

Describes any limitation placed upon funding for the project, whether in total value or over specified time frames.

- **Cost Estimate:**
The project's cost estimate factors into the project's expected overall cost, and is usually preceded by a modifier that provides some indication of accuracy, such as conceptual or definitive.
- **Project Configuration Management Requirements:**
It describes the level of configuration management and change control to be implemented on the project.
- **Project Specifications:**
Identifies those specification documents with which the project should comply.
- **Approval Requirements:**
It identifies approval requirements that can be applied to items such as project objectives, deliverables, documents, and work.

2. Requested Changes:

Requested changes to the project management plan and its subsidiary plans may be developed during the Scope Definition process. Requested changes are processed for review and disposition through the Integrated Change Control process.

3. Project Scope Management Plan (Updates):

The project scope management plan component of the project management plan may need to be updated to include approved change requests resulting from the project's Scope Definition process.

26.5.4 Scope Verification:

This process is carried out whenever one or more deliverables are ready to be handed over. It consists of obtaining the stakeholders' formal acceptance of the work completed.

Verifying the project scope includes reviewing deliverables to ensure that each is completed satisfactorily. If the project is terminated early, the project scope verification process should establish and document the level and extent of completion. Scope verification differs from quality control in that scope verification is primarily concerned with acceptance of the deliverables, while quality control is primarily concerned with meeting the quality requirements specified for the deliverables. Quality control is generally performed before scope verification, but these two processes can be performed in parallel.

26.5.5 Scope Change Control:

The scope changes that usually cause problems are those where the perception of what was in and out of scope was different between various parties. The Project Manager assumed there would only be four or five reports, and the business assumed ten to

twenty. Nobody felt it was worth talking about because they assumed the other person thought the same way they did.

The scope management section of the project plan is a formalized document that captures the processes for handling Scope Changes. The last output of scope management is that of “*Scope Control*”. The project manager should implement a process to ensure the project’s goals and objectives will be monitored throughout the project.

The project manager must be made aware of any discrepancies of project activities or potential risks promptly that deviate from the baseline or work breakdown schedule, in order to minimize any delays to the schedule which can ultimately cause project failure.

It is the project manager’s responsibility to provide guidance for any corrective action and means of communications to all team members involved at any level of the project.

With adequate scope control mechanisms executed, the team’s progress and performance can be measured. This will resolve any potential issues to the schedule and decrease resource conflicts.

Project scope control is concerned with influencing the factors that create project scope changes and controlling the impact of those changes. Scope control assures all requested changes and recommended corrective actions are processed through the project Integrated Change Control process.

Project scope control is also used to manage the actual changes when they occur and is integrated with the other control processes. Uncontrolled changes are often referred to as project scope creep. Change is inevitable, thereby mandating some type of change control process.

Scope creep (as already discussed) is a term which refers to the creeping forward of the scope of a project. It sometimes causes cost overrun. It is a term which refers to the incremental expansion of the scope of a project, which may include and introduce more requirements that may not have been a part of the initial planning of the project.

There are two distinct ways to separate scope creep management, the first is business scope creep, and the second is called features (also technology) scope creep. The type of scope creep management is nearly always dependent upon on the people who create the changes.

Business scope creep management occurs when decisions that are made with reference to a project are designed to solve or meet the requirements and needs of the business. Business scope creep changes may be a result of poor requirements definition early in development, or the failure to include the users of the project until the later stage of the systems development life cycle.

The type of scope creep management is always dependent upon on the people who create the changes.

Scope creep management is significant in many organizations all around the world, as many projects that an organization will set out on have a project scope. Since projects are expected to have strict deadlines with time, budget and quality restraints, the effect of a change in the scope can ultimately affect the success of the project.

If the approved change requests have an effect upon the project scope, then the project scope statement is revised and reissued to reflect the approved changes. The updated project scope statement becomes the new project scope baseline for future changes.

Scope Approval:

The *scope management plan* is a formal document that explains how the project scope will be managed and how scope changes will be factored into the project plan.

Once the scope is developed, the elements are thoroughly discussed and agreed on by the project team, stakeholders, sponsors and customers. Then scope definition is signed-off formally and the changes are discussed thoroughly by the project manager. With “acceptance/signed scope approval” project manager responds to ensure complete and monitored processing. Also, the customers are being noticed for every change to avoid project creep and risks.

PROJECT SCOPE MANAGEMENT

BROAD CONTENTS

Scope
Project Scope Management

27.1 SCOPE:

The term “scope” refers to:

- **Product Scope:**
This includes work to deliver a project’s product/service with specific features and functions. The result can be a single product or you can have several components. The features, functions, and characteristics to be included in a product are measured against set product requirements and are managed throughout the lifecycle.
- **Project Scope:**
Project scope refers to the work that must be done in order to deliver a product, service, result with specified features and functions. Project scope has a start and end date, possesses unique characteristics or attributes, and produces specific results during the lifecycle.

27.2 PROJECT SCOPE MANAGEMENT:

Scope management is concerned with defining and controlling the scope of a project. It includes product description, any known constraints and assumptions. Project scope is defined in project charter. It serves as a basis for development of Work Breakdown Structure (WBS). It must be verified and controlled throughout the life of the project.

Project scope management includes the processes required to ensure that the project includes all the work required to complete the project successfully. It is primarily concerned with defining and controlling what is or is not included in project.

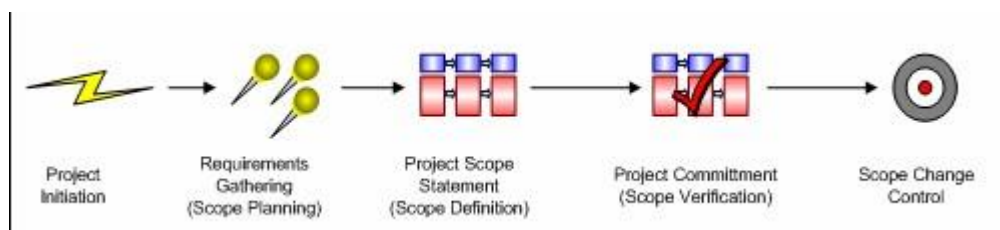
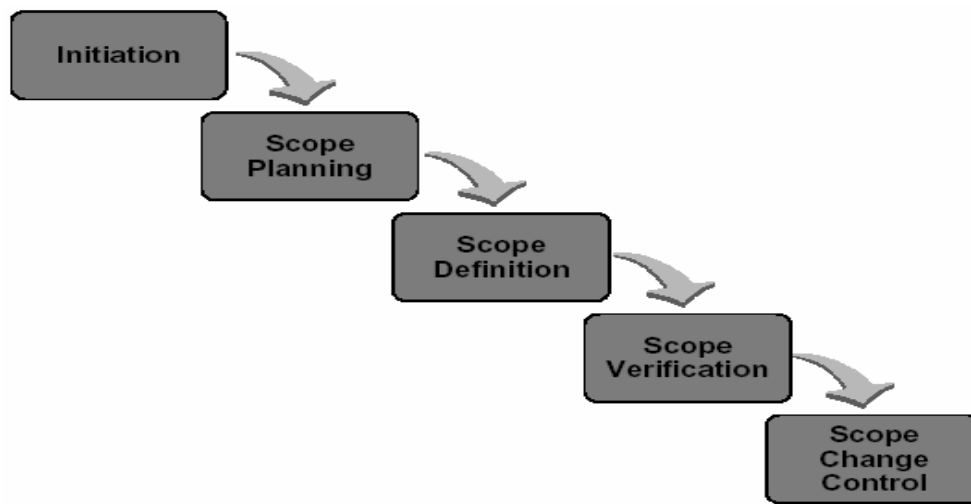


Figure 27.1: Scope Management Process

The scope management process comprises of the following:

- Project initiation: Approve Business case, feasibility, budget
- Scope planning: Gather requirements
- Scope definition: Create scope components, scope divide work
- Scope verification: Get approval from all stakeholders
- Scope change control: Manage scope change requests



27.2.1 Initiation Phase:

As described in the previous lecture, it is the process of formally recognizing that a new project exists or that an existing project should continue into its next phase

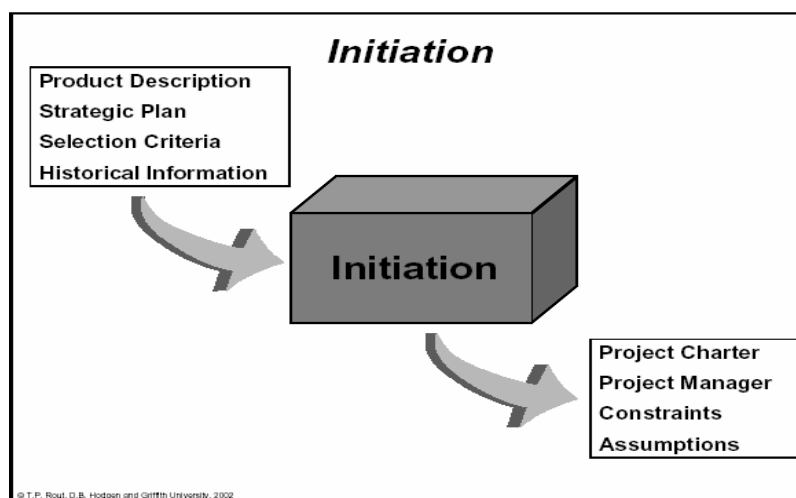


Figure 27.3: Initiation Phase

27.2.2 Project Scope Planning:

It refers to creating a project scope management plan that documents how project scope will be defined, verified, controlled and how the Work Breakdown Structure (WBS) will be created and defined.

Process of developing a written scope statement as the basis for future project decisions including, in particular, the criteria used to determine, if the project phase completed successfully.

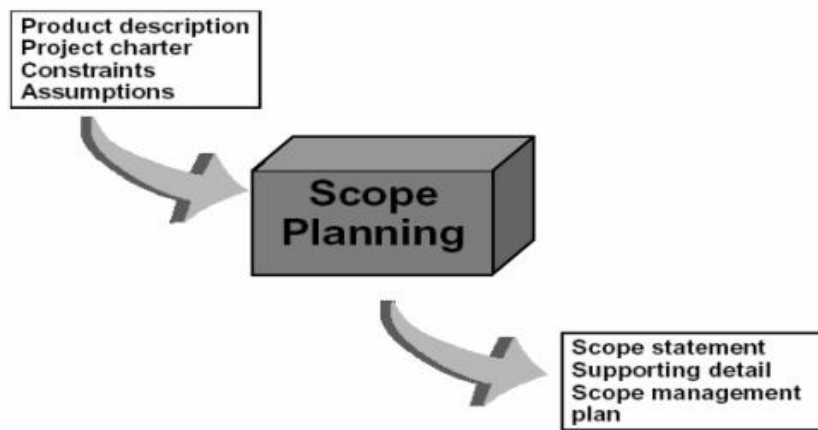


Figure 27.4: Scope Planning

27.2.2.1 Applying the Process Model:

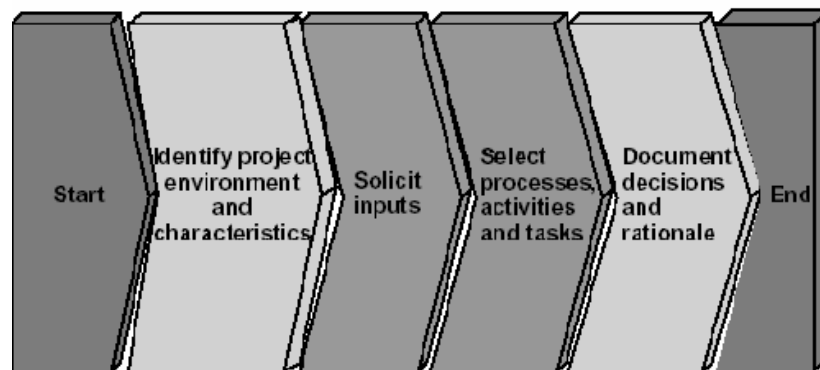


Figure 27.5: Process Model

1. **Define Scope:** I

It is always essential to know what the goals of the project are. This needs to be defined in exact and quantitative terms:

- What the project is supposed to achieve
- What the project is not supposed to achieve

This is achieved through the definition and management of the project scope.

2. **Identify Project Environment and Characteristics:**

Identify what processes are already in place. If process is fundamental to achieving organization's goals? Is there high risk involved in business? What the problem areas are? Also what type of an organizational culture exists (is it easily adaptable or adverse to change)? Lastly, identify what the requirements are?

3. **Solicit Inputs:**

The requirements for project are a major driver. The affected parties should be involved in the process. These people ensure resulting processes are:

- a) Feasible /useful
- b) Possible, including feedback of previous projects

4. **Select Processes, Activities and Tasks:**

Identify and prioritize processes or parts of process within the standards that will be implemented. It is useful to include “mapping current processes” practices and/or methods to processes activities and tasks. Mapping must be used to verify and to identify gaps between the *current situation* and *target situation*.

5. **Document Decisions and Rationale:**

Document refers to the mapping of defined processes, activities and tasks to determine relationships and reasons for adopting this approach. This document should be included into the Project Management Plan”.

27.2.3 Project Scope Definition:

This involves subdividing major project deliverables (as identified in scope statement) into smaller, more manageable components.

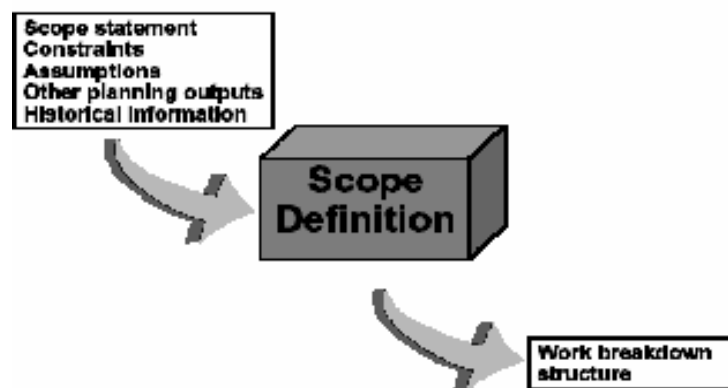


Figure 27.6: Scope Definition

The benefit of scope definition is to improve accuracy of estimated cost, time, and resources. The baseline for performance, measurement and control is defined. It facilitates clear responsibility and assignments.

27.2.3.1 Work Breakdown Structure (WBS):

Deliverable oriented grouping of project elements that organizes and defines the scope of the project that work not in Work Breakdown Structure (WBS) is outside the scope of project.

As with the scope statement, Work Breakdown Structure (WBS) is often used to develop or confirm a common understanding of project scope.

Each descending level represents an increasingly detailed description of project elements.

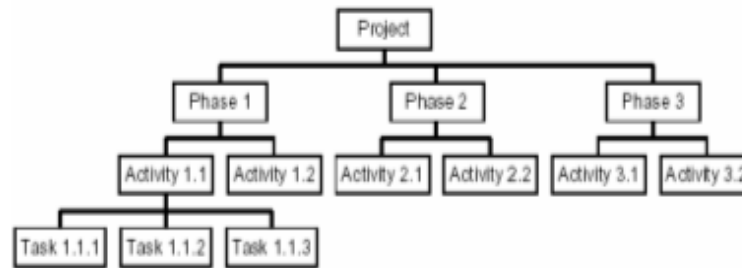


Figure 27.7: Model Work Breakdown Structure (WBS)

A Work Breakdown Structure (WBS) is normally presented in chart form. Each item in it is generally assigned a *unique identifier* often known collectively as “*code of accounts*”. Items at lowest level of Work Breakdown Structure (WBS) are known as *work packages*.

27.2.4 Scope Verification:

It is the process of formalizing acceptance of the project scope by stakeholders (sponsor, client, customer, etc.).

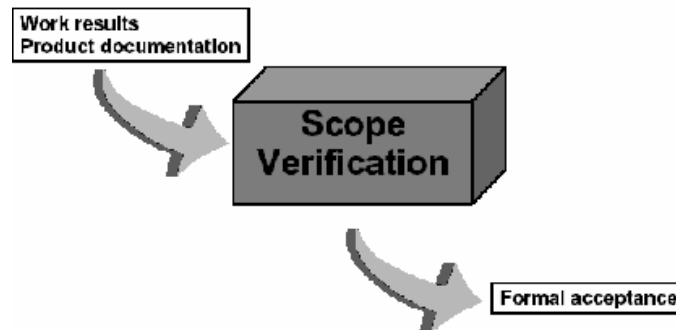


Figure 27.8: Scope Verification

27.2.4.1 Formal Acceptance:

It is the documentation of the product, project or phase acceptance by the client and/or sponsor. It must be prepared and distributed. Such acceptance must be conditional, especially at the end of every phase.

27.2.5 Scope Change Control:

It defines procedures by which project scope must be changed. It includes paperwork, tracking systems, and approval levels necessary for authorizing changes. Scope change control system should be integrated with overall change control system. In particular, with any system in place to control product scope.

Scope change control is concerned with:

- Influencing factors which create scope changes to ensure that changes are beneficial.
- Determining that a scope change has occurred.
- Managing the actual changes when and if they occur.

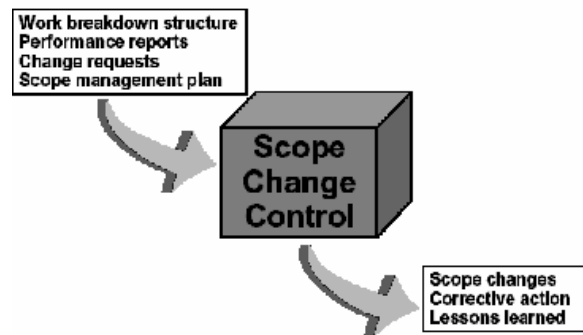
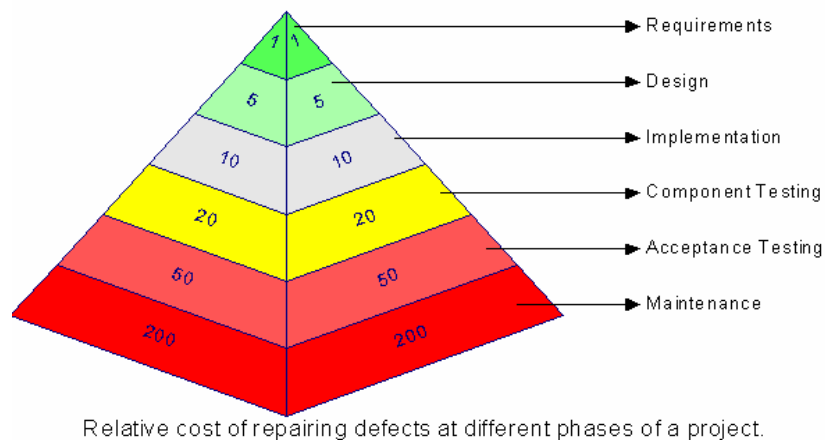


Figure 27.9: Scope Change Control



Relative cost of repairing defects at different phases of a project.

Figure 27.10: The Cost of Scope Change

NETWORK SCHEDULING TECHNIQUES

BROAD CONTENTS

Introduction
Benefits and Advantages of Scheduling
Historical Evolution of Network Scheduling
Network Fundamentals and Terminology
Pert/CPM and their Difference
Graphical Evaluation and Review Techniques (GERT)
Dependencies or Interrelationship
Slack Time

28.1 Introduction:

In today's highly competitive environment, management is continually seeking new and better control techniques to cope with the complexities, masses of data, and tight deadlines that are characteristic of many industries.

In addition, management is seeking better methods for presenting technical and cost data to customers.

Since World War II, scheduling techniques have taken on paramount importance. The most common of these techniques are shown below:

- Gantt or bar charts
- Milestone charts
- Line of balance
- 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)

28.2 Benefits and Advantages of Scheduling:

The ***Program Evaluation and Review Technique (PERT)*** perhaps is the best known of all the relatively new techniques. PERT has several distinguishing characteristics:

- It forms the basis for all planning and predicting and provides management with the ability to plan.
- It enables management for best possible use of resources to achieve a given goal within time and cost limitations.
- It provides visibility and enables management to control "one-of-a-kind" programs as opposed to repetitive situations.
- It helps management to handle uncertainties involved by answering the following questions that provides management with a means for evaluating alternatives:
 - a) How time delays in certain elements influence program completion?
 - b) Where slack exists between elements?
 - c) What elements are crucial to meet the completion date?

- It provides a basis for obtaining the necessary facts for decision making.
- It utilizes a time network analysis as the basic method to determine manpower, material, and capital requirements as well as providing a means for checking progress.
- It provides the basic structure for reporting information.
- It reveals interdependencies of activities.
- It facilitates "what if" exercises.
- It identifies the longest path or critical paths.
- It allows us to perform scheduling risk analysis.

The above-mentioned benefits apply to all network scheduling techniques, not just PERT.

28.3 Historical Evolution of Networks:

Before going further with the details, let us have an insight into the historical evolution of networks. 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 Navy was developing PERT, 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.

The basic requirements of PERT/time as established by the Navy, in the early 1960s, were as follows:

- All of the individual tasks to complete a given program must be visualized in a manner clear enough to be put down in a network, which comprises events and activities; that is, 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 important critical and sub-critical paths. Networks can have up to one hundred or more events, but not less than ten or twenty.
- Time estimates must be made for each activity of the network on a three-way basis. Optimistic, most likely, and pessimistic elapsed-time figures are estimated by the person(s) most familiar with the activity involved.
- Critical path and slack times are computed. The critical path is that sequence of activities and events whose accomplishment will require the greatest expected time.

28.3.1 Advantages of PERT:

1. Firstly, a major advantage of PERT is the kind of planning required to a major network. Network development and critical path analysis reveal interdependencies and problem areas that are neither obvious nor well defined by other planning methods. The technique therefore determines where the greatest effort should be made for a project to stay on schedule.
2. By using PERT one can determine the probability of meeting specified 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.
3. 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. Other resources and performance trade-offs may also be evaluated.
4. PERT can also evaluate the effect of a deviation in the actual time required for an activity from what had been predicted.
 5. Lastly, PERT allows a large amount of sophisticated data to be presented in a well-organized diagram from which both contractor and customer can make joint decisions.

Unfortunately, PERT is not without its disadvantages. The complexity of PERT adds to the implementation problems. There exist more data requirements for a PERT - organized MCCS reporting system than for most others. PERT, therefore, becomes an item that is 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 in recent years. The literature contains many diversified approaches toward applying PERT to other than large and complex programs. The result has been the PERT/LOB procedures, which, when applied properly, can do the following job:

- Cut project costs and reduce time scale
- 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

Note that even with these advantages, many companies should ask themselves whether they actually need PERT. Incorporation of PERT may not be easy, even if canned software packages are available. One of the biggest problems with incorporating PERT occurred in the 1960s when the Department of Defense requested that its customers adopt PERT/cost for relating cost and schedules. This resulted in the expenditure of considerable cost and effort on behalf of the contractor to overcome the numerous cost-accounting problems. Many contractors eventually went to two sets of books; one set was for program control (which was in compliance with standard company cost control procedures), and a second set was created for customer reporting. Therefore, before accepting a PERT system, management must perform a trade-off study to determine if the results are worth the cost.

28.3.2 Criticism of PERT:

The criticism that most people discover when using PERT includes:

- Time and labor intensive effort is required.
- Upper-level management decision-making ability is reduced.
- There exists a lack of functional ownership in estimates.
- There exists a lack of historical data for time–cost estimates.
- The assumption of unlimited resources may be inappropriate.
- There may exist the need for too much detail.

28.4 Network Fundamentals and Terminology:

It is important to know that 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 and is easily understood by all.

The 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

As we know that networks are composed of events and activities. An event is defined as the starting or ending point for a group of activities, and an activity is the work required to proceed from one event or point in time to another. Figure 28.1 below 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 begin).

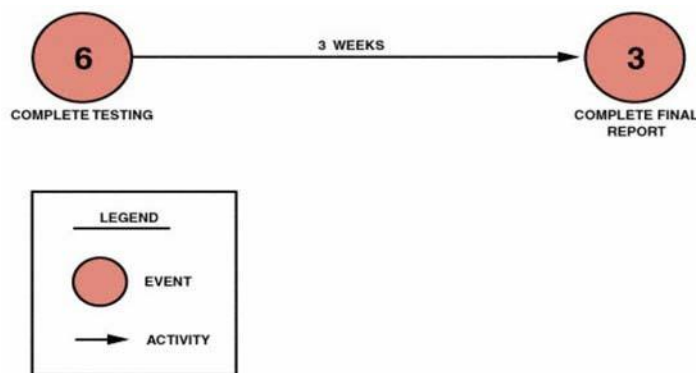


Figure 28.1: Standard PERT Nomenclature

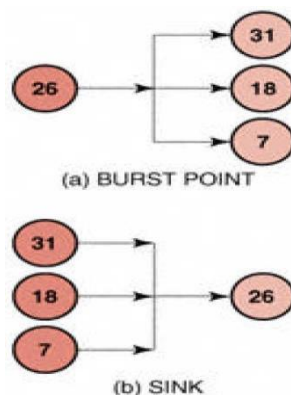


Figure 28.2: PERT Sources (Burst Points) and Sinks

As depicted in Figure 28.2 (a) above, event 26 must take place prior to events 7, 18, and 31. In Figure 28.2 (b), the opposite holds true, and events 7, 18, and 31 must take place prior to event 26. Thus, it is similar to "and gates" used in logic diagrams.

However, these charts can be used to develop the PERT network, as shown in Figure 28.3 below. The bar chart in Figure (A) below can be converted to the milestone chart in Figure (B) below. By then defining the relationship between the events on different bars in the milestone chart, we can construct the PERT chart in Figure (C) below.

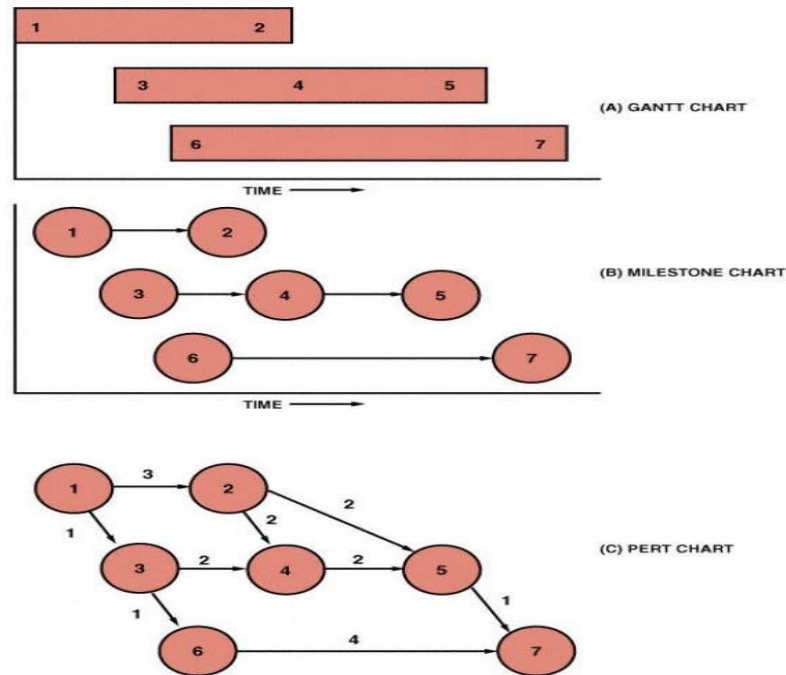


Figure 28.3: Conversion from Bar Chart to PERT Chart

Basically PERT is 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) have been completely identified together with their corresponding interrelations. PERT charts are often constructed from back to front because, for many projects, the end date is fixed and the contractor has front-end flexibility.

It is important to note here that 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, a selection must be made as to whether the events represent the start or the completion of an activity. Event completions are generally preferred.

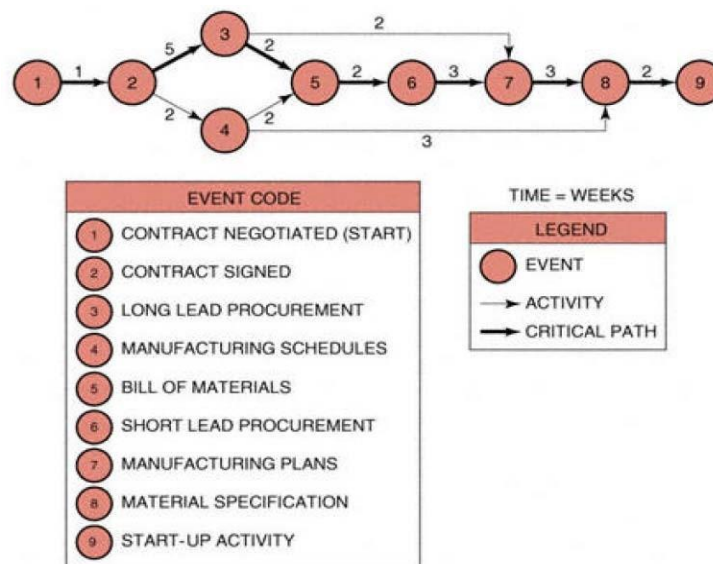
Activity	Title	Immediate Predecessors	Activity Time, Weeks
1-2	A	—	1
2-3	B	A	5
2-4	C	A	2
3-5	D	B	2
3-7	E	B	2
4-5	F	C	2
4-8	G	C	3
5-6	H	D,F	2
6-7	I	H	3
7-8	J	E,I	3
8-9	K	G,J	2

Table 28.1: Sequence of Events

The next step is to define the sequence of events, as shown in Table 28.1 above, which 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?

A typical PERT network is shown in the following figure 28.4.

**Figure 28.4:** Simplified PERT Network

The bold line 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:

1. 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).

2. 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.

Therefore, by 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 Work Breakdown Structure (WBS), the project manager's concerns are the activities.

28.5 Differences Between PERT and CPM:

Note that the principles that we have discussed so far apply not only to PERT, but to CPM as well. The nomenclature is the same for both, and both techniques are often referred to as arrow diagramming methods, or activity-on-arrow networks. The differences between PERT and CPM are as follows:

- PERT uses three time estimates (optimistic, most likely, and pessimistic). From these estimates, an expected time can be derived. CPM uses one time estimate that represents the normal time (that is, better estimate accuracy with CPM).
- 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 Research and Development 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 Research and Development, 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.

