each cost component, as is evident in Table 5.12.

5.17 Economies of scale (Cost capacity factor)

If a job is twice as large as the previous one, the question is whether it will cost twice as much. The answer is that it usually will not, for the following reasons:

- Indivisibility: There may be certain indivisibilities (or fixed costs) in the production process that are not related to output, e.g. manager, telephone, secretary etc. These costs are indivisible since one cannot have part of a manager if one wants to operate at a lower output.
- Specialisation: In small enterprises people have to do a variety of tasks but as the business grows, work is grouped and repetitive tasks are assigned to one person. This improves efficiency.
- Technical: Large scale production enables enterprises to benefit from the use of automated machinery. The high capital expenditure is divided over large production runs, thereby reducing the cost per unit.
- Scaling: The relationship between dimensions and volumes is not always linear e.g. the surface area on an oil tanker increases at two-thirds the rate of the volume. A tanker thus requires proportionally less steel per cubic meter of cargo as it increases in volume.

- Diseconomy of scale: It often happens that as output increases, the organisation structure becomes large and bureaucratic. As a result, co-ordination between the management departments become increasingly more complex, costly, and inefficient.

5.18 Unit Rates (Parameter Costs)

Although each project is unique, a great deal of the work may be repetitive. Parameter costs are developed from unit rates for common items of work associated with previous projects. Table 5.13 shows some parameters:

Table 5.13: Example of unit rate types.

Type of rate	Scope of work	Unit rate
Per linear metre	Piping, wiring, welding, textiles	
Per square metre	Decorating, painting, house building	
Per cubic metre	Concrete, water supply	
Per tonne	Ship building, cargo freight	
Per KW	Power, electrical supply, install a generator	
Per KM	Transport	
Per day	Plant hire, car hire	
Per hour	Labour	
Per minute	Fashion garment construction	

In a controlled work environment, unit rates work well. Unit rates are probably the most commonly used estimating technique as they provide a simple contract to measure and budget.

5.19 Project Budget

According to Schwalbe (2009:151), project cost budgeting involves the allocation of project cost estimates to different tasks over time. These tasks are based on the work breakdown structure (WBS) of the project.

The main aim of cost budgeting is to produce a cost baseline. A cost baseline may be defined as a time-phased budget that project managers use to measure and monitor cost performance. Estimating costs for each major project activity over time provides project managers and top management with a foundation for project cost control using earned value management which will be discussed later.

Clements and Gido (2011:229) describe the project budget as a two-step process:

- Aggregated total budgeted cost: The aggregated estimated costs of the specific activities for each work package will establish the total budgeted cost (TBC) or budget at completion (BAC). This aggregated budgeted cost should not exceed the total amount of funds that the sponsor budgeted for the project (Clements and Gido, 2011).
- Cumulative budgeted cost: Once the TBC for each work package is established, the next step is to distribute each TBC over the expected time span of its work package (Clements and Gido, 2011). This time-phased budget is useful to track the actual spend against the cumulative budgeted cost (CBC) for each time period.

5.20 Actual Costs

Clements and Gido (2012) suggest the use of processes, procedures and forms for gathering data which reflects the costs actually expended. For example, weekly time sheets can be used to collect actual labour hours. As invoices are received, these must be charged to the correct work package number. Committed costs (commitments, obligated costs or encumbered costs) should be treated in a special way as they extend across several cost reporting periods (Clements and Gido, 2011).

As portions of actual costs, including committed costs, are collected for a particular work package period (cumulative actual costs or CAC), they must be compared against the cumulative budgeted cost (CBC).

5.21 Earned Value Management

Earned value management may be defined as “a management methodology for integrating scope, schedule and resources, and for objectively measuring project performance and progress” (Kloppenborg, 2009:393). *Earned value* may be described as the value of work completed expressed in terms of the approved budget allocated to that work. Clements and Gido (2012) define earned value as “the value of work actually performed” and state that it is a “key parameter that must be determined throughout the project. Earned value is calculated by collecting data on the percent complete for each work package, and then converting this percentage to a monetary value. The formula used is: ***EV = TBC of work package x Percent complete.***

Earned value, according Kloppenborg (2009:393), makes it possible for a project team to understand their project’s progress with regard to cost and schedule as well as to make forecasts regarding the project’s schedule and cost control until the completion of the project. Earned value is an important decision-making tool. The project manager can do a quick assessment of how the project is doing according to the baseline plan and whether the project would end without any significant cost/schedule impacts. The earned value data permits a project manager to determine the status of a project at any given point in time.

When interpreting earned value management, one must consider cost and schedule independently. Firstly, in terms of the planned schedule, a project can be either ahead or behind; and in terms of budget, a project can be either over or under. Secondly, all earned value terms relate to one of two time frames. Each of the above either represents the current status as of the last date that project data was collected, or a forecast for the end of the project. Table 5.14 lists 12 questions and answers that reflect all the earned value management terms.

Table 5.14: Earned value management terms

Question	Timing	Answer	Acronym
How much work *should* be done?	Now	Planned value	PV
How much work *is* done?	Now	Earned value	EV
How much *did* the "is done" work cost?	Now	Actual cost	AC
How much was the total project *supposed* to cost?	End	Budget at completion	BAC
How much *is* the project schedule ahead or behind?	Now	Schedule variance	SV
How much *is* the project over or under budget?	Now	Cost variance	CV
How efficient is the project *so far* with its schedule?	Now	Schedule performance index	SPI
How efficient is the project *so far* with its budget?	Now	Cost performance index	CPI
How much *more* do we expect to spend to finish the project?	End	Estimate to complete	ETC
What do we *now* think the total project will cost?	End	Estimate at completion	EAC

We now learn how to calculate each of the earned value management terms as explained by Kloppenborg (2009:396).

5.23 Currently Known Values

Suppose the following values are provided:

PV = R250 000; EV = R200 000; AC = R400 000; BAC = R750 000

- Planned value (PV) refers to the budget that has been authorised for the scheduled work to be completed. In our case it will be R250 000.
- Earned value (EV) may be described as the value of work completed expressed in terms of the approved budget allocated to that work, which in our case is R200 000.
- Actual cost (AC) reflects the total costs actually incurred to accomplish the work performed during a given time period. In our case, R400 000 is owed for the work that was completed.
- Budget at completion (BAC) is the sum of all budgeted values determined for the work to be done on a project.

In other words, it's the total planned value of the project. In our case the approved budget for the entire project is R750 000.

5.24 Variances

Schedule variance (SV) measures schedule performance on a project. It is the difference between EV and PV. In our example the calculation will be:

EV – PV = R200 000 – R250 000 = –R50 000

The negative value is an indication that the project is behind schedule.

Cost variance (CV) measures the cost performance on a project. It is the difference between EV and AC. In our example the calculation is as follows:

EV – AC = R200 000 – R400 000 = –R200 000

The negative answer shows that the project is over budget.

These two variances show in monetary terms how well or poorly the project is performing in terms of cost and schedule. Clearly, the performance is poor in terms of both cost and schedule.

5.25 Indices

Some project managers prefer to use efficiency measures in percentage terms to understand how well or poorly the project is performing. **Schedule performance index (SPI)** measures schedule efficiency on a project. It is calculated as follows:

$$EV/PV \times 100$$

In our case, SPI will be calculated as follows:

$$R200000/R250000 \times 100 = 80\%$$

Since only 80% of what was planned has been accomplished, the project is behind schedule. When performance indexes are used: 100% means right on schedule; <100% means less efficient than planned; and >100% means more efficient than planned.

Cost performance index (CPI) measures cost efficiency on a project. It is calculated as follows:

$$EV/AC \times 100$$

In our case, CPI will be calculated as follows:

$$R200000/R400000 \times 100 = 50\%$$

The project is over budget since only R0.50 (fifty cents) of results was received for every Rand that was spent.

5.26 Estimates

Now that we understand the performance in the project thus far, we now predict performance for the remainder of the project. The easiest way of estimating future performance is to predict that past performance will continue. The following calculations are based on this assumption.

