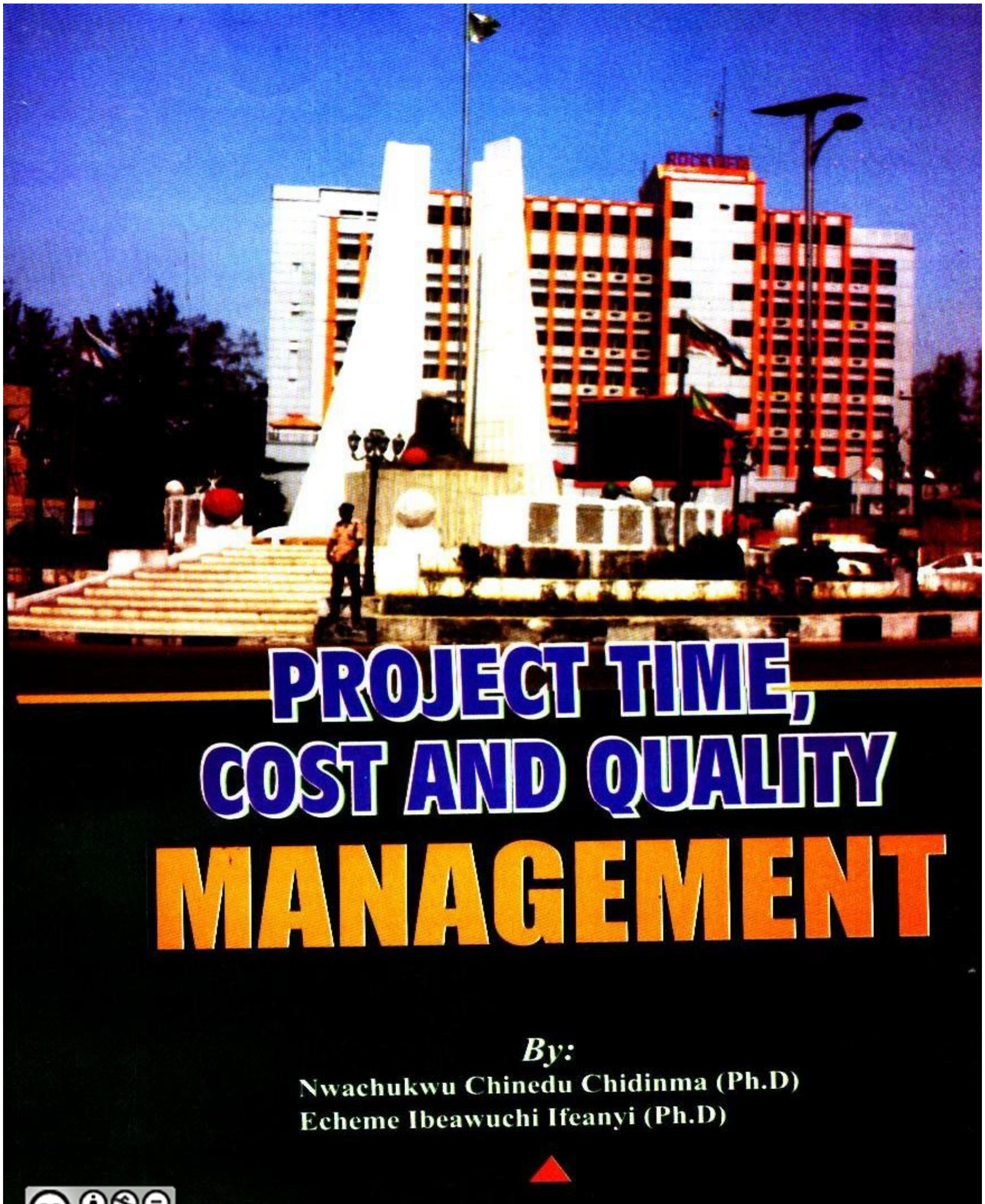

PROJECT TIME,
COST AND QUALITY
MANAGEMENT
By:
Nwachukwu Chinedu Chidinma (Ph.D)
Echeme Ibeawuchi Ifeanyi (Ph.D)

PROJECT TIME, COST AND QUALITY MANAGEMENT

by

Nwachukwu Chinedu Chidinma (Ph.D)
Association Professor of Project Management
and
Echeme Ibeawuchi Ifeanyi (Ph.D)
Project Management Technology

First Published: April, 2016

ISBN: 978 - 978 - 51860 - 1 - 9

Published in Nigeria
By Gabtony Prints Ltd.,
133/135 Wetheral Road, Opp. Villa Mariae, Owerri, Imo State.
08037083745, 08037788185, 08123055631

DEDICATION

This book is dedication to the families of Dr. C.C. Nwachukwu and Dr. I.I. Echeme

PREFACE

Every book is expected to present something new if not unique. This book is significant in the area of practical project management. The authors having taught project management to graduate and undergraduate students for many years needed little contact to appreciate the problems encountered by students and practitioners in the area of time, cost and quality management which are the criteria for judging projects. This book provides theoretical and practical approach that will guide project students, graduates, and practitioner on sound management of any given project.

This text adopts an approach that logically arrange the chapters and sections to make cohesive sequencing of topics. Project management issues are treated in details.

This book has Eighteen Chapters arranged in a way to encourage easy understanding.

We honestly apologize for any type of error due to commission or omission. All identified errors will be taken care of in the subsequent editions.

FOREWORD

Construction project is a complex and dynamic aspect of project management. There is no doubt that successful project is the driving force behind sustainable development. Nigeria is developing and the knowledge of construction project management should be practical to guaranty project success. The need for a more practical approach to construction projects management has become urgent so the aim of this book is to expose the reader to a systematic and comprehensive understanding of construction project management techniques. This book is a practical guide to students and practitioners in project management, Civil Engineering, Building Construction, etc. So, it is recommended that those studying for degrees and professional qualifications in the construction industry should avail themselves of this book because its contents satisfy the major requirements.

Dr. S.I. Emoh
Associate Professor Estate Survey Dept.
Nnamdi Azikiwe University, Awka Anambra State

TABLE OF CONTENT

CHAPTER THREE: BASICS FOR PREPARATION OF ESTIMATE

CHAPTER FOUR: LABOUR COST

CHAPTER FIVE: SAFEGUARDING COST ESTIMATES

CHAPTER SIX: PROJECT COST MANAGEMENT

CHAPTER SEVEN: CONSTRUCTION TENDERING PROCEDURE

CHAPTER EIGHT: SOURCES OF PROJECT FINANCE

CHAPTER NINE: CONSTRUCTION EQUIPMENT AND PLANT

CHAPTER TEN: MATERIALS AND SUPPLIES

CHAPTER ELEVEN: SUBCONTRACTED WORK

CHAPTER TWELVE: PROFIT

CHAPTER SIXTEEN: PROTEST OR LITIGATION CONCERNING THE GOVERNMENT ESTIMATE

CHAPTER SEVENTEEN: OTHER COSTS

CHAPTER EIGHTEEN: PROJECT QUALITY CONTROL

TABLES

FIGURES

CHAPTER ONE

PROJECT TIME MANAGEMENT

1.0 INTRODUCTION

Project Time Management includes the processes required to manage timely completion of the project. An overview of the processes involved in Project Time Management, is as follows:

(a) Define Activities The process of identifying the specific actions to be performed to produce the project deliverables.

(b) Sequence Activities The process of identifying and documenting relationships among the project activities.

(c) Estimate Activity Resources The process of estimating the type and quantities of material, people, equipment, or supplies required to perform each activity.

(d) Estimate Activity Durations The process of approximating the number of work periods needed to complete individual activities with estimated resources.

(e) Develop Schedule The process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.

(f) Control Schedule The process of monitoring the status of the project to update project progress and managing changes to the schedule baseline.

These processes interact with each other and with processes in the other Knowledge areas. Each process can involve effort from one group or person, based on the needs of the project. Each process occurs at least once in every project and occurs in one or more of the project phases, if the project is divided into phases. Although the processes are presented here as discrete components with well-defined interfaces, in practice they can overlap and interact in ways not detailed here

Some advanced practitioners distinguish the printed project schedule information (schedule) from the schedule data and calculations that produce the schedule, by referring to the scheduling engine populated with project data as the *schedule model*. However, in general practice the schedule and the schedule model are referred to as the schedule. Therefore, this book uses the term *schedule*. On some projects, especially activity durations, and developing the schedule are so tightly linked that they are viewed as a single process that can be performed by a person over a relatively short period of time. These processes are presented here as distinct processes because the tools and techniques for each are different.

Although not shown here as a discrete process, the work involved in performing the six processes of Project Time Management is preceded by a planning effort by the project management team. This planning effort is part of the Develop Project Management Plan process, which produces a schedule management plan that selects scheduling methodology, a scheduling tool, and sets the format and establishes criteria for developing and controlling the project schedule. A schedule methodology defines the rules and approaches of the scheduling process. Some of the better known methodologies include the Bar/Gantt chart, critical path method (CPM), program/project evaluation and review technique (PERT) and critical chain.

The Project Time Management processes and their associated tools and techniques are documented in the schedule management plan. The schedule management plan is contained in, or is a subsidiary plan of, the project management plan, and may be formal or informal, highly detailed or broadly framed, based upon the needs of the project, and includes appropriate control thresholds.

Project scheduling refers to the process of laying out all the activities of the project in the time order in which they are to be performed, keeping in view of the logical sequence of the activities. This schedule is used to establish a time table of start and finish times.

Developing the project schedule uses the outputs from the processes to define activities, sequence activities, estimate activity durations in combination with the scheduling tool to produce the schedule. The finalized and approved schedule is the baseline that will be used in the Control Schedule Process. As the project activities are being performed, the majority of effort in the Project Time Management Knowledge Area will occur in the Control Schedule process to ensure completion of project work in a timely manner.

1.1 TOOLS AND TECHNIQUES FOR ACTIVITY SCHEDULING

(a) Define Activities

Define Activities is the process of identifying the specific actions to be performed to produce the project deliverables. The Create WBS process identifies the deliverables at the level in the Work Breakdown Structure (WBS), the work package. Project work packages are typically decomposed into smaller components called activities that represent the work necessary to complete the work package. Activities provide a basis for estimating, scheduling, executing, and monitoring and controlling the project work. Implicit in this process is defining and planning the schedule activities such that the project will be met.

(b) Activity Attributes

Activity attributes extend the description of the activity by identifying the multiple components associated with each activity. The components for each activity evolve over time. During the initial stages of the project they include the Activity ID, WBS ID, and Activity Name, and when completed may include activity codes, activity description, predecessor activities, successor activities, logical relationships and lags, resource requirements, imposed dates, constraints, and assumptions. Activity attributes can be used to identify the person responsible for executing the work, geographic area, or place where the work has to be performed, and activity type such as level of effort (LOE), discrete effort and apportioned effort (AE). Activity attributes are used for schedule development and for ordering and sorting the planned schedule activities in various ways within reports. The number of attributes varies by application are.

(c) Milestone List

A milestone is a significant point or event in the project. A milestone list identifies all milestones and indicates whether the milestone is mandatory, such as those required by contract, or options such as those based upon historical information.

1.1.1 Define Activities

(i) Inputs in Defining Activities

a. Scope Baseline

The project deliverables, constraints, and assumptions documented in the project scope baseline are considered explicitly while defining activities.

b. Enterprise Environmental Factors

The enterprise environmental factors that can influence the

Define Activities process include, but are not limited to, the project management information system (PMIS).

c. Organizational Process Assets

The organizational process assets that can influence the Define Activities process include, but is not limited to:

- Existing formal and informal activity planning-related policies, procedures, and guidelines, such as the scheduling methodology, that are considered in developing the activity definitions, and
- Lessons-learned knowledge base containing historical information regarding activities lists used by previous similar projects.

(ii) Tools and Techniques in Defining Activities

a. Decomposition

The technique of decomposition, as applied to defining activities, involves subdividing the project work packages into smaller, more manageable components called activities. Activities represent the effort needed to complete a work package. The Define activities process defines the final outputs as activities rather than deliverables.

The activity list, WBS, and WBS dictionary can be developed either sequentially or concurrently, with the WBS and WBS dictionary as the basis for development of the final activity list. Each work package within the WBS is decomposed into the activities required to produce the work package deliverables. Involving team members in the decomposition can lead to better and more accurate results.

b. Rolling Wave Planning

Rolling wave planning is a form of progressive elaboration planning where the work to be accomplished in the near term is planned in detail and future work is planned at a higher level of the WBS. Therefore, work can exist at various levels of detail d   epending on where it is in the project life cycle. For example, during early strategic planning, when information is less defined, work packages may be decomposed to the milestone level. As more is known about the upcoming events in the near term it can be decomposed into activities

.

c. Templates

A standard activity list or a portion of an activity list from a previous project is often usable as a template for a new project. The related activity attributes information in the templates can also contain other descriptive information useful in defining activities. Templates can also be used to identify typical schedule'milestones.

d. Expert Judgment

Project team members or other experts, who are experienced and skilled in developing detailed project scope statements, the WBS, and project schedules, can provide expertise in defining activities.