28.6 Graphical Evaluation And Review Technique (GERT):

Graphical Evaluation and Review Techniques (GERT) are similar to PERT but have the distinct advantages of allowing for looping, branching, and multiple project end results. With PERT one cannot easily show that if a test fails, we may have to repeat the test several more times. With PERT, we cannot show that, based upon the results of a test, we can select one of several different branches to continue the project. These problems are easily overcome using GERT.

28.7 Dependencies or Interrelationships:

There are three basic types of interrelationships or dependencies:

1. ***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.
2. ***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.

3. **External Dependencies:**

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

28.7.1 **Dummy Activities:**

It is sometimes 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 the Figure 28.5 below, the dummy activity is required to show that D is preceded by A and B.

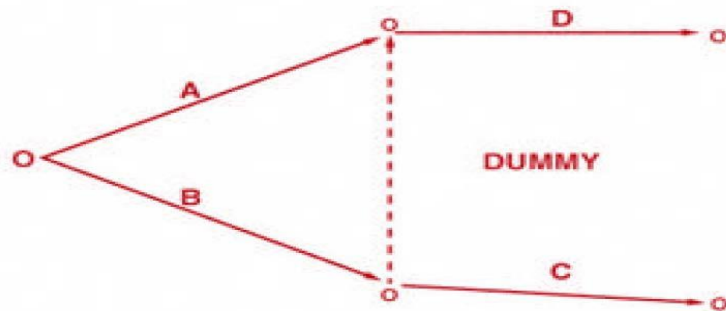


Figure 28.5: Dummy Activity

28.8 **Slack Time:**

It is essential to know that 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 28.4, 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.

Therefore, 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.

NETWORK SCHEDULING TECHNIQUES

BROAD CONTENTS

Slack Terminology
Slack Time Calculation
Slack Identification
Network Re-planning

29.1 Slack Terminology:

Slack can be defined as the difference between the latest allowable date and the earliest expected data 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 = $TL - TE$

29.2 Slack Time Calculation:

As shown in Figure 29.1 below, the calculation for slack time is performed for each event in the network, 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 non-critical path events. 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.

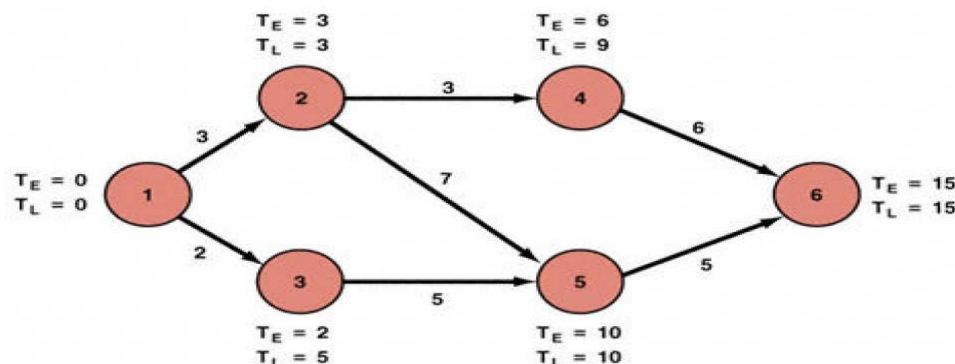


Figure 29.1: PERT Network with Slack Time

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 $TL = 9$.

The same figure 29.1 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.

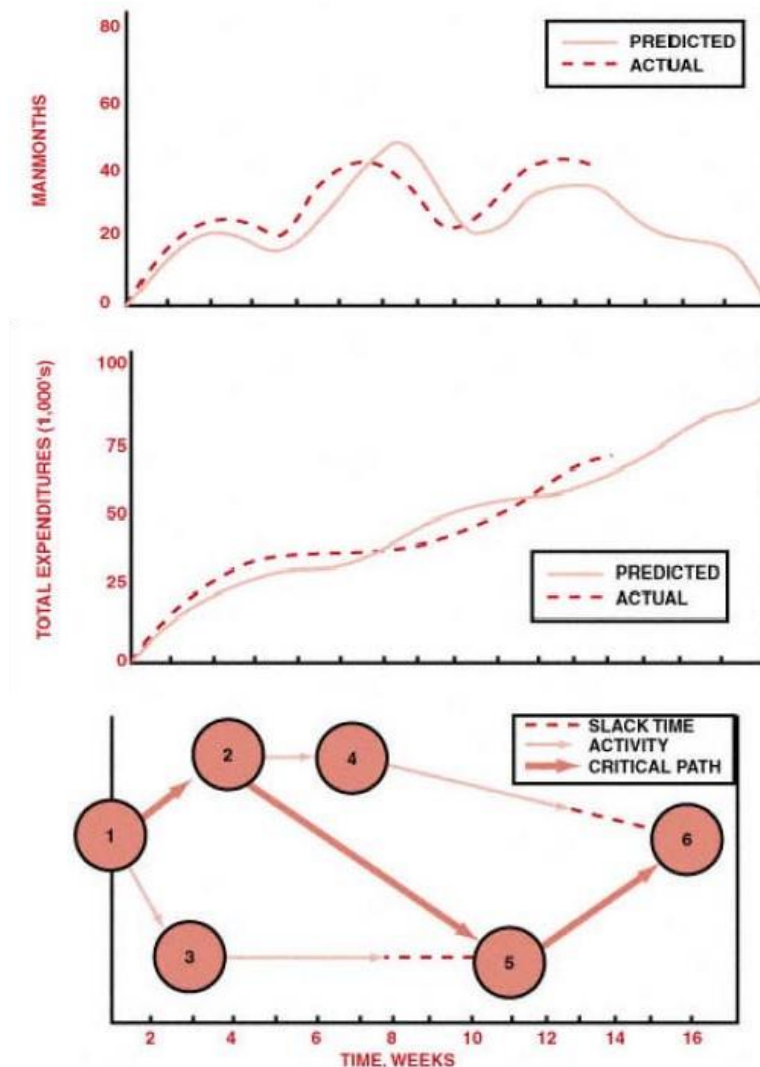


Figure 29.2: Comparison Models for a Time- Phase PERT Chart

We must understand that 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.

PERT networks are often not plotted with a time scale, because of these slack times. 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 29.2 above for comparison with total program costs and manpower planning. Early time requirements for slack variables are utilized in this figure.

Note that 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 29.1 below. 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 this table gives the probability that the earliest time will not be greater than the original schedule time for this event.

Event Number	Earliest Time		Latest Time		Slack	Orig Sche
	Expected	Variance	Expected	Variance		

Table 29.1: PERT Control Output Information

In the example shown in Figure 29.1, 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. To make full use of the capabilities of PERT/CPM, we could identify the following 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)

The following Figure 29.3 below shows the earliest and latest times identified on the activity.

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

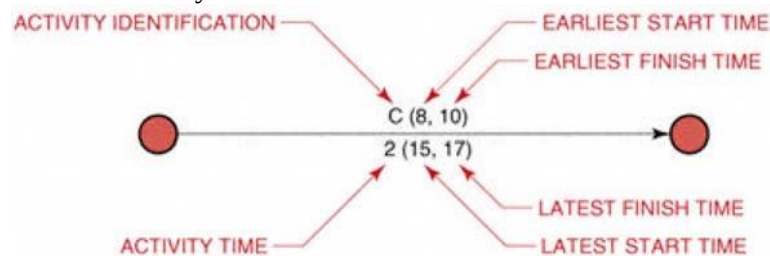


Figure 29.3: Slack Identification

It is important to note that to calculate the finishing 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 finishing time of the activities exiting the node.

Figure 29.4 below shows the earliest and latest starting and finishing times for a typical network.

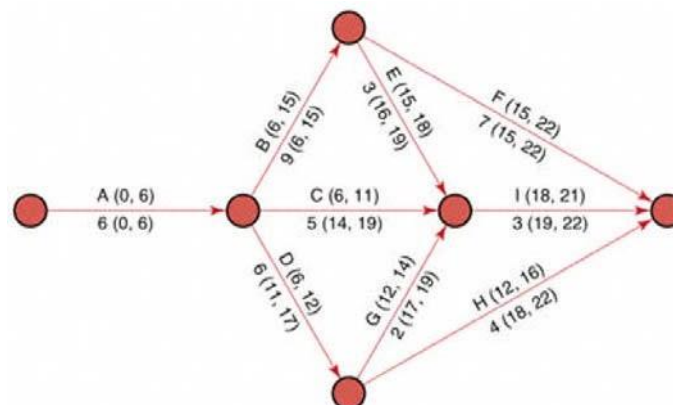


Figure 29.4: A Typical PERT Chart with Slack Times

29.3 Slack Identification:

Its significance is that 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.

By looking at the earliest and latest start and finish times, we can identify slack. As an example, look at the two situations below:

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

According to these, 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.

Here the question arises, what can cause the slack to be negative? Look at Figure 29.5 below. 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.

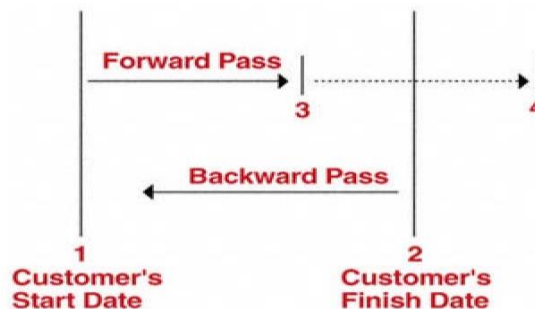


Figure 29.5: Slack Time

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.

Note that 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.

29.4 Network Re-planning:

We know that once constructed, the PERT/CPM charts provide the framework from which detailed planning can be initiated and costs can be controlled and tracked. Much iteration, however, are normally made during the planning phase before the PERT/CPM chart is finished.

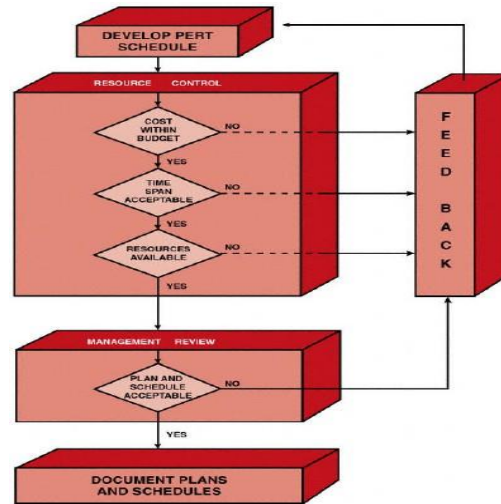


Figure 29.6: Iteration Process for PERT Schedule Development

This iteration process is shown in the Figure 29.6 above. The slack times form the basis from which additional iterations, or network replanning, can be performed. Network replanning 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?

Let us again consider Figure 29.1. Suppose that activities 1–2 and 1–3 in it 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 29.7 below, the length of the critical path is reduced by one week, and the corresponding slack events are likewise changed.

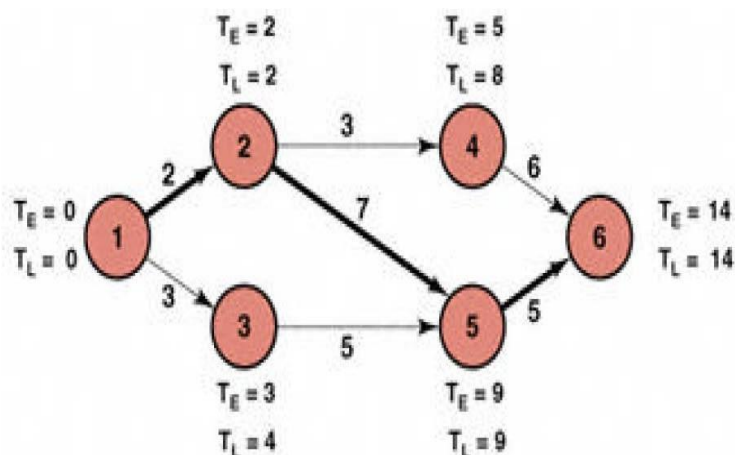


Figure 29.7: Network Replanning of Figure 29.1

29.4.1 Network Replanning Techniques:

There are two network replanning 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 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.

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

It is important to note here that transferring resources from slack paths to more critical paths is only one method for reducing expected project time. Several other methods are available. These are as follows:

- Elimination of some parts of the project
- Addition of more resources
- 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

In this regard, 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 in that the project may be canceled, or performance expectations may no longer be possible.

However, 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 to which to assign these additional people. However, if the project is the construction of a new facility, then the labor-union pool may be large enough that additional experienced manpower can be hired.

Another aspect is parallelization of activities. It can be regarded as accepting a risk by assuming that a certain event can begin in parallel with a second event that would normally be in sequence with it. This is shown in Figure 29.8 below. One of the biggest headaches at the beginning of any project is the purchasing of tooling and raw materials. As shown in Figure below, four weeks can be saved by sending out purchase

orders after contract negotiations are completed, but before the one-month waiting period necessary to sign the contract. Here the contractor incurs a risk. Should the effort be canceled or the statement of work change prior to the signing of the contract, the customer incurs the cost of the termination liability expenses from the vendors. This risk is normally overcome by the issuance of a long-lead procurement letter immediately following contract negotiations.

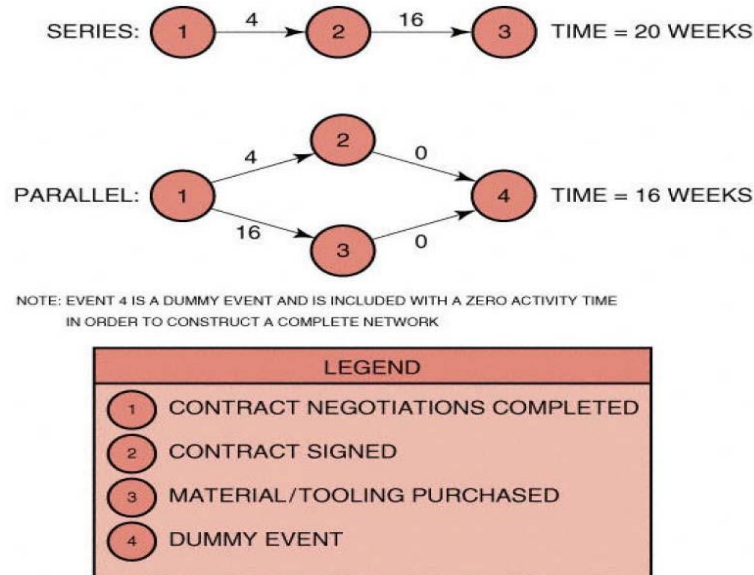


Figure 29.8: Parallelization of PERT Activities

In addition to this, there are two other types of risk that are common. In the first situation, engineering has not yet finished the prototype, and manufacturing must order the tooling in order to keep the end date fixed. In this case, engineering may finally design the prototype to fit the tooling.

In the second situation, the subcontractor finds it difficult to perform according to the original blueprints. In order to save time, the customer may allow the contractor to work without blueprints, and the blueprints are then changed to represent the as-built end-item.

As a result of the complexities of large programs, network re-planning becomes an almost impossible task when analyzed on total program activities. It is often better to have each department or division that develops its own PERT/CPM networks, on approval by the project office, and based on the work breakdown structure. The individual PERT charts are then integrated into one master chart to identify total program critical paths, as shown in Figure 29.9 below. It should not be inferred from this figure that department D does not interact with other departments or that department D is the only participant for this element of the project.

In addition, segmented PERT charts can also be used when a number of contractors work on the same program.

Each contractor (or subcontractor) develops his own PERT chart. It then becomes the responsibility of the prime contractor to integrate all of the subcontractors' PERT charts to ensure that total program requirements can be met.

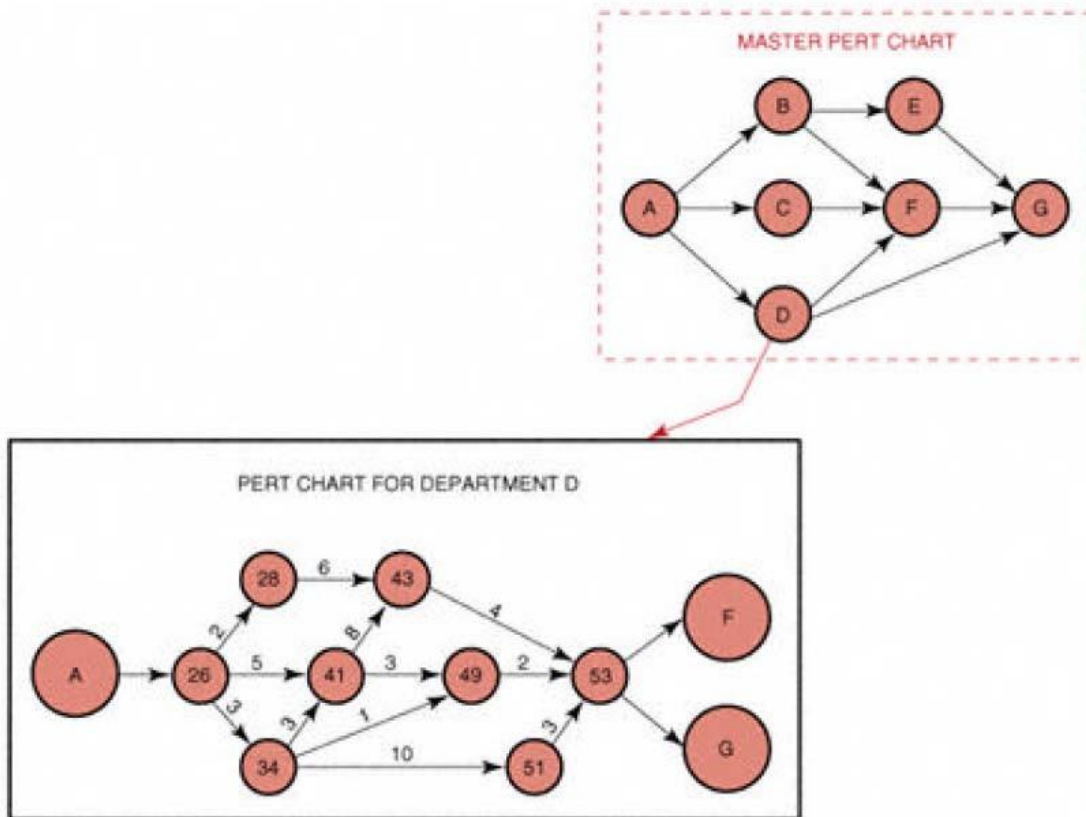


Figure 29.9: Master PERT chart breakdown by department

NETWORK SCHEDULING TECHNIQUES

BROAD CONTENTS

Estimating Activity Time
 Estimating Total Program Time
 Total PERT/CPM Planning
 Crash Times
 PERT/CPM Problem Areas
 Alternative PERT/CPM Model

30.1 Estimating Activity Time:

In order to determine 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.

Thus, 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 would be. 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:

- *Most optimistic completion time:*
 This time assumes that everything will go according to plan and with a minimal amount of difficulties. This should occur approximately 1 percent of the time.
- *Most pessimistic completion time:*
 This time assumes that everything will not go according to plan and that the maximum potential 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.

Two assumptions must be made before these three times can be combined into a single expression for expected time. 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:

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

In this, t_e = expected time, a = most optimistic time, b = most pessimistic time, and m = most likely time.

Here we take an example. If $a = 3$, $b = 7$, and $m = 5$ weeks, then the expected time, t_e , would be 5 weeks. This value for t_e 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 t_e 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.

30.2 Estimating Total Program Time:

It is important to know that 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:

$$\sigma_{t_e} = \frac{b - a}{6}$$

Where σ_{t_e} is the standard deviation of the expected time, t_e . Another useful expression is the variance, σ^2 , which is the square of the standard deviation. The variance is primarily useful for comparison to the expected values.

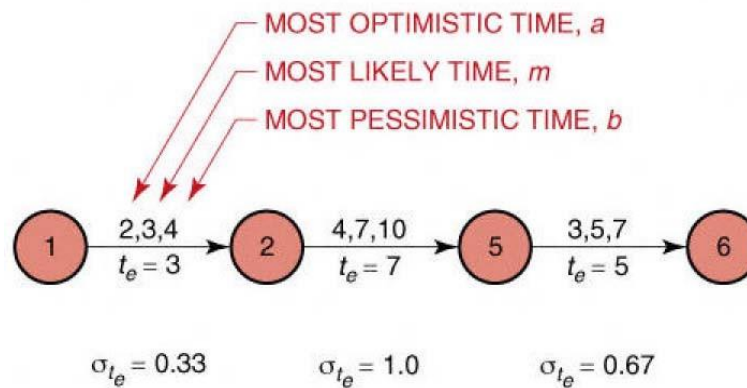


Figure 30.1: Expected Time Analysis for Critical Path Events in Figure 29.1 (Lecture 29)

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 30.1 above shows the critical path of Figure 29.1 (lecture 29), together with the corresponding values from which the expected times were calculated, as well as the standard deviations. 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:

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

30.3 Total PERT/CPM Planning:

It is necessary to discuss the methodology for preparing PERT schedules, before we continue further. 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 logic charts, arrow diagrams, work flow,

or simply networks. The arrow diagrams will look like Figure 29.1 (lecture 29) with two exceptions: The activity time is not identified, and neither is the critical path.

The next step that is step three is reviewing the arrow diagrams with the line managers (that is, 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.

Fifth step 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 using methods explained earlier or by asking 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 replanning 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.

The question arises that 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 are those individuals who 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

In addition to this, the 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

It is quite obvious that these objectives are limited by such constraints as:

- Calendar completion

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

30.4 Crash Times:

So far no distinction was made between PERT and CPM. The basic difference between PERT and CPM lies in the ability to calculate percent complete. PERT is used in Research and Development or just development activities, where a percent-complete determination is almost impossible.

Therefore, PERT is event oriented rather than activity oriented. In PERT, funding is normally provided for each milestone (i.e., event) achieved because incremental funding along the activity line has to be based on percent complete. CPM, on the other hand, is activity oriented because, in activities such as construction, percent complete along the activity line can be determined. CPM can be used as an arrow diagram network without PERT. The difference between the two methods lies in the environments in which each one evolved and how each one is applied.

In addition, the CPM (activity-type network) has been widely used in the process industries, in construction, and in single-project industrial activities. Common problems include no place to store early arrivals of raw materials and project delays for late arrivals.

Project managers can consider the cost of speeding up, or crashing, certain phases of a project using strictly the CPM approach. In order to accomplish this, it is necessary to calculate a crashing cost per unit time as well as the normal expected time for each activity. CPM charts, which are closely related to PERT charts, allow visual representation of the effects of crashing. There are these following requirements:

- For a CPM chart, the emphasis is on activities, not events. Therefore, the PERT chart should be redrawn with each circle representing an activity rather than an event.
- In CPM, both time and cost of each activity are considered.
- Only those activities on the critical path are considered, starting with the activities for which the crashing cost per unit time is the lowest.

The following Figure 30.2 below shows a CPM network with the corresponding crash time for all activities both on and off the critical path. The activities are represented by circles and include an activity identification number and the estimated time. The costs expressed in it are usually direct costs only.

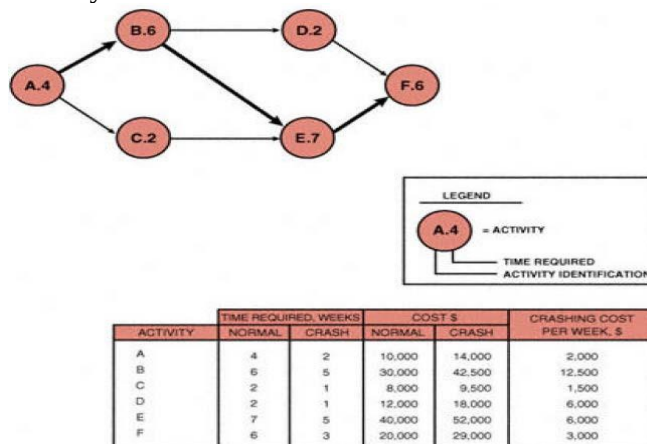


Figure 30.2: CPM Network

As shown in the figure 30.2, in order to determine crashing costs we begin with the lowest weekly crashing cost, activity A, at \$2,000 per week. Although activity C has a lower crashing cost, it is not on the critical path. Only critical path activities are considered for crashing. Activity A will be the first to be crashed for a maximum of two weeks at \$2,000 per week. The next activity to be considered would be F at \$3,000 per week for a maximum of three weeks. These crashing costs are additional expenses above the normal estimates.

It is important to remember a word of caution concerning the selection and order of the activities that are to crash: There is a good possibility that as each activity is crashed, a new critical path will be developed. This new path may or may not include those elements that were bypassed because they were not on the original critical path.

In the same Figure 30.2 (and assuming that no new critical paths are developed), activities A, F, E, and B would be crashed in that order. The crashing cost would then be an increase of \$37,500 from the base of \$120,000 to \$157,500. The corresponding time would then be reduced from twenty-three weeks to fifteen weeks. This is shown in Figure 30.3 below to illustrate how a trade-off between time and cost can be obtained. Also shown in it is the increased cost of crashing elements not on the critical path.

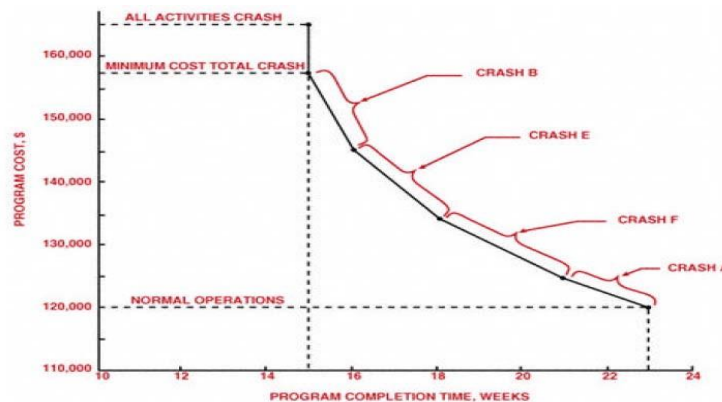


Figure 30.3: CPM Crashing Costs

Crashing these elements would result in a cost increase of \$7,500 without reducing the total project time. There is also the possibility that this figure will represent unrealistic conditions because sufficient resources are not or cannot be made available for the crashing period.

Importantly, the purpose behind balancing time and cost is to avoid the useless waste of resources. If the direct and indirect costs can be accurately obtained, then a region of feasible budgets can be found, bounded by the early-start (crash) and late-start (or normal) activities. This is shown in Figure 30.4 below.

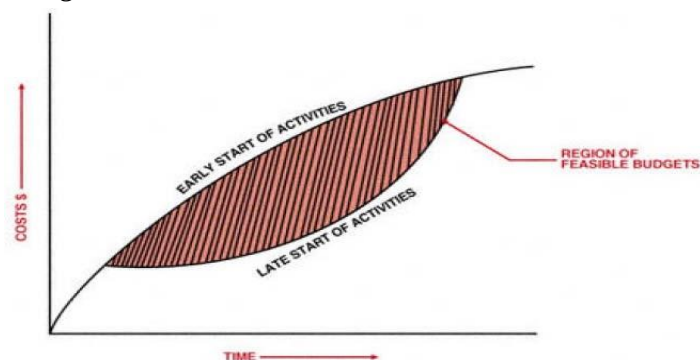


Figure 30.4: Region of Feasible Budgets

Since the direct and indirect costs are not necessarily expressible as linear functions, time–cost trade-off relationships are made by searching for the lowest possible total cost (that is, direct and indirect) that likewise satisfies the region of feasible budgets. This method is shown in Figure 30.5 below.

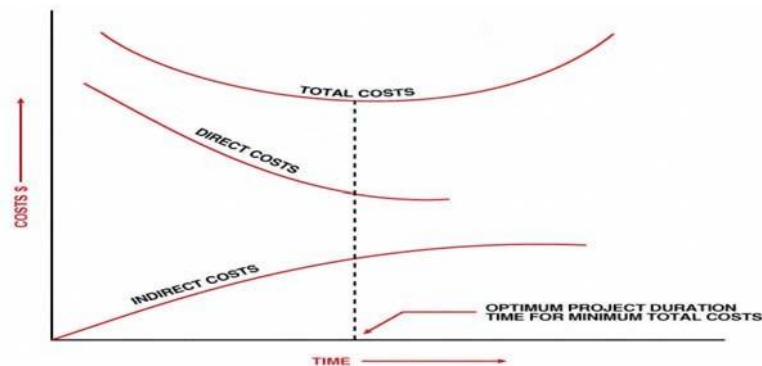


Figure 30.5: Determining Project Duration

Note that like PERT, CPM also contains the concept of slack time, the maximum amount of time that a job may be delayed beyond its early start without delaying the project completion time. Figure 30.6 below shows a typical representation of slack time using a CPM chart.

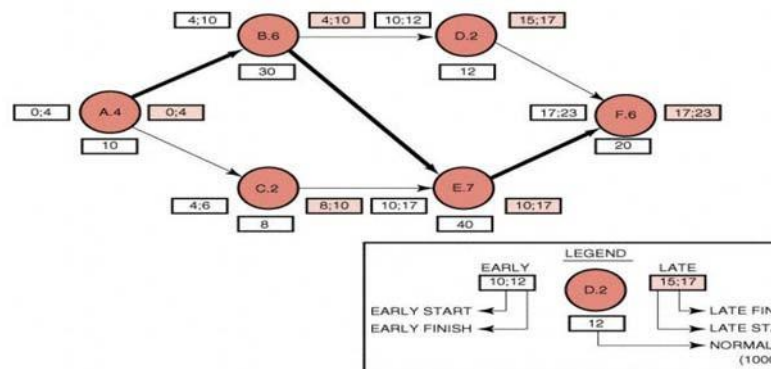


Figure 30.6: CPM Network with Slack

This figure also shows how target activity costs can be identified. It can be modified to include normal and crash times as well as normal and crash costs. In this case, the cost box in the figure would contain two numbers: The first number would be the normal cost, and the second would be the crash cost. These numbers might also appear as running totals.