Estimate to complete (ETC) refers to the expected cost required to complete the remaining work for the project.

Assuming that future performance will have the same efficiency as past performance, it is calculated as follows:

$$\frac{(BAC) - EV}{CPI}$$

Unless efficiency is improved, the company can expect to pay more for the remaining project work than the original cost of the project.

Estimate at completion (EAC) is the expected total cost of the project when the defined scope of work will be completed. It is calculated as follows:

$$EAC=AC+ETC$$

In our case, it will be calculated as follows:

R400 000 + R1 100 000 = R1 500 000

Since cost efficiency is only 50% of plan (refer to CPI), the original estimate will be double unless efficiency improves.

Each term in earned value management helps project managers understand something about the performance of the project. Collectively the terms provide project managers with added insight for monitoring and controlling cost and schedule.

5.27 Managing cash flow

According to Clements and Gido (2011), managing cash flow involves ensuring that the funds from the sponsor or income from payments received are carried out timeously so that there is enough money to cover the costs of executing the project. Cash must come in faster than it can go out. Payments to the contractor must also be made on time. Providing down payments at the start of the project, making equal monthly payments based on the expected duration of the project, or providing frequent payments are options to consider (Clements and Gido, 2011).

REFLECTION QUESTIONS

5.1 How does a project manager price out a job in which the specifications are not prepared until the job is half over?

5.2 Beta Corporation is in the process of completing a contract to produce 150 units for a given customer. The contract consisted of R&D, testing and qualification, and full production. The industrial engineering department had determined that the following number of hours were required to produce certain units:

Unit Hours	Required Per Unit
1	100
2	90
4	80
8	70
16	65
32	60
64	55
128	50

a. Plot the data points on regular graph paper with the Y-axis as hours and the X-axis as

number of units produced.

b. Plot the data points on log–log paper and determine the slope of the line.

c. Compare parts a and b. What are your conclusions?

d. How much time should it take to manufacture the 150th unit?

e. How much time should it take to manufacture the 1,000th unit? Explain your answer.

Is it realistic? If not, why?

f. As you are producing the 150th unit, you receive an immediate follow-on contract for another 150 units.

How many manufacturing hours should you estimate for the follow-on effort (using only the learning curves)?

g. Let’s assume that industrial engineering determines that the optimum number of hours (for 100 percent efficiency) of manufacturing is forty-five.

At what efficiency factor are you now performing at the completion of unit number 150?

After how many units in the follow-on contract will you reach the optimum level?

Section B: Costing

The following information is available for Project A

PV = R250 000; EV = R175 000; AC = R275 000; BAC = R600 000

5.3. Calculate the following:

a) Schedule variance (SV)

b) Cost variance (CV)

c) Schedule performance index (SPI)

d) Cost performance index (CPI)

e) Estimate to complete (ETC)

f) Estimate at completion (EAC)

5.4. Describe the results of each calculation in question 5.3.

SOLUTIONS:

5.3a) Schedule variance = EV – PV = R175 000 – R250 000 = –R75 000

5.3b) Cost variance = EV – AC = R175 000 – R275 000 = –R100 000

5.3c) Schedule performance index (SPI)

$R175000/R250000 \times 100 = 70\%$

5.3d) Cost performance index (CPI)

$R175000/R275000 \times 100 = 63.64\%$

5.3e) Estimate to complete (ETC)

$(R600000) - R17500063.64\% = R667819$

5.3f) Estimate at completion (EAC)

$EAC = R275000 + R667819 = R942819$

5.4.

Schedule variance (SV): The project is behind schedule since the variation is negative.

Cost variance (CV): The project is over budget since the variation is negative.

Schedule performance index (SPI): The project is behind schedule since only 70% of what was planned was accomplished.

Cost performance index (CPI): The project is over budget since only R0.64 worth of results was received for every Rand spent.

Estimate to complete (ETC): The cost to complete the remaining work for the project is R667 819 which is even greater than the original cost of the entire project.

Estimate at completion (EAC): Since the cost efficiency is only about two thirds of the plan, unless there is greater efficiency, it can be expected that the company would have to pay just over 1½ times the original estimate.

CHAPTER 6

PROJECT RISK MANAGEMENT

Chapter 6 Project Risk Management

CHAPTER OUTCOMES

Upon completion of this Chapter, students should be able to:

- Identify and distinguish the different terms in project risk management
- Comprehend the different categories of risk
- Explain and apply the risk management process
- Formulate a risk assessment in a project environment

Essential Reading

Textbooks:

- Kerzner. (2013). Project Management: A Systems Approach. 10th Edition. Wiley & Sons. Chapter 17
- Clements, J. P. and Gido, J. (2011). Effective Project Management. 6th Edition. Boston: Cengage Learning.
- Burke, R.J. and Barron, S. (2007). Project Management Leadership. Hampshire: Burke Publishing.
- Gray, C.F. and Larson, E.W. (2006). Project Management: The Managerial Process. 3rd Edition. New York: McGraw-Hill.
- Schwalbe, K. (2009). Introduction to Project Management. 2nd Edition. Boston: Cengage Learning.

6.1 Introduction

This section outlines the most essential knowledge that you should acquire in the field of project risk management. Be aware that, as a manager or coordinator of projects, there will come a time when your efforts will fall short of necessary requirements. This failure could be ascribed to numerous factors but, by engaging in constructive project risk management, you will be able to mitigate the risks to your project.

6.2 Definitions

Risk

According to Clements and Gido (2012), risk is an uncertain event that can jeopardise the project objective. Risk includes the expected losses (economic, time, infrastructure or resources) that a particular phenomenon might cause. It is a function of the probability of particular occurrences and the losses that each would cause (severity).

Risk management

Risk management includes the processes concerned with identifying, analysing and responding to project risks. It includes both minimising the impact of adverse events and maximising the likelihood of positive outcomes. Project risk management includes the processes of risk assessment, risk mitigation and risk response.

Hazard

A hazard in the project management domain can be defined as a rare or extreme event, or the probability of an occurrence in the natural or human-made environment, that adversely effects the successful completion of the project, to the extent that it may cause economic, time, infrastructure or resource loss.

Vulnerability

Vulnerability is the degree of loss to a given element (economic, time, infrastructure or resources) that is at possible risk from the impact of a hazard of a given severity. It is specific to a particular project and can be expressed on a scale of 0 to 10 (0 indicating no loss, 10 indicating total damage).

Probability

Risk probability in a project can be defined as which the risk event that is likely to occur. The probability of certain risks influencing a project is determined by the nature of the project.

Frequency

Frequency refers to the number of times a particular risk can impact on a project, for example rain interruption of a building project or systems downtime in an information technology project.

Severity

The impact of a risk on a project can be defined by its severity. The severity of a risk is mostly quantified into monetary terms, although other measuring tools are also often used.

6.3 Categories and types of risk

Clements and Gido (2011:271) identify the following categories of risk:

- Technical
- Schedule
- Cost
- Human resources
- External
- Sponsor/customer

Some specific examples of risk include:

Market or price risk

Market or price risk is the risk of a decrease in the value of a financial portfolio as a result of adverse movement in the market variables such as prices, currency exchange rates and interest rates. In other words, market risk is the exposure arising from adverse changes in the market value of a financial instrument or portfolio.

Interest rates risk

This is the risk of a loss that an organisation could suffer as a result of adverse consequences due to fluctuations in interest rates. Most financial institutions face interest rate risk. Interest rate risk is known to fluctuate and is by nature a speculative type of financial risk, since interest rate movements can result in profits or losses. It can thus be urged that interest rate risk depends on the state of the economy.

Liquidity

Liquidity is an organisation's ability to meet its financial obligations within a given time period. This risk will be reflected in insufficient funds or marketable assets being available.

Legal risk

Legal risk is the risk arising from violations of, or non-compliance with laws, rules, regulations, prescribed policies and ethical standards. This risk also arises when laws or rules governing certain products or activities of an organisation's customers are unclear or untested. Non-compliance can expose the organisation to fines, financial penalties, payment of damages, and the voiding of contracts.