(iii) Outputs in Define Activities

a. Activity List

The activity list is a comprehensive list including all schedule activities required on the project. The activity list includes the activity identifier and a scope of work description for each activity in sufficient detail to ensure that project team members understand what work is required to be completed.

1.1.2 Sequence Activities

Sequence Activities is the process of identifying and documenting relationships among the project activities. Activities are sequenced using logical relationships. Every activity and milestone except the first and last are connected to at least one predecessor and one successor. It may be necessary to use lead or lag time between activities to support a realistic and achievable project schedule. Sequencing can be performed by using project management software or by using manual or automated techniques.

(i) Inputs in Sequence Activities

a. Activity List

As described in section 1.1.1.iiia

b. Activity Attributes

Described in Section 1.1(b). Activity attributes may describe a necessary sequence of events or defined predecessor or successor relationships.

c. Milestone List

Described in Section 1.1(c). The milestone list may have scheduled dates for specific milestones.

d. Project Scope Statement

The project scope statement contains the product or project scope description, which includes product or project characteristics that may affect activity sequencing, such as the physical layout of a plant to be constructed or subsystem interfaces on a software project. While these effects are often apparent in the activity list, the product/project scope description is generally reviewed to ensure accuracy.

e. Organizational Process Assets

The organizational process assets that can influence the Sequence Activities process include, but is not limited to, project files from the corporate knowledge base used for scheduling methodology.

(ii) Tools and Techniques in Sequence Activities

a. Precedence Diagramming Method (PDM)

PDM is a method used in Critical Path Methodology (CPM) or Program/project Evaluation and Review Technique (PERT) for developing a project schedule network diagram that uses boxes or rectangles, referred to as nodes, to represent activities, and connects them with arrows that show the logical relationships that exist between them. This technique is also called Activity-On-Node (AON), and is the method used by most project management software packages. The figure below shows a simple project schedule network diagram drawn using PDM.

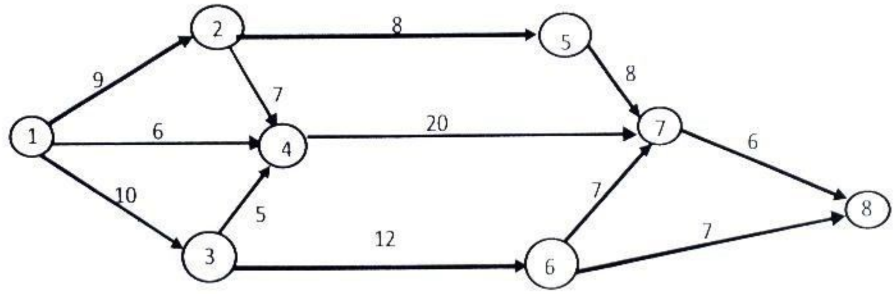


Figure 1.0 Precedence Diagramming Method

PDM includes four types of dependencies or logical relationships:

- **Finish-to-start (FTS).** The initiation of the successor activity depends upon the completion of the predecessor activity.
- **Finish-to-finish (FTF).** The completion of the successor activity depends upon the completion of the predecessor activity.
- **Start-to-start (STS).** The initiation of the successor activity depends upon the initiation of the predecessor activity.
- **Start-to-finish (STF).** The completion of the successor activity depends upon the initiation of the predecessor activity.

In PDM, finish-to-start is the most commonly used type of precedence relationship. The start-to-finish relationship is rarely used but is included here for a complete list of the PDM relationship types.

b. Dependency Determination

Three types of dependency are used to define the sequence among the activities:

- **Mandatory dependencies.** Mandatory dependencies are those that are contractually required or inherent in the nature of the work. The project team determines which dependencies are mandatory during the process of sequencing the activities. Mandatory dependencies often involve physical limitations, such as on a construction project where it is impossible to erect the superstructure until after the foundation has been built, or on an electronics project, where a prototype must be built before it can be tested. Mandatory dependencies are also sometimes referred to as hard logic.

- **Discretionary dependencies.** The project team determines which dependencies are discretionary during the process of sequencing the activities. Discretionary dependencies are sometimes referred to as preferred logic, preferential logic, or soft logic. Discretionary dependencies are established based on knowledge of best practices within a particular application area or some unusual aspect of the project where a specific sequence is desired, even though there may be other acceptable sequences. Discretionary dependencies should be fully documented since they can create arbitrary total float values and can limit later scheduling options. When fast tracking techniques are employed, these discretionary dependencies should be reviewed and considered for modification or removal.

- **External dependencies.** The project management team determines which dependencies are external during the process of sequencing the activities. External dependencies involve a relationship between project activities and non-project activities. These dependencies are usually outside the project team's control. For example, the testing activity in a software project can be dependent on the delivery of hardware from an external source, or governmental environmental hearings may need to be held before site preparation can begin on a construction project.

C. Applying Leads and Lags

The project management team determines the dependencies that may require a lead or a lag to accurately define the logical relationship. The use of leads and lags should not replace schedule logic. Activities and their related assumptions should be documented.

A lead allows an acceleration of the successor activity. For example, on a project to construct a new office building, the landscaping could be scheduled to start 2 weeks prior to the scheduled punch list completion. This would be shown as a finish-to-start with a 2-week lead.

A lag directs a delay in the successor activity. For example, a technical writing team can begin editing the draft of a large document 15 days after they begin writing it. This could be shown as a start-to-start relationship with a 15-day lag.

d. Schedule Network Templates

Standardized schedule network diagram templates can be used to expedite the preparation of networks of project activities. They can induce an entire project or only a portion of it. Portions of a project schedule network diagram are often referred to as a sub network or fragment network. Sub network templates are especially useful when a project includes several identical or nearly identical deliverables, such as floors on a high-rise office building, clinical trials on a pharmaceutical research project, coding program modules on a software project, or the start-up phase of a development project.

(iii) Outputs from Sequence Activities

a. Project Schedule Network Diagrams

Project schedule network diagrams are schematic displays of the project's schedule activities and the logical relationships among them, also referred to as dependencies. Figure 1.0 illustrates a project schedule network diagram. A project schedule network diagram can be produced manually or by using project management software. It can include full project details, or have one or more summary activities. A summary narrative can accompany the diagram and describe the basic approach used to sequence the activities. Any unusual activity sequences within the network should be fully described within the narrative.

B. Project Document Updates

Project documents that may be updated include, but are not limited to:

- Activity lists,
- Activity attributes, and
- Risk register.

1.1.3 Estimate Activity Resources

Estimate Activity Resources is the process of estimating the type of material, people, equipment, or supplies required to perform each activity. The estimate Activity Resource process is closely coordinated with the estimate costs process, for example:

- A construction project team will need to be familiar with local building codes. Such knowledge is often readily available from local contractors. However, if the local labor pool lacks experience with unusual or specialized construction techniques, the additional cost for a consultant might be the most effective way to secure knowledge of the local building codes.
- An automatic design team will need to be familiar with the latest in automated assembly techniques. The requisite knowledge might be obtained by hiring a consultant, by sending a designer to a seminar on robotics, or by including someone from manufacturing as a member of the project team.

(i) Inputs in Estimate Activity Resources

a. Activity List

The activity list (section 1.1.1.iiia) identifies the activities which will need resources.

b. Activity Attributes

The activity attributes (section 1.1 b) developed during the define activities and sequence activities processes provide the primary data input for use in estimating those resources required for each activity in the activity list.

c. Resources Calendars

Information on which resources (such as people, equipment, and material) are potentially available during planning activity period is used for estimating resources utilization. Resources calendars specify when and how long identified project resources will be available during the project. This information may be at the activity or project level. This knowledge includes consideration of attributes such as resource experience and /or skill level, as well as various geographical locations from which the resources originate and when they may be available.

The composite resource calendar includes the availability, capabilities, and skill of human resources; for example, during the early phases of an engineering design project, the pool of resources might include junior and senior engineers in large numbers. During later phases of the same project, however, the pool can be limited to those individuals who are knowledgeable about the project as a result of having worked on the earlier phases of the project.

d. Enterprise Environmental Factors

The enterprise environmental factors that can influence the Estimate Activity Resources process include but are not limited to resources availability and skills.

e. Organizational Process Assets

The organizational process assets that can influence the Estimate Activity Resources process include but are not limited to:

- Policies procedures regarding staffing,
- Policies are procedures relating to rental and purchase of supplies and equipment, and
- Historical information regarding types of resources used for similar work on previous projects

(ii) Tools and Techniques in Estimating Activity Resources

a. Expert Judgment

Expert judgment is often required to assess the resource-related inputs to this process. Any group or person with specialized knowledge in resources planning and estimating can provide such expertise

b. Alternative Analysis

Many schedule activities have alternative methods of accomplishment. They include using various levels of resource capability or skills, different size or type of machines, different tools (hand versus automated), and make-or-buy decisions regarding the resource.

c. Published Estimating Data

Several companies routinely publish updated production rates and unit costs of resources for an extensive array of labor trades, material, and equipment for different countries and geographical locations within countries.

d. Bottom-Up Estimating

When an activity cannot be estimated with a researchable degree of confidence, the work within the activity is decomposed into more detail. The resource needs are estimated. These estimates are then aggregated into a total quantity for each of the activity's resources. Activities may or may not have dependencies between them that can affect the application and use of resources. If there are dependencies, this pattern of resource usage is reflected and documented in the estimated requirements of the activity.

e. Project Management Software

Project management software has the capability to help plan, organize, manage resources pools and develop resources estimates. Depending on the sophistication of the software, resources breakdown structure, resources availability, resource rates and various resource calendars can be defined to assist in optimizing resource utilization.

(iii) Outputs from Estimate Activity Resources

a. Activity Resources Requirements

The output of the estimate Activity Resources process identifies the types and quantities of resources required for each activity in a work package. These requirements can then be aggregated to determine the estimate resources for each work package. The amount of detail and the level of specificity of the resource requirement descriptions can vary by application area. The resource requirements documentation for each activity can include the basis of estimate for each resource, as well as the assumptions that were made in determining which types of resources are applied, their availability, and what quantities are used.

b. Resource Breakdown Structure

The resource breakdown structure is a hierarchical structure of the identified resource category and resource type. Examples of resource categories include labor, material, equipment and supplies. Resource types can include the skill level, grade level or other information as appropriate to the project. The resource breakdown structure is useful for organizing and reporting project schedule data with resource utilization information.

c. Project Document Updates

Project documents that may be updated include, but are not limited to:

- Activity List
- Activity Attributes, and
- Resource Calendar

1.1.4 Estimate Activity Durations

Estimates Activity Durations is the process of approximating the number of work periods needed to complete individual activities with estimated resources. Estimating activity durations uses information on activity scope of work, required resource types, estimated resource quantities, and resource calendars. The inputs for the estimates of the activity duration originate from the person or group on the project team who is most familiar with the nature of the work in the specific activity. The duration estimate is progressively elaborated, and the process considers the quality and availability of the input data. For example, as the project engineering and design work evolves, more detailed and precise data is available, and the accuracy of the duration estimates improves. Thus, the duration estimate can be assumed to be progressively more accurate and better quality.

The estimate Activity Durations process requires that the amount of work effort required to complete the activity is estimated and the amount of resource to be applied to complete the activity is estimated; these are used to approximate the number of work periods (activity duration) needed to complete the activity. All data and assumptions that support duration estimating are documented for each estimate of activity duration.

Most project management software for scheduling will handle this situation by using a project calendar and alternative work-period resource calendars that are usually identified by the resources that requires specific work periods. In addition to the sequencing logic, the activities will be performed according to the project calendar and the appropriate resource calendars.

(i) Inputs in Estimate Activity Durations

a. Activity List

Described in Section 1.1.1.iiia

b. Activity Attributes

Described in Section 1.1(b
)

c. Activity Resource Requirements

The estimated activity resource requirements will have an effect on the duration of the activity, since the resources assigned to the activity and the availability of those resources will significantly influence the duration of most activities. For example, if additional or lower skilled resources are assigned to an activity, there may be reduced efficiency or productivity due to increased communication, training, and coordination needs.

d. Resource Calendars

The resource developed as part of the Estimating Activity Resources process, can include the type, availability, and capabilities of human resources. The type, quantity, availability, and capability, when applicable, of both equipment and material resources, which could significantly influence the duration of schedule activities, are also considered. For example, when a senior and a junior staff member are assigned full time, a senior staff member can generally be expected to complete a given activity in less time than a junior staff member.

E. Project Scope Statement

The constraints and assumptions from the project scope statement are considered when estimating the activity durations. Examples of assumptions include, but are not limited to:

- Existing conditions
- Availability of information, and
- Length of the reporting periods.