30.5 PERT/CPM Problem Areas:

Even the largest organizations with years of experience in using PERT and CPM have the same ongoing problems as newer or smaller companies. Thus, PERT/CPM models are not without their disadvantages and problems.

Due to its characteristics, many companies have a difficult time incorporating PERT systems because PERT is end-item oriented. Many upper-level managers feel that the adoption of PERT/CPM remove a good part of their power and ability to make decisions. This is particularly evident in companies that have been forced to accept PERT/CPM as part of contractual requirements.

In addition to this, there exists a distinct contrast in PERT systems between the planners and the doers. This human element must be accounted for in order to determine where the obligation actually lies. In most organizations PERT planning is performed by the program office and functional management. Yet once the network is constructed, the planners and managers become observers and rely on the doers to accomplish the job within time and cost limitations.

Management must convince the doers that they have an obligation toward the successful completion of the established PERT/CPM plans.

It is important to note that unless the project is repetitive, there usually exists a lack of historical information on which to base the cost estimates of most optimistic, most pessimistic, and most likely times. Problems can also involve poor predictions for overhead costs, other indirect costs, material and labor escalation factors, and crash costs. It is also possible that each major functional division of the organization has its own method for estimating costs. Engineering, for example, may use historical data, whereas manufacturing operations may prefer learning curves. PERT works best if all organizations have the same method for predicting costs and performance.

PERT networks are based on the assumption that all activities start as soon as possible. This assumes that qualified personnel and equipment are available. Regardless of how well we plan, there almost always exist differences in performance times from what would normally be acceptable for the model selected. For the selected model, time and cost should be well-considered estimates, not a spur-of-the-moment decision.

Another problem is that of cost control. It presents a problem in that the project cost and control system may not be compatible with company fiscal planning policies. Project-oriented costs may be meshed with non-PERT-controlled jobs in order to develop the annual budget. This becomes a difficult chore for cost reporting, especially when each project may have its own method for analyzing and controlling costs.

Furthermore, many people have come to expect too much of PERT -type networks. Figure 30.7 below illustrates a PERT/CPM network broken down by work packages with identification of the charge numbers for each activity. Large projects may contain hundreds of charge numbers. Subdividing work packages (which are supposedly the lowest element) even further by identifying all sub activities has the advantage that direct charge numbers can be easily identified, but the time and cost for this form of detail may be prohibitive. PERT/CPM networks are tools for program control, and managers must be careful that the original game plan of using networks to identify prime and supporting objectives is still met. Additional detail may mask this all-important purpose. Remember, networks are constructed as a means for understanding program reports. Management should not be required to read reports in order to understand PERT/CPM networks.

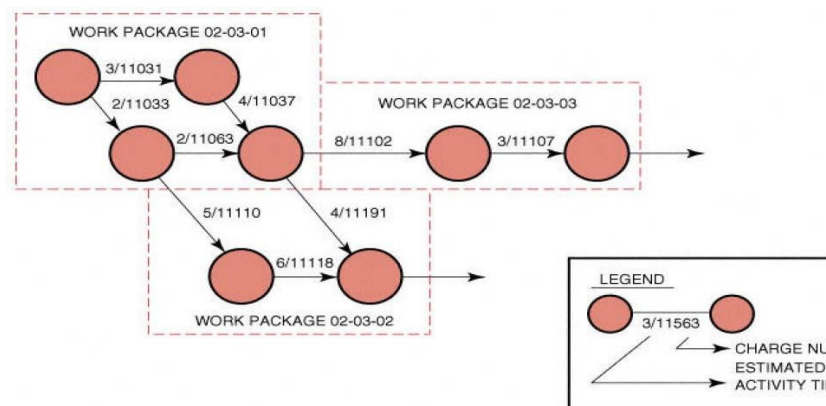


Figure 30.7: Using PERT for Work Package Control

30.6 Alternative PERT/CPM Models:

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

Remember that even with these advantages, in many situations PERT/time has proved ineffective in controlling resources. Earlier we have 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.

In addition, 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 Work Breakdown Structure (WBS) level

Note that the primary reason for the development of PERT/cost was so that project managers could identify critical schedule slippages and cost overruns in time for corrective action to be taken.

In this regard, many attempts have been made to develop effective PERT/schedule models. In almost all cases, the charts are constructed from left to right. An example of such current attempts is the *Accomplishment/Cost Procedure (ACP)*.

Summing up our discussion, unfortunately, the development of PERT/schedule techniques is still in its infancy. Although their applications have been identified, many companies feel locked in with their present method of control, whether it is PERT, CPM, or some other technique.

PRICING AND ESTIMATION**BROAD CONTENTS**

Computerized Software Packages
Pricing and Estimating
Global Pricing Strategies
Types of Estimates
Pricing Process

31.1 COMPUTERIZED SOFTWARE PACKAGES:

It has been seen that over the past ten 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 \$70,000.

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
- 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 31.1 below, which attempt to show interrelationships on bar charts. As shown in the figure, 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 either by putting an asterisk (*) beside the critical elements, by making the critical connections in a different-colored ink, or by making the critical path a boldface type.

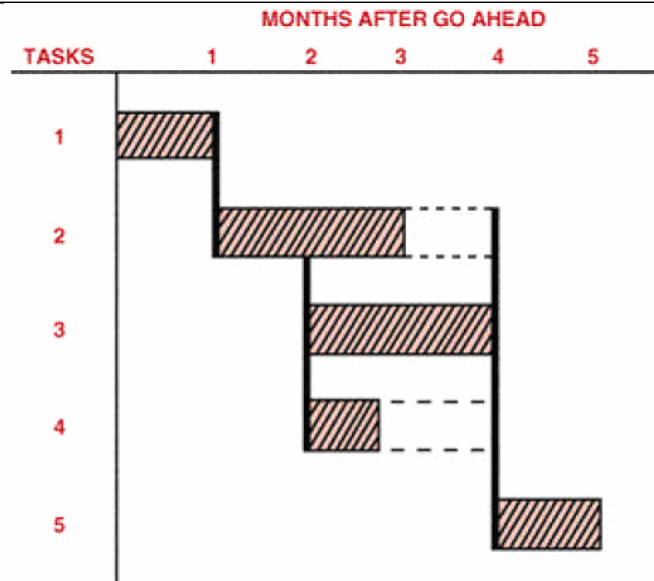


Figure 31.1: Precedence Network

The more sophisticated software packages display precedence networks in the format shown in Figure 31.2 below. 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.

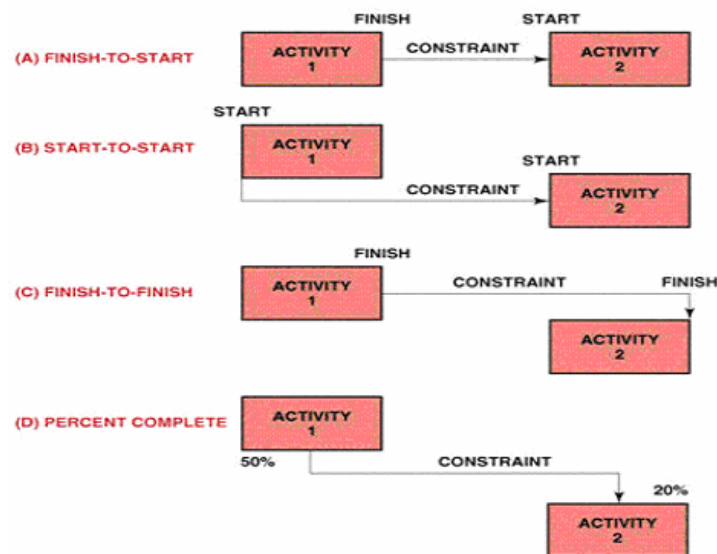


Figure 31.2: Typical Precedence Relationships

Figure above 31.2 (A) illustrates a finish-to-start constraint. In this figure, activity 2 can start no earlier than the completion of activity 1. Figure 31.2 (B) illustrates a start-to-start constraint. Activity 2 cannot start prior to the start of activity 1. Figure 31.2 (C) illustrates a finish-to-finish constraint. In this figure, activity 2 cannot finish until activity 1 finishes. Lastly, Figure 31.2 (D) 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.

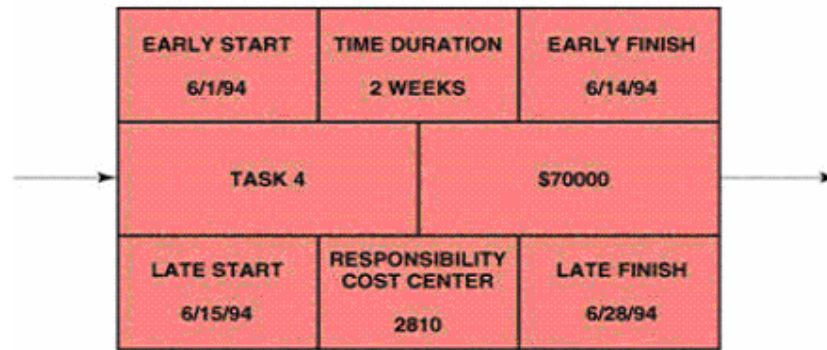


Figure 31.3: Computerized Information Flow

Figure 31.3 above shows the typical information that appears in each of the activity boxes shown in the previous figure. 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 31.4 below shows the comparison of three of the different network techniques.

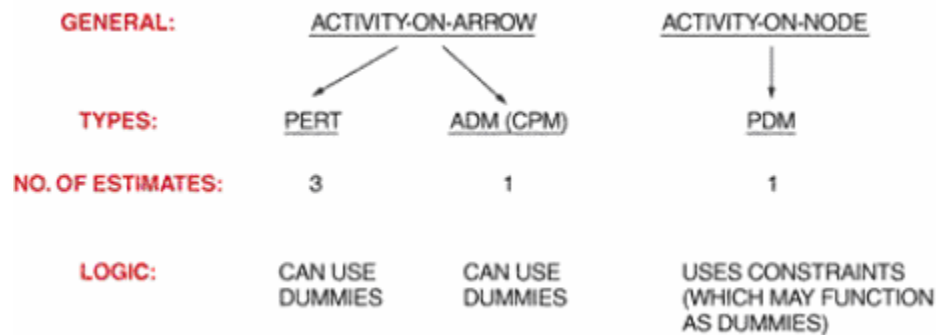


Figure 31.4: Comparison of Networks

31.2 PRICING AND ESTIMATION:

As we know that with the complexities involved, it is not surprising that many business managers consider pricing an art. Having the right intelligence 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. Even more important, intelligence sources are often unreliable. The only thing worse than missing information, is wrong or misleading information.

When it comes to competitive pricing, the old saying still applies: "Those who talk don't know; and those who know don't talk!" It is true, partially, that pricing remains an art. However, a disciplined approach certainly helps one to develop 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 point in 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 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–noncost relationships based on physical characteristics, technical parameters, or performance characteristics

31.3 **GLOBAL PRICING STRATEGIES:**

Specific pricing strategies must be developed for each individual situation. Frequently, however, one of two situations prevails 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 31.1 below.

Comparing the two pricing strategies for the two global situations (as shown in Table below) 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 the resources have been sent anyway, one might just 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 in time 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 TWO 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.

Table 31.1: Two Global Pricing Strategies

31.4 **TYPES OF ESTIMATES:**

Note that 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 (that is, \$/# of product or \$/KW electricity).

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 31.2 below would suffice as a starting point.

TABLE STANDARD PROJECT ESTIMATING

Estimating Method	Generic Type	WBS Relationship	Accuracy	Time to
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 31.2: Standard Project Estimating

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 31.3 below shows the table of contents for a construction estimating manual.

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 31.4 below). Using Table below, we can create the next three tables 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 Research and Development 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.

TABLE 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

Table 31.3: Estimating Manual Table of Contents

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	CLASSES OF ESTIMATES	
Class	Types	Accuracy
I	Definitive	±5%
II	Capital cost	±10–15%
III	Appropriation (with some capital cost)	±15–20%
IV	Appropriation	±20–25%
V	Feasibility	±25–35%
VI	Order of magnitude	> ± 35%

Table 31.4: Classes of Estimates

TABLE CHECKLIST FOR WORK NORMALLY REQUIRED FOR THE VARIOUS CLASSES (I–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		

Table 31.5: Checklist for Work Normally Required for the Various Classes of Estimates**31.5 PRICING PROCESS:**

This activity schedules the development of the Work Breakdown Structure (WBS) 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.

Note that 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.

TABLE DATA REQUIRED FOR PREPARATION OF ESTIMATES

	Classes of Estimates					
	I	II	III	IV	V	VI
<i>General</i>						
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		
<i>Process</i>						
Process block flow diagram						X
Process flow diagram (with equipment size and material)				X	X	
Mechanical P&I's	X	X	X			
Equipment list	X	X	X	X	X	
Catalyst/chemical specifications	X	X	X	X	X	
<i>Site</i>						
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
<i>Major Equipment</i>						
Preliminary sizes and materials			X	X	X	
Finalized sizes, materials, and appurtenances	X	X				
<i>Bulk Material Quantities</i>						
Finalized design quantity take-off		X				
Preliminary design quantity take-off	X	X	X	X		
<i>Engineering</i>						
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
<i>Construction</i>					
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
<i>Schedule</i>					
Overall timing of execution				X	X
Detailed schedule of execution	X	X	X		
Estimating preparation schedule	X	X	X		

Table 31.6: Data Required for Preparation of Estimates

The Work Breakdown Structure (WBS) and activity schedules are priced out through the lowest pricing units of the company. It is the responsibility of these pricing units, whether they are 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, will be the task level. 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 (that is, 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.

Remember that 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.

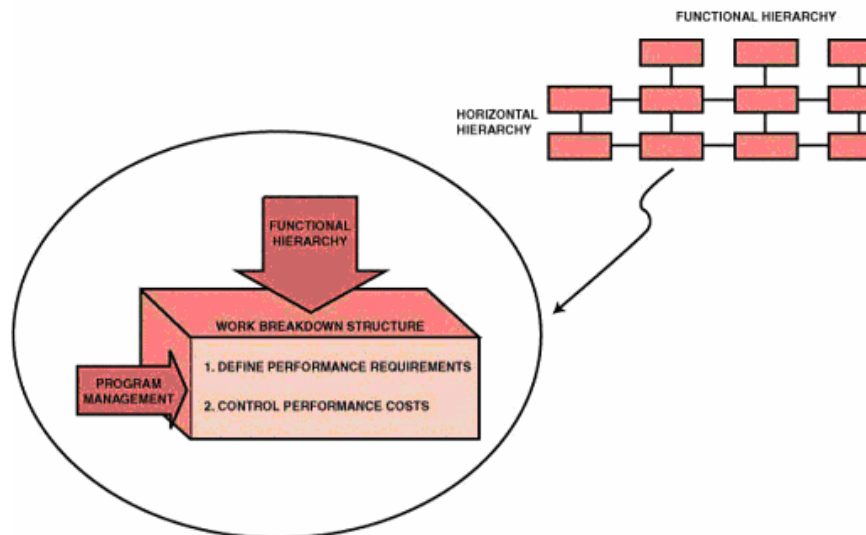


Figure 31.5: The Vertical Horizontal Interface

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 31.5 above. 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.

PRICING AND ESTIMATION (CONTD.)**BROAD CONTENTS**

Organizational Input Requirements
Labor Distributions
Overhead Costs

32.1 ORGANIZATIONAL INPUT REQUIREMENTS:

Note that once the work breakdown structure and activity schedules are established, the program manager calls a meeting for all organizations that will be required to 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 positions of several functional managers whose responsibilities may be similar to overlap on certain activities. 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. 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.

Time may be extremely important, during proposal activities. There are many situations in which a Request for Proposal (RFP) requires that all responders submit their bids no later than a specific date, say within thirty days. 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 Request for Proposal (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.

Remember that in the final analysis, it is the responsibility of the lowest pricing unit supervisors to maintain adequate standards, if possible, so that an almost immediate response can be given to a pricing request from a program office.

32.2 LABOR DISTRIBUTIONS:

The functional units supply their input to the program office in the form of man-hours as shown in Figure 32.1 below.

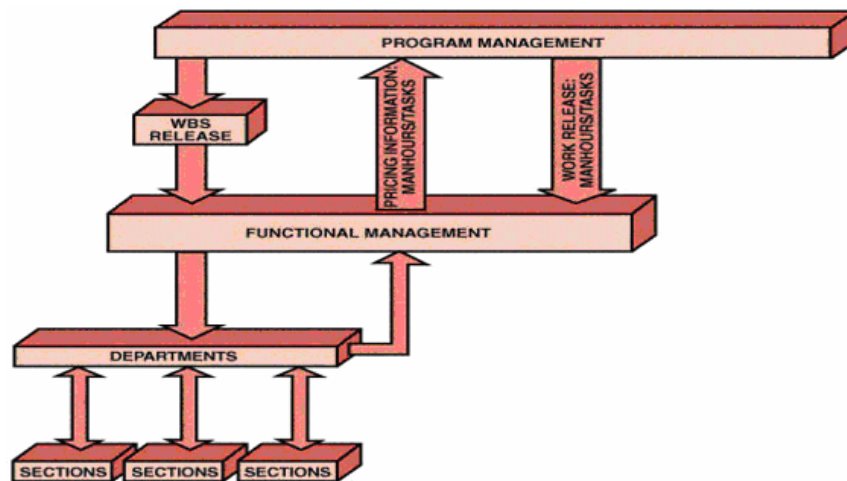


Figure 32.1: Functional Pricing Flow

The input may be accompanied by labor justification, if required. The man-hours are submitted for each task, assuming that the task is the lowest pricing element, and are time-phased per month. The man-hours per month per task are converted to dollars after multiplication by the appropriate labor rates. The labor rates are generally known with certainty over a twelve-month period, but from then on are only estimates. How can a company predict salary structures five years hence? If the company underestimates the salary structure, increased costs and decreased profits will occur. If the salary structure is overestimated, the company may not be competitive; if the project is government funded, then the salary structure becomes an item under contract negotiations.

In this regard, 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 reduction of man-hours often causes heated discussions between the functional and program managers. Program managers tend to think in terms of the best interests of the program, whereas functional managers lean toward maintaining their present staff.

To cater to this, 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.

The man-hours submitted by the functional units provide the basis for total program cost analysis and program cost control. To illustrate this process, consider the following Example 32.1:

Example 32.1:

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 as shown in Figure 32.2 below. 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.

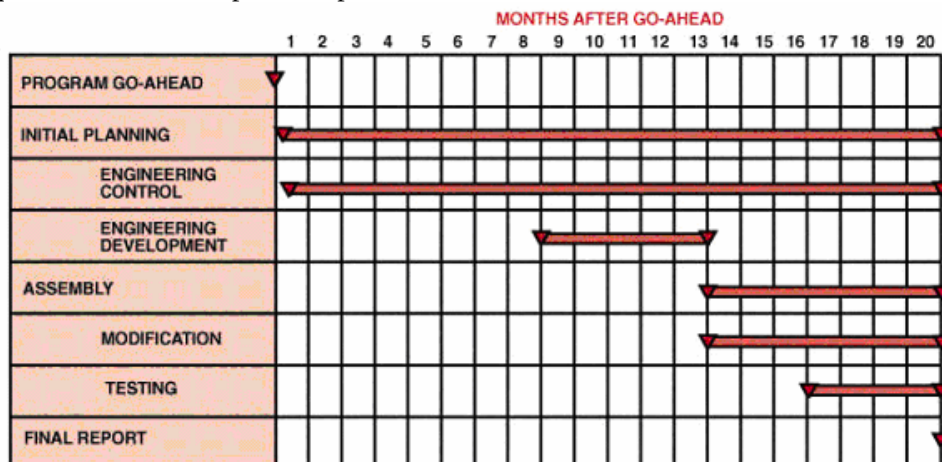


Figure 32.2: Activity Schedule for Assembly Line Updating

Note that 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 32.3 below. 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. It 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.

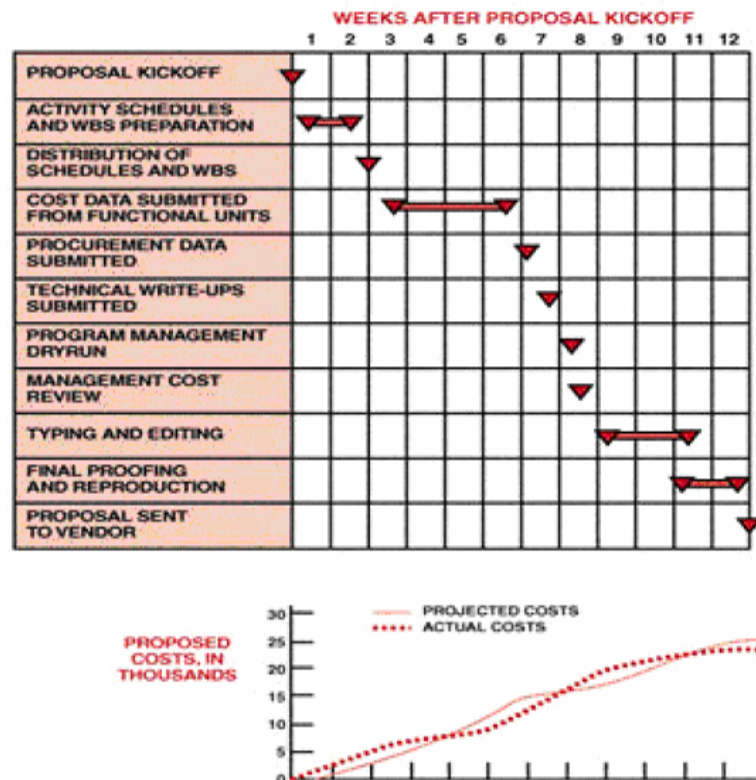


Figure 32.3: Proposal Activity Schedule

The checklist generally provides detailed explanations for the proposal activity schedule.

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 32.4 below. 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.

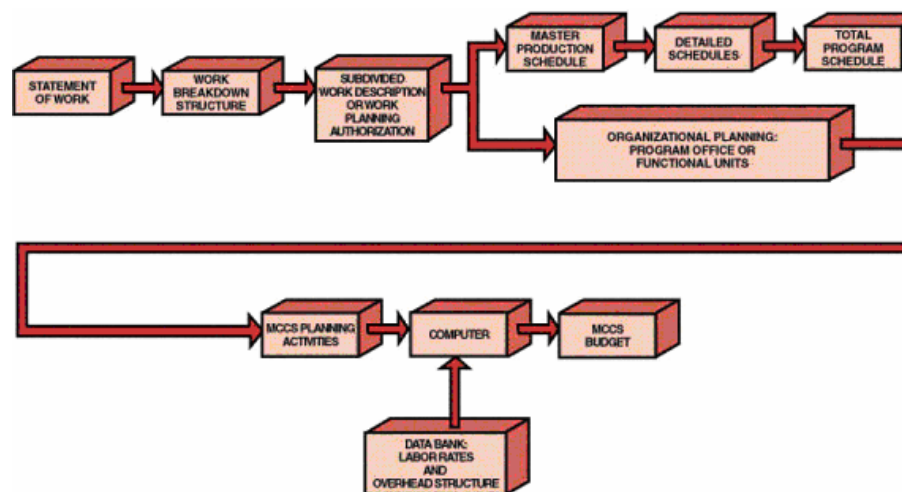


Figure 32.4: Labor Planning Flow Chart

In addition, 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.

32.3 OVERHEAD RATES:

We should know that the ability to control program costs involves more than tracking labor dollars and labor hours. Overhead dollars can be one of the biggest headaches in controlling program costs and must be tracked along with labor hours and dollars. 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 Example 32.2 below.

Example 32.2:

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:
 $(500 \text{ hours}) \times (\$15.00/\text{hour}) \times (100\% + 75\% \text{ burden}) = \$13,125$
- On overtime, the total cost is:
 $(500 \text{ hours}) \times (\$15.00/\text{hour} \times 1.5 \text{ overtime}) \times (100\% + 5\% \text{ burden}) = \$11,812.50$

Therefore, the company can save \$1,312.50 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.

Regardless of whether one analyzes a project or a system, all costs must have associated overhead rates. Unfortunately, many program managers and systems managers consider overhead rates as a magic number pulled out of the air. The preparation and assignment of overheads to each of the functional divisions is a science. Although the *total dollar pool* for overhead rates is relatively constant, management retains the option of deciding how to distribute the overhead among the functional divisions. A company that supports its Research and Development staff through competitive bidding projects may wish to keep the Research and Development overhead rate as low as possible. Care must be taken, however, that other divisions do not absorb additional costs so that the company no longer remains competitive on those manufactured products that may be its bread and butter.

Furthermore, 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

Additionally, the projection of the overhead expenses is made by an analysis of each of the elements that constitute the overhead expense. A partial listing of those items that constitute overhead expenses is shown in Table 32.1 below. 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
- IR&D tri-service agreements

In case of many industries, such as aerospace and defense, the federal government funds a large percentage of the Bid and proposal (B&P) and IR&D activities. This federal funding is a necessity since many companies could not otherwise be competitive within the industry. The federal government employs this technique to stimulate research and competition. Therefore, Bid and proposal (B&P) and IR&D are included in the above list.

The annual budget is the prime factor in the control of overhead costs. This budget, which is the result of goals and objectives established by the chief executive officer, is reviewed and approved at all levels of management. It is established at department level, and the department manager has direct responsibility for identifying and controlling costs against the approved plan.

The departmental budgets are summarized, in detail, for higher levels of management. This summarization permits management, at these higher organizational levels, to be aware of the authorized indirect budget in their area of responsibility.

Building maintenance	New business directors
Building rent	Office supplies
Cafeteria	Payroll taxes
Clerical	Personnel recruitment
Clubs/associations	Postage
Consulting services	Professional meetings
Corporate auditing expenses	Reproduction facilities
Corporate salaries	Retirement plans
Depreciation of equipment	Sick leave
Executive salaries	Supplies/hand tools
Fringe benefits	Supervision
General ledger expenses	Telephone/telegraph facilities
Group insurance	Transportation
Holiday	Utilities
Moving/storage expenses	Vacation

Table 32.1: Elements of Overhead Rates

Monthly reports are published indicating current month and year-to-date budget, actuals, and variances. These reports are published for each level of management, and an analysis is made by the budget department through coordination and review with management. Each directorate's total organization is then reviewed with the budget analyst who is assigned the overhead cost responsibility. A joint meeting is held with the directors and the vice president and general manager, at which time overhead performance is reviewed.

PRICING AND ESTIMATION (CONTD.)

BROAD CONTENTS

Materials/Support Costs
 Pricing out the Work
 System Pricing
 Developing the Supporting/Backup Costs
 The Low-Bidder Dilemma
 Special Problems
 Estimating Pitfalls

33.1 MATERIALS/SUPPORT COSTS:

Three of four major pricing input requirements are fulfilled by the salary structure, overhead structure, and labor hours. 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.

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.

As depicted in the Figure 33.1 below, upon release of the work statement, work breakdown structure, and subdivided work description, the end-item bill of materials and manufacturing plans are prepared. 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.

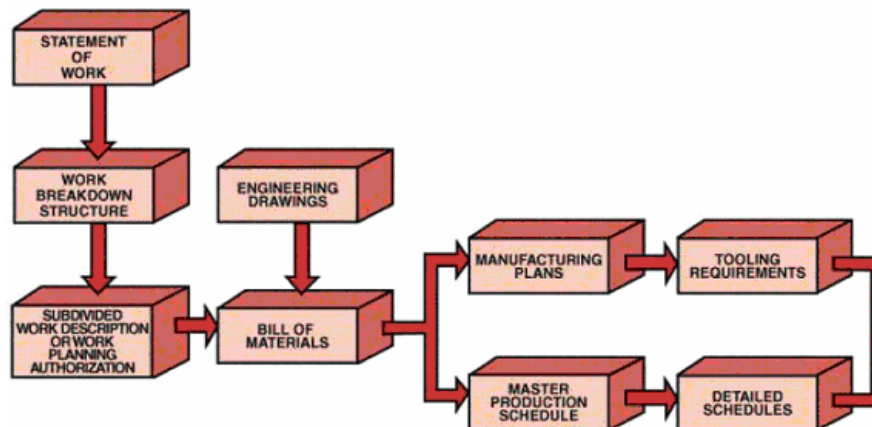


Figure 33.1: Material Planning Flow Chart

Furthermore, a procurement plan/purchase requisition is prepared as soon as possible after contract negotiations (using a methodology as shown in Figure 33.2 below). 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.

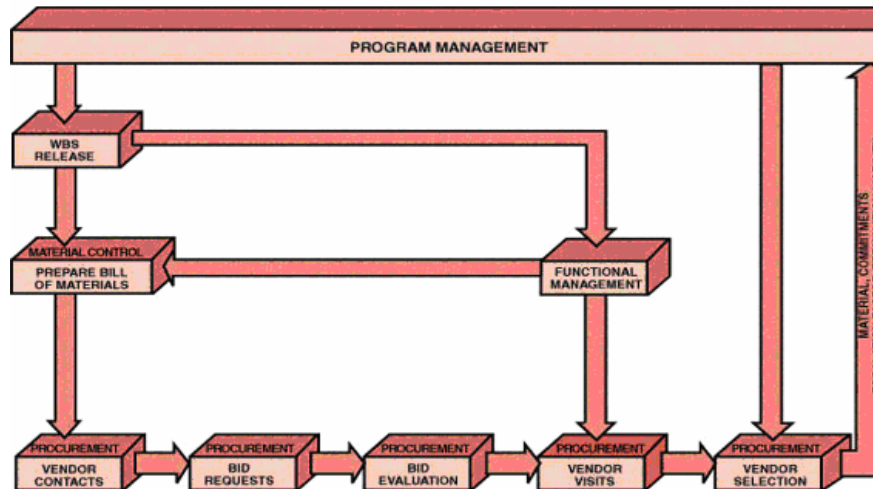


Figure 33.2: Procurement Activity

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 as 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.

33.2 PRICING OUT THE WORK:

Note that the logical pricing techniques are available in order to obtain detailed estimates. The following thirteen steps provide a logical sequence in order to better control the company's limited resources. These steps may vary from company to company.