Operational risk

Operational risk is the risk of loss occurring as a result of inadequate systems and control, human error, or management failure.

It is the risk of a loss arising from human error, management failure and fraud, or from shortcomings in systems or controls (Schwartz and Smith, 1997:322).

6.4 Risk assessment

Risk assessment is the identification, quantification and evaluation of the probability of the occurrence of risk events and the impact of the risk events on a project. Risk assessment addresses issues such as: What can go wrong? How likely is this to happen? If it does happen, what are the consequences? In essence, risk assessment is both proactive and reactive measures to project risk management. Clements and Gido (2012) suggest the preparation of a risk assessment matrix which would include the specific risk, the impact of the risk, probability of the risk, degree of impact of the risk, action trigger, responsibility and response plan.

A useful checklist for a risk assessment is provided below:

QUESTIONS	YES	NO
Has the project leader's authority been established?		
Is the core team appointed?		
Does the core team understand the project purpose?		
Have the stakeholders been identified		
Have stakeholder management responsibilities been allocated?		
Have the project objectives been established?		
Have the project benefits been identified and quantified?		
Are there clear deadlines and a project timescale?		
Is there a known business critical date established?		
Is there a scope statement?		
Are the project boundary limits clearly established?		
Is there an impact if the project fails?		
Are the right skills available in the team/organisation?		
Can the project brief be accurately derived?		
Have all the project constraints been identified?		
Are there identifiable consequences of late completion?		
Has the project brief been approved?		
Have all the key stages been clearly identified?		
Have the key stage dependencies been established and agreed on?		
Are the key stage durations agreed and accepted?		
Is the project schedule realistic and achievable?		
Have key stage responsibilities been allocated and accepted?		
Have workload priorities been clearly established?		
Have line managers accepted and committed their staff involvement?		
Have all resources required given commitment to their responsibilities?		
Has the plan been developed to a low enough level for effective control?		
Have key stakeholders signed off the project plans?		
Are project procedures established and understood?		
Has a milestone schedule been established?		
Have performance measures been derived?		

6.5 Risk management plan process

The risk management plan process includes the following steps:

a) Define objectives

b) Identify risk

c) Quantify risk

d) Develop a response

e) Risk control

a) Define objectives Risk may be defined as any event or constraint that prevents the project manager or team from achieving the project's goals and objectives. It is therefore necessary at the outset to define these goals and objectives in some detail, and to indicate who is responsible for achieving them.

b) Identify risk

Having defined the business objectives by one of the above breakdown structures, the next step is to identify what areas of risk, uncertainty and triggers could prevent the progress team from achieving these stated objectives.

Techniques for identifying risk include:

- Analysing historical records and closeout reports
- Safety reports (health and safety requirements)
- Structured questionnaires
- Structured interviews
- Brainstorming
- Structured checklists
- Flow charts
- Judgement based on knowledge
- Scenario analysis

c) Quantify risk

Having identified a range of possible risks, the next step is to quantify the probability (likelihood) of the risk occurring and the impact or consequence to the project, or to the amount at stake. These risks should be assessed in consultation with appropriate stakeholders.

For any given risk, whether it is a natural disaster, a liability, or a worker's compensation loss exposure, the following steps should be followed to analyse the frequency and severity of the risk:

i. Assign a category for the frequency of occurrence of a loss event.

ii. Assign a category for the severity of the loss event.

iii. Multiply the frequency value by the severity value.

iv. Prioritise the ratings for all loss exposures.

d) Develop a response

Risk response includes the development of proactive measures to counteract identified risks and changes in risk over the course of a contingency planning. Clements and Gido (2012) suggest the development of a separate risk response plan. Having identified, quantified and prioritised the risks, you need to develop a risk response plan which defines ways to address adverse risk and enhance entrepreneurial opportunities before they occur. The range of responses includes:

- Eliminate risk.
- Mitigate risk.
- Deflect risk.
- Accept risk (contingency).
- Turn risk into an opportunity.

A contingency plan must also be formulated. A typical contingency plan should contain the following information:

- Title
- WBS identification number

- Risk/risk events/threats
- Trigger events
- Contingency actions
- Responsible persons
- Cost implications
- Time implications
- Tasks effected
- Influence of critical path

e) Risk control

The risk control function implements the risk management plan to make it happen. This is the most important part, but surprisingly is often neglected. The risk management plan needs to be communicated to the entire project team, and where necessary, followed up with appropriate training and practice runs. The risk management plan should consider:

- Changes in the scope work.
- Changes in the build method.
- Changes in the team members.
- Changes in the suppliers.

The ultimate goal of risk management is risk mitigation. Risk mitigation involves defining the necessary steps to counter threats and to enhance opportunities. It is the active steps taken to lessen the effects that a particular identified risk might have on a project outcome. It is also the continuous measures taken during the life cycle of a project in order to ensure proactive actions to unforeseen circumstances.

6.6 Effective risk management involves:

- Commitment to risk management by stakeholders, top management, the project steering committee, the project manager and project team members, and

- An adequate project management approach (a capable project manager should take responsibility for risk management, and he/she and the project team should have an understanding of the technical and non-technical issues).

Risk management involves identifying, assessing, and responding to project risks in order to minimise the likelihood and impact of the consequences of adverse events on the achievement of the project objective. Risk identification includes determining which risks may adversely affect the project objective and what the consequences of each risk might be if they occur. Assessing each risk involves developing an action plan to reduce the impact or likelihood of each risk, establish a trigger point for when to implement the actions to address each risk, and assigning responsibility to specific individuals for implementing each response plan. During the project, it is important to evaluate all risks to determine if there are any of the risks, also, new risks maybe identified that were not considered as a risk earlier in the project.

REFLECTION QUESTIONS

6.1 Consider the following case study and apply it to a risk matrix (use the Internet to read up more about risk matrices). Use your results to determine the frequency, severity, probability and risk scores.

You have been appointed as the project manager for a shopping centre construction project. The area in which you are building is prone to excessive rain and occasional flooding. You are working with unfamiliar construction teams. After initial consultation with the local traffic department, it has become clear that they are not satisfied with the road layout as per your building plans. However, they did give the preliminary go-ahead for the project, with the proviso that the town engineer and town planner reconsider the plans. To date, all the suppliers you have contacted can supply all the relevant material but cannot guarantee on-time delivery.

CHAPTER 7

QUALITY MANAGEMENT

Chapter 7 Quality Management

CHAPTER OUTCOMES

Upon completion of this Chapter, students should be able to:

- Comprehend the core values, principles and process of the major quality management frameworks
- Critically analyse the core quality concepts
- Distinguish between quality assurance and control
- Identify and define the costs of quality
- Explain and apply common quality management tools and techniques

Essential Reading

Textbooks:

- Kerzner. (2013). Project Managent: A Systems Approach. 10th Edition. Wiley & Sons. Chapter 20
- Clements, J. P. and Gido, J. (2012). Effective Project Management. 6th Edition. Boston: Cengage Learning.
- Burke, R. (2009). Project Management Techniques. College Edition. Hampshire: Burke Publishing.
- Kloppenborg, T.J. (2009). Project Management: A Contemporary Approach. Boston: Cengage Learning.
- Rose, K.H. (2005). Project Quality Management: Why, What and How. Florida: J. Ross Publishing.
- Schwalbe, K. (2009). Introduction to Project Management. 2nd Edition. Boston: Cengage Learning.

7.1 Introduction

The Project Management Institute defines quality as “the degree to which a set of inherent characteristics fulfil requirements” (Rose, 2005:6). Rose (2005:12) states that:

- Quality involves products, defects, processes, customers and systems.
- Quality is the ability of a set of inherent characteristics of a product, system, or process to fulfil requirements of customers and other interested parties.
- Quality is a fourth among equals in relation to the project triple constraint of time, cost and scope

Project quality management includes the process required to ensure that the project will satisfy the needs for which it was undertaken. Burke (2007:254) offers two definitions of project quality management:

- “the processes required to ensure that the project will satisfy the need for which it was undertaken” (PMBOK Guide, 2004);
- “covering quality planning, quality control and quality assurance.”