Examples of constraints include, but are not limited to:

- Availability skilled Resources, and
- Contact terms and requirements.

f. Enterprise Environmental

The enterprise environmental factors that can influence the Estimate Activity Durations process include but are not limited to:

- Duration estimating databases and other reference data,
- Productivity metrics, and
- Published commercial information.

g. Organizational process Assets

The organizational process assets that can influence the Estimate Activity Durations process include but are not limited to:

- Historical duration information,
- Project calendars,

- Scheduling methodology, and
- Lessons learned.

(ii) Tools and Techniques in Estimate Activity Durations

a. Expert Judgment

Expert judgment, guided by historical information, can provide duration estimate information or recommended maximum activity durations from prior similar projects. Expert judgment can also be used to determine whether to combine methods of estimating and how to reconcile differences between them.

b. Analogue Estimating

Analogue estimating uses parameters such as duration, budget, size, weight, and complexity, from a previous, similar project, as the basis for estimating the same parameter or measure for a future project. When estimating durations, this technique relies on the actual duration of previous, similar projects as the basis for estimating the duration of the current project. It is a gross value estimating approach, sometimes adjusted for known differences in project complexity.

Analogue duration estimating is frequently used to estimate project duration when there is a limited amount of detailed information about the project for example, in the early phases of a project. Analogue estimating uses historical information and expert judgment.

Analogue estimating is generally less costly and time consuming that other techniques, but it is also generally less accurate. Analogue duration estimates can be applied to a total project or to segments of a project and may be used in conjunction with other estimating methods. Analogous estimating is most reliable when the previous activities are similar in fact and not just in appearance, and the project team members preparing the estimates have the needed expertise.

c. Parametric Estimating

Parametric estimating uses a statistical relationship between historical data and other variables (e.g., square footage in construction) to calculate an estimate for activity parameters, such as cost, budget, and duration.

Activity durations can be quantitatively determined by multiplying the quantity of work to be performed by labor hours per unit of work. For example, activity duration can be estimated on a design project by the number of drawings multiplied by the number of labor hours per drawing, or a capable installation in meters of cable multiplied by the number of labor hours per meter. For example, if the assigned resource is capable of installing 25 meters of cable per hour, the duration required to install 1,000 meters would be 40 hours. (1,000 meters divided by 25 meters per hour).

This technique can produce higher levels of accuracy depending upon the sophistication and underlying data built into the model. Parametric time estimates can be applied to a total project or to segments of a project, in conjunction with other estimating methods.

D. Three-Point Estimates

The accuracy of activity duration estimates can be improved by considering estimation uncertain and risk. This concept originated with the Program Evaluation and Review Technique (PERT). PERT uses three estimates to define an approximate range for an activity's duration:

Most likely time (t_m): The duration of the activity, given the resources likely to be assigned, their productivity, realistic expectations of availability for the activities, dependencies on other participants, and interruptions.

Optimistic time (t_o): The activity duration is based on the analysis of the best-case scenario for the activity.

Pessimistic time (t_p): The activity duration is based on analysis of the worst-case scenario for the activity.

PERT analysis calculates an **expected**(t_E) activity duration using a weighted average of these three estimates:

$t_E = (t_O + 4t_M + t_p)/6$

Duration estimates based on this equation (or even on a simple average of the three points) may provide more accuracy, and the three points clarify the range of uncertainty of the duration estimates.

e. Reserve Analysis

Duration estimates may include contingency reserves, (sometime referred to as time reserves or buffers) into the overall project schedule to account for schedule uncertainty. The contingency reserve may be a percentage of the estimated activity duration, a fixed number of work periods, or may be developed by using quantitative analysis methods.

As more precise information about the project becomes available, the contingency reserve may be used, reduced, or eliminated. Contingency should be clearly identified in schedule documentation.

(iii) Outputs from Estimate Activity Durations

a. Activity Duration Estimates

Activity duration estimates are quantitative assessments of the likely number of work periods that will be required to complete an activity. Duration estimates do not include any lags. Activity duration estimates may include some indication of the range of possible results. For example:

- 2 weeks 2 days to indicate that the activity will take at least eight days and no more than twelve (assuming a five-day workweek).
- 15% probability of exceeding three weeks to indicate a high probability -85% percent-that the activity will take three weeks or less.

b. Project Document Updates

Project documents that may be updated include, but are not limited to:

- Activity attributes, and
- Assumption made in developing the activity duration estimate such as skill levels and availability.

1.1.5 Develop Schedule

Develop Schedule is the process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule. Entering the activities, durations, and resources into the scheduling tool generates a schedule with planned dates for completing project activities. Developing an acceptable project schedule is often an iterative process. It determines the planned start and finish dates for project activities and milestones. Schedule development can require the review and revision of duration estimates and resource estimates to create an approved project schedule that can serve as a baseline to track progress. Revising and maintaining a realistic schedule continues throughout the project as work progresses, the project management plan changes, and the nature of risk events evolves.

(i) Inputs in Develop schedule

a. Activity List

Describe in section 1.1.1.iiia

b. Activity attributes

Describe in Section 1.1(b).

c. Project Schedule Network Diagrams

Describe in Section 1.1.2 iiia.

D. Activity Resource Requirements

Described in Section 1.1.3.iiia

e. Resource Calendars

Describe in Section 1.1.3.ic.

f. Activity Duration Estimates

Describe in Section 1.1.4.iiia.

g. Project Scope Statement

The project scope statement contains assumptions and constraints that can impact the development of the project schedule.

f. Enterprise Environmental Factors

The enterprise environmental factors that can influence the develop schedule process include, but are not limited to, a scheduling tool that can be used in developing the schedule.

h. Organizational Process Assets

The organizational process assets that can influence the Develop Schedule process include, but are not limited to:

i. Scheduling methodology, and

ii. Project calendar

(ii) Schedules Development Tools and Techniques

a. Schedule Network Analysis

Schedule network analysis is a technique that generates the project schedule. It employs various analytical techniques, such as critical path method, critical chain method, what-if analysis, and resource leveling to calculate early and late start and finish dates for the uncompleted portions of project activities. Some network paths may have points of path convergence or path divergence that can be identified and used in schedule compression analysis or other analysis.

b. Critical Path Method

The critical path methods calculates the theoretical early start and finish dates, and late start and finish dates, for all activities without regard for any resource limitations, by performing a forward and backward pass analysis through the schedule network. The resulting early and late and finish dates are not necessarily the project schedule; rather, they indicate time periods within which the activity can be scheduled, given activity durations, logical relationships, leads, lags, and other known constraints.

Calculated early start and finish dates, and late start and finish dates, may be affected by activity total float, which provides schedule flexibility and, may be positive, negative, or zero. On any network path, the schedule flexibility is measured by the positive difference between early and late dates, and is termed "total float." Critical paths have either a zero or negative total float, and schedule activities on a critical path are called "critical activities "A critical path is normally characterized by total float on the critical path. Networks can have multiple near critical paths. Adjustments to activity durations, logical relationships, leads and lags, or other schedule constraints may be necessary to produce network paths with a zero or positive total float. Once the total float for a network path has been calculated then the free float, the amount of time that an activity can be delayed without delaying the early start date of any immediate successor activity within the network path, can also be determined.

c. Critical Chain Method

Critical chain is a schedule network analysis technique that modifies the project schedule to account for limited resources. Initially, the project schedule network diagram is built using duration estimates with required dependencies and defined constraints as inputs. When critical path is calculated and identified, resource availability is entered and the resource-limited schedule result is determined. The resulting schedule often has an altered critical path.

The resource-constrained critical path is known as the critical chain. The critical chain method adds duration buffers that are non-work schedule activities to manage uncertainty. One buffer, placed at the end of the critical chain, is known as the project buffer and protects the target finish date from slippage along the critical chain. Additional buffers, known as feeding buffers, are placed at each point that a chain of dependent tasks not on the critical chain feeds into the critical chain. Feeding buffers thus protect the critical chain from slippage along the feeding chains. The size of each buffer should account for the uncertainty in the duration of the chain of dependent tasks leading up to that buffer. Once the buffer schedule activities are determined, the planned activities are scheduled to their latest possible planned start and finish dates. Consequently, in lieu of managing the total float of network paths, the critical chain method focuses on managing remaining buffer durations against the remaining durations of task chains.

d. Resources Leveling

Resource leveling is a schedule network analysis technique applied to a schedule that has already been analyzed by the critical path method. Resource leveling can be used when shared or critical required resources are only available at certain times, are only available in limited quantities, or keep resource usage at a constant level. Resource leveling is necessary when resources have been over-allocated, such as when a resource has been assigned to two or more activities during the same time period, when shared or critical required resources are only available at certain times or are only available in limited quantities. Resource leveling can often cause the original critical path to change.

e. What-If Scenario Analysis

This is an analysis of the question "What if the situation represented by scenario 'X' happens?" A schedule network analysis is performed using the schedule to compute the different scenarios, such as delaying a major component delivery, extending specific engineering durations, or introducing external factors, such as a strike or a change in the permitting process. The outcome of the what-if scenario analysis can be used to assess the feasibility of the project schedule under adverse conditions, and in preparing contingency and response plans to overcome or mitigate the impact of unexpected situations. Simulation involves calculating multiple project durations with different sets of activity assumptions. The most common technique is Monte

Carlo Analysis, in which a distribution of possible activity durations is defined for each activity and used to calculate a distribution of possible outcomes for the total project.

f. Applying Leads and Lags

Leads and lags are refinements applied during network analysis to develop a viable schedule.

g. Schedule Compression

Schedule compression shortens the project schedule without changing the project scope, to meet schedule constraints, imposed dates, or other schedule objectives. Schedule compression techniques include:

Crashing. A schedule compression technique in which cost and schedule tradeoffs are analyzed to determine how to obtain the greatest amount of compression for the least incremental cost. Examples of crashing could include approving overtime, bringing in additional resources, or paying to expedite delivery to activities on the critical path. Crashing only works for activities where additional resources will shorten the duration. Crashing does not always produce a viable alternative and may result in increased risk and/or cost.

Fast tracking. A schedule compression technique in which phases or activities normally performed in sequence is performed in parallel. An example is constructing the foundation for a building before completing all of the architectural drawings. Fast tracking may result in rework and increased risk. Fast tracking only works it activities can be overlapped to shorten the duration.

h. Scheduling Tool

Automated scheduling tools expedite the scheduling process by generating start and finish dates based on the inputs of activities, network diagrams, resources and activity durations. A scheduling tool can be used in conjunction with other project management software applications as well as manual methods.

(iii) Outputs from Develop Schedule

a. Project Schedule

As a minimum, the project schedule includes a planned start date and planned finish date for each activity. If resource planning is done at an early stage, then the project schedule would remain preliminary until, resource assignments have been confirmed and scheduled start and finish dates are established. This process usually happens no later than completion of the project management plan. Project target schedule may also be developed with a defined target start and target finish for each activity. The project schedule may be presented in summary form, sometimes referred to as the master schedule or milestone schedule. or presented in detail. Although a project schedule can be presented in tabular form, it is more often presented graphically, using one or more of the following formats:

Milestone charts. These charts are similar to bar charts, but only identify the scheduled start or completion of major deliverables and key external interfaces.

Bar charts. These charts, with bars representing activities, show activity start and end dates, as well as expected durations. Bar- charts are relatively easy to read, and are frequently used in management presentations. For control and management communication, the broader, more comprehensive summary activity, sometimes referred to as a hammock activity, is used between milestones or across multiple interdependent work packages, and is displayed in bar chart reports.

Project schedule network diagrams. These diagrams, with activity date information, usually show both the project network logic and the project's critical path schedule activities. These diagrams can be presented in the activity-on-node diagram format, or presented in a time scaled schedule network diagram format that is surnames called a logic bar chart. This also shows how each work package is planned as a series of related activities.

b. Schedule Baseline

A schedule baseline is a specific version of the project schedule developed from the schedule work analysis. It is accepted and approved by the project management team as the schedule baseline with baseline start dates and baseline finish dates. The schedule baseline is a component of project management plan.

c. Schedule Data

The schedule data for the project schedule includes at least the schedule milestones, schedule activities, activity attributes, and documentation of all identified assumptions and constraints. The amount of additional data varies by application area. Information frequently supplied as supporting Wei includes, but is not limited to:

- Resource requirements by time period, often in the form of a resource histogram.
- Alternative schedules such as best-case or worst-case, not resource-leveled or resource Leveled, with or without imposed dates. and
- Scheduling of contingency reserves.

  Schedule data could include such items as resource histograms, cash-flow projections, and order delivery schedules.

d. Project Document Updates

Project documents that may be updated include, but are not limited to:

- **Activity resource requirements.** Resource leveling can have a significant effect on preliminary estimates of the types and quantities of resources required. If the resource-leveling analysis changes the project resource requirements, then the project resource requirements are updated.
- **Activity attributes.** Activity attributes are updated to include any revised resource requirements and any other revisions generated by the Develop Schedule process.

- **Calendar**. The calendar for each project may use different calendar units as the basis for scheduling the project.
- **Risk register.** The risk register may need to be updated to reflect opportunities or threats perceived through scheduling assumptions.