- Step 1:** Provide a complete definition of the work
- 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 burden himself at each iteration point by developing cost summary reports 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 identified below shows the typical pricing reports:

- *A detailed cost breakdown for each Work Breakdown Structure (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.
- *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.

It is important to note that these tables are used by both project managers and upper-level executives. The project managers utilize these tables as the basis for project cost control. Top-level management utilizes them for selecting, approving, and prioritizing projects.

33.3 **SYSTEMS PRICING:**

The basis of successful program management is the establishment of an accurate cost package from which all members of the organization can both project and track costs. The cost data must

be represented in such a manner that maximum allocation of the corporate resources of people, money, and facilities can be achieved.

In addition, the systems approach to pricing out the activity schedules and the work breakdown structure provides a means for obtaining unity within the company. The flow of information readily admits the participation of all members of the organization in the program, even if on a part-time basis.

Functional managers obtain a better understanding of how their labor fits into the total program and how their activities interface with those of other departments. For the first time, functional managers can accurately foresee how their activity can lead to corporate profits.

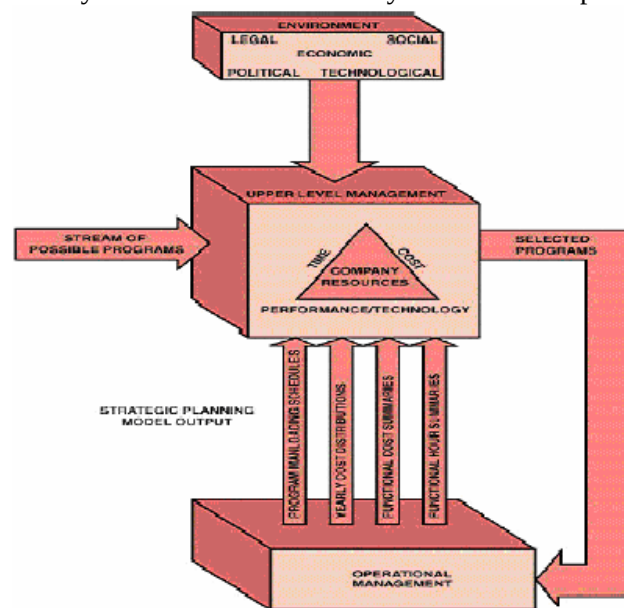


Figure 33.3: System Approach to Resource Control

As shown in Figure 33.3 above the project pricing model (sometimes called a strategic project planning model) acts as a management information system, forming the basis for the systems approach to resource control. The summary sheets from the computer output of the strategic pricing model provide management with the necessary data from which the selection of possible programs can be made so that maximum utilization of resources will follow.

The strategic pricing model also provides management with an invaluable tool for performing perturbation analysis on the base case costs. This perturbation analysis provides management with sufficient opportunity for design and evaluation of contingency plans, should a deviation from the original plan be required.

33.4 DEVELOPING THE SUPPORTING/BACKUP COSTS:

Remember that not all cost proposals require backup support, but for those that do, the backup support should be developed along with the pricing. Extreme caution must be exercised to make sure that the itemized prices are compatible with the supporting data. Government pricing requirements are a special case.

Most supporting data come from external (subcontractor or outside vendor) quotes. Internal data must be based on historical data, and these historical data must be updated continually as each new project is completed. The supporting data should be traceable by itemized charge numbers.

It must be kept in mind that customers may wish to audit the cost proposal. In this case, the starting point might be with the supporting data. It is not uncommon on sole-source proposals to have the supporting data audited before the final cost proposal is submitted to the customer.

Not all cost proposals require supporting data; the determining factor is usually the type of contract. On a fixed-price effort, the customer may not have the right to audit your books. However, for a cost-reimbursable package, your costs are an open book, and the customer usually compares your exact costs to those of the backup support.

Commonly, most companies usually have a choice of more than one estimate to be used for backup support. In deciding which estimate to use, consideration must be given to the possibility of follow-on work:

- If your actual costs grossly exceed your backup support estimates, you may lose credibility for follow-on work.
- If your actual costs are less than the backup costs, you must use the new actual costs on follow-on efforts.

We see that the moral here is that backup support costs provide future credibility. If you have well-documented, "livable" cost estimates, then you may wish to include them in the cost proposal even if they are not required.

Since both direct and indirect costs may be negotiated separately as part of a contract, supporting data such as those in the following four Tables (33.1, 33.2, 33.3 and 33.4 respectively) and Figure 33.4 following them may be necessary to justify any costs that may differ from company (or customer-approved) standards.

TABLE OPERATIONS SKILLS MATRIX

Functional areas of expertise	Technical Staff												
	Able, J.	Baker, P.	Cook, D.	Dirk, L.	Easley, P.	Franklin, W.	Green, C.	Henry, L.	Imhoff, R.	Jules, C.	Klein, W.	Ledger, D.	Mayer, Q.
Administrative management		a				a		a			a	a	
Control and communications	b		b	b	b		b	b		b	b	b	t
Environmental impact assessment	c	c	c						c		c		c
Facilities management		d					d				d		d
Financial management	e					e			e	e	e		
Human resources management	f							f				f	
Industrial engineering	g				g					g			
Intelligence and security								h				h	l
Inventory control	i						i					j	
Logistics			j		j			j					
OSHA	k									k			k
Project management	l			l		l					l		
Quality control		m	m			m	m	m	m				
R&D			n	n							n		n
Wage and salary administration		o			o				o	o		o	c

TABLE CONTRACTOR'S MANPOWER AVAILABILITY

	Number of Personnel			
	Total Current Staff		Available for This Project and Other New Work 1/93	Anticipated Growth by 1/93
	Permanent Employees	Agency Personnel	Permanent + Agency	Permanent + Agency
Process engineers	93	—	70	4
Project managers/engineers	79	—	51	4
Cost estimating	42	—	21	2
Cost control	73	—	20	2
Scheduling/scheduling control	14	—	8	1
Procurement/purchasing	42	—	20	1
Inspection	40	—	20	2
Expediting	33	—	18	1
Home office construction management	9	—	6	0
Piping	90	13	67	6
Electrical	31	—	14	2
Instrumentation	19	—	3	1
Vessels/exchangers	24	—	19	1
Civil/structural	30	—	23	2
Other	13	—	8	0

Tables 33.1 and 33.2

TABLE STAFF TURNOVER DATA

	For Twelve-Month Period 1/1/92 to 1/1/93	
	Number Terminated	Number Hired
Process engineers	5	2
Project managers/engineers	1	1
Cost estimating	1	2
Cost control	12	16
Scheduling/scheduling control	2	5
Procurement/purchasing	13	7
Inspection	18	6
Expediting	4	5
Home office construction management	0	0
Design and drafting—total	37	29
Engineering specialists—total	<u>26</u>	<u>45</u>
Total	119	118

Table 33.3: Staff Turnover Data

TABLE STAFF EXPERIENCE PROFILE

	Number of Years' Employment with Contractor				
	0–1	1–2	2–3	3–5	5 or more
Process engineers	2	4	15	11	18
Project managers/engineers	1	2	5	11	8
Cost estimating	0	4	1	5	7
Cost control	5	9	4	7	12
Scheduling and scheduling control	2	2	1	3	6
Procurement/purchasing	4	12	13	2	8
Inspection	1	2	6	14	8
Expediting	6	9	4	2	3
Piping	9	6	46	31	22
Electrical	17	6	18	12	17
Instrumentation	8	8	12	13	12
Mechanical	2	5	13	27	19
Civil/structural	4	8	19	23	16
Environmental control	0	1	1	3	7
Engineering specialists	<u>3</u>	<u>3</u>	<u>3</u>	<u>16</u>	<u>21</u>
Total	64	81	161	180	184

Table 33.4: Staff Experience Profile

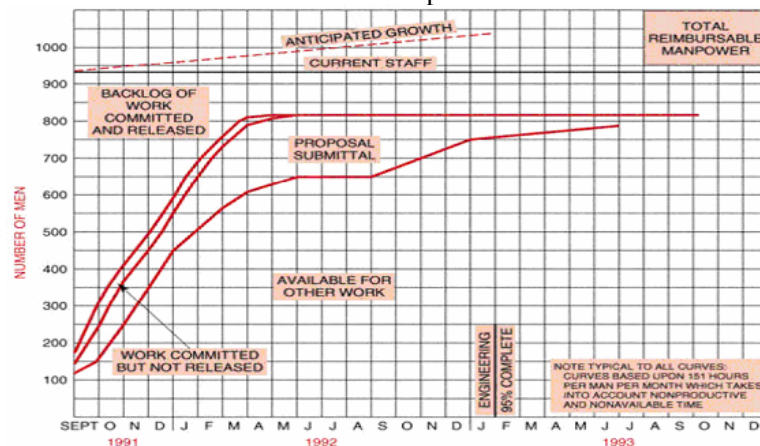


Figure 33.4: Total Reimbursable Manpower

33.5 THE 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? Everyone has an answer to this question. 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, hopefully, 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 per se; 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.

In addition to this, 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.

33.6 SPECIAL PROBLEMS:

It is essential to note that there are always special problems that, although often overlooked, have a severe impact on the pricing effort. As an example, pricing must include an understanding of cost control— specifically, how costs are billed back to the project. There are three possible situations:

1. *Work is priced out at the department average, and all work performed is charged to the project at the department average salary, regardless of who accomplished the work.* This technique is obviously the easiest, but encourages project managers to fight for the highest salary resources, since only average wages are billed to the project.
2. *Work is priced out at the department average, but all work performed is billed back to the project at the actual salary of those employees who perform the work.* This method can create a severe headache for the project manager if he tries to use only the best employees on his project. If these employees are earning substantially more money than the department average, then a cost overrun will occur unless the employees can perform the work in less time. Some companies are forced to use this method by government agencies and have estimating problems when the project that has to be priced out is of a short duration where only the higher-salaried employees can be used. In such a situation it is common to "inflate" the direct labor hours to compensate for the added costs.
3. *The work is priced out at the actual salary of those employees who will perform the work, and the cost is billed back the same way.* This method is the ideal situation as long as the people can be identified during the pricing effort.

In this regard, some companies use a combination of all three methods. In this case, the project office is priced out using the third method (because these people are identified early), whereas the functional employees are priced out using the first or second method.

33.7 ESTIMATING PITFALLS:

There are several pitfalls that can impede the pricing function. Probably the most serious pitfall, and the one that is usually beyond the control of the project manager, is the "buy-in" decision, which is based on the assumption that there will be "bail-out" changes or follow-on contracts later. These changes and/or contracts may be for spares, spare parts, maintenance, maintenance

manuals, equipment surveillance, optional equipment, optional services, and scrap factors. Other types of estimating pitfalls include:

- Misinterpretation of the statement of work
- Omissions or improperly defined scope
- Poorly defined or overly optimistic schedule
- Inaccurate work breakdown structure
- Applying improper skill levels to tasks
- Failure to account for risks
- Failure to understand or account for cost escalation and inflation
- Failure to use the correct estimating technique
- Failure to use forward pricing rates for overhead, general and administrative, and indirect costs.

Unfortunately, many of these pitfalls do not become evident until detected by the cost control system, well into the project.

QUALITY IN PROJECT MANAGEMENT

BROAD CONTENTS

What is Quality?

Quality from Different Perspective

Quality Dimensions

Competitive Advantage

Quality Evolution and Quality Stages in Japan

TQM (Total Quality Management) and Its Philosophy

34.1 WHAT IS QUALITY?

Quality is by no means a new concept in modern business. In October 1887, William Cooper Procter, grandson of the founder of Procter and Gamble, told his employees, "The first job we have is to bring out quality merchandise that consumers will buy and keep on buying. If we produce it efficiently and economically, we will earn a profit, in which you will share." Procter's statement addresses three issues that are critical to managers of manufacturing and service organizations: productivity, cost, and quality. Productivity (the measure of efficiency defined as the amount of output achieved per unit of input), the cost of operations, and the quality of the goods and services that create customer satisfaction all contribute to profitability. Of these three determinants of profitability, the most significant factor in determining the long-run success or failure of any organization is quality. High quality goods and services can provide an organization with a competitive edge. High quality reduces costs due to returns, rework, and scrap. It increases productivity, profits, and other measures of success. Most importantly, high quality generates satisfied customers, who reward the organization with continued patronage and word-of-mouth advertising.

Quality can be a confusing concept, partly because people view quality in relation to differing criteria based on their individual roles in the production-marketing value chain. In addition, the meaning of quality continues to evolve as the quality profession grows and matures. Neither consultants nor business professionals agree on a universal definition. A study that asked managers of 86 firms in the eastern United States to define quality produced several dozen different responses, including the following:

1. Perfection
2. Consistency
3. Eliminating waste
4. Speed of delivery
5. Compliance with policies and procedures
6. Providing a good, usable product
7. Doing it right the first time
8. Delighting or pleasing customers
9. Total customer service and satisfaction

Thus, it is important to understand the various perspectives from which quality is viewed in order to fully appreciate the role it plays in the many pails of a business organization.

The concept of quality is subjective and difficult to define. While certain aspects of quality can be identified, ultimately, the "judgement of quality" rests with the customer.

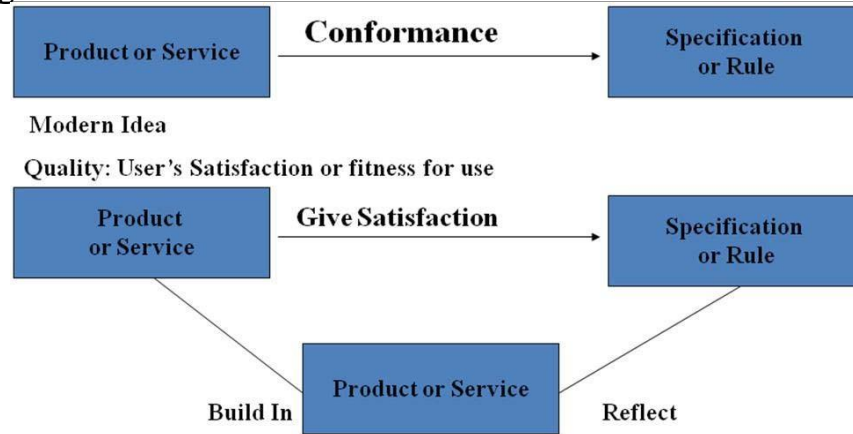


Figure 34.1

34.2 QUALITY FROM DIFFERENT PERSPECTIVES: _

- **Judgmental Perspective:**

One common notion of quality, used by consumers, is that it is synonymous with superiority or excellence. In 1931 Walter Shewhart first defined quality as the goodness of a product. This view is referred to as the *transcended* (to rise above or extend notably beyond ordinary limits), definition of quality. In this sense, quality is "both absolute and universally recognizable, a mark of uncompromising standards and high achievement." As such, it cannot be defined precisely—you just know it when you see it. It is often loosely related to a comparison of features and characteristics of products and promulgated by marketing efforts aimed at developing quality as an image variable in the minds of consumers. Common examples of products attributed with this image are Koles watches and BMW and Lexus automobiles.

- **Product-Based Perspective:**

Another definition of quality is that it is a function of a specific, measurable variable and that differences in quality reflect differences in quantity of product attribute, such as in the number of stitches per inch on a shirt or in the number of cylinders in an engine. This assessment implies that higher levels or amounts of product characteristics are equivalent to higher quality. As a result, quality is often mistakenly assumed to be related to price: the higher the price, the higher the quality. Just consider the case of a Florida man who purchased a \$262,000 Lamborghini only to find a leaky roof, a battery that quit without notice, a sunroof that detached when the car hit a bump, and doors that jammed. However, a product refers to either a manufactured good or a service—need not be expensive to be considered a quality product by consumers. Also, as with the notion of excellence, the assessment of product attributes may vary considerably among individuals.

- **User-Based Perspective:**

A third definition of quality is based on the presumption that quality is determined by what a customer wants. Individuals have different wants and needs and, hence, different quality standards, which leads to a user-based definition: quality is defined as fitness for *intended use*, or how well the product performs its intended function. Both a Cadillac sedan and a Jeep Cherokee are fit for use, for example, but they serve different needs and different groups of customers. If you want a highway-touring vehicle with luxury amenities, then a Cadillac may better satisfy your needs. If you want a vehicle for camping, fishing, or skiing trips, a Jeep might be viewed as having better quality.

- **Value-Based Perspective:**

A fourth approach to defining quality is based on *value*; that is, the relationship of usefulness or satisfaction to price. From this perspective, a quality product is one that is as useful as competing products and is sold at a lower price, or one that offers greater usefulness or satisfaction at a comparable price. Thus, one might purchase a generic product, rather than a brand name one, if it performs as well as the brand-name product at a lower price. An example of this perspective in practice is evident in a comparison of the U.S. and Japanese automobile markets. A Chrysler marketing executive noted "one of the main reasons that the leading Japanese brands—Toyota and Honda—don't offer the huge incentives of the big Three (General Motors, Ford, and Chrysler) is that they have a much better reputation for long-term durability." In essence, incentives and rebates are payments to customers to compensate for lower quality.

- **Manufacturing-Based Perspective:**

A fifth view of quality is manufacturing-based and defines quality as the desirable outcome of engineering and manufacturing practice, or *conformance to specifications*. Specifications are targets and tolerances determined by designers of products and services. Targets are the ideal values for which production is to strive; tolerances are specified because designers recognize that it is impossible to meet targets all of the time in manufacturing. For example, a part dimension might be specified as "0.236 ± 0.003 cm." These measurements would mean that the target, or ideal value, is 0.236 centimeters, and that the allowable variation is (MHB centimeters from the target (a tolerance of 0.006 cm.). Thus, any dimension in the range 0.233 to 0.239 centimeters is deemed acceptable and is said to conform to specifications. Likewise, in services, "on-time arrival" for an airplane might be specified as within 15 minutes of the scheduled arrival time. The target is the scheduled time, and the tolerance is specified to be 15 minutes.

- **Integrating Perspectives on Quality:**

Although product quality should be important to all individuals throughout the value chain, how quality is viewed may depend on one's position in the value chain, that is, whether one is the designer, manufacturer or service provider, distributor, or customer. The customer is the driving force for the production of goods and services, and customers generally view quality from either the transcendent or the product-based perspective. The goods and services produced should meet customers' needs; indeed, business organizations' existences depend upon meeting customer needs. It is the rule of the marketing function to determine these needs. A product that meets customer needs can rightly be described as a quality product. Hence, the user-based definition of quality is meaningful to people who work in marketing.

The manufacturer must translate customer requirements into detailed product and process specifications. Making this translation is the role of research and development, product design, and engineering. Product specifications might address such attributes as size, form, finish, taste, dimensions, tolerances, materials, operational characteristics, and safety features. Process specifications indicate the types of equipment, tools, and facilities to be used in production. Product designers must balance performance and cost to meet marketing objectives; thus, the value-based definition of quality is most useful at this stage.

- **Customer-Driven Quality:**

I

The American National Standards Institute (ANSI) and the American Society for Quality (ASQ) standardized official definitions of quality terminology in 1978. These groups defined quality as *the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs*. This definition draws heavily

on the product- and user-based approaches and is driven by the need to contribute value to customers and thus to influence satisfaction and preference. By the end of the 1980s, many companies had begun using a simpler, yet powerful, customer-driven definition of quality that remains popular today:

“Quality is meeting or exceeding customer expectations”

34.3 QUALITY DIMENSIONS:

Following are the “principal quality dimensions”:

- Performance – a product’s primary operating characteristics. For example: A car’s acceleration, braking distance, steering and handling.
- Features – the “bells and whistles” of a product. A car may have power options, a tape or CD (compact disk) player, antilock brakes, reclining seats.
- Reliability – the probability of a product’s surviving over a specified period of time under stated “conditions of use”. Examples of reliability factors could be a car’s ability to start on cold days and frequency of failures.
- Conformance – the degree to which physical and performance characteristics of a product match with the pre-established standards. For example, car’s fit/finish, freedom from noises can reflect this.
- Durability – the amount of use one gets from a product before it physically deteriorates or until replacement is preferable. If we take the example of a car its corrosion resistance and long wear of upholstery fabric reflects this.
- Serviceability – this refers to the speed, courtesy, competence of repair work. Auto owner access to spare parts also comes under serviceability.
- Aesthetics – refers to how a product looks, feels, sounds, tastes, or smells. Car’s color, instrument panel design and “feel of road” make it aesthetically pleasing.
- Perceived quality – the “subjective assessment of quality” resulting from image. For example: Advertising, or brand names, car, shaped by magazine reviews-manufacturers’ brochures.
- Affordability, Variety, simplicity etc. are also the principal quality dimensions.

34.4 COMPETITIVE ADVANTAGE:

When a firm sustains profits that exceed the average for its industry, the firm is said to possess a **competitive advantage** over its rivals. The goal of much of business strategy is to achieve a sustainable competitive advantage.

Michael Porter identified two basic types of competitive advantage:

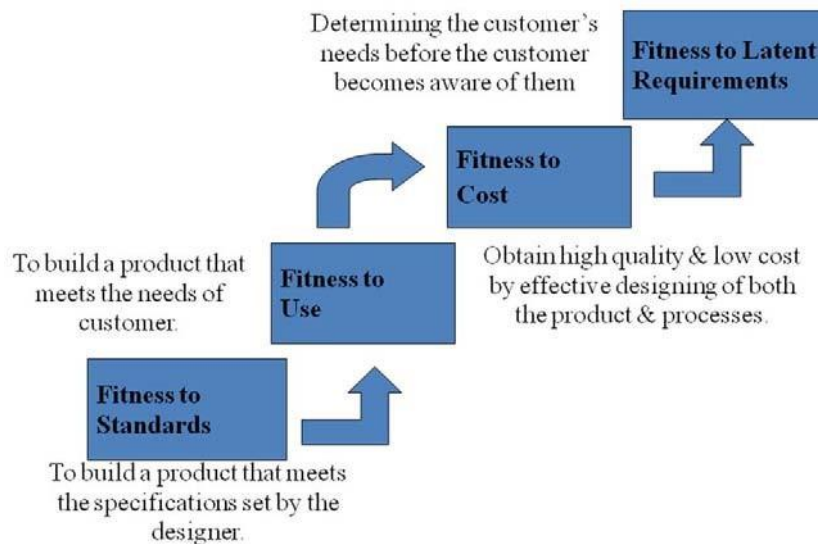
- Cost advantage
- Differentiation advantage

A competitive advantage exists when the firm is able to deliver the same benefits as competitors but at a lower cost (cost advantage), or deliver benefits that exceed those of competing products (differentiation advantage). Thus, a competitive advantage enables the firm to create superior value for its customers and superior profits for itself.

Cost and differentiation advantages are known as *positional advantages* since they describe the firm's position in the industry as a leader in either cost or differentiation.

A *resource-based view* emphasizes that a firm utilizes its resources and capabilities to create a competitive advantage that ultimately results in superior value creation.

34.5 QUALITY EVOLUTION AND QUALITY STAGES IN JAPAN:

**Figure 34.2:** Quality Evolution and Quality Stages in Japan

34.6 TOTAL QUALITY MANAGEMENT (TQM) AND ITS PHILOSOPHY:

34.6.1 Quality as a Management Framework:

In the 1970s a General Electric (GE) task force studied consumer perceptions of the quality of various GE product lines. Lines with relatively poor reputations for quality were found to deemphasize customer's viewpoint, regard quality as synonymous with tolerance and conformance to specifications, tie quality objectives to manufacturing flow, express quality objectives as the number of defects per unit, and use formal quality control systems only in manufacturing. In contrast, product lines that received customer praise were found to emphasize satisfying customer expectations, determine customer needs through market research, use customer-based quality performance measures, and have formalized quality control systems in place for all business functions, not just for manufacturing. The task force concluded that quality must not be viewed solely as a technical discipline, but rather as a management discipline. That is, quality issues permeate all aspects of business enterprise: design, marketing, manufacturing, human resource management, supplier relations, and financial management, to name just a few.

As companies came to recognize the broad scope of quality, the concept of total quality (TQ) emerged. A definition of total quality was endorsed in 1992 by the chairs and CUOs of nine major U.S. corporations in cooperation with deans of business and engineering departments of major universities, and recognized consultants:

Total Quality (TQ) is a people-focused management system that aims at continual increase in customer satisfaction at continually lower real cost. TQ is a total system approach (not a separate area or program) and an integral part of high-level strategy; it works horizontally across functions and departments, involves all employees, top to bottom, and extends backward and forward to include the supply chain and the customer chain. TQ stresses learning and adaptation to continual change as keys to organizational success.

The foundation of total quality is philosophical: the scientific method. TQ includes systems, methods, and tools. The systems permit change, the philosophy stays the same. TQ is anchored in values that stress the dignity of the individual and the power of community action.

Procter and Gamble uses a concise definition: Total quality is the unyielding and continually improving effort by everyone in an organization to understand, meet, and exceed the expectations of customers.

Actually, the concept of TQ has been around for some time. A. V. Feigenbaum recognized the importance of a comprehensive approach to quality in the 1950s and coined the term Total quality control. Feigenbaum observed that the quality of products and services is directly influenced by what he terms the 9 Ms: markets, money, management, men and women, motivation, materials, machines and mechanization, modern information methods, and mounting product requirements. Although he developed his ideas from an engineering perspective, his concepts apply more broadly to general management.

The Japanese adopted Feigenbaum's concept and renamed it companywide quality control. Wayne S. Keiker listed five aspects of total quality control practiced in Japan:

1. Quality emphasis extends through market analysis, design, and customer service rather than only the production stages of making a product.
2. Quality emphasis is directed toward operations in every department from executives to clerical personnel.
3. Quality is the responsibility of live individual and the work group, not some other group, such as inspection.
4. The two types of quality characteristics as viewed by customers are those that satisfy and those that motivate. Only the latter are strongly related to repeat sales and a "quality" image.
5. The first customer for a part or piece of information is usually the next department in the production process.

The term *total quality management* was developed by the Naval Air Systems Command to describe its Japanese-style approach to quality improvement and became popular with businesses in the United States during the 1980s. As we noted earlier, TQM has fallen out of favor, and many people simply use TQ.

34.6.2 Principles of Total Quality:

Whatever the language, total quality is based on three fundamental principles:

1. A focus on customers and stakeholders.
2. Participation and teamwork by everyone in the organization.
3. A process focus supported by continuous improvement and learning.

Despite their obvious simplicity, these principles are quite different from traditional management practices. Historically, companies did little to understand external customer requirements, much less those of internal customers. Managers and specialists controlled and directed production systems; workers told what to do and how to do it, and rarely were asked for their input. Teamwork was virtually nonexistent. As certain amount of waste and error was tolerable and was controlled by postproduction inspection. Improvements in quality generally resulted from technological breakthroughs instead of a relentless mindset of continuous improvement. With total quality, an organization actively seeks to identify customer needs and expectations, to build quality into work processes by tapping the knowledge and experience of its workforce/ and to continually improve every facet of the organization.

Customer and Stakeholder Focus the customer is the principal judge of quality. Perceptions of value and satisfaction are influenced by many factors throughout the customer's overall purchase, ownership, and service experiences. To accomplish this task, a company's efforts need to extend well beyond merely meeting specifications, reducing defects and errors, or resolving complaints. They must include both designing new products that truly delight the customer and responding rapidly to changing consumer and market demands. A company close to its customer knows what the customer wants, how the customer uses its products, and anticipates needs that the customer may not even be able to express. It also continually develops new ways of enhancing customer relationships. A firm also must recognize that internal customers are as important in assuring quality as are external customers who purchase the product. Employees who view themselves as both customers of and suppliers to other employees understand how their work links to the final product. After all, the responsibility of any supplier is to understand and meet customer requirements in the most efficient and effective way possible.

Customer focus extends beyond the consumer and internal customer relationships, however. Employees and society represent important stakeholders. An organization's success depends on the knowledge, skills, creativity, and motivation of its employees and partners. Therefore, a TQ organization must demonstrate commitment to employees, provide opportunities for development and growth, provide recognition beyond normal compensation systems, share knowledge, and encourage risk taking. Viewing society as a stakeholder is an attribute of a world-class organization. Business ethics, public health and safety, the environment, and community and professional support are necessary activities that fall under *social responsibility*.

Participation and Teamwork Joseph Juran credited Japanese managers' full use of the knowledge and creativity of the entire workforce as one of the reasons for Japan's rapid quality achievements. When managers give employees the tools to make good decisions and the freedom and encouragement to make contributions, they virtually guarantee that better quality products and production processes will result. Employees who are allowed to participate—both individually and in teams—in decisions that affect their jobs and customer can make substantial contributions to quality. His attitude represents a profound shift in the typical philosophy of senior management; the traditional view was that the workforce should be "managed"—or to put it less formally, the workforce should leave their brains at the door. Good intentions alone are not enough to encourage employee involvement. Management's task includes formulating the systems and procedures and then putting them in place to ensure that participation becomes a part of the culture.

QUALITY IN PROJECT MANAGEMENT (CONTD.)

BROAD CONTENTS

The Quality Movement
Quality Development Stages
Quality Audit
Deming Philosophy

35.1 THE QUALITY MOVEMENT:

During the past 100 years, the views of quality have changed dramatically. Prior to World War I, quality was viewed predominantly as inspection, sorting out the good items from the bad. Emphasis was on problem identification. Following World War I and up to the early 1950s, emphasis was still on sorting good items from bad.

However, quality control principles were now emerging in the form of:

- Statistical and mathematical techniques
- Sampling tables
- Process control charts

From the early 1950s to the late 1960s, quality control evolved into quality assurance, with its emphasis on problem avoidance rather than problem detection. Additional quality assurance principles emerged, such as:

- The cost of quality
- Zero-defect programs
- Reliability engineering
- Total quality control

35.2 DEVELOPMENT OF QUALITY STAGES:

This comprises of the following “five level model”:

1. Inspection
2. Quality Control
3. Quality Assurance
4. Quality Management
5. Total Quality Management

1. Inspection:

“Activity such as measuring, examining, testing, or gauging one or more characteristics of an entity and comparing the results with specified requirements in order to establish whether conformity is achieved for each characteristic” (ISO 8402)

2. Quality Control:

Quality control is a collective term for activities and techniques, within the process, that are intended to create specific quality characteristics. Such activities include continually monitoring processes, identifying and eliminating problem causes, use of statistical

process control to reduce the variability and to increase the efficiency of processes. Quality control certifies that the organization's quality objectives are being met.