Project quality management is about the synergy of continuous improvement of the project and the principle of project delivery. Using a quality approach plays a key role in assuring that the project meets customer requirements. Quality management is the process for ensuring that all project activities necessary to design, plan and implement a project are effective and efficient with respect to the purpose of the objective and its performance.

This section covers the broad concepts associated with quality management, the different costs of quality, quality planning, assurance and control, and quality management tools.

7.2 Concepts and definitions associated with quality management

Garvin developed a list of eight quality dimensions which describe product quality:

- Performance: the efficiency with which a product achieves its intended purpose;

- Features: attributes of a product that supplement the basic performance;
- Reliability: propensity of a product to perform consistently over its useful design life;
- Conformance: compliance with numeric dimensions (specifications);
- Durability: the degree to which a product tolerates stress or trauma without failing; - Serviceability: the ease of repair of a product;
- Aesthetics: subjective sensory characteristics such as taste, feel, sound, look and smell. Quality is measured as the degree to which product attributes are matched to customer preferences in terms of aesthetics;
- Perceived quality: based on customer opinion (Foster, 2007:6).

Burke (2007: 255) provides the following definitions:

- Quality Management philosophy – the involvement of all project participants in order to ensure that the goals and objectives of the project and the resulting product or service meets the needs of the client, project team and other stakeholders.
- Quality Assurance - a systematic process of defining planning, implementing and reviewing the management processes in order to provide adequate confidence that the product will be consistently produced to the required condition.
- Quality Planning – the process of identifying the standards the project needs to comply with order to achieve the required condition.
- Quality Control – defines the method of inspection (testing), in-process inspection and final inspection to confirm that the product meets the required condition.
- Quality Audit – “a structured review of other quality management (QM) activities”.
- Project Quality Plan – a detailed document explaining how the company will assure that the product will be made to the client’s requirements.
- Project Quality Management includes the processes and activities that determine the quality policies, objectives, and responsibilities necessary to

assure that project requirements are met. Processes critical to the Quality Management System include Quality Planning, Quality Assurance, and Quality Control.

- Quality Planning is an integral part of project management. It identifies relevant quality standards and determines how they can best be satisfied.
- Quality Assurance ensures that project management utilizes the quality processes needed to meet project requirements in a planned and systematic manner.
- Quality Control monitors specific project outputs and determines compliance with applicable standards. It also identifies project risk factors, their mitigation, and looks for ways to prevent and eliminate unsatisfactory performance.

The work of quality ‘gurus’ has been incorporated into three popular quality frameworks: Total Quality Management (TQM), International Organisation for Standardisation (ISO) and Six Sigma. Many organisations use these frameworks to define and organize their quality initiatives (Kloppenberg, 2009:284).

7.3 Total Quality Management, International Organisation for Standardisation and Six Sigma

Total Quality Management (TQM) considers the wider aspects of quality by integrating quality management components into a quality management system. TQM is a systems approach to quality management that focuses on the system and not any particular components of the system. TQM has a people focus and an outcome focus. It advances the rationale that each project needs a unique quality management system. It first identifies what the client really wants and how it can best be achieved. It keeps an emphasis on continuous improvement, but always endeavors to keep the customer satisfied. For quality to be effective, it needs to be introduced to all members and all aspects of the operations. TQM is underpinned by the following concepts:

- Quality is defined by customers,
- There must be a respect for people,
- All levels of the organization must want to participate,
- There must be an emphasis on continuous improvement,
- Prevention is better than detection (Burke, 2007:266).

Kloppenborg (2009:285) highlights the core values of TQM:

- Organisational and personal learning,
- Valuing employees,
- Agility,
- Focus on the future,
- Managing for innovation,
- Management by fact,
- Social responsibility,
- Focus on results and creating value,
- Systems perspective.

The ISO 9000 series of standards addresses quality management systems. The ISO standards encompass eight quality management principles as listed in Table 8.1.

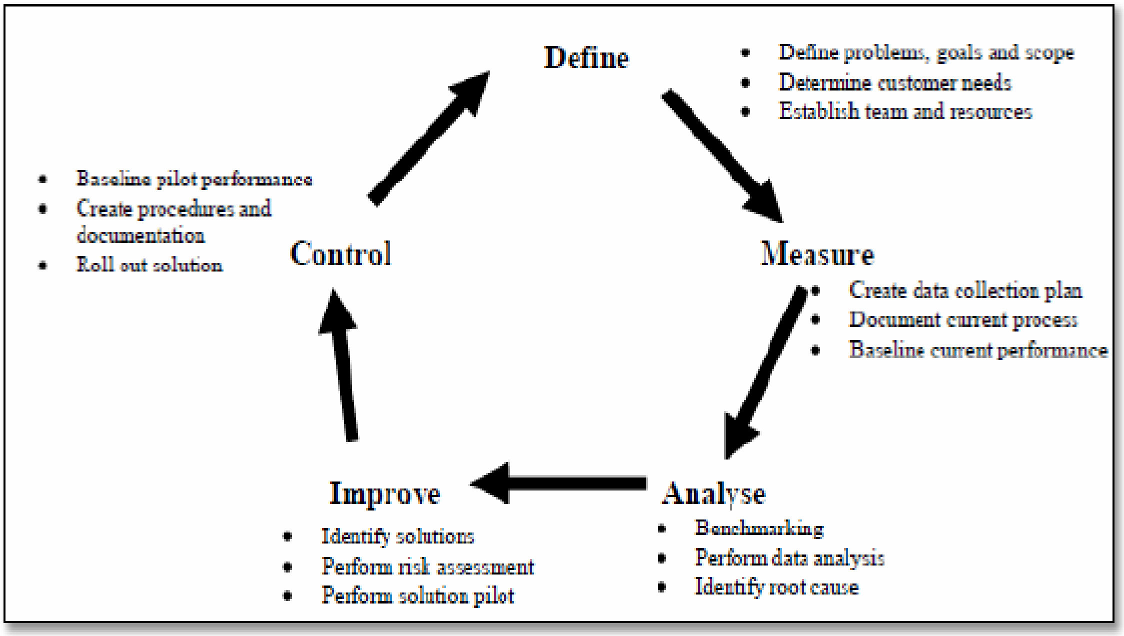
Table 8.1: ISO Principles

Principle	Brief Description
Customer focus	Understand current and future customer needs; meet requirements; strive to exceed expectations; link organisation's needs to customer needs.
Leadership	Leaders establish unity of purpose and direction for the organisation.
Involvement of people	Motivated, committed, and involved people at all levels accept ownership of problems, evaluate their own performance, and freely share information.
Process approach	Activities and related resources are managed as processes resulting in predictable results and improvement opportunities.
Systems approach to management	Integrate and align processes; focus effort on key processes; understand interdependencies, capabilities and constraints before starting projects.
Continual improvement	Use a consistent organization-wide approach to continual improvement to include training in methods, goals to guide and measures to track.
Factual approach to decision-making	Ensure data and information are accurate, reliable and accessible; make decisions and take action based upon analysing facts; challenge opinions and decisions.
Mutually beneficial supplier relationships	Identify and select key partners; jointly develop and improve with partners; openly share communication with them.

ISO implementation provides many benefits. It forces analysis of all quality management activities; it documents all aspects of the quality management system. The ISO approach is prevention based; it focuses on prevention, not inspection. It is a framework for quality improvement. Continual improvement is an essential part of the ISO approach (Rose, 2005:33).

Six Sigma uses a process called DMAIC (define, measure, analyse, improve and control) to plan and manage improvement. The DMAIC methodology is a 15-step process broken up into 5 phases (Figure 8.1).

Figure 7.1: DMAIC Methodology



7.4 Costs of quality

Cost of quality refers to the total cost of all efforts related to quality. The appraisal, prevention, and failure costs are included in this term.