1.1.6 Control Schedule

Control Schedule is the process of monitoring the status of the project to update project progress and manage changes to the schedule baseline. Schedule control is concerned with:

- Determining the current status of the project schedule,
- Influencing the factors that create schedule changes,
- Determining that the project schedule has changed, and
- Managing the actual changes as they occur.

(i) Inputs in Control Schedule

a. Project Management Plan

The project management plan contains the schedule management plan and the schedule baseline. The schedule management plan describes how the schedule will be managed and controlled. The schedule baseline is used to compare actual results to determine if a change, corrective action, or preventive action is necessary.

b. Project Schedule

The most recent version of the project schedule with notations to indicate updates, completed activities, and started activities as of the indicated data date.

c. Work Performance Information

Information about project progress, such as which activities have started, their progress, and which activities have finished.

d. Organizational Process Assets

The organizational process assets that influence the Control Schedule process include but are not limited to:

- Existing formal and informal schedule control-related policies, procedures. and guidelines:
- Schedule control tools; and
- Monitoring and reporting methods to be used.

(ii) Tools and Techniques in Control Schedule

a. Performance Reviews

Performance reviews measure, compare, and analyze schedule performance such as actual start and finish dates, percent complete, and remaining duration for work in progress. If earned value management (EVM) is utilized the schedule variance (SV) and schedule performance index (SPI) are used to assess the magnitude of schedule variations. An important part of schedule control is to decide if the schedule variation requires corrective action. For example, a major delay on any activity not on the critical path may have little effect on the overall project schedule while a much shorter delay on a critical or near-critical activity may require immediate action.

If using the critical chain scheduling method, comparing the amount of buffer remaining to the amount of buffer needed to protect the delivery date can help determine schedule status.

The difference between the buffer needed and the buffer remaining can determine whether corrective action is appropriate.

b. Variance Analysis

Schedule performance meas ments (SV, SPI) are used to assess the magnitude tion of the original schedule baseline. The total floa nce is also an essential planning component to evaluate project time performance, important aspects of project schedule control include determine the cause and degree of vari ce relative to the schedule baseline and decide whether corr tive or preventive action is required.

c. Project Mana nent Software

Project management software for scheduling provides the ability to track planned dates versus actual dates and to forecast the effects of changes to the project schedule.

d. Resource Leveling

Resource leveling is used to optimize the distribution of work among resources.

e. What-If Scenario Analysis

What-if scenario analysts are used to review various scenarios to bring the schedule into alignment with the plan.

f. Adjusting Leads and Lags

Adjusting leads and lags is used to find ways to bring project activities that are behind into alignment with plan.

g. Schedule Compressions

Schedule compression techniques are used to find ways to bring project activities that are behind into alignment with the plan.

h. Scheduling Tool

Schedule data is updated and compiled into the schedule to reflect actual progress of the project and remaining work to be completed. The scheduling tool and the supporting schedule data are used in conjunction with manual methods or other project management software to perform schedule network-analysis to generate an updated project schedule.

(iii) Outputs from Control Schedule

a. Work Performance Measurements

The calculated SV and SPI values for WBS components, in particular the work packages and control accounts, are documented and communicated to stakeholders

b. Organizational Process Assets Updates

Organizational process assets that may be updated include but are not limited to:

- Causes of variances,
- Corrective action chosen and the reasons, and
- Other types of lessons learned from project schedule control.

c. Change Requests

Schedule variance analysis, along with review of progress reports, results of performance measures, and modifications to the project schedule can result in change requests to the schedule baseline and/or to other components of the project management plan. Change requests are processed for review and disposition through the Integrated Change Control process. Preventive actions may include recommended changes to reduce the probability of negative schedule variances.

d. Project Management Plan Updates

Elements of the project management plan that may be updated include but are not limited to:

Schedule baseline. Changes to the schedule baseline are incorporated in response to approved change requests related to project scope changes, activity resources, or activity duration estimates.

Schedule management plan. The schedule management plan may be updated to reflect a change in the way the schedule is managed.

Cost baseline. The cost baseline may be updated to reflect changes caused by compression or crashing techniques.

e. Project Document Updates

Project documents that may be updated include but are not limited to:

Schedule Data. New project schedule network diagrams may be developed to display approved remaining durations and modifications to the work plan. In some cases, project schedule delays can be so severe that development of a new target schedule with forecasted start and finish dates is needed to provide realistic data for directing the work, and for measuring performance and progress.

Project Schedule. An updated project schedule will be generated from the updated schedule data to reflect the schedule changes and manage the project.

1.2 PERT Network Analysis

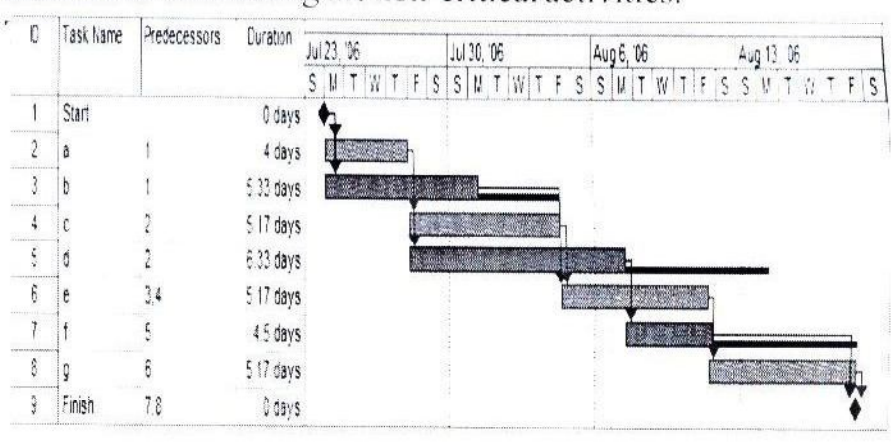
Analyzing network diagrams of a project can enable managers obtain a great deal of information. For instance, network diagrams show the sequence of activities involved in a project. This sequence will in turn help managers to determine which activities must take place before others can commence, and which can occur independently of another. Managers can also ascertain valuable insight by examining paths other than the critical path, and also identify those activities with slack which can help them accommodate slippage without affecting the project completion time. Knowledge about where slack is located enable managers to allocate scarce resources and direct their efforts to control activities.

For complex problems involving hundreds of activities, computers are used to create and analyze the project networks by means of a Project Management Software which can appear in the following example with tasks labeled A-G

Table 1.0 Pert Hypothetical Example

		Time Estimates			
Activities	Predecessor	Optimistic(O)	Most likely (M)	Pessimistic (P)	Expected Time
A	-	2	4	6	4.00
B	-	3	5	9	5.33
C	A	4	5	7	5.17
D	A	4	6	10	6.33
E	B,C	4	5	7	5.17
F	D	3	4	8	4.50
G	E	3	5	8	5.17

With the software, one can draw a Gantt chart as shown below or a network diagram. The Gantt chart is created using Microsoft Project where the critical path is in red, the slack is in black lines connecting the non-critical activities.



The project information input into the computer includes the earliest start time for each activity, earliest finished time for each activity, latest start time and latest finish time for each activity without delaying project completion. From the values, a computer algorithm can determine the expected project duration and the activities located on the critical path. With this, managers can use the information to determine where project time can be shortened by injecting additional resources like workers or equipment. PERT offers a number of advantages to manager. It enables them to organize and quantify project information and provides them with a graphic display of the project. It also help them to identify which activities are critical to the project completion time and should be watched closely. and which activities involve slack time and can be delayed without affecting the project completion time.

The Chief disadvantage of PERT lies in the nature of reality. Complex systems and plans with many suppliers and channels of supply involved sometimes make it difficult to predict precisely what will happen. It works best in well-understood engineering projects where sufficient experience exists to predict tasks accurately in advance.

One distinctive feature of Program Evaluation and Review Technique is that it is a probabilistic tool used where the time of the activities is not known, while the Critical Path Method is a deterministic tool used where the time estimates of activities are known with certainty.

1.2.1 Illustration of PERT Network Diagrams

One of the key features of PERT analysis is that a network diagram provides a visual depiction of the major project activities and the sequence in which they must be completed. It shows the activities that are concurrent, succeeding and preceding each other and the events.

PERT is typically represented as an activity on arc network, in which the activities are represented on the lines and milestones on the nodes.

For each activity, managers provide an estimate of the time required to complete it. The sequence of activities leading from the starting point of the diagram to the finishing point of the diagram is called a path. The amount of time required to complete the work involved in any path can be figured by adding up the estimated times of all activities along that path. The path with the longest total time is then called the critical path. The critical path is the most important path of the diagram for managers. Delay in completing activities along the critical path leads to an extension of the final deadline for the project. If there is any need for a manager to shorten the time required to complete the project, the manager must focus on finding ways to reduce the time involved in activities along the critical path. Planning with PERT involves the following steps:

(a) Identify the Specific activities and Milestone:

It would be helpful to list the tasks in a table that in later steps can be expanded to include information on sequence and duration.

(b) Determine the proper sequence of the activities:
This step may be combined with the activity identification step since the activity sequence is evident for some tasks. Some tasks may require more analysis to determine the exact order in which they must be performed.

(c) Construct a network diagram:
From the activity sequence information, a network can be drawn showing the sequence of the serial and parallel activities.

(d) Estimate activity times:
Weeks are a commonly used unit of time for activity completion, but any consistent unit of time can be used. A distinguishing feature of PERT is its ability to deal with uncertainty in activity completion time. PERT uses three times estimates. Project managers might be interested in completing a project at the minimum time possible but it is not always in their hands to do so. There are factors both internal and external to the organization which might influence the completion time of each activity in a project. Thus, there is an element of uncertainty in deciding upon the completion time of each activity and consequently the estimated project completion time. For each activity, PERT uses three estimates for each activity with a view to overcoming the uncertainty in project time estimates.

(i) **Optimistic Time Estimate (t_o)**
This is the estimate of the shortest possible time in which an activity can be completed under ideal conditions. For this estimate, no provision for delay or setbacks is made. In arriving at the optimistic time estimate, it is assumed that

everything is favorable in completing the activity in the shortest possible time.

ii) **Most Likely Time (t_m)**

This is a time estimate of an activity which lies between the optimistic and pessimistic time estimates. It is the time in which an activity can be completed under normal condition. In arriving at the most likely time, it is assumed that conditions are neither favourable nor unfavourable but normal. Of note is the fact that this time is different from the expected time.

(iii) **Pessimistic Time Estimate (t_p)**

This is the maximum possible time which an activity could take to accomplish the job, if everything went wrong and abnormal situations prevailed, this would be the time estimate.

PERT assume that the optimistic time (t_o), the pessimistic time (t_p) are equally likely to occur while most likely time (t_m) is four times more likely to occur than the other two. Thus, for arriving at the expected time (t_e) equal weights are assigned to t_o and t_p while weight of t_m is given as four times that of t_o and t_p. The following weighted average is given:

$$Expected\ Time = \frac{Optimistic + 4 \times Most\ Likely + Pessimistic}{6}$$

$$\therefore \quad t_e = \frac{t_0 + 4t_m + t_p}{6}$$

This expected time may be displayed on the network diagram. PERT uses the following formula to arrive at the variance and standard deviation of activity times.

$$Vairiance\ (\sigma^2) = \left[\frac{(t_p - t_o)}{6}\right]^2$$

$$Standard\ deviation\ (\sigma) = \sqrt{\left[\frac{(t_p - t_o)}{6}\right]^2} = \left[\frac{(t_p - t_o)}{6}\right]$$

e) **Determine the Critical Path**

The critical path is determined by adding the times for the activities in each sequence and determining the longest path in the project. It also determines the total calendar time required for the project. The total project time does not change if activities outside the critical path speed up or slows down. The amount of time that a non-critical path activity can be delayed without delaying the project is referred to as slack time. It may be helpful to determine the following four quantities for each activity, if the critical path is not obvious immediately.

(i) Earliest start time (E_s)
(ii) Earliest finish time (E_f)
(iii) Latest start time (L_s)
(iv) Latest finish time (L_f)

They are calculated by using the expected time for the relevant activities. The earliest state time and earliest finish of each

activity are determined by working forward through the network putting the predecessor activities into consideration.
The latest start and finish times are the latest times that an activity can start and finish without delaying the project. Latest start and Latest finish are determined by working backward through the network.

(f) Update as project progresses:
It makes adjustment in the PERT chart as the project progresses. The project estimated times can be replaced with actual times as the project unfolds. In cases where there are delays, additional resources may be needed to stay on schedule and PERT chart may be modified to reflect the new situation.

Estimate of probability: Due to variability in the activity duration, the total project may not be completed exactly in time. Thus, it is necessary to calculate the probability of actual schedule time of the project as well as activities.
The probability of completing the project by schedule time is given by:

$$Z = \frac{T_s - T_e}{\sigma_e}$$

T_e can be calculated by adding the expected time of each activity lying on the critical path. represents standard deviation of the critical path. Variance of the critical path can be calculated by adding variances of critical activities. is the square root of variance of the critical path.