Quality control is also referred to as the technical aspect of quality management. They set up the technical processes and procedures that ensure that each step of the project provides a quality output from design and development through implementation and maintenance. Each step's output must conform to the overall quality standards and quality plans, thus ensuring that quality is achieved.

A good quality control system will:

- Select what to control
- Set standards that provide the basis for decisions regarding possible corrective action
- Establish the measurement methods used
- Compare the actual results to the quality standards
- Act to bring nonconforming processes and material back to the standard based on the information collected
- Monitor and calibrate measuring devices
- Include detailed documentation for all processes

3. Quality Assurance:

Quality assurance is the collective term for the formal activities and managerial processes that are planned and undertaken in an attempt to ensure that products and services that are delivered are at the required quality level. Quality assurance also includes efforts external to these processes that provide information for improving the internal processes. It is the quality assurance function that attempts to ensure that the project scope, cost, and time functions are fully integrated.

The Project Management Institute Guide to the Body of Knowledge (PMBOK) refers to quality assurance as the management section of quality management. This is the area where the project manager can have the greatest impact on the quality of his project. The project manager needs to establish the administrative processes and procedures necessary to ensure and, often, prove that the scope statement conforms to the actual requirements of the customer. The project manager must work with his team to determine which processes they will use to ensure that all stakeholders have confidence that the quality activities will be properly performed. All relevant legal and regulatory requirements must also be met.

A good quality assurance system will:

- Identify objectives and standards.
- Be multifunctional and prevention oriented.
- Plan for collection and use of data in a cycle of continuous improvement.
- Plan for the establishment and maintenance of performance measures.
- Include quality audits.

4. Quality Management:

During the past twenty years, there has been a revolution toward improved quality. The improvements have occurred not only in product quality, but also in quality leadership and quality project management. Unfortunately, it takes an economic disaster or a recession to get management to recognize the need for improved quality. Prior to the recession of 1979–1982, Ford, General Motors, and Chrysler viewed each other as the

competition rather than the Japanese. Prior to the recession of 1989–1994, high-tech engineering companies never fully recognized the need for shortening product development time and the relationship between project management, total quality management, and concurrent engineering. The push for higher levels of quality appears to be customer driven. Customers are now demanding:

- Higher performance requirements
- Faster product development
- Higher technology levels
- Materials and processes pushed to the limit
- Lower contractor profit margins
- Fewer defects/rejects

One of the critical factors that can affect quality is market expectations. The variables that affect market expectations include:

- Salability: the balance between quality and cost
- Produceability: the ability to produce the product with available technology and workers, and at an acceptable cost
- Social acceptability: the degree of conflict between the product or process and the values of society (i.e., safety, environment)
- Operability: the degree to which a product can be operated safely
- Availability: the probability that the product, when used under given conditions, will perform satisfactorily when called upon
- Reliability: the probability of the product performing without failure under given conditions and for a set period of time
- Maintainability: the ability of the product to be retained in or restored to a performance level when prescribed maintenance is performed

Customer demands are now being handled using total quality management (TQM). Total quality management is an ever-improving system for integrating various organizational elements into the design, development, and manufacturing efforts, providing cost-effective products or services that are fully acceptable to the ultimate customer. Externally, TQM is customer oriented and provides for more meaningful customer satisfaction. Internally, TQM reduces production line bottlenecks and operating costs, thus enhancing product quality while improving organizational morale.

5. Total Quality Management (TQM):

For this, we first explain what “*total quality*” is. Total Quality means:

- Quality of work
- Quality of Service
- Quality of information
- Quality Process
- Quality of Organization
- Quality of People
- Quality of Company
- Quality of Objectives

Mature organizations today readily admit that they cannot accurately define quality. The reason for this is because quality is defined by the customer. The Kodak definition of quality is those products and services that are perceived to meet or exceed the needs and expectations of the customer at a cost that represents outstanding value.

The ISO 9000 definition is "the totality of feature and characteristics of a product or service that bears on its ability to satisfy stated or implied needs." Terms such as fitness for use, customer satisfaction, and zero defects are goals rather than definitions. Most organizations today view quality more as a process than a product. To be more specific, it is a continuously improving process where lessons learned are used to enhance future products and services in order to:

- Retain existing customers
- Win back lost customers
- Win new customers

Therefore, companies today are developing quality improvement processes. Figure 35.1 shows the five quality principles that support Kodak's quality policy. Figure 35.2 shows a more detailed quality improvement process.

Total Quality Management (TQM) is a management strategy aimed at embedding awareness of quality in all organizational processes. Total Quality Management (TQM) has been widely used in manufacturing, education, government, and service industries, as well as NASA space and science programs.

Total Quality provides an umbrella under which everyone in the organization can strive and create customer satisfaction at continually lower real costs.

Total Quality Management (TQM) is the management of total quality. We know that management consists of planning, organizing, directing, control, and assurance. Then, one has to define "total quality". Total quality is called **total** because it consists of the following three qualities:

1. **Quality** of return to satisfy the needs of the shareholders
2. **Quality** of products and services to satisfy some specific needs of the consumer (end user)
3. **Quality** of life - at work and outside work - to satisfy the needs of the people in the organization.

This is achieved with the help of upstream and downstream partners of the enterprise. To this, we have to add the corporate citizenship, that is the **social, technological, economical, political, and ecological (STEPE)** responsibility of the enterprise concerning its internal (its people) and external (upstream and downstream) partners, and community. Therefore, total quality management goes well beyond satisfying the customer, or merely offering quality products (goods and/or services). Note that we use the term consumer or end customer. The reason is that in a Supply Chain Management approach, we do not have to satisfy our customers' needs but the needs of our customers' customers' all the way to the end customer, the consumer of a product and/or service.



Figure 35.1: Kodak's Five Quality Principles

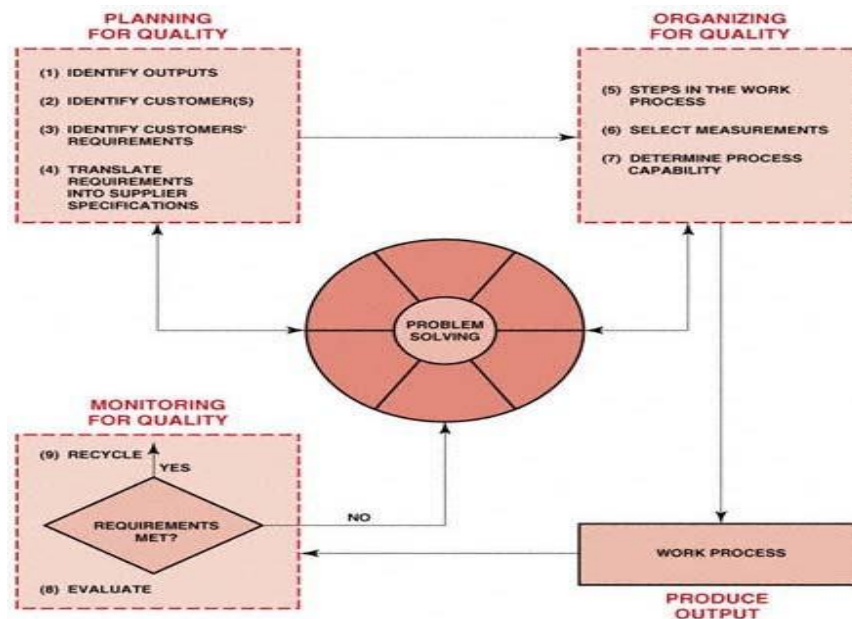


Figure 35.2: The Quality Improvement Process

These two figures (35.1 and 35.2) seem to illustrate that organizations are placing more emphasis on the quality process than on the quality product and, therefore, are actively pursuing quality improvements through a continuous cycle.

35.3 QUALITY AUDIT:

A quality audit is an independent evaluation performed by qualified personnel that ensures that the project is conforming to the project's quality requirements and is following the established quality procedures and policies.

A good quality audit will ensure that:

- The planned quality for the project will be met.
- The products are safe and fit for use.
- All pertinent laws and regulations are followed.
- Data collection and distribution systems are accurate and adequate.

- Proper corrective action is taken when required.
- Improvement opportunities are identified.

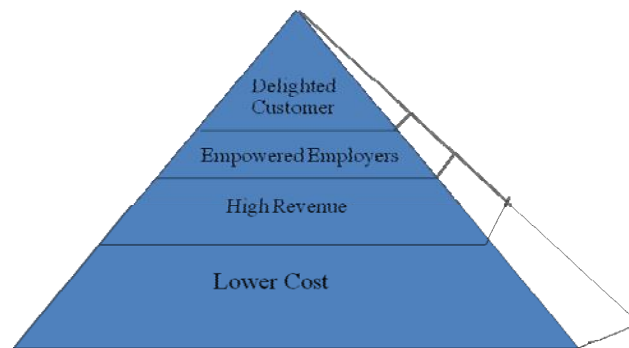


Figure 35.3: The Result of Total Quality

35.4 DEMING'S PHILOSOPHY:

Deming postulated that 85 percent of all quality problems required management to take the initiative and change the process. Only 15 percent of the quality problems could be controlled by the workers on the floor. As an example, the workers on the floor were not at fault because of the poor quality of raw materials that resulted from management's decision to seek out the lowest cost suppliers. Management had to change the purchasing policies and procedures. Management had to develop long-term relationships with vendors.

- Dr. Deming's Dreadful Diseases:
 1. Looking elsewhere for examples, or concluding that "our problems are different."
 2. "Creative accounting" rather than "commitment"
 3. Purchasing to an "acceptable level of quality."
 4. Management's failure to delegate responsibility.
 5. That employees cause all the problems.
 6. Quality can be "assured by inspection".
 7. False starts: no organization-wide commitment.

Although many experts have contributed to the success of the quality movement; the three most influential contributors in this country and internationally are W. Edwards Deming, Joseph M. Juran, and Phillip B. Crosby. Dr. Deming pioneered the use of statistics and sampling methods from 1927 to 1940 at the U.S. Department of agriculture. Dr. Deming applied Dr. Shewhart's Plan/Do/Check/Act cycle to clerical tasks. Figure 35.4 shows the Deming Cycle for Improvement.

Deming contended that workers simply cannot do their best. They had to be shown what constitutes acceptable quality and that continuous improvement is not only possible, but necessary. For this to be accomplished, workers had to be trained in the use of statistical process control charts. Realizing that even training required management's approval, Deming's lectures became more and more focused toward management and what they must do.

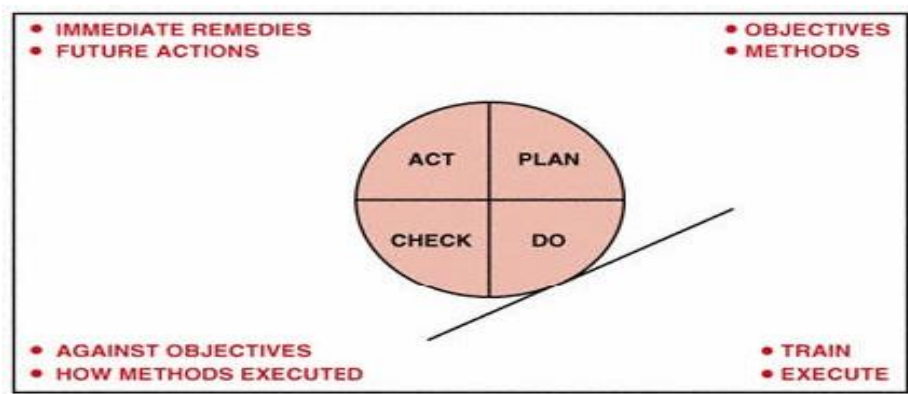


Figure 35.4: The Deming Cycle for Improvement

<u>Conventional Wisdom</u>	<u>Deming's Approach</u>
Quality is meeting conformance standards.	Quality is meeting & exceeding customer expectation.
Quality is an intangible good.	Quality is defined by the customer.
Finding and Fixing problems results in improvements, which may or may not be sustainable.	Making changes to the system to prevent problems results in sustainable improvements.
Effectiveness & efficiency are achieved by meeting acceptable defect levels.	Effectiveness & efficiency are achieved by continually improving.
Crisis management is the dominant management mode.	Preventative management.
Performance standards & quotas improve productivity.	Changes in the process improve productivity.
Decisions are made by "superiors."	Decisions are made through collaboration between staff & management.

Table 35.1

PRINCIPLES OF TOTAL QUALITY

BROAD CONTENTS

Definitions of Total Quality
Total Quality Practices
Principles of Total Quality
Scope of Total Quality Management (TQM)
Empowerment
Cost of Quality

36.1 DEFINITIONS OF TOTAL QUALITY:

1. According to Crosby:
 - Quality is not only free, it is profit maker
 - Increase of 5% -10% in profitability by concentrating on quality
 - Quality provides a lot of money for free

2. PandG Total Quality Management (TQM) Definition:

Total Quality is the unyielding and continually improving effort by everyone in an organization to understand, meet, and exceed the expectations of customers.

3. A V. Feigenbaum:

As already discussed in lecture 34, A V. Feigenbaum introduced comprehensive approach to quality in 50s by virtue of which, quality of products and services were influenced by the following 9Ms:

- *Market*
- *Money*
- *Material*
- *Management*
- *Machines*
- *Men/Women*
- *Motivation*
- *Mechanizations*
- *Modern Information Methods*
- *Mounting Products Requirements*

As already discussed in the previous lecture, total quality is a people-focused management system that aims at continual increase in customer satisfaction at continually lower real cost. Not a separate area or program.

- Integral part of high-level strategy
- Works horizontally across functions and departments
- Involves all employees, top to bottom
- Extends backward and forward to include “supply chain and customer chain”

36.2 TOTAL QUALITY PRACTICES:

It includes the following:

- Encouraging openness

- Creating climates of trust and eliminate fear
- Listening and providing feedback
- Leading and participating in group meetings
- Solving problems with data
- Clarifying goals and resolving conflicts
- Delegating and coaching
- Implementing change
- Making continuous improvement a way of life

36.3 PRINCIPLES OF TOTAL QUALITY:

There are three basic principles of total quality. These are as follows:

- Customer Focus
- Participation and Team work
- Continuous improvement (CI) and learning

36.4 SCOPE OF TOTAL QUALITY MANAGEMENT:

The figure 36.1 below depicts the scope of Total Quality Management (TQM). It is explained in the ensuing paragraphs.



Figure 36.1: Scope of Total Quality Management (TQM)

Infrastructure: Basic management system necessary to function as a high performing organization.

Practices: Activities that occurs within a management system to achieve high performance objectives.

Tools: A wide variety of graphical and statistical methods to plan work activities, collect data analyze results, monitor progress, and solve problems.

36.5 EMPOWERMENT:

Empowerment means that managers must relinquish some of power that they previously held. Power shift creates management fears that workers will abuse this privilege.

Employees have authority and responsibility to make things happen. No one can be best at everything. But when all of us combine our talents, we can be best at virtually anything. Everyone in organization is “captain of his game”. He thinks of his work unit as his “own business”, and perceives that his “work unit” is key part of “corporate enterprise”. It builds “confidence in workers” by showing them that company has confidence in them “to make decision” on their own. Empowerment can be viewed as vertical teamwork between managerial

and non-managerial personnel. People can be trusted to make important decisions about management of their work activities. When people make decisions about management of their work, its result is greater organizational effectiveness.

As a whole participation and empowerment assumes that employees are willing to improve their “daily work process” and “relationships”. Employee participation is essential active, enthusiastic participation by employees essential to success of performance improvement initiative.

Workers know what goes wrong and where hurdle in their processes. If given targets and support they are best to develop creative and effective ideas for “positive change”.

Problem for many project based organization reduction of “bureaucratic red tape” “that prevents employees from seizing the initiative.

36.5.1 Participative Management:

Participative organizations are those that give:

- Information
- Knowledge
- Power
- Rewards to all employees so that everyone can be involved in organization’s performance Participative management. It is essential basis for empowered workforce. Put “everybody’s intellect” to work good thinking is not solely province of managers. Different points of view can help shape better decision.

Participative management require that “responsibility and accountability” takes to lowest possible level empowerment- for three eyes only creation of “corporate” spirit of participation required that workforce have information, involvement and influence.

Participative management does not imply abrogation by management of its responsibility it does imply workforce involvement in decision making process, but final decision on corporate matters remains responsibility of manager.

When empowered employees become convinced that their duty is to their “process” not to their “boss”, wonderful things begin to happen. Teams shoulder responsibility for their “process”, and new, more “cooperative style” of work evolves.

Empowerment encourages “innovation” because employees have authority to “try out” new ideas and make decisions that result in new ways of doing things. Access to information when employees are given access to information their willingness to cooperation and to use empowerment is enhanced.

Due to this “Accessibility”, Teams “Manage and Control Opportunity” More Effectively Than under old “Hierarchical Rules and Structure” where access to info provided on A Need to Know Basis”.

36.5.2 Accountability:

Employees empowered to make decision, yet also held accountable for results. Accountability is not to punish person or to generate immediate, short term results.

Intent is to ensure that empowered employees are:

Giving their best efforts

- a) Working toward “agreed-upon goals”
- b) Behaving responsibly toward each other

36.5.3 *Empowerment – Some Key Principles:*

- People are valuable resource because they have “knowledge and ideas”.
- People want to participate.
- When people participate, they feel empowered; they think like owners.
- When people participate, they look for ways to improved opportunities.
- When people have importance into “corporate and department decisions”, better solutions are developed.
- People should be treated fairly and with respect.

Organizations should make long term commitment for development of people because it makes them valuable to organization. People can develop knowledge to make important decision about management of their work activities.

36.5.4 Six Ways of Empowering Employees for Quality Improvement in Projects:

1. Involve employees in developing strategies for continuous improvement.
2. Provide employees with skills required solving problems and making decisions.
3. Define involvement and empowerment based on mission of organization.
4. Establish organizational and individual goals.
5. Establish customer-driven performance measurement at individual level.
6. Involve and empower everyone to focus on continuous improvement.

Successful empowerment of employees requires:

- Employees should be provided with:
 - Education
 - Resources
 - Encouragement
- Policies and procedures should be examined for needless restrictions.
- Atmosphere of trust should be fostered rather than resentment and punishment for failure.
- Information should be shared “freely” rather than “closely guarded” as “source of control and power”.

36.6 COST OF QUALITY:

To verify that a product or service meets the customer's requirements requires the measurement of the cost of quality. For simplicity's sake, the costs can be classified as "the cost of conformance" and "the cost of nonconformance." Conformance costs include items such as training, indoctrination, verification, validation, testing, maintenance, calibration, and audits. Nonconforming costs include items such as scrap, rework, warranty repairs, product recalls, and complaint handling.

Trying to save a few project dollars by reducing conformance costs could prove disastrous. For example, an American company won a contract as a supplier of Japanese parts. The initial contract called for the delivery of 10,000 parts. During inspection and testing at the customer's (that is, Japanese) facility, two rejects were discovered. The Japanese returned all 10,000 components to the American supplier stating that this batch was not acceptable. In this example, the nonconformance cost could easily be an order of magnitude greater than the conformance cost. The moral is clear:

Feigenbaum divided cost of quality into two categories and four sub categories:

- *Costs of Control*
 - Prevention costs
 - Appraisal costs
- *Costs of Failure of Control*
 - Internal defect costs
 - External defect costs

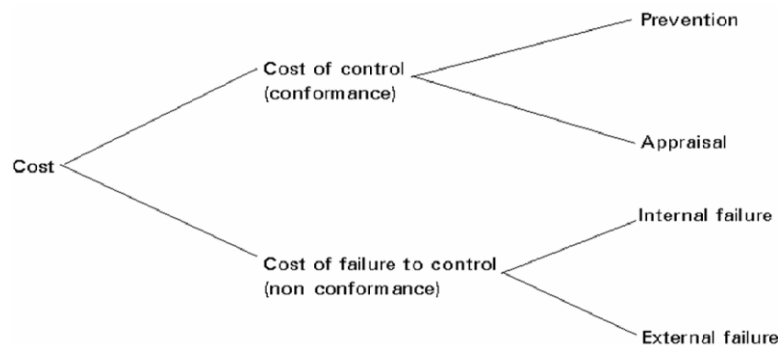


Figure 36.2: Cost of Quality

- **Prevention costs** are the up-front costs oriented toward the satisfaction of customer's requirements with the first and all succeeding units of product produced without defects. Included in this are typically such costs as design review, training, quality planning, surveys of vendors, suppliers, and subcontractors, process studies, and related preventive activities.
- **Appraisal costs** are costs associated with evaluation of product or process to ascertain how well all of the requirements of the customer have been met. Included in this are typically such costs as inspection of product, lab test, vendor control, in-process testing, and internal–external design reviews.
- **Internal failure costs** are those costs associated with the failure of the processes to make products acceptable to the customer, before leaving the control of the organization. Included in this area are scrap, rework, repair, downtime, defect evaluation, evaluation of scrap, and corrective actions for these internal failures.
- **External failure costs** are those costs associated with the determination by the customer that his requirements have not been satisfied. Included are customer returns and allowances, evaluation of customer complaints, inspection at the customer, and customer visits to resolve quality complaints and necessary corrective action.

Prevention costs are expected to actually rise as more time is spent in prevention activities throughout the organization. As processes improve over the long run, appraisal costs will go down as the need to inspect in quality decreases. The biggest savings will come from the

internal failure areas of rework, scrap, reengineering, redo, etc. The additional time spent in up-front design and development will really pay off here. And, finally, the external costs will also come down as processes yield first-time quality on a regular basis. The improvements will continue to affect the company on a long-term basis in both improved quality and lower costs. Also, as project management begins to mature, there should be further decreases in the cost of both maintaining quality and developing products.

Prevention costs actually decrease without sacrificing the purpose of prevention if we can identify and eliminate the costs associated with waste, such as waste due to:

- Rejects of completed work
- Design flaws
- Work in progress
- Improperly instructed manpower
- Excess or noncontributing management (who still charge time to the project)
- Improperly assigned manpower
- Improper utilization of facilities
- Excessive expenses that do not necessarily contribute to the project (that is, unnecessary meetings, travel, lodgings, etc.)

Cost of Quality

Prevention

1. Quality planning
2. Process control
3. Data acquisition and analysis
4. Training and personnel development
5. Design verification
6. Quality system development and management
7. Quality reporting
8. Improvement projects

Appraisal

1. Test and inspection of incoming material
2. Lab-based acceptance sampling
3. In-line inspection and testing
4. Setup for test and inspection
5. Test/inspection equipment and supplies
6. Quality audits
7. Quality endorsements (ISO etc.)
8. Field testing
9. Test/inspection equipment maintenance

Cost of Quality

Internal

1. Scrap
2. Rework
3. Retest
4. Downtown
5. Yield Losses
6. Disposition
7. Engineering Analysis
8. Tracking and Reporting
9. Expediting

External

1. Customer Complaints
2. Warranty Costs
3. Service and Repair Expense
4. Product Liability
5. Recall Expense and Management
6. Returned Material Processing
7. Credit Allowance
8. Loss of Goodwill

Table 36.1: Cost of Quality

CUSTOMER FOCUSED PROJECT MANAGEMENT**BROAD CONTENTS**

Who is customer?
Key Goals for Businesses
Type of customers
Customer Driven Project Organizations
Customer identification
Kano Model
Customer Satisfaction Measurement
CRM (Customer Relationship Management)
Gathering Customer Information
Four Steps to Quality Customer Service

37.1 Who is a customer in any project?

World class projects and organizations are obsessed with meeting and exceeding customer expectations. Firms should learn to have “customer focused projects”, often in response to competitive crises. Customers in any project refer to:

1. Any individual or group that receives and must be satisfied with the work product or output of a process.
2. Individual or group whose request a process is intended to fulfill.
3. Anyone who is impacted by the product or process.

Looking at your project organization from you customers’ point of view and “improving processes” to enable you to meet and exceed your customers’ expectations is the only way to achieve quality.

It important to meet customer expectations as it is the prime responsibility of every organization to meet the needs of its customers. Understanding of one’s customers leads to customer satisfaction. Japanese relate quality to customer satisfaction.



Figure 37.1: Importance of Customer Satisfaction (CS) in Project Management

37.2 Key goals for businesses:

Following are the four key goals for any business:

1. Satisfy customers
2. Achieve higher customer satisfaction than competitors
3. Retain customers in long run
4. Gain market share

To achieve aims and goals, a business must deliver ever-improving value to its customers. Value refers to “quality related to price”. It is important as consumers no longer buy solely on the basis of price.

Customer Satisfaction

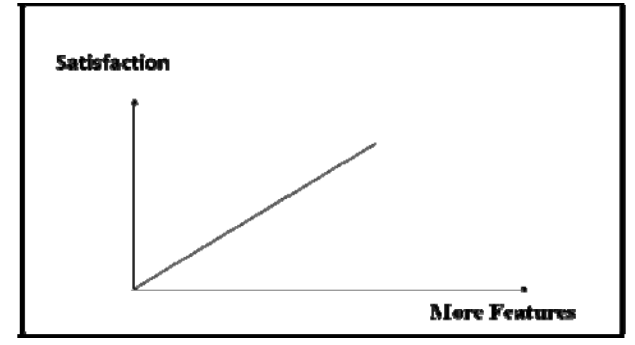


Figure 37.2: Customer Satisfaction

37.3 Types of Customers:

- **Primary:**

“Direct receiver of output of the process” (bank loan seeker, lab test report receiver). It is the source of product and process requirement.

- **Secondary:**

Secondary customers are from “outside of process” boundaries, who also receive any process output, but not reason for “process” existence” (bank’s head office receiver secondary output)

- **Indirect:**

When original boundaries do not receive process output directly but are affected if process output is incorrect or late (logistic department)

- **External Customers:**

Those who are located outside the organizational boundaries, receive end product or service but is not the actual user. (Power supplier for computers manufacturing, distributors)

- **Consumer End User:**

This refers to the final user of the product. Sometimes the external customers and consumers are the same.

- **Intermediary:**

In between producer and end user (Transporter).

- **False:**

When a process that performs activities that do not add value to product or service. Inspectors doing 100 % inspection. It needs to be eliminated.

- **Internal:**

Next person to whom product passed on for further processing. His requests must be met, but not at cost of external customers.

37.4 Customer-Driven Project Organizations:

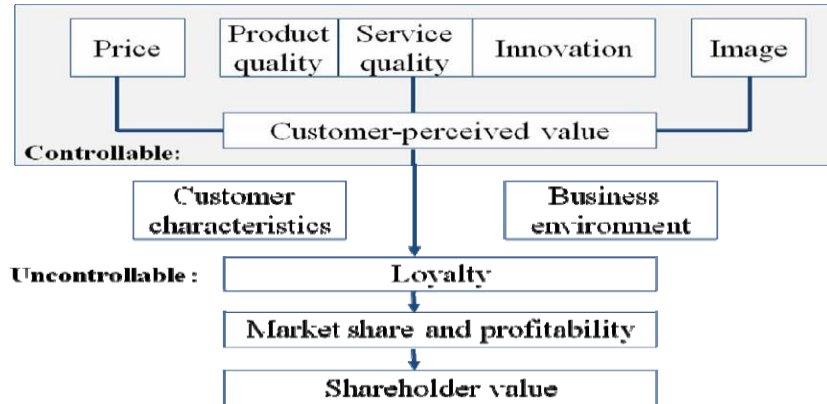


Figure 37.3: Customer Value Package

If competitors offer better choices for similar price, consumers naturally select package with highest “perceived quality”.

37.5 Customer Identification:

37.5.1 Fundamental Questions in Identifying Customers:

Identifying customers begins with asking some fundamental questions:

- What products/services are produced?
- Who uses products/ services?
- Do employees call/ write to/ answer questions for?
- Supplies inputs

37.5.2 Importance of Identifying Customer Types:

Every customer type, source of product, product requirements must be identified and process effectiveness must be measured.

Information on what satisfies customer, and what improvements are necessary. It comes from lost, prospective, and competitors’ customer, who provide useful insights.

37.6 Kano Model:

The Kano Model of Customer (Consumer) Satisfaction classifies product attributes based on how they are perceived by customers and their effect on customer satisfaction. These classifications are useful for guiding design decisions in that they indicate when good is good enough, and when more is better.

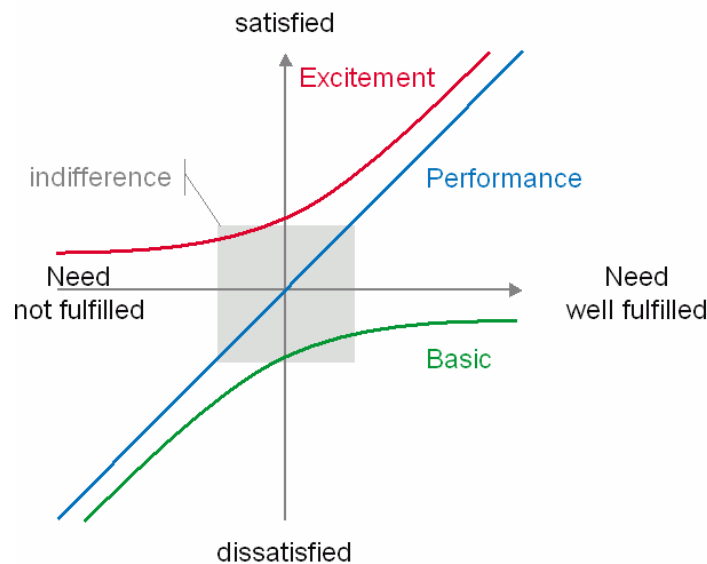


Figure 37.4: Analyzing Customer Satisfaction Data – Kano Model

Project activities in which the Kano Model is useful:

1. Identifying customer needs
2. Determining functional requirements
3. Concept development
4. Analysing competitive products

Other tools that are useful in conjunction with the Kano Model:

1. Eliciting Customer Input
2. Prioritisation Matrices
3. Quality Function Deployment
4. Value Analysis

Introduction

The Kano Model of Customer satisfaction (Figure 37.4) divides product attributes into three categories: threshold, performance, and excitement. A competitive product meets basic attributes, maximises performances attributes, and includes as many “excitement” attributes as possible at a cost the market can bear.