Cost of Poor Quality (COPQ): Cost of poor quality addresses the cost of not performing work correctly the first time or not meeting customer's expectations.

Cost of Doing Nothing Different (CODND): Cost of Doing Nothing Different is the cost of not changing standard practice, even when it is dysfunctional.

The cost of quality is the sum of costs a project will spend to prevent poor quality and any other costs incurred as a result of outputs of poor quality. Poor quality is the waste, errors, or failure to meet stakeholder needs and project requirements. The costs of poor quality can be broken down into the three categories of prevention, appraisal, and failure costs.

Prevention costs: These are planned costs an organisation incurs to ensure that errors are not made at any stage during the delivery process of that product or service to a beneficiary.

Examples of prevention costs include quality planning costs, education and training costs, quality administration staff costs, process control costs, market research costs, field testing costs, and preventive maintenance costs (www.pm4dev.com).

Appraisal costs**:** These include the costs of verifying, checking, or evaluating a product or service during the delivery process. Examples of appraisal costs include receiving or incoming inspection costs, internal production audit costs, test and inspection costs, instrument maintenance costs, process measurement and control costs, supplier evaluation costs and audit report costs (www.pm4dev.com).

Failure costs: A project incurs these costs because the product or service did not meet the requirements and had to be fixed or replaced, or the service had to be repeated. (www.pm4dev.com).

7.5 Core project quality concepts

Kloppenborg (2009: 285) describes four core project quality concepts:

a. Stakeholder satisfaction

b. Process management

c. Fact-based management

d. Empowered performance

a) Stakeholder satisfaction

Stakeholder satisfaction consists of identifying all stakeholders, using a structured process to determine relevant quality standards, and understanding the ultimate quality goals with respect to stakeholders. The decision-process for developing relevant quality standards on a project consists of the following steps:

i. Identify all stakeholders

ii. Prioritise among the stakeholders

iii. Understand the prioritized stakeholders requirements

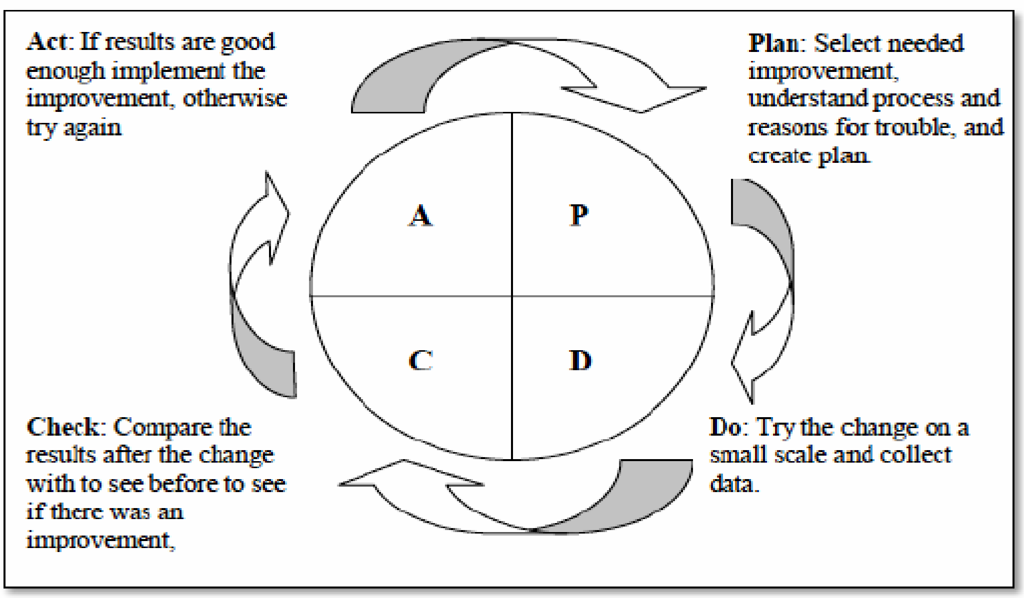
iv. Develop standards to ensure the requirements are met

v. Make trade-off decisions.

b) Process management

Kloppenborg (2009:290) defines a process as a set of interrelated actions and activities performed to achieve a set of products, results or services. In order to effectively manage project processes, project managers need to understand, control and improve them. One aspect of process management is process control. Control is comparing actual performance with planned performance, analysing variances, evaluating possible alternatives and recommending appropriate corrective action as needed. Another aspect of process management is process improvement. Processes can be improved in either a continuous or breakthrough fashion. Improvement models are based upon the plan-do-check-act (PDCA) improvement cycle (Figure 8.2).

Figure 7.2: PDCA



c) Fact-based management

Making decisions based on facts is a challenge facing many project managers. Making decisions using facts is difficult because:

- Opinions get in the way
- It is hard to know what data needs to be collected, and
- Projects operate with time pressures so that decisions need to be made quickly.

Project decision-makers need to understand the difference between two types of variation (Kloppenborg, 2009). Common cause is a source of variation that is inherent in a system and predictable. On the other hand, special cause is a source of variation that is not inherent in a system, is not predictable and is intermittent. It is important to determine when there is a variation on a project whether it is within the range of what can be expected for that particular work activity or deliverable (common cause) or whether something unusual is happening (special cause). If the variation is common cause, and the results are not acceptable, some change will need to be made to the system (the way in which the work is accomplished). However, if the change is due to a particular cause, then the way to improve is to change that particular cause and not the entire system. Management by facts requires an understanding that variation can be either common or special cause, a determination to discover which type, and the resolve to act appropriately on that discovery (Kloppenborg, 2009).

d) Empowered performance

The goal of empowered performance is to have capable and willing workers at every level and every function within a project. Kloppenborg (2009:295) lists four components of empowered performance in order to create capable and willing workers:

- The recognition of individuality
- Being able to capitalise on individual strengths

- Emphasizing individual responsibilities, and
- Using appropriate collaboration.

7.6 Project quality planning

Rose (2005:57) provides a summary of project quality planning:

- Quality management includes quality planning, quality assurance, quality control, and quality improvement.
- The quality management plan is part of the project plan. It includes the quality policy (intended direction of the organisation regarding quality) and answers the questions: Who is in charge (infrastructure and responsibilities)? Where are we going (goals)? How are we going to get there (processes)?
- Quality planning is identifying which quality standards are relevant to the project and how to satisfy them.
- Customers (internal or external) are the base in project quality.
- Customer and requirement identification and prioritisation should be performed early in project planning so that the project starts in the right direction.
- Identifying specifications is also part of the quality journey. Specifications are specific and measurable statements of requirements.
- Operational definitions provide a link between requirements and specifications. Operational definitions remove ambiguity of terms by describing what something is and how it is measured.
- Standards are closely related to specifications. Standards address how something is to be done. Specifications provide specific targets for performance.

The inputs to quality planning are:

- **Quality policy**

  This is the overall intentions and direction of an organization with regard to quality, as formally expressed by the top management.

In the case of a joint venture, a quality policy for the individual project should be developed. The management team is responsible for dissipating the quality policy to all project stakeholders through appropriate information distribution channels.

- **Scope statement**

  The scope statement is a key input to quality planning because it documents major project deliverables as well as project objectives which serve to define important stakeholder requirements.

- **Product description**

  Although the elements of the product description may be embodied in the scope statement, the product description often contains details of technical issues and other concerns that may affect quality planning.

- **Standards and regulations**

  The project management team any application-area-specific standards or regulations that may affect the project.

Other process outputs

In addition to the scope statement and product description, processes in other knowledge areas may produce outputs that should be considered as part of the quality planning.

The tools and techniques for quality planning are:

- Benefit / cost analysis

The planning process must consider benefit/cost trade-offs. The primary benefit is less work, higher productivity, lower costs and increased stakeholder satisfaction. The primary cost is the expenses associated with project quality management activities.

- Benchmarking

Benchmarking involves comparing actual or planned project practices to those of other projects to generate ideas for improvement and provide a standard for measurement of performance.