An illustration will better explain how PERT can be applied using the three times estimate, variance and standard deviation.

1.2.1 Illustration A

A small project composed of 7 activities whose time estimates are listed in the table below.

Table 3.0 PERT Estimated Activities

ACTIVITY ESTIMATED DURATION IN WEEKS			
Activities	**Optimistic**	**Most likely**	**Pessimistic**
1-2	1	1	7
1-3	1	4	7
1-4	2	2	8
2-5	1	1	1
3-5	2	5	14
4-6	2	5	8
5-6	3	6	15

The first step is to draw the project network and identify all the paths through it.

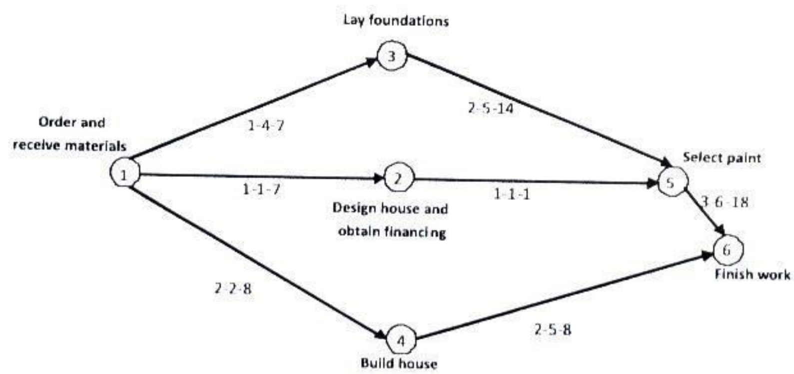


Figure 2.0 Project Network Diagram

The second step is to find the expected duration and variance activity and also the expected project duration.

The expected duration and variances for various activities are computed below:

$$T_e = \frac{t_0 + 4t_m + t_p}{6}$$

$1-2; \quad \frac{1+4+7}{6} = 2$

$1-3; \quad \frac{1+16+7}{6} = 4$

$1-4; \quad \frac{2+8+8}{6} = 3$

$2-5; \quad \frac{1+4+1}{6} = 1$

$3-5; \quad \frac{2+20+14}{6} = 6$

$4-6; \quad \frac{2+20+8}{6} = 5$

$5-6; \quad \frac{3+24+15}{6} = 7$

Compute the earliest and latest start to identify the critical path

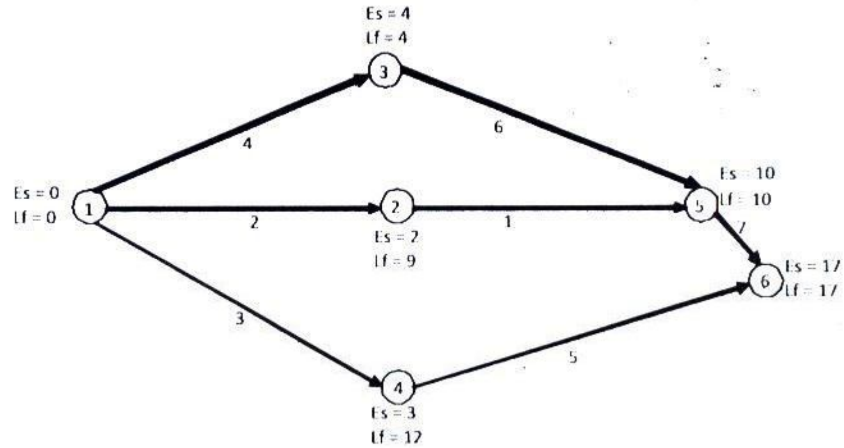


Figure 3.0 Project Network Diagram showing Critical Path

Variance $\sigma^2 \quad \dfrac{(T_p - T_o)^2}{6}$

$1-3; \quad \dfrac{7-1}{6} = 1^2 = 1$

$3-5; \quad \dfrac{14-2}{6} = 2^2 = 4$

$5-6; \quad \dfrac{15-3}{6} = 2^2 = 4$

From the network, the expected project length = 17 weeks

The variance of the critical path; 1 3 5 6 = 1 + 4 + 4 = 9

So, standard deviation = $\sqrt{9} = 3$

If the project due date is 18 weeks, the probability of meeting the due date is: $Z = \dfrac{T_s - T_e}{SD}$

$$T_e = 17, \quad T_c = 18$$

$$\therefore Z = \frac{18 - 17}{3} = 0.333$$

Therefore, the probability of meeting due to date after checking the Z table is 63%

1.2.2 Illustration B

In the following illustration, the project manager knows the succession of the project activities and the optimistic and most likely time (in weeks) for the following activities:

Table 4.0 PERT Estimates Showing Expected Task Duration

Activities	Description	Predecessors	T_o	T_m	T_p	$t_e = \frac{T_o + 4T_m + T_p}{6}$
A	Execution		9	12	15	12
B	Lay the foundation		5	9	13	9
C	Put off the rough wall	A	8	10	12	10
D	Put off the roof	B	7	9	17	10
E	Plumbing	B	18	23	34	24
F	Exterior sliding	A	9	9	15	10
G	Exterior painting	C	30	35	40	35
H	Electrical work	D	35	39	49	40
I	Put up the wall board	A	12	15	18	15
J	Flooring	E,G,H	3	3	9	4
K	Interior painting	F,I,J	7	9	11	9

Network diagram for the activities

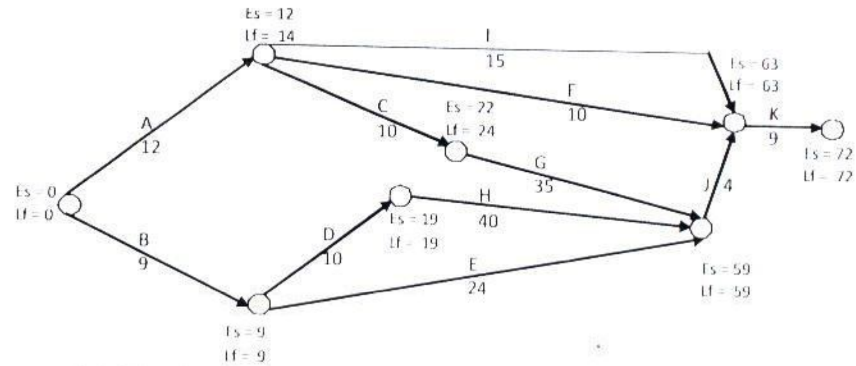


Figure 4.0 Project Network Diagram showing ES, LF and Critical Path

The following table shows the computation of the earliest start time, earliest finish time, latest start time and latest finish time.

Table 4.0 PERT Estimates Showing ES, ES, LF, LS, TF, FF

Activity	Duration	ES	EF	LF	LS	TF	FF	Critical activity
A	12	0	12	0	12	12	12	
B	9	9	18	9	0	9	9	
C	10	22	32	24	14	8	0	*
D	10	19	29	19	9	10	0	*
E	24	59	83	59	35	24	74	
F	10	63	73	63	53	10	26	
G	35	59	94	59	24	35	2	
H	40	59	99	59	19	40	0	*
I	15	63	78	63	48	15	36	
J	4	63	67	59	55	8	0	*
K	9	72	81	72	63	9	0	*

1.2.3 UPDATING THE NETWORK

Periodically, the progress of activities in a project network is measured. Most at times it could be that some of the activities are ahead or behind the schedule. It would be necessary to update or redraw the network periodically to know the exact position of completion of each project activity. The updating could be done once in a month as the case may be. Updating the network sometime may provide useful information that might demand the revision of even those activities that are yet to start. Some of the existing activities may be dropped and new activities may be added up. In brief the network should be amended accordingly in the light of new developments.

To understand how the task of updating is carried out, consider the following illustration:

1.2.4 Illustration C

After 15 days of working, the following progress is noted for the network of an erection job.

(a) Activity 24, 13 and 14 completed as per original schedule.

(b) Activity 2 4 is in progress and will be completed in 3 more days.

(c) Activity 36 is in progress and will need 18 days more for completion.

(d) Activity 67 appears to present some problem and its new estimated time of completion is 12 days.

(e) Activity 68 can be completed in 5 days instead of original planned for 7 days.

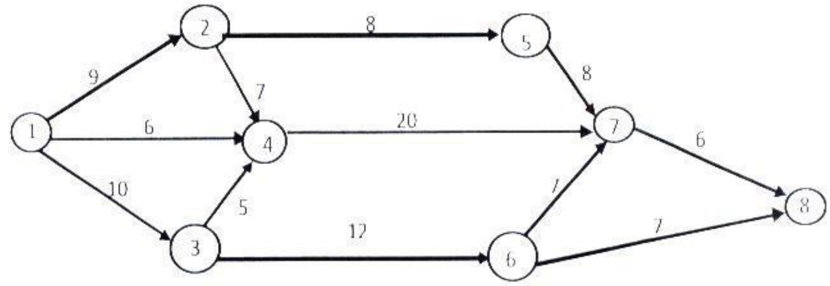


Figure 5.0 Project Follow-up Network Diagram

We are to:

(i) Update the above diagram after 15days of the start of work based on the assumptions given above.

(ii) Write down the critical path with total solution.

Table 5.0 Forward Pass Computation

Path	Duration
1-2-5-7-8	9 + 18 + 8 + 6 = 41
1-2-4-7-8	9 + 7 + 20 + 6 = 42
1-4-7-8	6 + 20 + 6 = 32
1-3-4-7-8	10 + 5 + 20 + 6 = 41
1-3-4-7-8	10 + 12 + 7 + 6 = 35
1-3-6-8	10 + 12 + 7 = 29

Critical path = 1-2-4-7-8 = 42 days

The new formulation of the problem is as follows:

(i) Activity 1-2, 1-3, and 1-4 need 9, 10 and 6 days respectively as per original programme.

(ii) Activity 2-4 needs 15 + 3-9= 9 days instead of original programme of 7 days.

(iii) Activity 3-6 needs 15 + 18 12 = 21 days

(iv) Activity 3-4 needs 5 days

(v) Activity 2-5, 4-7 and 5-7 need, 18, 20 and 8 days respectively.

(vi) Activity 6-7 needs 12 days as no work was scheduled to be started for this activity on the 15^{th} day

(vii) Activity 6-8 and 7-8 need 5 and 6 days respectively.

Drawing the revised path again, we have

Table 6.0 Backward Pass Computation

Path	Duration
1-2-5-7-8	9 + 18 + 8 + 6 = 41
1-2-4-7-8	9 + 9 + 20 + 6 = 44
1-4-7-8	6 + 20 + 6 = 32
1-3-4-7-8	10 + 5 + 20 + 6 = 41
1-3-6-7-8	10 + 23 + 12 + 6 = 51
1-3-6-8	10 + 23 + 5 = 38

Critical path 1-3-6-7-8 = 51 days

The new diagram will be as follows:

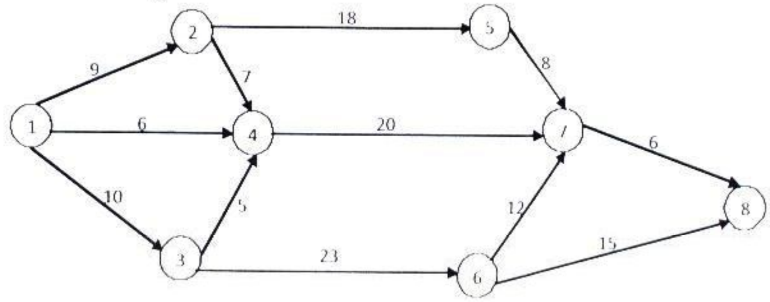


Figure 6.0 Updated Project Network Diagram

Updating network provides the project manager the latest information about the happenings till date and the revised future estimate of what is likely to happen. It is likely that even the path that is once identified as critical path may get shifted and updated network diagram may indicate a different critical path. Updating, thus shows that the project manager is alert and on the move.

Advantages of Program Evaluation and Review Technique (PERT)

(1) PERT chart explicitly defines and make visible dependencies between the work breakdown structure elements.

(2) PERT facilitates identification of early start, late start, and slack for each activity.

(3) The large amount of project data can be organized and presented in diagram for use in decision making.

There no doubt that PERT is a scheduling tool that helps in planning any type of project.

CHAPTER TWO

COST ESTIMATION

2.0 PURPOSE

This chapter establishes uniform guidance to describe methods, procedures, and formats for the preparation of construction cost estimates and construction contract modification estimates. This guidance represents where services have common requirements, however, for instances where there are differences, the use of cognizant design agencies policy and procedures becomes relevant.

This chapter also addresses all phases of construction cost estimating from the initial start of design through modification estimates during construction provides guidance for cost estimating during the initial planning, programming, and budget review phases. The term construction includes remedial action on environmental projects, dredging and other construction type works often implemented as service contracts. For the purposes of this book, the term cost engineer applies to all individuals who are engaged in the preparation or review of cost estimates.