Threshold Attributes

Threshold (or basic) attributes are the expected attributes or “musts” of a product, and do not provide an opportunity for product differentiation. Increasing the performance of these attributes provides diminishing returns in terms of customer satisfaction; however the absence or poor performance of these attributes results in extreme customer dissatisfaction. An example of a threshold attribute would be brakes on a car.

Kano Model Analysis

Threshold attributes are not typically captured in QFDs (Quality Function Deployment) or other evaluation tools as products are not rated on the degree to which a threshold attribute is met, the attribute is either satisfied or not.

Performance Attributes

Performance attributes are those for which more is generally better, and will improve customer satisfaction. Conversely, an absent or weak performance attribute reduces customer satisfaction. Of the needs customers verbalise, most will fall into the category of performance attributes. These attributes will form the weighted needs against which product concepts will be evaluated. The price for which customer is willing to pay for a product is closely tied to performance attributes. For example, customers would be willing to pay more for a car that provides them with better fuel economy.

Excitement Attributes

Excitement attributes are unspoken and unexpected by customers but can result in high levels of customer satisfaction, however their absence does not lead to dissatisfaction. Excitement attributes often satisfy latent needs – real needs of which customers are currently unaware. In a competitive marketplace where manufacturers' products provide similar performance, providing excitement attributes that address “unknown needs” can provide a competitive advantage. Although they have followed the typical evolution to a performance then a threshold attribute, cup holders were initially excitement attributes.

Other Attributes

Products often have attributes that cannot be classified according to the Kano Model. These attributes are often of little or no consequence to the customer, and do not factor into consumer decisions. An example of this type of attribute is a plate listing part numbers can be found under the hood on many vehicles for use by repairpersons.

Application of the Kano Model Analysis

A relatively simple approach to applying the Kano Model Analysis is to ask customers two simple questions for each attribute:

1. Rate your satisfaction if the product has this attribute?; and
2. Rate your satisfaction if the product did not have this attribute?

Kano Model Analysis

Customers should be asked to answer with one of the following responses:

- A) Satisfied;
- B) Neutral (Its normally that way);
- C) Dissatisfied;
- D) Don't care.

Basic attributes generally receive the “Neutral” response to Question 1 and the “Dissatisfied” response to Question 2. Exclusion of these attributes in the product has the potential to severely impact the success of the product in the marketplace.

- Eliminate or include performance or excitement attributes that their presence or absence respectively lead to customer dissatisfaction. This often requires a trade-off analysis against cost. As Customers frequently rate most attributes or functionality as important, asking the question “How much extra would you be willing to pay for this attribute or more of this attribute?” will aid in trade-off decisions, especially for performance attributes. Prioritisation matrices can be useful in determining which excitement attributes would provide the greatest returns on Customer satisfaction.
- Consideration should be given to attributes receiving a “Don't care” response as they will not increase customer satisfaction nor motivate the customer to pay an increased price for the product. However, do not immediately dismiss these attributes if they play a critical role to the product functionality or are necessary for other reasons than to satisfy the customer. The

information obtained from the Kano Model Analysis, specifically regarding performance and excitement attributes, provides valuable input for the Quality Function Deployment process.

37.7 CUSTOMER SATISFACTION MEASUREMENT:

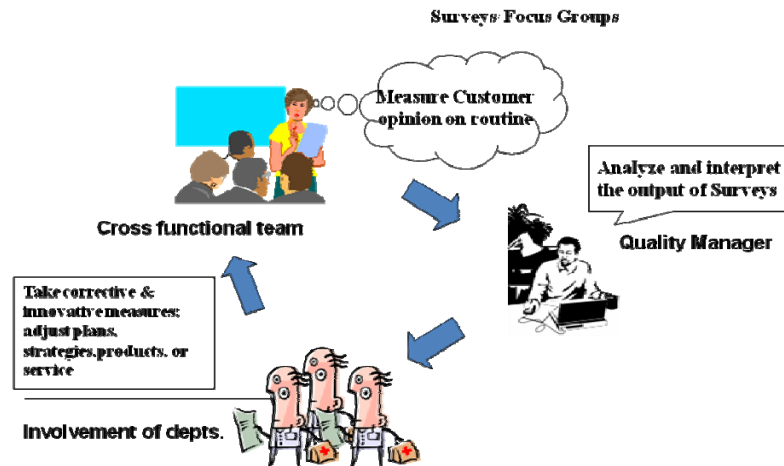


Figure 37.5: Measuring Customer Satisfaction Levels

37.7.1 Methods of Customer Retention:

Following are the methods for retaining customers:

- Establish honest relationship and empathize
- Reward loyalty (airline's frequent flyer)
- Reward usage (Coupons, credit points, preferential treatment)
- Provide unpaid service (free product targets, after sales service)

37.7.2 Seven Steps to Customer Satisfaction System:

- Step 1: Total management commitment
- Step 2: Get to know your customers
- Step 3: Develop “performance and process standards” of service quality
- Step 4: Hire, train, and compensate good staff
- Step 5: Reward service accomplishments
- Step 6: Stay close to your customers
- Step 7: Work towards continuous improvement in “service quality performance”

37.7.3 Customer Defections:

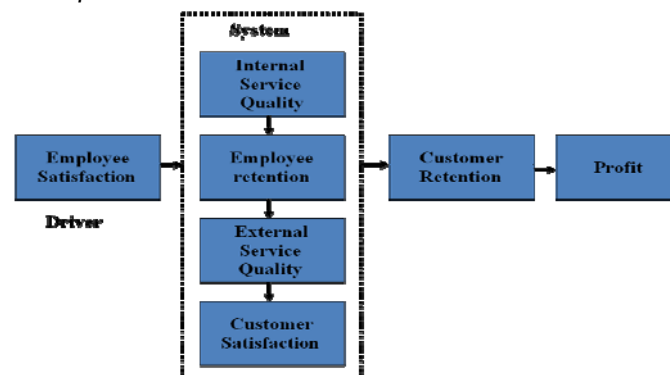


Figure 37.6: Customer Retention and Profitability

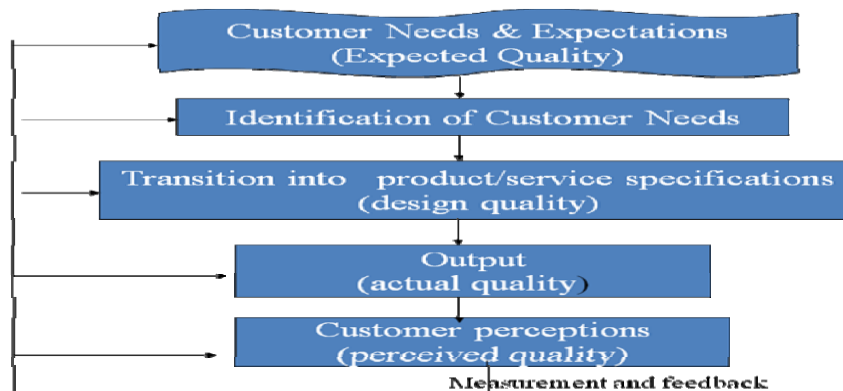


Figure 37.7: Customer Driven Quality Cycle

1. Leading practices for *profitability and market share* must understand linkages between voice of customer and design, production, and delivery processes.
2. Ensures that no critical requirements fall through cracks and minimizes potential gaps between expected quality and actual quality.
3. Make commitment to customer that promotes trust and confidence in products and services.
4. Must have effective Customer Relationship Management (CRM) processes by which customer can easily seek assistance, comment, complain and receive prompt resolution of their concerns.

37.7.4 Must measure Customer Satisfaction:

1. Compare results relative to competitors
2. Use information to evaluate
3. Improve internal processes

37.7.5 Methods of Measuring Customer Satisfaction:

There are the following two methods of measuring customer satisfaction:

1. Quality Dimension Development
2. Generate Critical Incidents

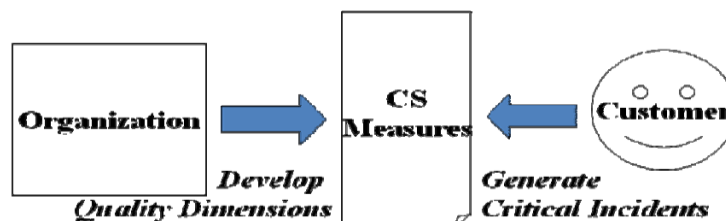


Figure 37.8: Methods of Measuring Customer Satisfaction

37.7.5.1 Quality Dimensions Development Method:

Step 1: Creating list of quality dimensions (Table 37.1):

- a) Read professional literature and enlist quality dimensions
- b) Generate list from personal experience

Step 2: Write definitions of each dimensions:

- a) Definition can be in general terms

Step 3: Develop specific examples for each quality dimension:

- a) Examples: Specific-reflecting service or product
- b) Examples: Specific behaviors of providers
- c) Declarative statements

Product Quality Dimensions

- Basic Functions
- Features
- Reliability
- Conformance
- Durability
- Serviceability
- Aesthetics
- Perceived Quality

Service Quality Dimensions

- Truthfulness
- Respectfulness
- Responsiveness
- Reliability
- Competence
- Communication
- Courtesy
- Access
- Credibility
- Confidentiality/security
- Empathy
- Tangibles

Table 37.1: Quality Dimensions

37.7.5.2 Five Key Dimensions of Service Quality:**1. Reliability:**

- Ability to provide what was promised, dependably and accurately.
- Customer service representatives respond in promised time.
- Following customer instructions.
- Providing error free invoices and statements.
- Making repairs correctly first time.
- Assurance: Knowledge and courtesy of employees.
- Their ability to convey “trust and confidence”.
- Ability to answer questions.
- Having capabilities to do necessary work.
- Monitoring credit card transactions to avoid possible fraud.
- Being polite and pleasant during customer transactions.

2. Tangibles:

- Physical facilities
- Equipment and appearance of persons include:
 - Attractive facilities
 - Appropriately dressed employees
 - Well designed forms that are easy to read and interpret

3. Empathy:

- Degree of Caring and include attention provided to customer
- Explaining “Tech Jargon” in: layman’s language
- Recognizing regular customers by name

4. Responsiveness:

- Willingness to help customer and provide prompt service. For example:
 - Acting quickly to resolve problems
 - Promptly crediting returned merchandise
 - Rapidly replacing defective products

Quality Dimension	Manufactured Product (stereo Amplifier)	Service Product (Checking Account)
Performance	Signal-to-noise ratio; power	Time to process customer requests
Features	Remote Control	Automatic Bill Paying
Conformance	Workmanship	Accuracy
Reliability	Mean time to failure	Variability of time to process requests
Durability	Useful Life	Keeping pace with industry trends
Serviceability	Ease of Repair	Resolution of errors
Aesthetics	Oak Cabinet	Appearance of bank lobby

Table 37.2: Quality Dimensions of a Manufactured Product and Service**5. Timeliness of Support:**

- They completed the job when expected
- They met my deadlines
- They finished their responsibilities within stated time frame
- The project was completed on time

6. Responsiveness of Support:

- They were quick to respond when I asked for help
- They immediately helped me when I needed help
- I waited a short period of time to get help after I asked for it

37.8 Customer Relationship Management (CRM):

Customer Relationship Management (CRM) includes attention to:

- Target and developing customer contact employees.
- Empowering them to do whatever is necessary to satisfy customers.

37.9 Gathering Customer Information:

- **Customer requirements called “voice of customer”:**

There are a variety of methods to “listen” to the Voice of Customer. To do it effectively, information needs to be collected about the customer like:

- a) Needs and expectations
- b) Importance
- c) Satisfaction with company's performance

37.10 Four Steps to Quality Customer Service:

There are the following four steps to quality customer service:

Step 1: Send positive attitude:

- Product Knowledge / command
- Appearance (dress, quality, cleanliness, orderliness, etc)
- Body language (head, arms facial, smile, body movement, eye contact)
- Sound of your voice (tone and how you say it)
 - Face to face
 - On telephone (telephone skills)
- Staying energized
- Empathize (concern for customer's benefits)

Step 2: Identify needs of your customers, guests, clients

- a) Human Needs: (welcomed, respected, comfortable, orderly, understood, helped, important, appreciated, recognized)
- b) Timing Needs: (hold time on telephone, waiting in office, letter response, return calls, appropriate time to meet, width and depth of product/service needs)
- c) Location Needs:
- d) Product Needs: (stated, unstated, basic, delighter)
- e) Create an environment to listen
- f) Careful Listening and Understanding
- g) Feedback / Evaluation

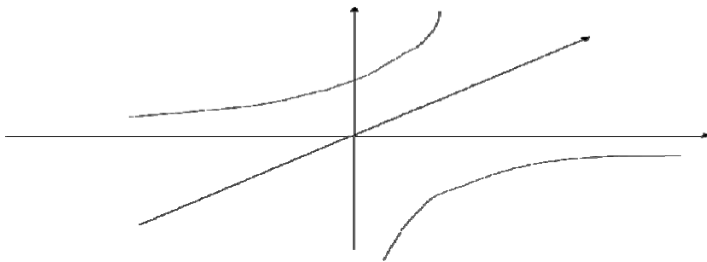


Figure 37.9: Use of Kano Model to Identify Must-be, Delighters and One Dimensional Qualities

Step 3: Provide for needs of your customers, guests, clients

- Are you ready to fulfill the human, timing, location, and product needs of the customer?
- Are you capable to fulfill the human, timing, location, and product needs of the customer?
- Do you have the required product / service to meet the needs of the customer?
- Have you actually fulfilled the human, timing, location, and product needs of the customer?

Step 4: Make sure your customers, clients, guests return to you

- Make sure you delivered both the procedures and the personal
- Be sensitive to check your performance by the outcomes before, during and after the service delivery
- Handling complaint for cases of gaps, customers will complain (within themselves, gestures, light words, strong words, strong reactions).
 - Listen to their stated and non-stated complains carefully

- Empathize
- Repeat and confirm whether you understood clearly
- Apologize genuinely
- Acknowledge sympathy
- Correct the situation
- Identify root-causes and prevent recurrence
- Types of difficult customers with whom you have to deal nicely
 - Angry
 - Nasty or Obnoxious
 - Demanding
 - Constant Critic
 - Non-Stop Talker
 - Indecisive
 - Intoxicated
 - Argumentative
- They are usually difficult for their own reasons - not because of you

Why companies lose customers?

- 1 % of lost customers die
- 3 % move away
- 4 % just naturally float
- 5 % change on a friend's recommendations
- 9 % can buy it cheaper somewhere else
- 10% are chronic complainers
- 68% go elsewhere because the people they deal with are indifferent to their needs

Figure 37.10: Why Companies Lose Customers?

- **Reasons Why Customers are Difficult:**
 - Negative experience
 - Frustrated
 - Confused
 - Satisfy their ego or self-esteem
 - Ignored
 - Treated poorly
 - In bad mood
- **Get Difficult Customers on Your Side:**
 - Do not take it personally, hold on to your confidence
 - Remain calm; listen carefully
 - Do not just protect yourself or your company, share his/her grievance
 - Focus on the problem, not the person
 - Turn the difficult one into a satisfied, consider it an accomplishment
- **Take an extra step - surprise the customer. For example:**
 - Ticket agent: would you like me to select a seat for your return flight now?
 - Salesperson: I will deliver it personally this afternoon
 - Nurse: Since you are awake, let me give you a drink
 - Waiter: may I bring extra glass of coffee
 - Hotel desk clerk: may I call a cab for you
 - Mechanic: since car will take long, may I give you a newspaper
 - Grocer: may I give you help to carry your goods
 - Bank Cashier: may I give you brand new notes

Re-engineer your Customer Satisfaction into Quality Customer Satisfaction:

- Customer Satisfaction Vision and Policy
- Customer Satisfaction Training
- Customer Satisfaction Personality Grooming and Development
- Customer Satisfaction Systems and Procedures
- Customer Satisfaction Consistency
- Customer Satisfaction Measurement (e.g. customer retention rate)
- Develop and regularize Customer Satisfaction Delighters

1. Determine Questions:

- Be Concise, Precise
- Be Direct
- Discard Superfluous Words
- Be Unambiguous

Examples: How are these questions?

- The SDO was good
- The bank manager listened to me and took a short time to handle my complaint
- The SDO was not available when he was needed
- The SDO was available when he was needed
- **The staff was courteous**

2. Response Format:

- Checklist Format (yes/no)
- Liker-type (1-5 scale)

1	2	3	4	5
Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Very Dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very Satisfied
Very Poor	Poor	Neither Poor nor Good	Good	Very Good

Table 37.3: Liker Scale**“Introduction” to Questionnaires:**

For example: “To better serve you, we would like to know your opinion of the quality of our service at XYZ Company. You recently received service from our company. Please indicate the extent to which you agree or disagree with the following statements about the service you received from the staff. Circle the appropriate number using the scale below.

1, 2, 3, 4, 5

Finally, select appropriate questions; ensure critical customer requirements are addressed properly.

Sampling

Some of the common sampling techniques used are briefly defined below:

1. **Census**
 - To gather information from all of customers (sample is the total population) for example, doctors response by drug manufacturers.
2. **Judgmental Sampling**
 - Use judgment in the selection of customers.
3. **Statistical Sampling**
 - Select sample based on statistical probability (rely on chance). It becomes easy to generalize, if not biased.

QUALITY IMPROVEMENT TOOLS

BROAD CONTENTS

Seven Basic Tools of Statistical Process Control

38.1 Seven Basic Tools of Statistical Process Control (SPC):

They are as follows:

1. Data Tables
2. Cause-and Effect Analysis
3. Histograms
4. Pareto Analysis
5. Scatter Diagrams
6. Trend Analysis
7. Process Control Charts

Quality Improvement Tools:

Over the years, statistical methods have become prevalent throughout business, industry, and science. With the availability of advanced, automated systems that collect, tabulate, and analyze data; the practical application of these quantitative methods continues to grow. Statistics today plays a major role in all phases of modern business.

More important than the quantitative methods themselves is their impact on the basic philosophy of business. The statistical point of view takes decision making out of the subjective autocratic decision-making arena by providing the basis for objective decisions based on quantifiable facts.

This change provides some very specific benefits:

- Improved process information
- Better communication
- Discussion based on facts
- Consensus for action
- Information for process changes

Statistical Process Control (SPC) takes advantage of the natural characteristics of any process. All business activities can be described as specific processes with known tolerances and measurable variances. The measurement of these variances and the resulting information provide the basis for continuous process improvement. The tools presented here provide both a graphical and measured representation of process data. The systematic application of these tools empowers business people to control products and processes to become world-class competitors.

The basic tools of statistical process control are data figures, Pareto analysis, cause-and-effect analysis, trend analysis, histograms, scatter diagrams, and process control charts. These basic tools provide for the efficient collection of data, identification of patterns in the data, and measurement of variability.

The following Figure 38.1 shows the relationships among these seven tools and their use for the identification and analysis of improvement opportunities. We will review these tools and discuss their implementation and applications.

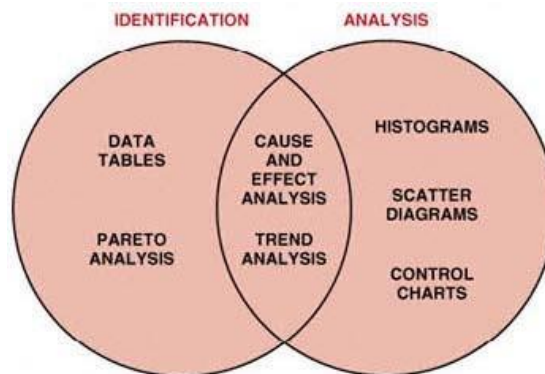


Figure 38.1: Seven Quality Improvement Tools

38.1.1 Data Tables:

Data tables or data arrays provide a systematic method for collecting and displaying data. In most cases, data tables are forms designed for the purpose of collecting specific data. These tables are used most frequently where data is available from automated media. They provide a consistent, effective, and economical approach to gathering data, organizing them for analysis, and displaying them for preliminary review. Data tables sometimes take the form of manual check sheets where automated data are not necessary or available. Data figures and check sheets should be designed to minimize the need for complicated entries. Simple-to-understand, straightforward tables are a key to successful data gathering.

Figure 38.2 is an example of an attribute (pass/fail) data figure for the correctness of invoices. From this simple check sheet several data points become apparent. The total number of defects is 34. The highest number of defects is from supplier A, and the most frequent defect is incorrect test documentation. We can subject this data to further analysis by using Pareto analysis, control charts, and other statistical tools.

In this check sheet, the categories represent defects found during the material receipt and inspection function. The following defect categories provide an explanation of the check sheet:

- *Incorrect invoices:* The invoice does not match the purchase order.
- *Incorrect inventory:* The inventory of the material does not match the invoice.
- *Damaged material:* The material received was damaged and rejected.
- *Incorrect test documentation:* The required supplier test certificate was not received and the material was rejected.

DEFECT	SUPPLIER				
	A	B	C	D	TOTAL
INCORRECT INVOICE	////	/		//	7
INCORRECT INVENTORY	////	//	/	/	9
DAMAGED MATERIAL	///		//	///	8
INCORRECT TEST DOCUMENTATION	/	///	////	//	10
TOTAL	13	6	7	8	34

Figure 38.2: Check Sheet for “Material Receipt and Inspection”

38.1.2 Cause-and -Effect Analysis (C and EA) “Fishbone”:

After identifying a problem, it is necessary to determine its cause. The cause-and-effect relationship is at times obscure. A considerable amount of analysis often is required to determine the specific cause or causes of the problem.

Cause-and-effect analysis uses diagramming techniques to identify the relationship between an effect and its causes. *Cause-and-effect diagrams are also known as fishbone diagrams.* Figure 38.3 demonstrates the basic fishbone diagram. Six steps are used to perform a cause-and-effect analysis.

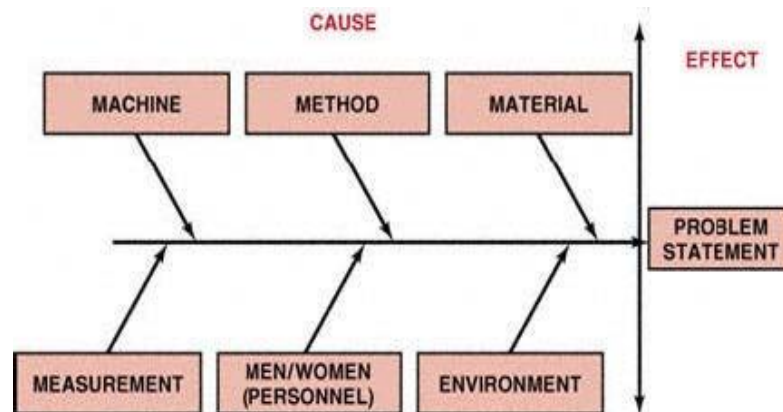


Figure 38.3: Cause-and-Effect Diagram

Step 1 – Identify the problem:

This step often involves the use of other statistical process control tools, such as Pareto analysis, histograms, and control charts, as well as brainstorming. The result is a clear, concise problem statement.

Step 2 – Select interdisciplinary brainstorming team:

Select an interdisciplinary team, based on the technical, analytical, and management knowledge required determining the causes of the problem.

Step 3 – Draw problem box and prime arrow:

The problem contains the problem statement being evaluated for cause and effect. The prime arrow functions as the foundation for their major categories.

Step 4 – Specify major categories:

Identify the major categories contributing to the problem stated in the problem box. The six basic categories for the primary causes of the problems are most frequently

personnel, method, materials, machinery, measurements, and environment, as shown in Figure 38.3. Other categories may be specified, based on the needs of the analysis.

Step 5 – Identify defect causes:

When you have identified the major causes contributing to the problem, you can determine the causes related to each of the major categories. There are three approaches to this analysis: *the random method*, *the systematic method*, and *the process analysis method*.

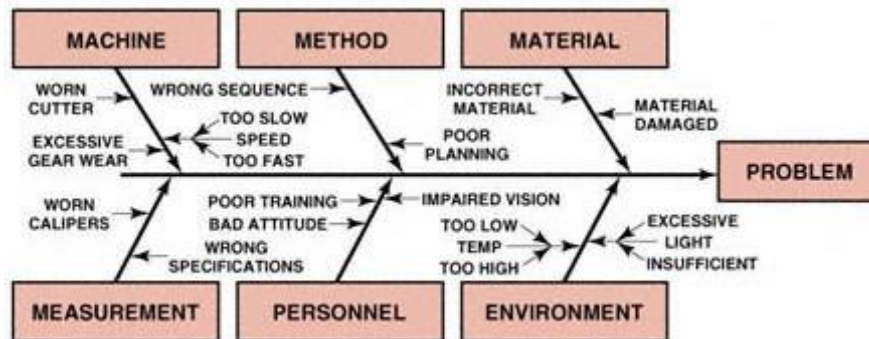


Figure 38.4: Random Method

Random method: List all six major causes contributing to the problem at the same time. Identify the possible causes related to each of the categories, as shown in Figure 38.4.

Systematic method: Focus your analysis on one major category at a time, in descending order of importance. Move to the next most important category only after completing the most important one. This process is diagrammed in Figure 38.5.

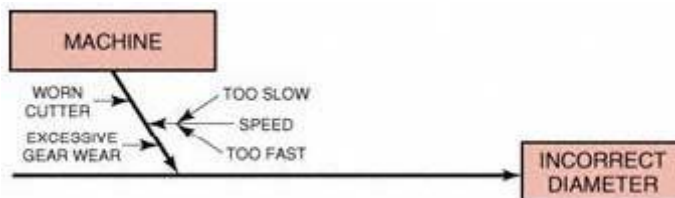


Figure 38.5: Systematic Method

Process analysis method: Identify each sequential step in the process and perform cause-and-effect analysis for each step, one at a time. Figure 38.6 represents this approach.

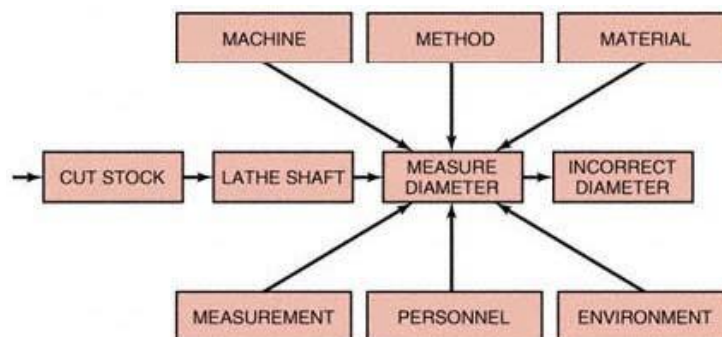


Figure 38.6: Process Analysis Methods

Step 6 – Identify corrective action:

Based on (1) the cause-and-effect analysis of the problem and (2) the determination of causes contributing to each major category, identify corrective action.

The corrective action analysis is performed in the same manner as the cause-and-effect analysis. The cause-and-effect diagram is simply reversed so that the problem box becomes the corrective action box. Figure 38.7 displays the method for identifying corrective action.

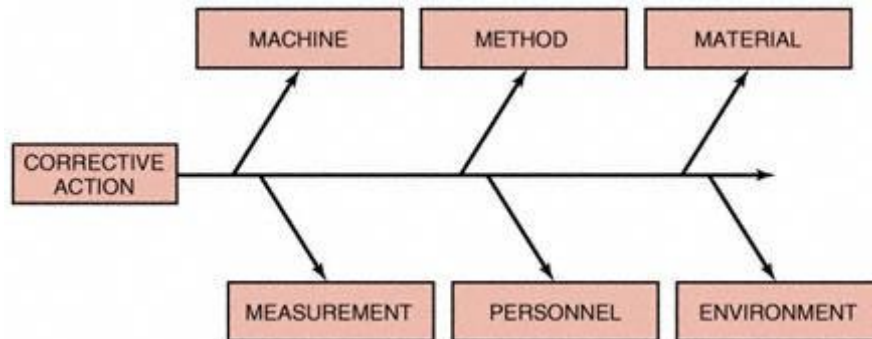


Figure 38.7: Identify Corrective Action

38.1.3 Histogram-(HG):

A histogram is a graphical representation of data as a frequency distribution. This tool is valuable in evaluating both attribute (pass/fail) and variable (measurement) data. Histograms offer a quick look at the data at a single point in time; they do not display variance or trends over time. A histogram displays how the cumulative data looks *today*. It is useful in understanding the relative frequencies (percentages) or frequency (numbers) of the data and how that data are distributed. Figure 38.8 illustrates a histogram of the frequency of defects in a manufacturing process.

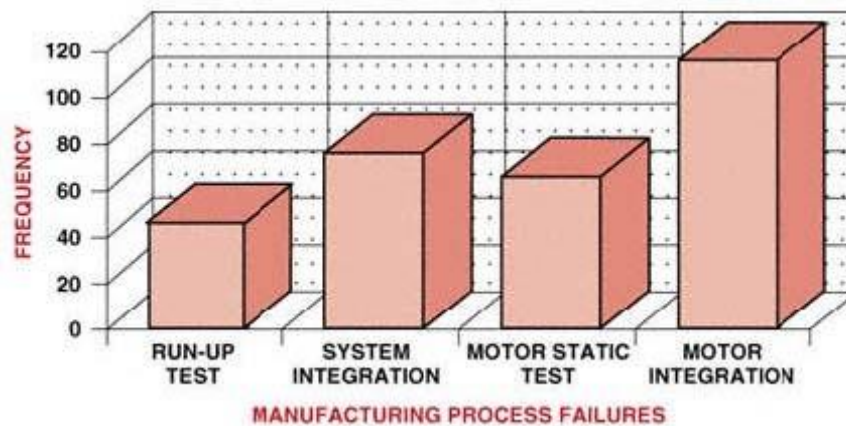


Figure 38.8: Histogram for Variables

38.1.4 Pareto Analysis (PA):

A Pareto diagram is a special type of histogram that helps us to identify and prioritize problem areas. The construction of a Pareto diagram may involve data collected from data figures, maintenance data, repair data, parts scrap rates, or other sources. By identifying types of nonconformity from any of these data sources, the Pareto diagram directs attention to the most frequently occurring element.