- Flowcharting

The flowcharting techniques in quality management generally include cause and effect diagrams and system or process flow charts. Flowcharting can help in anticipating probable quality problems and thus helps to develop approaches for dealing with them.

- Design of experiments

This is an analytical technique which aims to define variables that have most influence on the overall outcome.

The outputs from quality planning are:

- Quality Management Plan

The quality management plan should describe how a project management team will implement its quality policy. The plan should define the organisational structure, roles and responsibilities and resources needed for implementation of quality management. The quality management plan should address Quality Control of the project, Quality Assurance and Quality Improvement of the project.

- Quality metrics and quality checklists
- Process improvement plan and quality baseline.

7.7 Quality assurance

Quality assurance is evaluating the overall project performance on a regular basis to provide a confidence that the project will satisfy the relevant quality standards.

Inputs to Quality Assurance

- Quality management plan
- Operational definitions
- Results of quality control measurements which are records of quality control testing and measurement in a format of comparison or analysis.

Tools and techniques for Quality Assurance

- Quality planning tools and techniques
- Quality audits which are a structured review of other quality management activities. They may be timely or carried out randomly. They may be carried out by properly trained internal auditors or by third parties such as quality systems registration agencies.

Outputs from Quality Assurance

Quality Improvement

Quality improvement includes taking action to increase the effectiveness and efficiency of the project to be able to provide added benefits to the stakeholders of that project. In many cases, the implementation of quality improvements will require preparation of change requests or taking corrective actions and will be handled according to procedure for overall change control.

- Recommended corrective actions
- Organisational process assets updates
- Project management plan updates.

7.8 Quality control

Quality control involves monitoring specific project results to determine if they comply with relevant standards and identifying ways to eliminate causes of unsatisfactory results. Project results mentioned include both product results such as deliverables and management results such as cost and schedule performance. The project management team should have a working knowledge of statistical quality control especially sampling and probability to help evaluate and control outputs.

The project manager and team should be aware of the following:

- Prevention (keeping errors out of the process)

- Inspection (keeping errors out of the customer's hand)

- Special cause (unusual events)

- Random causes (normal process variations)

- Tolerances (where results should fall within a defined tolerance range)

- Control limits (the process is in control if it falls within these defined limits).

The inputs to Quality Control are:

- Work results: including both product results and process results
- The quality management plan
- Operational definitions
- Checklists.

Tools and techniques for Quality Control

Inspection

Inspection includes activities such as measuring, examining and testing undertaken to determine whether results conform to requirements. Inspection can be carried out on the level of a single activity or a final product. Inspections can be called reviews, product reviews, audit and walk-throughs.

Control charts

These charts are graphical representations that display the result of a process over time and are used to determine if the process is “in control”. Control charts may be used to monitor any type of output variable. Control charts are most often used to monitor repetitive activity in production but can also be used to monitor cost and schedule variances.

Pareto diagram

A Pareto diagram is a histogram ordered by frequency of occurrence which shows how many results were generated by what category or identified cause. Typically, the Pareto diagram reflects that a relatively small number of causes are responsible for the majority of the problems or defects.

- Statistical sampling involves choosing a part of a population of interest for inspection.
- Flowcharting is used in quality control to help analyse how a problem occurs.

- Trend analysis involves the use of mathematical techniques to forecast future outcomes based on historical results.

It is often used to monitor technical performance and cost and schedule performance.

The outputs for Quality Control are:

- Quality improvement
- Acceptance decisions, where the inspected items will either be accepted or rejected and those rejected may be reworked.
- Rework, which is action taken to bring defects or nonconforming items into compliance with requirements and specifications. Rework is a frequent cause of project over-runs.

Completed checklists

Process adjustments which involves immediate corrective or preventive action as a result of quality control measurements. In some cases the adjustment may need to be handled according to procedures for overall change control.

Difference between Quality Assurance and Quality Control

Quality assurance is often confused with quality control; quality control is done at the end of a process or activity to verify that quality standards have been met. Quality control by itself does not provide quality, although it may identify problems and suggest ways to improving it. In contrast, quality assurance is a systematic approach to obtaining quality standards.

Quality assurance is something that must be planned for from the earliest stages of a project, with appropriate measures taken at every stage. Unfortunately, far too many development projects are implemented with no quality assurance plan, and these projects often fail to meet quality expectations of the donor and beneficiaries (www.pm4dev.com).

7.9 Quality management tools

a) Check sheets

Check sheets are data gathering tools. They are used to compile and record data from observations or historical data.

b) Graphs

The purpose of a graph is to organise, summarise and display data, usually over time. The different types of graphs include line graphs, bar graphs and circle graphs.

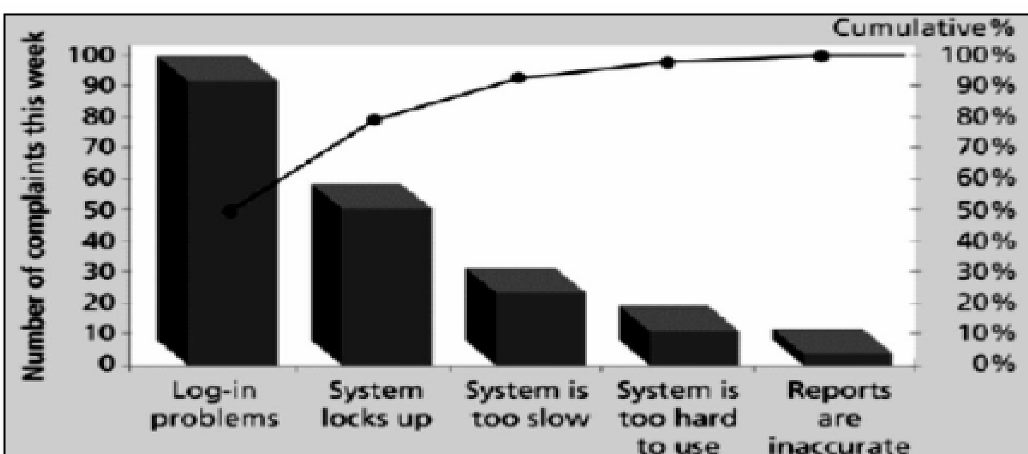
c) Histograms

A histogram is a type of bar graph that deals with data that exist in a continuous range from a low number to a high number. Histograms display frequency distribution.

d) Pareto charts

Pareto charts are used to identify and prioritise problems to be solved. They are actually frequency charts that are aided by the 80/20 rule. This rule states that roughly 80% of problems are created by roughly 20% of causes (Pareto Principle). This means that there are a vital few causes that create most of the problems. A Pareto chart is a bar graph with data in descending order. It involves identifying the vital few contributors that account for most quality problems in a system and uses a histogram or column chart that can help identify and prioritize problem areas.

Figure 7.3: Pareto Chart



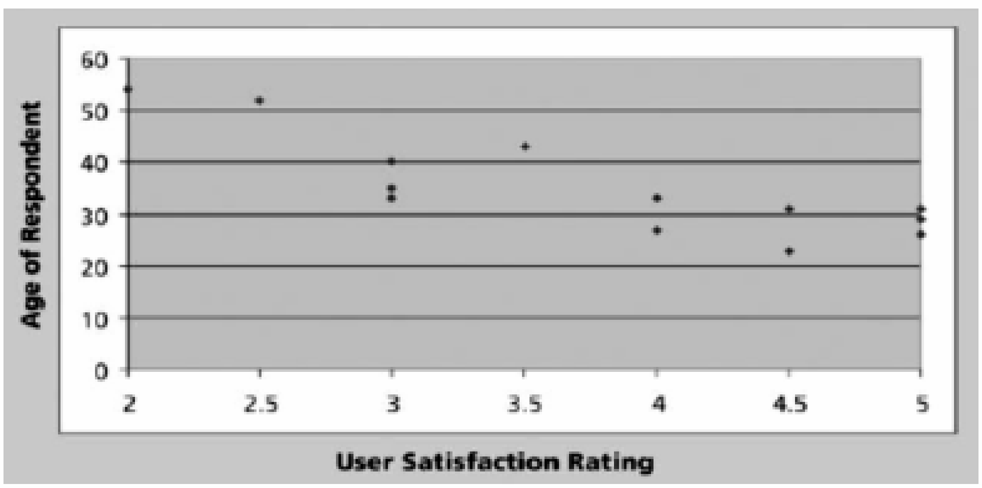
Pareto charts disclose two important types of information. First, the left-most bar indicates the greatest opportunity for improvement because it represents the source of error responsible for the most problems. Second, the chart identifies the “vital few”, those sources that account for most of the defects or errors, and the “trivial many”. The steps in Pareto analysis include:

a. Gathering categorical data relating to quality problems.
b. Drawing a frequency chart of the data (the data is arranged in descending order from left to right on the chart).
c. Focusing on the tallest bars first when solving the problem.

e) Scatter diagrams

A scatter diagram identifies possible relationships between two variables. The closer data points are to a diagonal line, the more closely the two variables are related.