All construction cost estimates, whether prepared in-house or by contract, will be given an independent review by government cost engineers as prescribed by the cognizant agency review procedures. The estimate should be reviewed for the purpose of confirming the validity of the assumptions and the logic used in estimating the cost of construction tasks. The review should always include a check of the quantities, unit prices, and arithmetic. It is important that the reviewer develops and uses a uniform checklist procedure in the review process to better assure that important considerations have not been overlooked.

2.1 ESTIMATE FORMAT STRUCTURE

It is important that the format of all estimates be as consistent as possible. Two formats have been established for this purpose, Work Breakdown Structure (WBS) and Uniform at II (ASTM Standard E1557-97). They are a hierarchical presentation of the scope of work. They provide a common, ordered hierarchy framework for summarizing information and for quantitative reporting to customers and management. The purpose of the formats are to: (1) provide an organized manner of collecting project cost data in a standard format for cost reporting and cost tracking; (2) provide a checklist for categorizing costs; and (3) provide a basis to maintain historical cost data in a standard format. The appropriate format is to be used in accordance with the cognizant design agency requirement.

2.2 COST ESTIMATING METHODOLOGY

The Association for the Advancement of Cost Engineering (AACE) International publishes cost engineering community

All construction cost estimates, whether prepared in-house or by contract, will be given an independent review by government cost engineers as prescribed by the cognizant agency review procedures. The estimate should be reviewed for the purpose of confirming the validity of the assumptions and the logic used in estimating the cost of construction tasks. The review should always include a check of the quantities, unit prices, and arithmetic. It is important that the reviewer develops and uses a uniform checklist procedure in the review process to better assure that important considerations have not been overlooked.

2.1 ESTIMATE FORMAT STRUCTURE

It is important that the format of all estimates be as consistent as possible. Two formats have been established for this purpose, Work Breakdown Structure (WBS) and Uniform at II (ASTM Standard E1557-97). They are a hierarchical presentation of the scope of work. They provide a common, ordered hierarchy framework for summarizing information and for quantitative reporting to customers and management. The purpose of the formats are to: (1) provide an organized manner of collecting project cost data in a standard format for cost reporting and cost tracking; (2) provide a checklist for categorizing costs; and (3) provide a basis to maintain historical cost data in a standard format. The appropriate format is to be used in accordance with the cognizant design agency requirement.

2.2 COST ESTIMATING METHODOLOGY

The Association for the Advancement of Cost Engineering (AACE) International publishes cost engineering community recommended practices. AACE publishes matrixes of acceptable levels of cost accuracy for various stages of project definition. The matrixes show both positive and negative values. For a given project scope and project definition, this range represents the amount of uncertainty that the prepared estimate can be either higher or lower than determined in the market place at the time of contract award. This does not mean that any given estimate is too high and can be reduced. Rather it represents an acceptable variability in cost estimating given various levels of design information, assumptions on the contractor's means and methods to execute the project, and other assumptions about bid competition and market conditions.

There are four general methods used to estimate construction costs, described below in order from least- to most-accurate. Increased accuracy provides a greater level of confidence in the estimate but requires more information about specific project requirements and local conditions. Use the most accurate method for the amount of information known when preparing the estimate.

2.2.1 Project Comparison Estimating

Project Comparison Estimating is used in early planning stages when little information is known about the project other than overall project parameters. Project comparison estimating uses historical information on total costs from past projects of similar building types. For example, the number of beds in a hospital, or number of spaces in a parking garage, or number personnel in an administration building can form the basis of a project comparipn estimate by comparing them to recent projects of similar scope in the same geographic region. Supporting facilities are estimated as a percentage of total facilities cost. This method is considered 'preliminary" and is accurate only from -25% to +40% notwithstanding abnormal market conditions (i.e. natural disasters, market volatility, etc).

2.2.2 Square Foot/Square Meter Estimating

Square Foot/Square Meter Estimating is another method of developing both preliminary and intermediate budgets based on historical data. This method is effective in preparing fairly accurate estimates if the design is developed enough to allow measurement and calculation of floor areas and volumes of the proposed spaces. There are several historical databases such as UFC 3-701-01 for the current year, RSMeans, Tn-Service Parametric adjusted models (PACES) available to support this method of estimating providing unit costs ($/SF). More accurate estimates made with this method make adjustments and additions for regional cost indices, escalation rates, and size adjustment costables. Further adjustments may be made to account for other unique aspects of the design such as special site conditions or design features being planned. In addition, the estimate can develop overall "core and shell" costs along with build-out costs of different space types, allowing for relative ease of determining the impact of changes to the program. Estimates made with this method can be expected to be accurate between -15% to +25% not withstanding abnormal market conditions (i.e. natural disasters, market volatility, etc).

The Unit Cost table supports a Square Foot /Square Meter Estimating method, and is generally applicable during the planning phase of a project. The unit costs in the table are national average historical costs with a known standard deviation for each facility type. When additional information allows a more detailed estimate using the Parametric or Quantity-Take-Off methods, the unit costs in should not govern the estimate

2.2.3 Parametric Cost Estimating

Parametric Cost Estimating is an intermediate-level estimate performed when design drawings are typically between 10% and 35% complete. Parametric costs are based on assemblies or systems grouping the work of several trades, disciplines and/or work items into a single unit for estimating purposes. For example, a foundation usually requires excavation, formwork, reinforcing, concrete, including placement, finish and backfill. A parametric cost estimate prices all of these elements together by applying engineered values developed in assemblies cost databases. These databases are based on historical data, typically organized in Uniform format. Estimates made with this method can be expected to be accurate between -10% to +15% notwithstanding abnormal market conditions (i.e. natural disasters, market volatility, etc).

2.2.4 Quantity Take Off (QTO) Estimating

In Quantity Take Off (QTO) Estimating, the work is divided into the smallest possible work increments, and a "unit price" is established for each piece. These work increments are typically organized by Master Format. The unit price is then multiplied by the required quantity to find the cost for the increment of work. All costs are summed to obtain the total estimated cost. For example, the cost to erect a masonry wall can be accurately determined by finding the number of bricks required and estimating all costs related to delivering, storing, staging, cutting, installing, and cleaning the brick along with related units of accessories such as reinforcing ties, weep-holes, flashings, and the like. Accuracy is more likely to be affected by supply and demand forces in the current market. A QTO can be based on a site adapt design cost estimate or using a 35% or more of the design. This method provides the most accurate estimate, which is typically between -7.5% to +10% of construction costs notwithstanding abnormal market conditions (i.e. natural disasters, market volatility, etc).

2.3 DEGREE OF DETAIL

2.3.1 Construction Tasks

All cost estimates within the scope of a particular activity will be prepared on the basis of calculated quantities and unit prices that are commensurate with the degree of detail of the design known or assumed. This is accomplished by separating construction into its incremental parts. These parts are commonly referred to as construction tasks and are the line-by-line listings of every activity that make up the estimate. Each task or minor activity is then defined and priced as accurately as possible. Tasks are seldom spelled out in the contract documents, but are necessary for evaluating the requirements and developing their cost.

2.3.2 Analyzing Construction Tasks

When analyzing construction tasks in an estimate, the cost engineer should identify the tasks that account for the major costs in the estimate. These tasks can be identified by applying the 80/20 rule, which states that approximately 80% of the project cost is contained in 20% of the tasks. Because these significant tasks account for most of the project cost, they should receive prime emphasis and effort in both preparation and review.

2.3.3 At the Most Detailed Level

At the most detailed level; each task is usually related to and performed by a crew or team. The cost engineer develops or selects the task description by defining the type of effort or item to be constructed. Task descriptions should be as complete and accurate as possible to lend credibility to the estimate and aid in later review and analysis. Whenever a significant amount of design assumptions are necessary such as in design-build process, the cost engineer should use historical cost data from previous similarly designed projects and/or use parametric estimating models.

2.4 ACCURACY AND COMPLETENESS

Accuracy and completeness are critical factors in all cost estimates. An accurate and complete estimate establishes accountability with the cost engineer and enables management to place greater confidence in the cost estimate.

2.5 ROUNDING FIGURES

2.5.1 Total Distributed Cost (Markup)

For cost estimates prepared manually, rounding of costs is desirable to avoid the use of decimals when allocating the total distributed cost (markup) to the direct subtotal costs for each work item.

2.5.2 Preliminary or Alternative Cost Estimates

Cost estimates prepared manually to determine preliminary or alternative cost estimates when design details are limited may be rounded based on the experience of the cost engineer, whereby the end cost is not significantly affected.

2.5.3 Total Cost of the Project

Rounding the total cost of construction projects to the nearest thousand Naira or dollars for design estimates and Independent Government Estimates (IGE) is acceptable for reporting purposes.

CHAPTER THREE

BASICS FOR PREPARATION OF ESTIMATES

3.0 GENERAL:

This chapter establishes uniform guidance to be used prior to estimate preparation. In the normal sequence of events toward the preparation of any estimate, it is of utmost importance to understand basic fundamental principles and responsibilities. Construction cost estimates consist of:

- Descriptions of work elements to be accomplished (tasks).
- A quantity of work required for each task.
- A cost for each task quantity.

A unit cost for each task is developed to increase the accuracy of the estimating procedure and should provide a reference comparison to historic experience. Lump sum estimating when used at the task level must be fully documented to show the intent and extent of the item.

3.1 PLANNING THE WORK

The cost engineer must thoroughly understand the project scope of work, the biddability, constructibility, operability, environmental (BCOE) and aspects of the project being estimated. The cost engineer must also review drawings, specifications, and construction sequences and durations to determine total construction costs. A site visit is strongly recommended to enable the cost engineer to relate the physical characteristics of the project to the available design parameters and details. This is particularly important on projects with difficult site conditions, major maintenance and repair projects, and alteration/addition projects. The construction sequence must be developed as soon as possible and should be used to provide a checklist of construction requirements throughout the cost estimating process. The overall format of major cost elements in an estimate must be compatible with current standards, management needs, the anticipated bidding schedule, and the appropriate WBS.

3.2 QUANTITIES

The quantity take-off" is an important part of the cost estimate. It must be as accurate as possible, and should be based on all available engineering and design data, and use of appropriate automation tools as available.

- After the scope has been analyzed and broken down into the construction tasks, each task must be quantified prior to pricing. Equal emphasis should be placed on both accurate quantity calculation and accurate pricing. Quantities should be shown in standard units of measure and should be consistent with design units. Assistance for preparing "takeoffs" may be provided by others within the organization in support of cost engineering or by A-E contracts; however, the responsibility for the accuracy of the quantities remains with the cost engineer.

- The detail to which the quantities are prepared for each task is dependent on the level of design detail. Quantity calculations beyond design details are often necessary to determine a reasonable price to complete the overall scope of work for the cost estimate. Project notes will be added at the appropriate level in the estimate to explain the basis for the quantity calculations, to clearly show contingencies, and to note quantities determined by cost engineering judgment that will be reconciled upon design refinement.

3.3 TYPES OF COSTS

Various types of cost elements must be evaluated in detail.

- Direct costs are those costs, which can be attributed to a single task of construction work. These costs are usually associated with a construction labor crew performing a task using specific equipment and materials for the task. Labor foreman cost should normally be considered as a direct cost. Subcontracted costs should be considered as direct costs to the prime contractor in estimates.

- Indirect costs are those costs, which cannot be attributed to a single task of construction work. These costs include overhead, profit, and bond. Indirect costs are also referred to as distributed costs.

- Estimates based on detailed design will be developed from separate direct conpricing of labor, material, construction equipment, and supplies. Appllicable indirect costs will be added to reflect the total construction cost. Other costs, including escalation, design contingencies, design-build, design costs, building commissioning, sustainment, construction contingencies, construction supervision, inspections and overhead (SIOH), and Operation and Maintenance (O&M) Manuals, may be added to the construction costs to determine the total project cost as requiied by program specific requirements.

3.4 PRICE SOURCES

Various pricing sources should be obtained and be available to the cost engineer. In pricing from any source, experience and ability to relate data in hand to a specific circumstance is important. The following discussion is provided on commonly used sources and source development.

a. Cost Book

The Cost Book is the common name for the Tn-Services construction direct costs database. It coriains repetitive construction tasks with direct cost pricing (labor, equipment, materàl) based on a typical crew and production rate for new construction. Some Cost Book line items may include quotes for work that is fully provided and installed by subcontractor.

All quotes for work fully priced by subcontractor shall be shown in the appropriate column. Each office is encouraged to use this pricing source and to refine the database by obtaining quotes to more accurately reflect local costs at the project site.

b. Historical Data

Historical costs from past similar work are excellent pricing sources when adequate details have been saved and adjustment to project specifics and can be defined. Portions of other estimates having similar work can be retrieved and repriced to the current project rates. Automated historical databases can be used in preparing historical data.

c. Parametric Database

A parametric database of predefined-assernblies for buildings and site work has been developed and is available.