There are three uses and types of Pareto analysis:

1. The basic Pareto analysis identifies the vital few contributors that account for most quality problems in any system.
2. The comparative Pareto analysis focuses on any number of program options or actions.
3. The weighted Pareto analysis gives a measure of significance to factors that may not appear significant at first— such additional factors as cost, time, and criticality.

The basic Pareto analysis chart provides an evaluation of the most frequent occurrences for any given data set. By applying the Pareto analysis steps to the material receipt and inspection process described in Figure 38.9, we can produce the basic Pareto analysis demonstrated in Figure 38.10. This basic Pareto analysis quantifies and graphs the frequency of occurrence for material receipt and inspection and further identifies the most significant, based on frequency.

MATERIAL RECEIPT AND INSPECTION FREQUENCY OF FAILURES			
SUPPLIER	FAILING FREQUENCY	PERCENT FAILING	CUMULATIVE PERCENT
A	13	38	38
B	6	17	55
C	7	20	75
D	9	25	100

Figure 38.9: Material Receipt and Inspection Frequency of Failures

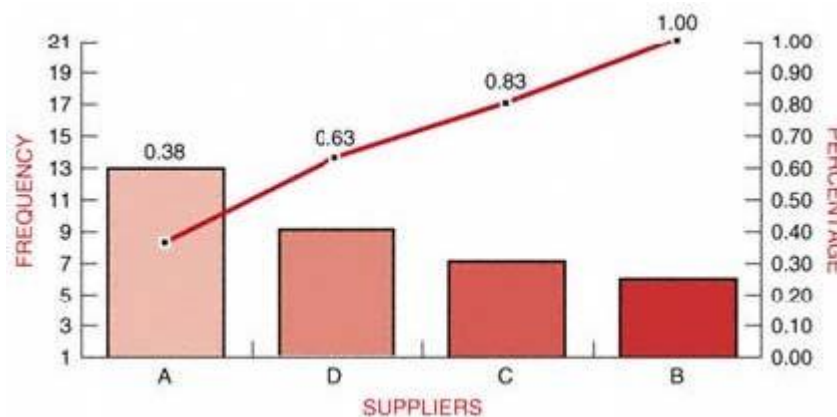


Figure 38.10: Basic Pareto Analysis

A review of this basic Pareto analysis for frequency of occurrences indicates that supplier A is experiencing the most rejections with 37 percent of all the failures.

Pareto analysis diagrams are also used to determine the effect of corrective action, or to analyze the difference between two or more processes and methods. Figure 38.11

displays the use of this Pareto method to assess the difference in defects after corrective action.

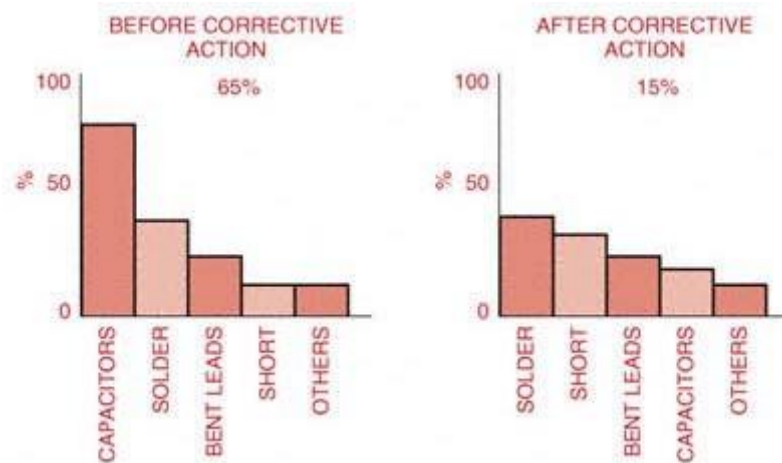


Figure 38.11: Comparative Pareto Analysis

38.1.5 Scatter Diagrams:

Another pictorial representation of process control data is the scatter plot or scatter diagram. A scatter diagram organizes data using two variables: an independent variable and a dependent variable. These data are then recorded on a simple graph with *X* and *Y* coordinates showing the relationship between the variables. Figure 38.12 displays the relationship between two of the data elements from solder qualification test scores. The independent variable, experience in months, is listed on the *X*-axis. The dependent variable is the score, which is recorded on the *Y*-axis.

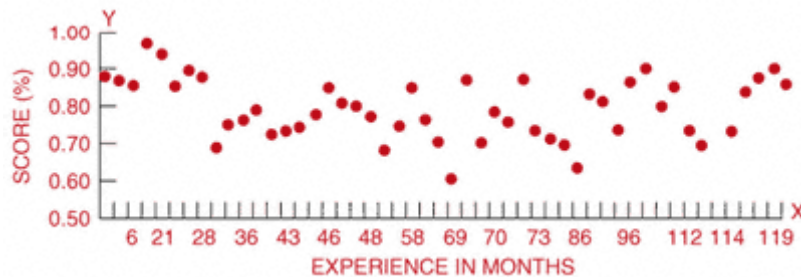


Figure 38.12: Solder Certification Test Score

These relationships fall into several categories, as shown in Figure 38.13 below. In the first scatter plot there is no correlation—the data points are widely scattered with no apparent pattern.

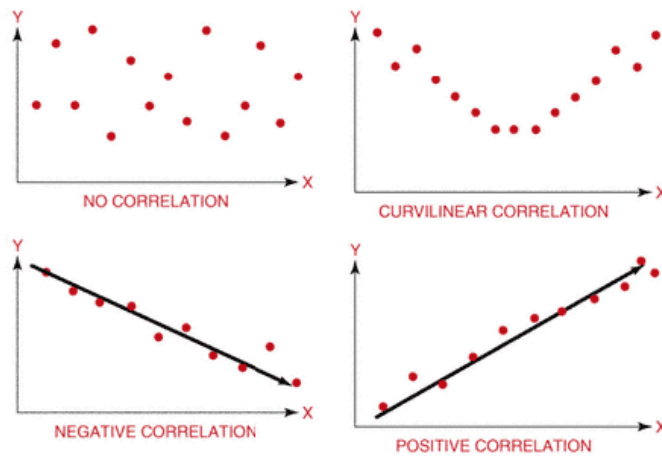


Figure 38.13: Scatter Plot Correlation

The second scatter plot shows a curvilinear correlation demonstrated by the U shape of the graph. The third scatter plot has a negative correlation, as indicated by the downward slope. The final scatter plot has a positive correlation with an upward slope.

From Figure 38.12 we can see that the scatter plot for solder certification testing is somewhat curvilinear. The least and the most experienced employees scored highest, whereas those with an intermediate level of experience did relatively poorly. The next tool, trend analysis, will help clarify and quantify these relationships.

38.1.6 Trend Analysis (T/A):

Trend analysis is a statistical method for determining the equation that best fits the data in a scatter plot. Trend analysis quantifies the relationships of the data, determines the equation, and measures the fit of the equation to the data. This method is also known as curve fitting or least squares.

Trend analysis can determine optimal operating conditions by providing an equation that describes the relationship between the dependent (output) and independent (input) variables. An example is the data set concerning experience and scores on the solder certification test (see Figure 38.14).

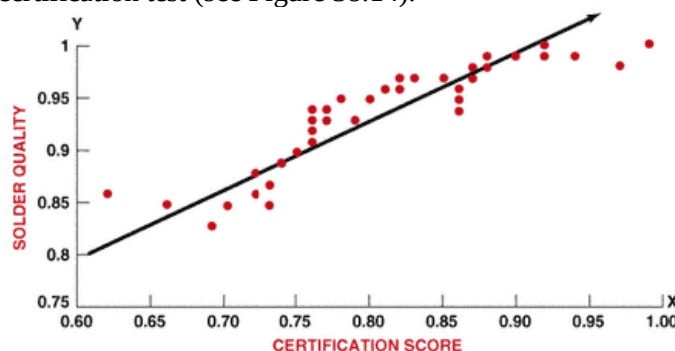


Figure 38.14: Scatter Plot Solder Quality and Certification Score

The equation of the regression line, or trend line, provides a clear and understandable measure of the change caused in the output variable by every incremental change of the input or independent variable. Using this principle, we can predict the effect of changes in the process.

One of the most important contributions that can be made by trend analysis is forecasting. Forecasting enables us to predict what is likely to occur in the future. Based on the regression line we can forecast what will happen as the independent variable attain values beyond the existing data.

38.1.7 Process Control Charts (C/C):

The use of control charts focuses on the prevention of defects, rather than their detection and rejection. In business, government, and industry, economy and efficiency are always best served by prevention. It costs much more to produce an unsatisfactory product or service than it does to produce a satisfactory one. There are many costs associated with producing unsatisfactory goods and services. These costs are in labor, materials, facilities, and the loss of customers. The cost of producing a proper product can be reduced significantly by the application of statistical process control charts.

- **Control Charts and the Normal Distribution:**

The construction, use, and interpretation of control charts is based on the normal statistical distribution as indicated in Figure 38.15. The centerline of the control chart represents the average or mean of the data ($\bar{x}$). The *upper and lower control limits (UCL and LCL)*, respectively, represent this mean plus and minus three standard deviations of the data either the lowercase s or the Greek letter σ . (σ) represents the standard deviation for control charts.

The normal distribution and its relationship to control charts are represented on the right of the figure. The normal distribution can be described entirely by its mean and standard deviation. The normal distribution is a bell-shaped curve (sometimes called the Gaussian distribution) that is symmetrical about the mean, slopes downward on both sides to infinity, and theoretically has an infinite range. In the normal distribution 99.73 percent of all measurements lie within and; this is why the limits on control charts are called three-sigma limits.

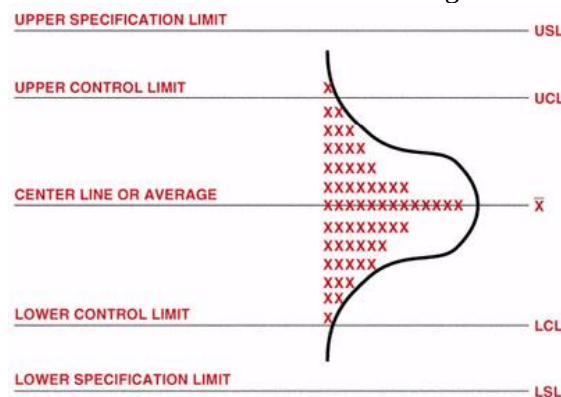


Figure 38.15: The Control Chart and Normal Curve

Companies like Motorola have embarked upon a six-sigma limit rather than a three-sigma limit. The benefit is shown in Table 38.1 below. With a six-sigma limit, only two defects per billion are allowed. The cost to maintain a six-sigma limit can be extremely expensive unless the cost can be spread out over, say, 1 billion units produced

Control chart analysis determines whether the inherent process variability and the process average are at stable levels, whether one or both are out of statistical control

(not stable), or whether appropriate action needs to be taken. Another purpose of using control charts is to distinguish between the inherent, random variability of a process and the variability attributed to an assignable cause. The sources of random variability are often referred to as common causes. These are the sources that cannot be changed readily, without significant restructuring of the process. Special cause variability, by contrast, is subject to correction within the process under process control.

Common cause variability or variation: This source of random variation is always present in any process. It is that part of the variability inherent in the process itself. The cause of this variation can be corrected only by a management decision to change the basic process.

Special cause variability or variation: This variation can be controlled at the local or operational level. Special causes are indicated by a point on the control chart that is beyond the control limit or by a persistent trend approaching the control limit.

TABLE 1. ATTRIBUTES OF THE NORMAL (STANDARD) DISTRIBUTION

Specification Range (in $\pm$ Sigmas),	Percent within Range,	Defective Parts
1	68.27	317,300,000
2	95.45	430,000
3	99.73	730,000
4	99.9937	63,000
5	99.999943	57
6	99.999998	2

Table 38.1: Attributes of the Normal (Standard) Distribution

To use process control measurement data effectively, it is important to understand the concept of variation. No two product or process characteristics are exactly alike, because any process contains many sources of variability. The differences between products may be large, or they may be almost immeasurably small, but they are always present. Some sources of variation in the process can cause immediate differences in the product, such as a change in suppliers or the accuracy of an individual's work. Other sources of variation, such as tool wear, environmental changes, or increased administrative control, tend to cause changes in the product or service only over a longer period of time.

To control and improve a process, we must trace the total variation back to its sources. Again the sources are common cause and special cause variability. Common causes are the many sources of variation that always exist within a process that is in a state of statistical control. Special causes (often called assignable causes) are any factors causing variation that cannot be adequately explained by any single distribution of the process output, as would be the case if the process were in statistical control. Unless all the special causes of variation are identified and corrected, they will continue to affect the process output in unpredictable ways.

The factors that cause the most variability in the process are the main factors found on cause-and-effect analysis charts: people, machines, methodology, materials, measurement, and environment. These causes can either result from special causes or be common causes inherent in the process.

The theory of control charts suggests that if the source of variation is from chance alone, the process will remain within the three-sigma limits. When the process goes out of control, special causes exist. These need to be investigated and corrective action must be taken.

- **Control Chart Types:**

Just as there are two types of data, continuous and discrete, there are two types of control charts: variable charts for use with continuous data and attribute charts for use with discrete data. Each type of control chart can be used with specific types of data. Table 38.2 provides a brief overview of the types of control charts and their applications.

Variables charts: Control charts for variables are powerful tools that we can use when measurements from a process are variable. Examples of variable data are the diameter of a bearing, electrical output, or the torque on a fastener.

Variables Charts

$\bar{X}$ and R charts: To observe changes in the mean and range (variance) of a process.

$\bar{X}$ and s charts: For a variable average and standard deviation.

$\bar{X}$ and s^2 charts: for a variable average and variance.

Attributes Charts

p chart: For the fraction of attributes nonconforming or defective in a sample of varying size.

np charts: For the number of attributes nonconforming or defective in a sample of constant size.

c charts: For the number of attributes nonconforming or defects in a single item within a subgroup, lot, or sample area of constant size.

u charts: For the number of attributes nonconforming or defects in a single item within a subgroup, lot, or sample area of varying size.

Table 38.2: Types of Control Charts and Application

As shown in Table 38.2, $\bar{X}$ and R charts are used to measure control processes whose characteristics are continuous variables such as weight, length, ohms, time, or volume. The p and NP charts are used to measure and control processes displaying attribute characteristics in a sample. We use p charts when the number of failures is expressed as a fraction, or NP charts when the failures are expressed as a number. The c and u charts are used to measure the number or portion of defects in a single item. The c control chart is applied when the sample size or area is fixed, and the u chart when the sample size or area is not fixed.

Attribute charts: Although control charts are most often thought of in terms of variables, there are also versions for attributes. Attribute data have only two values (conforming/nonconforming, pass/fail, go/no-go, present/absent), but they can still be counted, recorded, and analyzed. Some examples are: the presence of a required label, the installation of all required fasteners, the presence of solder drips, or the continuity of an electrical circuit. We also use attribute charts for characteristics that are measurable, if the results are recorded in a simple yes/no fashion, such as the conformance of a shaft diameter when measured on a go/no-go gauge, or the acceptability of threshold margins to a visual or gauge check.

It is possible to use control charts for operations in which attributes are the basis for inspection, in a manner similar to that for variables but with certain differences. If

we deal with the fraction rejected out of a sample, the type of control chart used is called a p chart. If we deal with the actual number rejected, the control chart is called an NP chart. If articles can have more than one nonconformity, and all are counted for subgroups of fixed size, the control chart is called a c chart. Finally, if the number of nonconformities per unit is the quantity of interest, the control chart is called a u chart.

The power of control charts (Shewhart techniques) lies in their ability to determine if the cause of variation is a special cause that can be affected at the process level, or a common cause that requires a change at the management level. The information from the control chart can then be used to direct the efforts of engineers, technicians, and managers to achieve preventive or corrective action.

The use of statistical control charts is aimed at studying specific ongoing processes in order to keep them in satisfactory control. By contrast, downstream inspection aims to identify defects. In other words, control charts focus on prevention of defects rather than detection and rejection. It seems reasonable, and it has been confirmed in practice, that economy and efficiency are better served by prevention rather than detection.

- **Control Chart Components:**

All control charts have certain features in common (Figure 38.16). Each control chart has a centerline, statistical control limits, and the calculated attribute or control data. Additionally, some control charts contain specification limits.

The centerline is a solid (unbroken) line that represents the mean or arithmetic average of the measurements or counts. This line is also referred to as the $\bar{X}$ line ($\bar{X}$). There are two statistical control limits: the upper control limit for values greater than the mean and the lower control limit for values less than the mean.

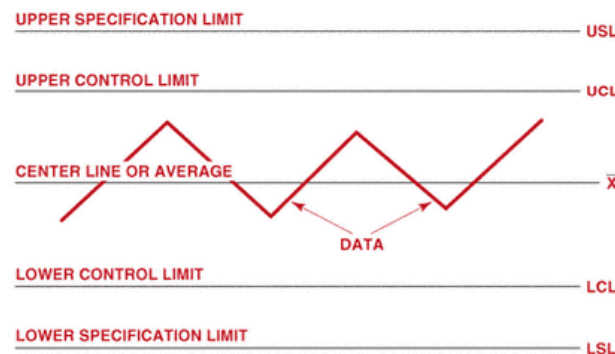


Figure 38.16: Control Chart Elements

Specification limits are used when specific parametric requirements exist for a process, product, or operation. These limits usually apply to the data and are the pass/fail criteria for the operation. They differ from statistical control limits in that they are prescribed for a process, rather than resulting from the measurement of the process.

The data element of control charts varies somewhat among variable and attribute control charts. We will discuss specific examples as a part of the discussion on individual control charts.

- **Control Chart Interpretation:**

There are many possibilities for interpreting various kinds of patterns and shifts on control charts. If properly interpreted, a control chart can tell us much more than simply whether the process is in or out of control. Experience and training can lead to much greater skill in extracting clues regarding process behavior, such as that shown in Figure 38.17. Statistical guidance is invaluable, but an intimate knowledge of the process being studied is vital in bringing about improvements.

A control chart can tell us when to look for trouble, but it cannot by itself tell us where to look, or what cause will be found. Actually, in many cases, one of the greatest benefits from a control chart is that it tells when to leave a process alone. Sometimes the variability is increased unnecessarily when an operator keeps trying to make small corrections, rather than letting the natural range of variability stabilize. The following paragraphs describe some of the ways the underlying distribution patterns can behave or misbehave.

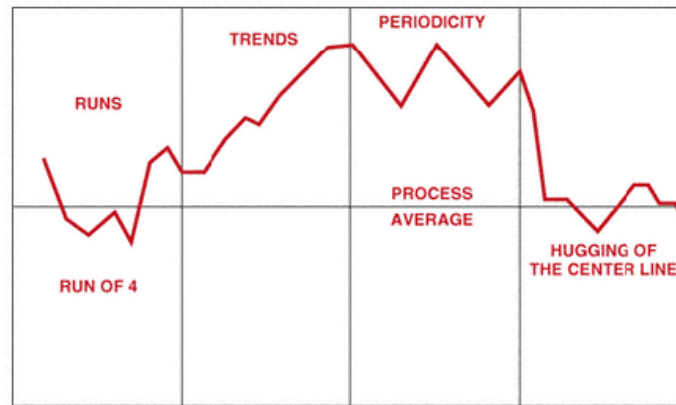


Figure 38.17: Control Chart Interpretation

Runs: When several successive points line up on one side of the central line, this pattern is called a run. The number of points in that run is called the length of the run. As a rule of thumb, if the run has a length of seven points, there is an abnormality in the process. Figure 38.18 demonstrates an example of a run.

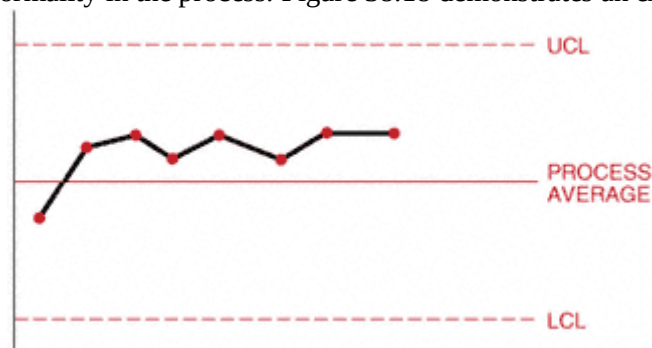


Figure 38.18: Process Run

Trends: If there is a continued rise of all in a series of points, this pattern is called a trend. In general, if seven consecutive points continue to rise or fall, there is an abnormality. Often, the points go beyond one of the control limits before reaching seven. Figure 38.19 demonstrates an example of trends.

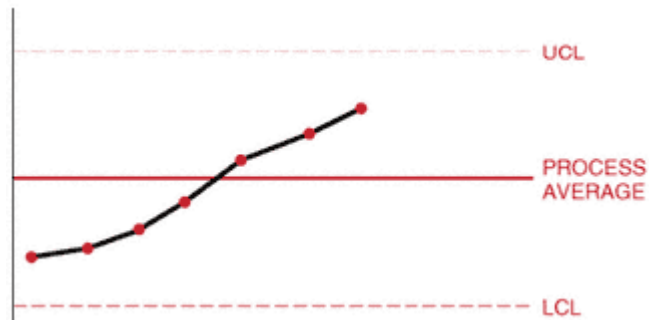


Figure 38.19: Control Chart Trends

Periodicity: Points that show the same pattern of change (rise or fall) over equal intervals denote periodicity. Figure 38.20 demonstrates an example of periodicity.

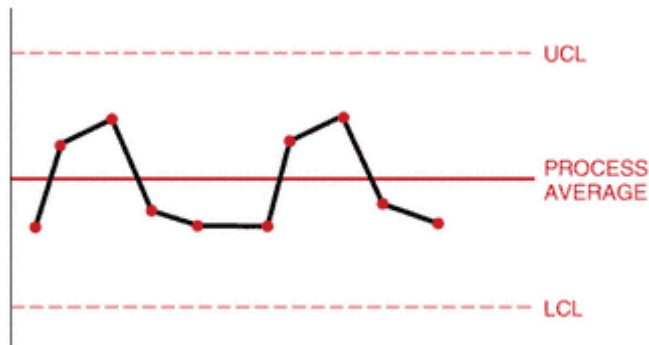


Figure 38.20: Control Chart Periodicity

Hugging the centerline or control limit. Points on the control chart that are close to the central line or to the control limit are said to hug the line. Often, in this situation, different types of data or data from different factors have been mixed into the subgroup. In such cases it is necessary to change the sub-grouping, reassemble the data, and redraw the control chart. To decide whether there is hugging of the center line, draw two lines on the control chart, one between the centerline and the UCL and the other between the center line and the LCL. If most of the points are between these two lines, there is an abnormality. To see whether there is hugging of one of the control limits; draw line two-thirds of the distance between the center line and each of the control lines. There is abnormality if 2 out of 3 points, 3 out of 7 points, or 4 out of 10 points lie within the outer one-third zone. The abnormalities should be evaluated for their cause(s) and the corrective action taken. Figure 38.21 demonstrates data hugging the LCL.

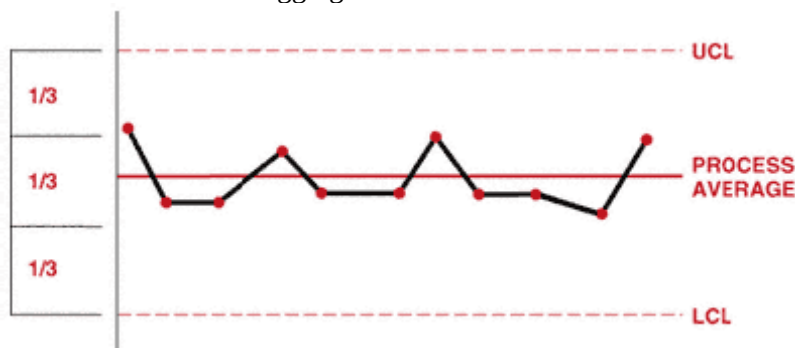


Figure 38.21: Hugging the Centerline

Out of control: An abnormality exists when data points exceed either the upper or lower control limits. Figure 38.22 illustrates this occurrence.

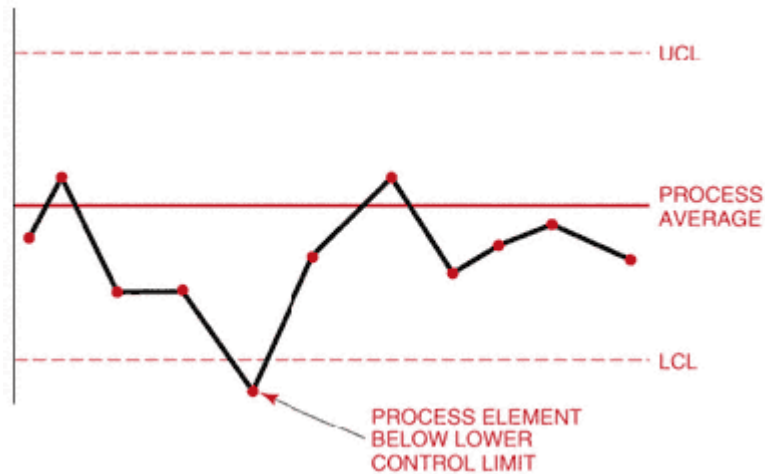


Figure 38.22: Control Chart Out of Control

In control: No obvious abnormalities appear in the control chart. Figure 38.23 demonstrates this desirable process state.

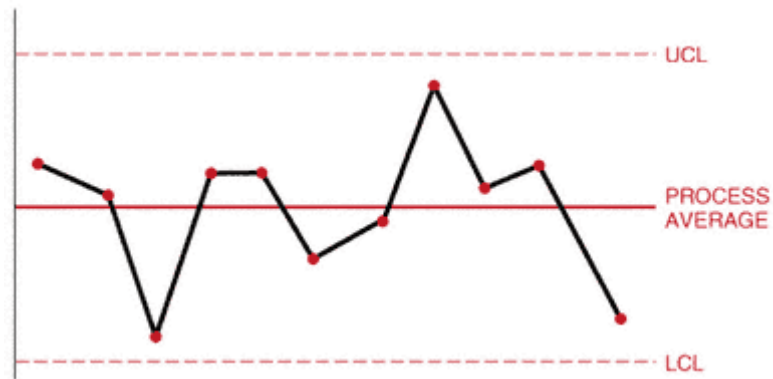


Figure 38.23: Process in Control

PROJECT EFFECTIVENESS THROUGH ENHANCED PRODUCTIVITY**BROAD CONTENTS**

Competitiveness
Productivity in the Context of PM
Definitions of Effectiveness and Efficiency
Types of Productivity
White Collar Productivity
Critical Barriers/ Problems to Productivity
Causes of Productivity Decline in Organizations
Productivity Improvement
Categories of Productivity Factors
Soft Factors

39.1 Competitiveness:

Competitiveness emerged strongly in new era of globalization describes “economic strength” of any “organization” or position of certain company” with respect to its competitors in market place.

Competitiveness is process by which one entity strives to outperform another. Competitiveness in Organization is Ability to get customers to choose your prod or svc over competing alternatives on sustainable basis.

Competitiveness continually “sustained incorporated in productivity” resulting in high wages and living standards competitiveness - demonstrated by “ability to meet, rest of free international markets” while “expanding real income.”

39.1.1 Indicators of Competitiveness:

Macro level competitiveness of nations reflects standard of living of their citizens. National competitiveness consolidation of micro-level performances of company’s and individual is true “Agents of Economic Growth”.



Figure 39.1: Competitiveness Pyramid

Competitiveness depends on productivity:

"Standard of living is determined by productivity of a nation's economy which is measured by the value of goods and services (products) produced per unit of the nation's human, capital and natural resources".

Indicators of competitiveness:

Productivity: Efficiency with which goods and services are produced and provided and determined by:

- Previous investments
- Quality and performance of workforce,
- Technology innovation
- Quality of plant and equipment
- Efficiency with which these factors of production are utilized

Productivity of “local” industries is of fundamental importance to competitiveness. It depends on:

1. Sophistication with “which company’s compete”
2. Quality of “microeconomic business environment”.

When productivity and quality considered together competitiveness can be enhanced. Definition of productivity successful project management organization create surplus through productive output, productivity is output input agreement on consideration “quality and time”.

$$\text{Productivity} = \frac{\text{Outputs (Time /Quality)}}{\text{Inputs}}$$

39.2 Productivity in the Context of Project Management:**39.2.1 Definition of Productivity:**

1. Ratio of output to input by large number of professionals.
2. ILO Definition: “Ratio between “output of wealth produced” and “input resources used up” in “process of production”.
3. Comparative tool for managers, industrial engineers, economists, and politicians.

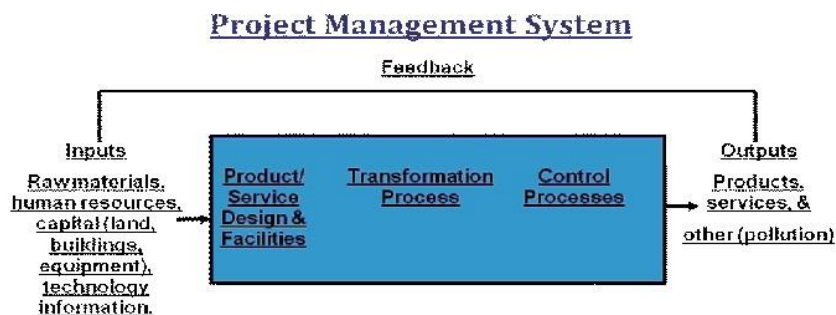


Figure 39.2: Project Management System

39.2.2 Difference between Production and Productivity:

Production: Concerned with activity of “producing goods and or services”.

Productivity: “Efficient utilization of resources” (input) in “producing goods/services” (output).

The basic differences between production and productivity are as follows:

- Production is quantity of output produced.
- Productivity “ratio of output produced in input (s) used”.
- Higher productivity means accomplishing more with same “amount of resources” or achieving higher output In terms of volume/quality for same input.

39.2.3 Messages of Productivity:

Taylor’s Message of Productivity:

- Various pay plans based on output for surplus increase labor productivity not possible work order:
 - a. Provided ample reward
 - b. Adequate targets
 - c. Managerial help
- Careful advance planning by manager
- Managers to design work system for worker to do their best.