Figure 7.4: Scatter Diagram

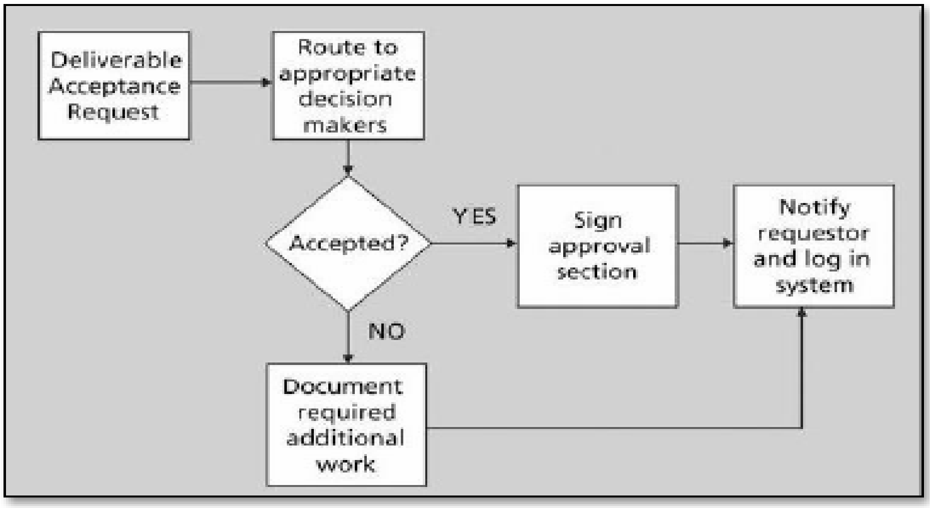


f) Flowcharts

A flow chart identifies the sequence of events in a process.

Flow charts are graphic displays of the logic and flow of processes that help analyse how problems occur and how processes can be improved. They show activities, decision points, and the order of how information is processed.

Figure 7.5 Flow Chart

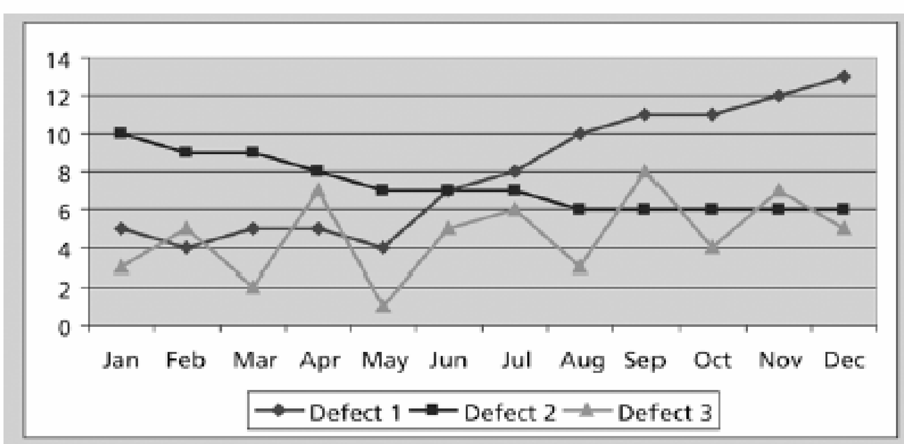


f) Run charts

A run chart is used to observe process performance over time. It is a line graph with data that vary around a center-line, usually the mean. Run charts a used for the following:

- Display the history and pattern of variation of a process over time.
- Are line charts that show data points plotted in the order in which they occur.
- Can be used to perform trend analysis to forecast future outcomes.

Figure 7.6 Run Chart



g) Quality control charts

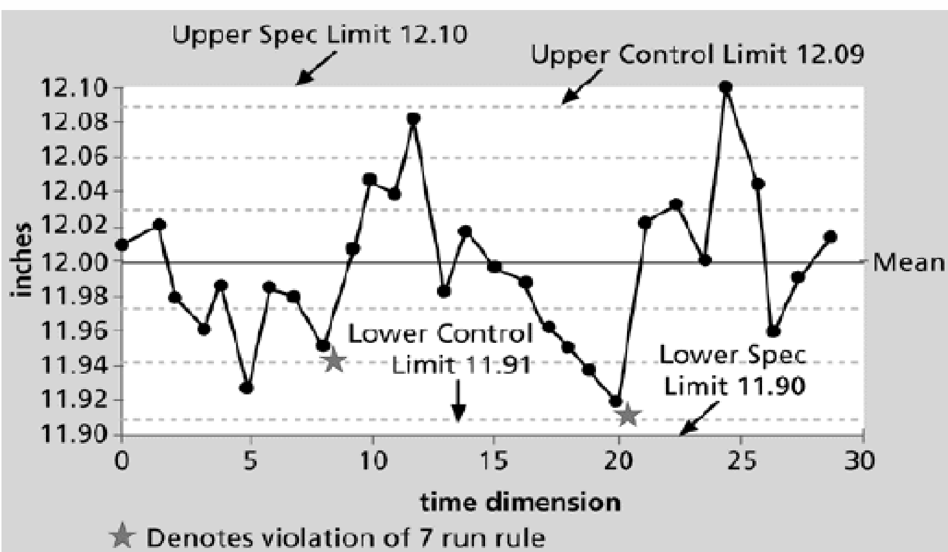
Control charts are tools for monitoring, controlling and improving processes over time.

Quality control charts:

- Are a graphic display of data that illustrates the results of a process over time.
- Are mainly used to prevent defects, rather than to detect or reject them.
- Allow the determination of whether a process is in control or out of control.

When a process is in control, any variations in the results of the process are created by random events; processes that are in control do not need to be adjusted. When a process is out of control, variations in the results of the process are caused by non-random events; one needs to identify the causes of those non-random events and adjust the process to correct or eliminate them. Quality control charts and the seven-run rule can be used to look for patterns in data. The seven-run-rule states that if seven data points in a row are all below the mean, above the mean, or are all increasing or decreasing, then the process needs to be examined for non-random problems.