3.4.1 Development of Specific Tasks

When standard tasks do not meet project needs, specific new tasks may need to be developed. Such development requires experience. Descriptions developed must adequately define the scope and material requirement for each task. Unit cost for each task is developed as a direct cost with separate costing for the labor, equipment, and material components. Notes, which explain key factors in the pricing and methodology, should accompany the task development. Comparison with existing pricing guides is recommended.

- **Labor unit cost** - This cost is based on a defined crew from the Cost Book or on a newly developed crew, which performs the tasks at an assigned production rate. Hourly rates for each craft are applied to the crew labor to arrive at the hourly crew labor cost. The total crew labor cost/hour is divided by the expected production rate (units/hour) to derive the labor cost/unit.

- **Equipment unit cost** - This cost is derived similar to labor unit cost. Hourly equipment rates are obtained from the appropriate regional manual, entitled, Construction Equipment Ownership and Operating Expense Schedule (herein referenced as, Equipment Ownership Schedule), Engineer Pamphlet (EP) developed according to the methodology as described in the pamphlet.

- **Material unit cost** - This cost is developed using vendor quotes, historical costs, commercial pricing sources, or component calculations. The price should include delivery to the project site.

- **Commercial unit cost books** - These common sources are typically available through subscription or purchase. Basis of costs shown are typically explained along with adjustment methodology. Such publications are valuable for verification and appropriate for commercial type work item pricing.

3.5 COSTS AND PRICING

The cost for each task should be developed by summing the direct cost elements for labor, equipment and materials. The indirect costs and other markups associated with each task or work item should be identified and are considered separately for the specific project.

a. Minor Direct Costs

The direct cost on construction tasks of minor overall cost significance and of a repetitive nature can normally be priced from any of those sources discussed above.

b. Historical Pricing

When using historical pricing, adjustments must be made for project location, work methodology, quantity of work, and other dissimilarities, which affect prices.

c. Lump Sum Items

Use of lump sum items is discouraged. If lump sum items are used in the estimate, they must have backup cost data relating to their tasks and source of the data.

3.5.1 Detailed Backup of Cost

As a general rule-of-thumb, it is highly recommended that when a task extended direct cost is $10,000 or more, or 5 percent or more of the total direct cost, whichever is less, a detailed backup for the cost should be prepared or vendor quotations obtained as pricing support to the cost estimate.

3.5.2 Predetermined Bid Items

Applying a similar rule-of-thumb, in some instances, unit price bid items for Government estimates may be based on suitable experienced bid prices or historical cost data, i.e., predetermined bid item does not exceed $100,000, or 5 percent or more of the estimated total cost, whichever is less. For cost estimates prepared during preliminary or planning phases, where design is limited or not available, predetermined unit prices adjusted to current pricing level may be used by the cost engineer. Use of experienced prices should consider any necessary adjustments in prime contractor's profit or distributed costs appropriate to the contract requirements. The cost engineer must use extreme care and sound judgment when using predetermined unit costs. The basis for the unit costs should be well documented and included in the supporting data of the estimate. Where a bid item consists mostly of equipment and labor costs, with very little materials and supplies, it is advisable to develop the cost as indicated above, even though the item may fall under this rule-of-thumb.

3.6 COST ESTIMATE FORMAT AND SUPPORTING DOCUMENTATION

All construction cost estimates are generally composed of contract cost and other allowable project costs authorized by directives or regulations. The oveall format of the cost estimate should be in accordance with the appropriate WBS. The cost engineer should always remain mindful of the documentation necessary to support the cost estimate submission requirements specified for each phase of project development. Support documentation such as project narrative. pricing schedule, plan of construction, backup data, and drawings and sketches are still part of support documents.

3.7 COMPOSITION OF GOVERNMENT ESTIMATES

The Government estimate is the formal, approved construction cost estimate prepared and submitted to the Contracting Officer to support contract award. Each Agency may have its own requirements and procedures. The presentation format for this type of estimate generally is: Government Estimate of Contract Cost, Narrative of Contract Cost, Government Estimate Back-up Data, and Miscellaneous Support Data.

3.8 GOVERNMENT ESTIMATE OF CONTRACT COST

The Government estimate is the portion of the cost estimate to be submitted as required by procurement regulations. It includes the title page, signature page, and pricing schedule.

a. Title Page

The title page should include the name and location of the project, the office responsible for the project design, the cost engineer responsible for preparation of the cost estimate, and the date and price level of the cost estimate.

b. Signature Page

The signature page should contain the names and signatures of those individuals responsible for the preparation, review, submittal, and approval of the cost estimate. It is necessary that the sheet contain the total amount of the estimated costs. The number of amendments included in the estimate should appear on the same page so that there will be no question as to the approved amount.

c. Pricing Schedule

The pricing schedule required by the solicitation documents must be completed as part of the Government estimate. As part of the design team, the cost engineer should be involved in the development of the pricing schedule. The format of the pricing schedule must be anticipated in planning and design estimates. When the pricing schedule is finalized for procurement, it must show unit prices, quantities, extension of unit prices, lump sum items, and total costs. Rounding off is not permitted on the pricing schedule between the unit price and extension. Any rounding adjustments must be performed in the detail estimate. Instructions in the bidding request documents also pertain to the Government estimate.

3.9 NARRATIVE OF CONTRACT COSTS

This part of the estimate of construction cost consists primarily of those sheets, with notes, which describe the scope tasks and costing. It also contains discussions, considerations, and the developed construction plan.

The types of items normally included are as follows:

a. Table of Contents

This page denotes the backup content.

b. Project Narrative

The project narrative provides general details of the project. The narrative defines the assumptions made during the preparation of the cost estimate. It describes the project requirements that must be performed in sufficient detail to give a clear understanding of the scope of work. It also describes project details including length, width, height and shape of primary features, special problems that will be encountered in performing the work, site conditions affecting the work, reasons for selection of major plant and equipment, method and time for mobilization and demobilization of all equipment, and the reasons for unusually high or low unit prices,. Each estimate will include a statement, which relates both to the development of design, as appropriate, and date of effective pricing. Other factors to be considered in the project narrative include: Construction schedule, use of overtime, construction windows, phasing, acquisition plan and subcontracting.

Project related details including site access, borrow areas, construction methodology, unusual conditions (soil, water or weather), unique techniques of construction, equipment/labor availability and distance traveled, environmental concerns, contingencies by feature or sub feature, if appropriate, and effective dates and sources for labor, equipment and material pricing.

c. Construction Schedule

The cost engineer may prepare a construction schedule to support the cost estimate that is consistent with the schedule for completion of the project. It may be in the form of bar chart or network analysis system. It must identify the sequence and duration of the tasks upon which the cost estimate is developed. The schedule must be prepared in sufficient detail to adequately develop the required labor, equipment, crew sizes, and production rates required for each of the identified construction tasks.

d. Equipment and Materials Utilization

On those projects involving considerable heavy construction equipment, it is necessary to sufficiently plan the equipment usage against the work schedule to identify the actual number of cranes, dozers, and allow for proper mobilization to assure that demand for the equipment is not over or understated. For equipment selected from Construction Equipment Ownership and Operating Expense, the schedule should indicate the region and date of the equipment used for the pricing. Materials, which require long lead-time and can become critical to the construction schedule should be isolated, planned, and adequately considered.

e. Labor Discussion and Utilization

The estimate should clearly state the sources for the various labor classifications and rates and include tabulation by crafts of the various composite wage rates used. When extensive overtime beyond the normal workday is used in the estimate, an explanation should be included.

3.10 GOVERNMENT ESTIMATE BACKUP DATA

This part of the estimate consists of all the support and backup documentation. The various categories of support documentation contained in this part are:

- Cost analysis summary sheets. The automated or manually prepared summary sheets for direct, indirect and owner costs are used to summarize cost components for each bid item and by the appropriate Work Breakdown Structure. Distribution of overhead and profit is shown on this sheet.
- Mobilization, preparatory work, and demobilization. These costs should be itemized and costed separately. These costs may be combined at summary level with overhead if these costs are not paid as a separate bid item. This item may be shown as a lump sum on the bid schedule.
- Profit computation sheet. When profit is included, the weighted guidelines will be used to compute the profit and will be part of the cost estimate backup.
- Overhead costs. The itemization and calculations of overhead costs, both job site and home office, should be accomplished in accordingly.
- Bond costs. Bond costs should be calculated in accordance with bid items similar to or as part of overhead costs distribution.
- Automated detail sheets. The completed direct costs should be organized with the proper sequence by the appropriate Work Breakdown Structure for each bid item.
- Production rates. The automated or manually prepared details are used to express production rate analysis of crews. Crew, labor, equipment rates. These automated or

manually prepared details are used to express the crew composition, and associated rates for labor and equipment costs. The information contained on these sheets provides the backup support for the task unit labor and equipment costs shown.

- Quantity computations. The quantity takeoff computation for the tasks estimated, should be organized as task for the bid items and kept as backup. The takeoff should reference the drawing and clearly explain the computation.
- Quotations. Quotations should be collected and compiled as bid item into an organized reference. When quotations were not obtained for significant material and supply items, the basis for the cost used should be fully described. Quotations should be considered proprietary information and should be kept confidential to protect the information entrusted to the cost engineer.

Projects outside continental United States (OCONUS) should include International Balance of Payment (IBOP) analysis under normal or revised procedures. Estimates will not include the IBOP statement but the documentation will be retained at the cognizant design agency office.

3.11 MISCELLANEOUS SUPPORT DATA

Include all other information pertinent to the estimate such as drawings, sketches, which were used as the basis of the cost estimate. Drawings may include a project map showing the location of the work with respect to principal cities, roads, railways, and waterways; a site map showing the location of the work, borrow, quarry, and spoil areas, and existing work access roads; any existing facilities usable by the contractor; a general plan and elevation, or profile of the work with typical sections; and a construction layout.

Supporting documents that are publicly available as parts of the solicitation, such as plans, specifications and project description, or that contain no cost information, such as sketches, soil boring and material classifications, are not part of the Government estimate or back-up.

REQUIREMENTS FOR REVISION TO GOVERNMENT ESTIMATE FOR BIDDING

Prior to award, the Government estimate may be changed or revised as a result of errors, differing conditions or additional information. Approval authority for revision to the estimate remains the responsibility of the Contracting Officer or authorized original estimate-approving official. Each office should assure that appropriate justification is attached to the revised cost estimate. Estimates may be revised by supplementary sheets or by actually changing the contents of the original estimate pages. The method used will be determined by the nature of the revision and the format of the estimate. Whichever the method, all revisions to the estimate must be clearly indicated, dated, justified, and approved. A new signature sheet relating to both the previously approved total and revised total will be re-approved. A copy of each estimate that has been approved should be included in a file along with the details and circumstances reflecting the revisions.

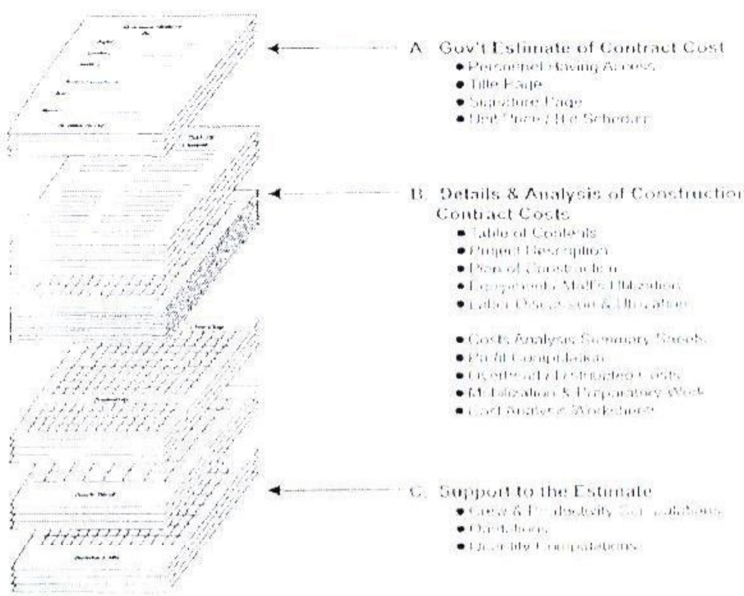


Figure 7.0 Composition of an estimate

CHAPTER FOUR

LABOUR COST

4.0 TYPES OF LABOUR COST

a. Direct Labor Costs

Direct labor costs are defined as base wages plus labor cost additives including payroll taxes, fringe benefits, travel, and overtime allowances paid by the contractor for personnel who perform a specific construction task. In addition to the actual workers, there are generally working crew foremen who receive an hourly wage and are considered part of the direct labor costs.

b. Indirect Labor Costs

Indirect labor costs are wages and labor cost additives paid to contractor personnel whose effort cannot be attributed to a specific construction task. Personnel such as superintendents, engineers, clerks, and site cleanup laborers are usually included as indirect labor costs (overhead).

4.1 CREWS

Direct labor cost requirements are broken into tasks of work. Since each task is usually performed by a labor crew including equipment, the crew must be defined, costed, and a production rate established for the task. Crews may vary in size and mix of skills. The number and size of each crew should be based on such considerations as having sufficient workers to perform a task within the construction schedule and the limitation of workspace. Once the crews have been developed, the task labor costs can be determined based on the production rate of the crew and the labor wage rates.