Fredrick Concluded:

Low productivity is matter of ignorance on part of labor and management ignorance. “Fair day’s work” and “fair day pay” productivity enhancement answer to high wages/profits.

Peter Drucker Says:

Problem faced in developing countries is problem not of “underdevelopment but rather of under management”. Actually productivity is most serious challenge confronting management.

39.2.4 Perspectives on Productivity:

Productivity – Manager’s Perspective:

Use “accounting ratios” for management-usually interested in productivity measures that enable it to easily assess the present profitability of company.

Productivity – Engineer’s Perspective:

- Seek measures of physical assets and other resources. For example: Production/hour.
- Man hours/unit
- Material required/unit, material/consumption, utilization,
- Space utilization

May fail to relate to overall productivity.

Productivity – Behaviorist’s Perspective:

View productivity of people in organization in terms of time they spend at work versus total time available a misleading measure.

Productivity – Accountant’s Perspective:

“Costing and budgeting” approach to productivity budget figure, rather than optimum achievable values, used as standards can be a false impression of high productivity.

Productivity – Economist’s Perspective:

Partial measures, such as “labor productivity” employed by economists, total factor and total productivity but again definitions do not agree.

39.3 Definition of Effectiveness and Efficiency:

Productivity implies effectiveness and efficiency both individual and organization performance.

- **Effectiveness** is “achievement of objectives”. It entails promptly achieving stated objective.
- **Efficiency** is “achievement of ends with least amount of resources. Resources to achieve objective weighted against what is actually accomplished.

39.3 Types of Productivity:

1. Partial Productivity
2. Total Factor Productivity
3. Total Productivity

Total – Factor Productivity:

Ratio of “net output to sum of associated labor and capital” (factor) inputs net output- total output minus intermediate goods and services purchased.

Finding of Survey in Different Industries

- Average, only 4.4 hours per day used productively
- 1.2 hours lost due to personal and other unavoidable delays
- hrs are simply wasted because of management’s inability to effectively “plan and control” the worker’s tasks.

Productivity Loss:

- Percent due to poor: “Planning and scheduling” of work.
- 25 Percent due to: “Unclear and untimely instructions”.
- Percent due to: “Inability to adjust staff size” and duties during “peak and valley workload periods”.
- 25 Percent due to: “Poor co-ordination” of material flow, unavailability of needed tools, excess travel time.

39.5 White-Collar Productivity:

Productivity of “white-collar workers” is no less important than that of direct labor or manufacturing employees. It is usually least known, least analyzed, and least managed of all factors of productivity. White collar employees are productive only 50% of time. Remainder is non-productive time and can be traced to personal delays (15%) and improper management (35%).

Examples of White Collar Waste:

- Poor staffing
- Inadequate communication
- Unproductive meeting and telephone conversations

- Poor scheduling
- Slack start and quiet times
- Lack of communication between function
- Information overload

39.6 Critical Barriers/Problems to Productivity:

- Family-controlled industry
- Earning easy money
- Monopolistic market, in some segments, some high competitive
- Erratic inflow of orders
- Lack of productivity and quality culture
- Shortage of funds low level codification
- Automation -not encouraged
- Low priority of market and commercial activities
- Poor after service
- Complicated government policy, rules and regulations
- Poor infra structure support/road transport
- Energy shortage
- Poor working conditions, light, ventilation, safety, housekeeping
- Non availability of basic material components (to be imported)
- Unreliable suppliers

39.7 Causes of Productivity Decline in Organizations:

- Inability to measure, evaluates, and manages productivity of white collar employees. This causes shocking waste of resources.
- Rewards and benefits given without requiring equivalent in productivity and accountability
- Diffused authority and inefficiency in complex organizations, thereby, causing delays and time lags.
- Organization expansion lowers productivity growth result in soaring costs.
- Low motivation among rising number of affluent workers with new attitudes.
- Late Deliveries caused by schedule have been disrupted by limited materials.
- Unresolved human conflicts difficulties in teamwork, resulting in project inefficiencies.
- Include legislative intrusions antiquated laws, resulting in constrained “management options and prerogatives”.
- Specialization in work processes resulting in monotony and Boredom.
- Rapid technology changes and high costs, resulting in decline in new opportunities and innovation.
- Include demand of leisure time causing disruption in operations.
- Project manager’s inability to keep pace with the latest information and knowledge.

39.8 Productivity Improvement (PI):

- How can projects improve their productivity?

Productivity is composed of:

- People
- Operations variables

To improve productivity, management needs to focus on the following two points:

- Productivity does not just happen by “trying harder”. It must be planned.
- But how do you plan for productivity, and what factors are involved?

Improvement means “increase ratio of output of goods and services produced divided by input used to produce”. Ratio can be included by either increase output, reducing input or both.

Financial and social benefits of “productivity improvement strategy” in project manager should be greater than “implementation cost”, in long run.

Task of project manager is to evaluate those factors that have bearing on productivity and take appropriate measures to use effectively. In order to raise productivity and to reduce cost, we must eliminate bad features in design and specifications that cause excessive work contents.

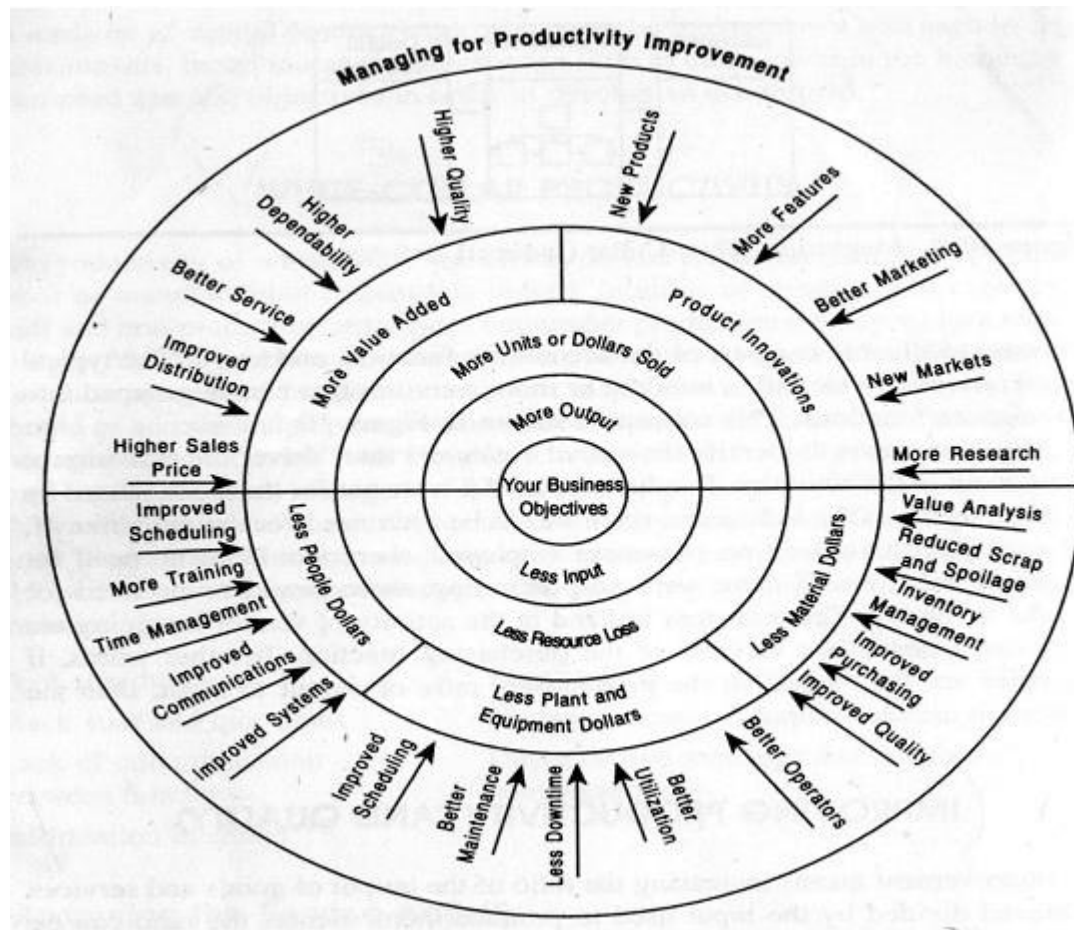


Figure 39.3: Productivity Wheel

39.8.1 Productivity Improvement Factors:

Productivity improvement (PI) is not just “doing things better”, but more importantly, it is “doing right things better”. Inter-relationships between labor, capital and socio-organizational environment are important in a way that they are balanced and co-ordinate into integrated whole.

Three Main Productivity Factor Groups:

There are three major productivity factor groups:

- Job-related
- Resource-related
- Environment-related

39.9 Categories of Productivity Factors:

There are the two following major categories of productivity factors:

- External (not controllable)
- Internal (controllable)

External Factors: Beyond control of individual enterprise. Understanding of them can motivate certain actions which migrates change enterprise's or project behavior and its productivity in LR.

Internal Factors: Within its control first step towards productivity improvement is to identify problem areas within these factor groups.

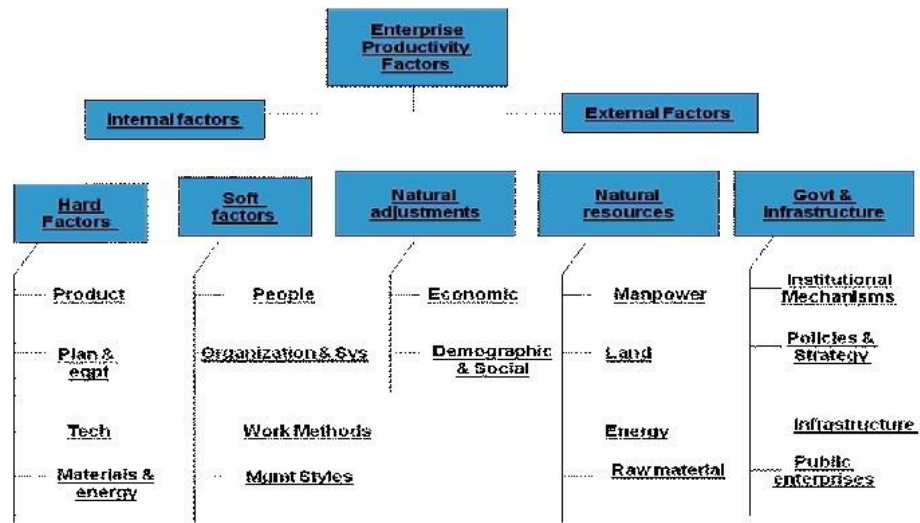


Figure 39.4: Integrated Model of Project Productivity Factors

39.10 Soft Factors:

People: Principal resource central factor in productivity improvement, drives people in organization all have role to play as workers, engineers, managers, entrepreneurs, trade union members.

Each role has two aspects:

- Application
- Effectiveness

Application: Degree to which people apply themselves to their work. People differ not only in their ability but also in their will to work.

Law of Behavior: Motivation decreases if it is either satisfied or blocked from satisfaction. Workers may do their jobs work order working hard (no motivation), but even if they work to their full capacity they would not be satisfied (motivation is blocked from satisfaction).

Motivation is basic to all human behavior and to efforts in productivity improvement. Material needs predominant, but does not mean that non-financial incentives not effective or have no place.

Project manager see what stimulates and maintains motivation to bring about changes in attitude of managers, engineers and workers. Develop set of values conducive to higher productivity.

Workers' success in increasing productivity by:

- Rewards
- Improving recognition
- Involvement

- Learning Opportunities
- Elimination of negative rewards

Execute effective incentive schemes, result significant improvement in productivity. Wage incentives related to amount of change accomplishes.

Project manager should work to encourage workers to apply their creative talents by taking special interest in their problems by promoting favorable social climate.

2. Effectiveness: *Effectiveness is extent to which application of human effort brings desired results in output and quality. It is the ability to do productive job improved through:*

- Training and development
- Job rotation and placements, systematic job progression (promotion)
- Career planning

Key approaches, methods and techniques to improve labor productivity:

- Wages and salaries
- Training and education
- Social security – pensions and health plans
- Rewards
- Incentive plans
- Participation or co-determination
- Contract negotiations
- Attitudes to work, to supervision and to change
- Motivation to higher productivity
- Co-operation
- Organization development
- Improved communications
- Suggestion systems
- Career planning
- Attendance
- Turnover
- Job security

Financial Incentives (Individual and Group):

Individual plan *is made to give financial incentives on basis of individual performance.*

Types of Individual Plan:

- Piece work plan
- Standard hour plan
- Measured day work plan
- Emerson plan

Group plan is made to give financial incentives on basis of group performance.

Types of Group Plan:

- Scanlon plan
- Rucker plan
- Kaiser plan
- Tonnage plane
- Dollar sales plan

- Profit sharing
- Improshare

Fringe Benefits:

Some intangible means of rewarding and encouraging management employee. These are referred to as “fringes” and include the following:

- Free Medical
- Insurance
- Free Air
- Fares
- Entertainment
- Company Car
- Telephone
- Subsidized education etc.

Employee Promotion:

- Both financial and non-financial form of motivation: Up gradation of employee status is natural way to recognize skill knowledge, proficiency, and efforts to job.

Maslow’s Hierarchy of Needs.

Only dissatisfied needs can motivate workers to high productivity,) physiological, safety, security, belongingness, self esteem, self actualization (realizations of one potential)

- Japanese on basis of seniority
- USA on basis of extra ordinary performance
- Debatable issue

Job Enrichment:

Non-financial-motivation technique that provides

- Variety in assigned tasks
- Employment autonomy and discretion in performing tasks
- Feed back on performance
- Herzberg’s two-factor theory applied

Two Factors Theory:

“Motivators” factors leading to job satisfaction. Achievement recognition, nature of work responsibility, growth etc. Factors leading to dissatisfaction avoidance are Hygiene, Company’s policy, admin, supervision, pay status

Job Enlargement:

- Enlargement of responsibilities associated with job.
- Enhanced scope and responsibility. Proponents say job get to be boring and monotonous, causing high absenteeism, high turnover, and low morale, with consequent low productivity.
- Volvo Sweden. Worker could stamp name on engine.

Job Rotation:

Involves rotation of workers in different jobs for short periods of time provide “all-rounder” in company’s op –for which - not originally hired for:

- Relieves boredom by flexibility in job assignments.
- Not retraining conscious -on going basis effort to provide opportunity to exercise freedom in staying on a job for a fixed period.

Workers Participation and Empowerment:

Over coming resistance to change through employee involvement in planning and implementing change, mental and emotional involvement in groups encourage workers to contribute in group goals sharing of responsibility.

Workers Participation Approaches:

Following are the approaches for workers participation in quality culture change and empowerment:

- Quality control circles
- Productivity quality teams
- Productivity action teams
- Productivity circles
- Productivity maintenance group
- Employee participation group

Skill Enhancement:

Formalized techniques to increase skills needed to perform job. Skill training needed for employee when employee’s attitude is positive but his abilities are low.

- In information age there is a great need for skill at all levels.

Management by Objectives (MBO):

Managerial motivation techniques, aids motivation on all participation by having superior and subordinate managers jointly identify common goals, carefully define them. Together monitor progress towards achieving results to both employer and employee.

- In setting up goals care must be taken.
- Set simplistic goals.
- Set goals without adequate resources.
- Not set harsh goals that cause resentment.
- If properly administered, MBO can create joint goals and can help in team building.
- MBO goals provide fairness to both employee and employer.

Working Condition Improvement – Quality of Work Life (QWL):

It is often emphasized but rarely applied technique that involves detailed audit of working conditions designing improved conditions of working installing and maintaining improvements in working conditions.

Designing Improved Factors:

They include:

- Temperature, light and humidity
- Noise
- Colors of surroundings
- Extent of handling hazardous material, parts or product
- Extent of manual handling of heavy items

Training:

- Seeks to achieve improved human productivity by increasing ability levels of workforce
- Seeks to meet demands of growth and change
- Training may actually decrease total productivity initially
- Some type of training
- On the job targets
- Apprenticeship
- Internship
- Outside course
- Visitation training

Role Perception:

- Refer to manner in which individual defines his or her job
- Type of effort employee believes is essential for effective job performance.
- If workers see high or low productivity as path to attainment of one or more of their personal goals in work situation, they will tend to be high or low processors.

Quality of Supervision:

- Concerned with work of creating and maintaining environments in which people can accomplish goals efficiently and effectively.
- In order to improve supervision quality itself, supervisors must be trained in
 - Interpersonal skills
 - Human management
 - Group dynamic
 - Other behavioral tools

Recognition:

Management shows acknowledgement of employee's outstanding performance in terms of improved productivity, ideas, or any act of good workmanship. They include:

- Pay raise
- Bonus
- Awards
- Certificate of appreciation
- Special highlights in company newsletter
- Special parking provision
- Engraving on plaque in cafeteria

Punishment:

- Punishment contingency attempt to decrease likelihood of particular behavior occurring by making punishment contingency on behavior.
- Common punishment contingencies used in work organizations include:
 - Disciplinary layoffs
 - Transfer to undesirable jobs
 - Withholding salary increases

Quality Circles: Group of employees who voluntarily cooperative to solve problems related to production, quality, work environment, maintenance scheduling, or anything that affects these areas.

Productivity and Quality Teams:

Small groups of people doing similar tasks meet regularly to select, investigate, and solve problems related to workplace, products, and services. Effective means of improving employee morale, quality,

and productivity in organizations. Team spirit, positive thinking, and philosophy of achieving excellence are three important characteristics of productivity and quality teams.

Zero Defects:

Zero defects program attempts to improve quality by changing workers attitudes. Their theme, “do it right first time” stresses error free performance. It relies on workers to identify error prone situations with assumption that people best prepared to eliminate errors are those who create them.

Time Management:

- Powerful technique, particularly for white collar, supervisory and management personnel
- Time management involves minimization of wasteful elements of person’s administrative work.
- Interruptions by drop-in visitors (without appointment)
- Attending lengthy and unnecessary meetings that accomplish very little
- Inability to say “no” for some tasks
- Procrastination and lack of decisiveness
- Inability to delegate work
- Taking on much more than can be handled
- Lack of responsibility and authority to do certain jobs
- Delayed, inaccurate or inadequate information
- Taking orders from too many people
- Handling too many “crisis” situations
- Lack of organization of tasks by priority or target dates
- Lack of determination to complete tasks assigned
- Lack of organization on and around desk
- Unnecessary socialization
- Poor filing system
- Making unnecessary trips to people, departments, copy machines etc.
- Excessive conversation time
- Too many rescheduling of meeting, personal engagements etc.

To minimize these “time-wasters”, time management applies simple, common-sensible but very effective programming rules to every item of work, one of which is: “never handle same paper twice”. Time management always improves human productivity. It is too often ignored, particularly by management people who preach productivity to their subordinates.

Flex Time:

- Employees are given freedom in determining their hours of work
- Core time (hours when all employees must be at work)
- Flexible time (hours when employees can vary their time of arrival and departure)

Compressed Work Week:

- Working for same number of hours but for fewer days week
- Hours
- 08 hours 05 days
- 10 hours 04 days

Harmonization:

Integration of interest of stockholders, board of directors, management at all levels and all employees in consistent manner both within and outside physical boundaries of organization.

COST MANAGEMENT AND CONTROL IN PROJECTS**BROAD CONTENTS**

Cost Management
Cost Control
Management Cost and Control System (MCCS)
Understanding Control
Operating Cycle
Cost Account Codes
Budgets

40.1 Cost Management:

It is widely used in business today and is the process whereby companies use cost accounting to report or control various costs of doing business. Cost Management generally describes approach and activities of managers in short range and long range planning and cost decisions that incorporate value for customer and lower costs of product and services.

Manager make decisions on amount and kind of material used, changes of plant processes, changes in product designs and information from accounting system helps managers make such decisions, but information and accounting system not “cost management” project cost management broad focus includes continuous control of costs. Planning and cost is usually linked with revenue and profit planning.

In the context of project:

Cost management involves overall planning, co-ordination, and control and reporting of all cost-related aspects from “project initiation” to “operation and maintenance”.

Process of identifying all costs associated with investment, making informed choices about options that will deliver best “value for money” and managing those costs throughout life of project. Techniques (value management) help to improve value and reduce costs.

40.2 Cost Control:

Cost control is equally important to all companies, regardless of size. Small companies generally have tighter monetary controls, mainly because of the risk with the failure of as little as one project, but with less sophisticated control techniques. Large companies may have the luxury to spread project losses over several projects, whereas the small company may have few projects.

Cost control is not only "monitoring" of costs and recording perhaps massive quantities of data, but also analyzing of the data in order to take corrective action before it is too late. Cost control should be performed by all personnel who incur costs, not merely the project office. Cost control implies good cost management, which must include:

- Cost estimating
- Cost accounting
- Project cash flow
- Company cash flow
- Direct labor costing
- Overhead rate costing
- Others, such as incentives, penalties, and profit-sharing

40.3 Management Cost and Control System (MCCS):

Cost control is actually a subsystem of the *Management Cost and Control System (MCCS)* rather than a complete system per se. This is shown in Figure 40.1, where the Management Cost and Control System (MCCS) is represented as a two cycle process: a planning cycle and an operating cycle. The operating cycle is what is commonly referred to as the cost control system. Failure of a cost control system to accurately describe the true status of a project does not necessarily imply that the cost control system is at fault. Any cost control system is only as good as the original plan against which performance will be measured. It is more common for the plan to be at fault than the control system.

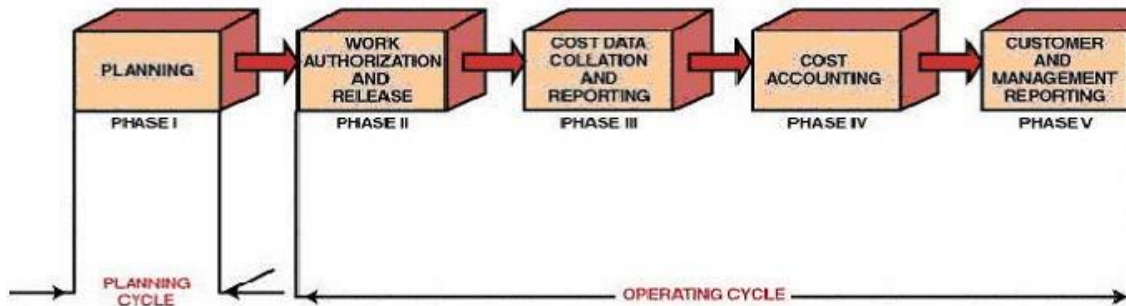


Figure 40.1: Phases of a Management Cost and Control System

Therefore, the designing of a company's planning system must take into account the cost control system as well. *For this reason, it is common for the planning cycle to be referred to as planning and control, whereas the operating cycle is referred to as cost and control.*

Note that the planning and control system selected must be able to satisfy management's needs and requirements in order that they can accurately project the status toward objective completion. The purpose of any management cost and control system is to establish policies, procedures, and techniques that can be used in the day-to-day management and control of projects and programs. The planning and control system must, therefore, provide information that:

- Gives a picture of true work progress
- Will relate cost and schedule performance
- Identifies potential problems with respect to their sources.
- Provides information to project managers with a practical level of summarization
- Demonstrates that the milestones are valid, timely, and auditable

The planning and control system, in addition to being a tool by which objectives can be defined that is *hierarchy of objectives* and *organization accountability*, exists as a tool to develop planning, measure progress, and control change. As a tool for planning, the system must be able to:

- Plan and schedule work
- Identify those indicators that will be used for measurement
- Establish direct labor budgets
- Establish overhead budgets
- Identify management reserve

The project budget that is the final result of the planning cycle of the MCCS must be reasonable, attainable, and based on contractually negotiated costs and the statement of work. The basis for the budget is historical cost, best estimates, or industrial engineering standards.

The budget must identify planned manpower requirements, contract-allocated funds, and management reserve. Establishing budgets requires that the planner fully understand the meaning of standards.

We should know that there are two categories of standards. Performance results standards are quantitative measurements and include such items as quality of work, quantity of work, cost of work, and time-to-complete. Process standards are qualitative, including personnel, functional, and physical factors relationships.

Standards are advantageous in that they provide a means for unity, a basis for effective control, and an incentive for others. The disadvantage of standards is that performance is often frozen, and employees are quite often unable to adjust to the differences. As a tool for measuring progress and controlling change, the systems must be able to:

- Measure resources consumed
- Measure status and accomplishments
- Compare measurements to projections and standards
- Provide the basis for diagnosis and re-planning

In using the Management Cost and Control System (MCCS), the following guidelines usually apply:

- The level of detail is specified by the project manager with approval by top management.
- Centralized authority and control over each project are the responsibility of the project management division.
- For large projects, the project manager may be supported by a project team for utilization of the Management Cost and Control System (MCCS).

Almost all project planning and control systems have identifiable design requirements. These include:

- A common framework from which to integrate time, cost, and technical performance
- Ability to track progress of significant parameters
- Quick response
- Capability for end-value prediction
- Accurate and appropriate data for decision making by each level of management
- Full exception reporting with problem analysis capability
- Immediate quantitative evaluation of alternative solutions

Management Cost and Control System (MCCS) planning activities include:

- Contract receipt (if applicable)
- Work authorization for project planning
- Work breakdown structure (WBS)
- Subdivided work description
- Schedules
- Planning charts
- Budgets

Management Cost and Control System (MCCS) planning charts are worksheets used to create the budget. These charts include planned labor in hours and material dollars. Management Cost and Control System (MCCS) planning is accomplished in one of these ways:

- One level below the lowest level of the Work Breakdown Structure (WBS)
- At the lowest management level
- By cost element or cost account

Even with a fully developed planning and control system, there are numerous benefits and costs. The appropriate system must consider a cost-benefit analysis, and include such items as:

- **Project benefits:**
 - Planning and control techniques facilitate:
 - Derivation of output specifications (project objectives)
 - Delineation of required activities (work)
 - Coordination and communication between organizational units
 - Determination of type, amount, and timing of necessary resources
 - Recognition of high-risk elements and assessment of uncertainties
 - Suggestions of alternative courses of action
 - Realization of effect of resource level changes on schedule and output performance
 - Measurement and reporting of genuine progress
 - Identification of potential problems
 - Basis for problem solving, decision making, and corrective action
 - Assurance of coupling between planning and control
- **Project cost:**
 - Planning and control techniques require:
 - New forms (new systems) of information from additional sources and incremental processing (managerial time, computer expense, etc.)
 - Additional personnel or smaller span of control to free managerial time for planning and control tasks (increased overhead)
 - Training in use of techniques (time and materials)

A well-disciplined Management Cost and Control System (MCCS) will produce the following results:

- Policies and procedures that will minimize the ability to distort reporting
- Strong management emphasis on meeting commitments
- Weekly team meetings with a formalized agenda, action items, and minutes.
- Top-management periodic review of the technical and financial status
- Simplified internal audit for checking compliance with procedures

Furthermore, for Management Cost and Control System (MCCS) to be effective, both the scheduling and budgeting systems must be disciplines and formal in order to prevent inadvertent or arbitrary budget or schedule changes. This does *not* mean that the baseline budget and schedule, once established, is static or inflexible. Rather, it means that changes must be controlled and result only from deliberate management actions.

Disciplined use of Management Cost and Control System (MCCS) is designed to put pressure on the project manager to perform exceptionally good project planning so that changes will be minimized. As an example, government subcontractors may not:

- Make retroactive changes to budgets or costs for work that has been completed.
- Re-budget work-in-progress activities
- Transfer work or budget independently of each other
- Reopen closed work packages

In some industries, the Management Cost and Control System (MCCS) must be used on all contracts of \$2 million or more, including firm fixed-price efforts. The fundamental test of whether to use the MCCS is to determine whether the contracts have established end-item deliverables, either hardware or computer software, that must be accomplished through measurable efforts.

Currently, two new programs are being used by the government and industry in conjunction with the Management Cost and Control System (MCCS) as an attempt to improve effectiveness in cost control. The zero-base budgeting program was established to provide better estimating techniques for the verification portion of control. The design-to-cost program assists the decision-making part of the control process by identifying a decision-making framework from which re-planning can take place.

40.4 Understanding Control:

Effective management of a program during the operating cycle requires that a well-organized cost and control system be designed, developed, and implemented so that immediate feedback can be obtained, whereby the up-to-date usage of resources can be compared to target objectives established during the planning cycle. The requirements for an effective control system (for both cost and schedule/performance) should include:

- Thorough planning of the work to be performed to complete the project
- Good estimating of time, labor, and costs
- Clear communication of the scope of required tasks
- A disciplined budget and authorization of expenditures
- Timely accounting of physical progress and cost expenditures
- Periodic re-estimation of time and cost to complete remaining work
- Frequent, periodic comparison of actual progress and expenditures to schedules and budgets, both at the time of comparison and at project completion

It is essential that the management must compare the time, cost, and performance of the program to the budgeted time, cost, and performance, not independently but in an integrated manner. Being within one's budget at the proper time serves no useful purpose if performance is only 75 percent. Likewise, having a production line turn out exactly 200 items, when planned, loses its significance if a 50 percent cost overrun is incurred.

All three resource parameters (time, cost, and performance) must be analyzed as a group, or else we might "win the battle but lose the war." The use of the expression "management cost and control system" is vague in that the implication is made that only costs are controlled. This is not true— an effective control system monitors schedule and performance as well as costs by setting budgets, measuring expenditures against budgets and identifying variances, assuring that the expenditures are proper, and taking corrective action when required.

Previously, we defined the Work Breakdown Structure (WBS) as the element that acts as the source from which all costs and controls must emanate. The Work Breakdown Structure (WBS) is the total project broken down into successively lower levels until the desired control levels are established. The Work Breakdown Structure (WBS) therefore serves as the tool from which performance can be subdivided into objectives and sub-objectives. As work progresses, the WBS provides the framework on which costs, time, and schedule/performance can be compared against the budget for each level of the WBS.

The first purpose of control therefore becomes a verification process accomplished by the comparison of actual performance to date with the predetermined plans and standards set forth in the planning phase. The comparison serves to verify that:

- The objectives have been successfully translated into performance standards.
- The performance standards are, in fact, a reliable representation of program activities and events.
- Meaningful budgets have been established such that actual versus planned comparisons can be made.