Figure 7.7 Quality Control Chart

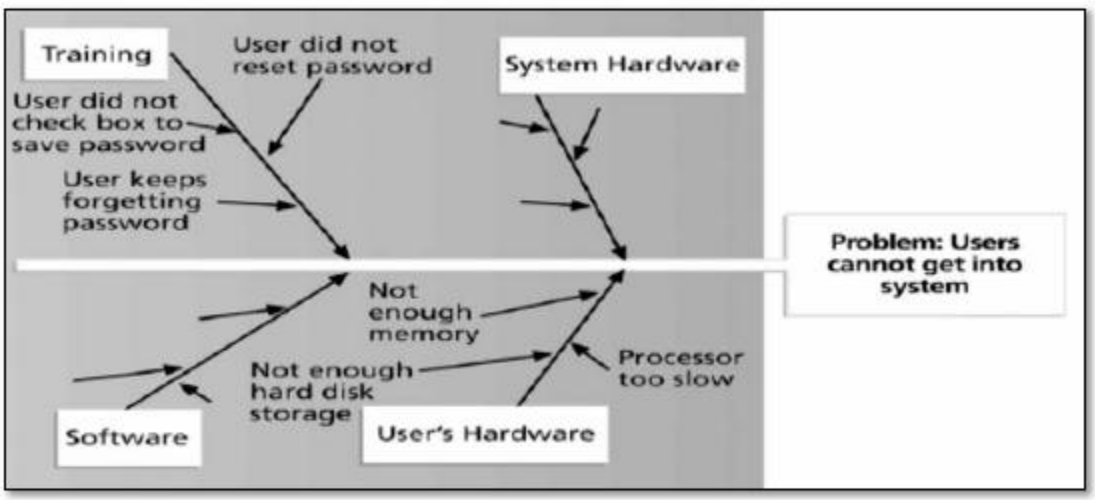


h) Cause and effect diagrams (Fishbone or Ishikawa diagrams)

These are used to identify, explore and graphically display all possible causes related to a problem. Cause-and-effect diagrams are used to:

- Trace complaints about quality problems back to the responsible production operations.
- Help find the root cause of a problem.
- Can also use the 5-whys technique where question “Why” is repeated five times to peel away the layers of symptoms that can lead to the root cause.

Figure 7.8 Fishbone Diagram



Quality management is the process for ensuring that all project activities necessary to design, plan and implement a project are effective and efficient with respect to the purpose of the objective and its performance. Quality management is a continuous process that starts and ends with the project. It is more about preventing and avoiding than measuring and fixing poor quality outputs. It is part of every project management process from the moment the project initiates to the final steps in the project closure phase. Quality planning, assurance and control are the three main components of quality management. Various quality management tools can be used to ensure that these three processes are facilitated.

REFLECTION QUESTIONS

7.1 Project quality management is the process for ensuring that all project activities necessary to design, plan and implement a project are effective and efficient with respect to the purpose of the objective and its performance. Briefly discuss the core project quality concepts.

Case Study: Factory Expansion

Factory Expansion

Jacob Clemson is the owner of Digitsig, Inc., a growing Canadian electronics company. The company has been receiving orders from customers worldwide and sales have been expanding rapidly. The factory is now working three shifts and is at capacity. Jacob had to lease additional space in a building several miles away. He knows he must expand his factory to keep up with growing demand, to increase efficiency, and to reduce the costs associated with trucking materials and product back and forth between his factory and the building he is leasing.

The cost of the lease was very high because there just wasn't much good available space in the area, and Jacob was desperate to get additional space right away, or he would not be able to keep up with demand and customers would go to his competitors.

Jacob met Andy Gibson, part-owner of AG Contractors, at a recent business networking event. He told Andy about his expansion needs. Andy said, ''We can do that for you, Mr. Clemson. We've done many similar projects. As you may know, business is booming in the region, and getting a contractor won't be easy. But, it could be lucky we met because we are just finishing up another project and could probably get working on yours if we can get an agreement soon. I've got four other proposals pending, and if they come in we won't be able to handle any other projects. And like I said, I understand all the other contractors are just as busy. It sounds like you really need to start on this factory expansion right away, and I think we can help you out.''

Jacob became worried that he might not be able to get another contractor, and he didn't want to waste any more time. So, he signed a contract with AG Contractors, for what he thought was a reasonable price, to design and build the expansion to his factory.

The expansion space would be used primarily for inventory storage of incoming materials and finished goods. He agreed to a bonus clause in the contract to pay AG Contractors a 10 percent bonus if they completed the building in 12 months rather than the 15 months Andy told him it would normally take.

It is now 14 months later. Andy Gibson and Gerri Penk, a recently hired project manager for AG Contractors, walked into Jacob Clemson's office. The receptionist asked, ''May I help you?''

Andy asked, ''Is Jacob in?''
''Yes, he is. Do you have an appointment?'' responded the receptionist. Andy hurried by the receptionist, saying, ''I don't need one. This will only take a minute.'' A surprised Gerri followed after him. He knocked on Mr. Clemson's door once, opened it, and walked in without waiting for a response. Astonished, Jacob Clemson looked up and said, ''I'm right in the middle of this important . . .'' Andy interrupted. ''This will only take a minute. I just wanted to say that we got your factory expansion project completed on time and within budget. We finished in 12 months, just like I knew we, I mean, like I hoped we would. I had to kick butt with some of our subcontractors, but that's the way it goes in this business. Sometimes you've got to be an SOB to get the job done. I'm sure you're the same way, Jacob, or you wouldn't be where you're at.'' Jacob Clemson spoke up. ''Well, there were some problems . . .'' But Andy interrupted again. ''In a big project like this there are always problems, and some people's feathers get ruffled. But that always happens. Don't be concerned about that. In the end, it all worked out. I thought maybe we could go to lunch to celebrate, but we have another meeting across town. Give me a call sometime, and maybe we can get together and see if I can help you with any other projects' you might have.'' Andy then turned and quickly left Jacob's office, walking right past Gerri, who ran to catch up with him.

As they left, Jacob was somewhat stunned and became furious. He thought to himself, ‘‘Another project? Over my dead body. An SOB? What kind of person does he think I am? Getting the project done on time and within budget—does he think that is all that it’s about? This project was a nightmare. It finished up costing about 50 percent more than AG’s original price because of all the changes they came back with. They never asked, never listened, never told me what was going on, and never returned my phone calls. What a bunch of jerks! I’ll never do business with them again.’’ As Andy and Gerri walked to Andy’s car, he told Gerri, ‘‘There you go, another satisfied AG customer. And a pretty naive one too [chuckled Andy]. I knew we could get the project done in 12 months. But I knew he was desperate, and I told him it would take 15 months, and then got him to agree to a bonus payment if we got it done in 12 months.’’ Gerri asked, ‘‘Andy, isn’t that unethical?’’ ‘‘Hey, business is booming for Digitsig, they have plenty of money. Besides, it’s his problem for waiting so long before deciding on doing the expansion anyway. He was lucky we helped him out of a bind. But I’ve got to tell you, Gerri, I wondered why he was building all that warehouse space for inventory when most other businesses are going to just-in-time deliveries. But I wasn’t about to tell him that. It’s amazing he’s in business at all. Oh, well, you’ll find out it’s a dog-eat-dog world out there, Gerri.’’ Gerri responded, ‘‘Andy, I got a sense that maybe Mr. Clemson wasn’t totally satisfied. I mean he really didn’t say he was.’’ ‘‘He didn’t say he wasn’t either,’’ snapped Andy. ‘‘Besides, he never seemed interested in the project, he never asked to have any meetings, and when I tried to schedule a meeting, he was too busy. And then his payments were always late—like he was anal or something. Believe me, he’s tickled with what AG did. He was desperate to get the project done, and we did it for him—on time and within budget. And made a bunch of money on the project. So we both came out winners.’’

‘‘In fact, I’ll use old Jacob as a reference with the new customer we’ll be meeting this afternoon to review their RFP. Customers always ask for references from previous projects, but quite frankly, they hardly ever call them.’’ ‘‘Hey, Gerri, you’ll learn that you’ve got to focus on the next customer and not worry about the old ones. It works, believe me, or I wouldn't be driving this Porsche. Maybe they didn't teach you that in MBA school Gerri, but I learned from the school of hard knocks when I took this business over from my father. He was well liked in the community, and I'm just following in his footsteps.'' Source: Clements, J. P. and Gido, J. (2012). Effective Project Management. 6th Edition. Boston: Cengage Learning.

CASE QUESTIONS

1. Determine the alternate actions Andy Gibson could have taken differently in his meeting with Jacob Clemson in Jacob's office?
2. Examine what Andy could have done differently from his initial contact with Mr. Clemson and during the project?
3. Discuss what Jacob could have done differently from the time he met Andy Gibson initially and during the project?

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