4.2 WAGE RATES

A wage rate must be developed for each labor craft, which will represent the total hourly cost rate to the construction contractor. This total rate will include the base wage rate plus labor overtime, payroll taxes and insurance, fringe benefits, and travel or subsistence costs as further described in this chapter. The composite wage rate for each craft will be used for development of the estimate. The computation will be prepared on similar local forms, or cognizant design agency approved cost estimating software.

Wage rates are generally well defined. The Davis-Bacon Act, PL 74-403, requires a contractor performing construction in the United States for the Government to pay rates less than the prevailing rates set by the Department of Labor. A schedule of minimum rates is included in the project specifications and is normally kept on file for each location by each local Office or Counsel. The cost engineer should consult with the Contracting Officer on any questions regarding determination coverage, specific definitions, or concerns. Where labor is in short supply for certain crafts in the area, or the work is in a remote area, or it is well known that rates higher than the set rate scale will be paid, these higher wage rates should be used instead of the minimum wage since this would be required of the contractor in order to attract labor to the job. The wage rate should be adjusted to include travel time or night differential where these are a customary requirement.

Long Duration Projects

For a long duration project, where future wage rates are known and used, care must be taken to avoid duplication by also applying an escalation rate to such costs.

4.3 OVERTIME AND SHIFT DIFFERENTIAL

The cost engineer should carefully consider the available working time in the construction schedule for each task accomplishment in a normal time period. The efficiency of both the second and third shifts should be adjusted to recognize that production will not be as high as the day shift for most types of construction operations. A three-shift operation should normally be avoided due to lower labor efficiency and the requirement to include equipment maintenance.

a. Overtime

Overtime should be included in the labor cost computation when work in excess of regular time is required by the construction schedule or is the custom of labor in the local vicinity. Overtime labor cost is normally calculated as a percentage of the base wage rate. It is usually based on time and one-half, but may be double time depending on the existing labor agreements. Tax and insurance costs are applied to overtime, but fringe benefits and travel and/or subsistence costs are not. Example for overtime calculation for 40 hours regular time, plus 8 hours overtime at time and one half:

48 hours at straight time	= 48.00 hours
8 hours at 1/2 time	= 4.00 hours paid
equivalent straight time	= 52,00 hours
(52 hrs paid/48 hrs worked	
= 1.0833) -1 100%	= 8.33%

b. Shift Operations

Many construction projects utilize multiple shift operations. When estimating direct labor costs for multiple shift operations, the cost engineer should estimate the number of hours to be worked (include shift differential work loss) and the number of hours to be paid for each shift based upon the developed construction schedule. Differential shift premiums may need to be added to the hourly rate.

c. Tabulation of Overtime Percentages

A tabulation of overtime percentages for most conditions is shown above. The percentage also includes an allowance for the direct work loss of multiple shift or shift differential, where applicable.

Table of Overtime and shift differential

	Actual Hours Worked		Hours Paid		Percentages for OT and Shift Differential		
					1.5x Wk/Sat 2x Sun	1.5x Week 2x Sat/Sun	Week 2x All OT
	Day	Week	Reg	OT			
One shift operation							
5 Day Week	8	40	40	0	0	0	0
	9	45	40	5	5.55	5.55	11.11
	10	50	40	10	10.00	10.00	20.00
	11	55	40	15	13.64	13.64	27.27
	12	60	40	20	13.37	13.37	33.33
6 Day Week	8	48	40	8	8.33	16.67	16.67
	9	54	40	14	12.96	21.30	25.93
	10	60	40	20	16.67	25.00	33.33
	11	66	40	26	19.70	28.03	39.39
	12	72	40	32	22.22	30.56	44.44
7 Day Week	8	56	40	16	21.43	28.57	28.57
	9	63	40	23	25.40	32.54	36.51
	10	70	40	30	28.57	35.71	42.86
	11	77	40	37	31.17	38.31	48.05
	12	84	40	44	33.33	40.68	52.38
Two Shift Operation (one 8 hours and one 7.5 hours)							
5-Day Week	15.5	77.5	80	0	3.23	3.23	3.23
	18	90	80	12.5	9.72	9.72	16.67
	20	100	80	22.5	13.75	13.75	25.00
	22	110	80	32.5	17.05	17.05	31.82
	24	120	80	42.5	19.79	19.79	37.50
6 Day Week	15.5	93	80	16	11.83	20.43	20.43
	18	108	80	31	17.13	25.69	31.48
	20	120	80	43	20.42	28.96	38.33
	22	132	80	55	23.11	31.63	43.94
	24	144	80	67	25.35	33.85	48.61
7 Day Week	15.5	108.5	80	32.0	25.35	32.72	32.72
	18	126	80	49.5	29.76	37.10	42.06
	20	140	80	63.5	32.50	39.82	47.86
	22	154	80	77.5	34.74	42.05	52.60
	24	168	80	91.5	36.61	43.90	56.55

	Actual Hours Worked		Hours Paid		Percentages for OT and Shift Differential		
					1.5x Wk/Sat 2x	1.5x Week 2x	Week 2x
	Day	Week	Reg	OT	Sun	Sat/Sun	All OT
Two-Shift Operation (each 7.5 hours)							
5-Day Week	15	75	80	0	6.67	6.67	6.67
	18	90	80	15	13.89	13.89	22.22
	20	100	80	25	17.50	17.50	30.00
	22	110	80	35	20.45	20.45	36.36
	24	120	80	45	22.92	22.92	41.67
6-Day Week	15	90	80	10	15.56	24.44	24.44
	18	108	80	34	21.30	30.09	37.04
	20	120	80	46	24.17	32.92	43.33
	22	132	80	58	26.52	35.23	48.48
	24	144	80	70	28.47	37.15	52.28
7-Day Week	15	105	80	32	29.52	37.14	37.14
	18	126	80	53	34.13	41.67	47.62
	20	140	80	67	36.73	43.93	52.86
	22	154	80	81	38.31	45.78	57.14
	24	168	80	95	39.88	42.37	60.71
Three-Shift Operation							
5-Day Week	22.5	112.5	120	0	6.67	6.67	6.67
6-Day Week	22.5	135.0	120	24	15.56	24.44	24.44
7-Day Week	22.5	157.5	120	48	29.52	37.14	37.14

4.4 TAXES AND INSURANCE

a. Rates

Rates for all taxes and insurance should be verified prior to computation.

b. Workman's Compensation

Workman's compensation and employer's liability insurance costs applicable for the state in which the work is performed should be included in the composite wage rate. Insurance rates may be obtained from the state if the state law provides a monopoly or from insurance companies providing this type of Insurance. The project compensation rate is based on the classification of the major construction work and applies to all crafts employed by the contractor.

c. Unemployment Compensation Taxes

Unemployment compensation taxes are composed of both state and Federal taxes. This form of tax obtains mostly in the developed economy like the United States. Unemployment compensation tax will vary with each state while the Federal unemployment tax will be constant for all projects. Insurance rates can be obtained from the state unemployment office, commercial publications, or the Bureau of Labor Statistics.

d. Social Security Tax Rates

The social security tax rates and the income ceilings on which social security taxes must be paid vary from year to year. Therefore, the cost engineer must verify the rate to be used in the cost estimate. Current and future rates can be obtained from the Social Security Administration.

e. Total Percentage of Taxes and Insurance

The total percentage of the above taxes and insurance is summed and then applied to the basic hourly wage rate plus overtime for the various crafts. The example below illustrates the method for deriving the total tax and insurance percentage. Since rates are subject to change and in some cases vary by region, the calculations shown are presented as an example only. Actual values must be determined by the cost engineer for the specific project.

Workman's compensation and employers liability (varies with state and contractor)	7.60%
State unemployment compensation (varies with each state)	3.20%
Federal unemployment compensation	0.80%
Social Security Medicare	7.65%
Total taxes and insurance	19.25%

Note: Foreman and overhead labor rates must also include these applicable costs.

4.5 FRINGE BENEFITS AND TRAVEL/SUBSISTENCE

a. Fringe Benefits

Fringe benefits may include health and welfare, pension, apprentice training, depending on the craft and the location of the work. These summed costs are usually expressed as an hourly cost with the possible exception of vacation, which may be easily converted to an hourly cost. The type of fringe and the amount for the various crafts can usually be found with the Davis-Bacon Act wage determination in the specifications. Non-union contractors pay comparable fringe benefits directly to their employees.

The example below illustrates the calculations for fringe benefits. Since the values change and vary by region and union agreement, the calculations shown are presented as an example

only. Actual values must be determined by the cost engineer.
Health and welfare $0.70/hr
Pension 0.75/hr
Apprentice training 0.00/hr
(N/A in this case)
Total fringe benefits..................... $ 1.45/hr

b. Travel and Subsistence

Travel and subsistence costs are normally expressed as a daily or weekly cost. When included in the cost estimate, they should be converted to an hourly cost and excluded from an overtime premium unless travel and subsistence are part of an increased hourly wage. Some fringe benefits and travel/subsistence are subject to payroll taxes. For example, vacation benefits are taxable and should be added to the basic wage rate.

4.6 LABOUR PRODUCTIVITY

Estimating labor productivity is subject to many diverse and unpredictable factors. There is no substitution for the knowledge and experience of the cost engineer when estimating labor productivity. For some types of work, the task productivity of crewmembers such as equipment operators, helpers, or oilers is determined by the productivity of the equipment. For some labor based crews, the task productivity of craftsman such as carpenters, steel workers, and masons may be based on average experience in the Cost Book, tempered with the experience of the cost engineer, historical records, or other appropriate reference manuals.

4.6.1 Productivity Adjustment Considerations

a. Labor Effort

The labor effort needed to perform a particular task varies with many factors, such as the relative experience, capability and morale of the workers, the size and complexity of the job, the climatic and topographic conditions, the degree of mechanization, the quality of job supervision, amount of similar task repetition, and the existing labor-management agreements and/or trade practices. The effort from these labor efficiency factors and work practices that exist in the project locality must be considered in each productivity assignment.

b. Complexity of the Variable

The complexity of the variables affecting productivity makes it difficult to estimate a production rate. Therefore, production rates should be based on averaging past production rates for the same or similar work. The cost engineer must incorporate particular job factors and conditions to adjust historical data to the project being estimated. Other sources for production rates include reference manuals, field office reports, construction logbooks, and observation of ongoing construction.

CHAPTER FIVE

SAFEGUARDING COST ESTIMATES

5.0 INTRODUCTION

Although not required by regulations, estimates based on less than a completed design should be handled in a discretionary manner. Access to each estimate and its contents will be limited to those persons whose duties require knowledge of the estimate. Any request by the public for information and pricing in the estimate will not be provided until coordination, verification of data, and approvals have been given by the designated authority.

5.1 SECURITY AND DISCLOSURE OF CLIENT ESTIMATE

a. Contents of the Client Estimate

Client estimate normally consists of a title page, signature page, and price schedule. Supporting documents that are publicly available as parts of the solicitation (such as plans, specifications, and project descriptions) are not part of the estimate, estimates for contract awards and contract modifications are treated the same:

b. Access to the Client Estimate

Access to the estimate and its contents will be limited to personnel whose duties require they have knowledge of the subject. Submitted client estimate should include a list of individuals name that have had access to the total amount of the estimate. Client personnel also should sign the same or a similar list.

c. Marking the Client Estimate

Client estimate will be marked in accordance with cognizant design agency requirement. The estimate will ensure that the protective marking "For Official Use Only" (FOUO) is properly applied to all pertinent documents, computer files, compact discs (CDs), printouts, and other documents prepared manually or electronically for incorporation into the client estimate.

d. Disclosure Outside of the Client

After contract award, ordinarily, only the title page, signature page, and price schedule are disclosed outside the client. The client estimate back-up data should not be released since it contains sensitive cost data (e.g., contractor quotes, crews and productivity) that are proprietary or might compromise cost estimates for future similar procurement.

e. Bid Protests and Litigation

During bid protests and litigation, if appropriate and to the extent possible, Counsel should have the estimate and/or the cost estimate backup data placed under a "protective order."

There are valid reasons for not releasing the cost back-up data supporting the clients estimate to the contractors. In the case of a bid protest, there is a possibility that the contract could be re-advertised or converted to a negotiated procurement. Release of the clients back-up data would provide bidders with the detailed cost data that supports the cost estimate. If, however, the apparent low bidder protests the details of the estimate, the client may provide the client estimate and cost backup data, to the protestor only, upon receipt of complete details of the protestor's estimate. If the protest is not sustained and the proposal is re-advertised, all bidders are entitled to have the same information as the protestor.

5.2 RELEASE OF CLIENTS ESTIMATES UNDER THE FREEDOM OF INFORMATION ACT (FOIA)

The clients estimate and cost estimate back-up data, prepared for construction contracts and modifications, are sensitive procurement information and should in many cases be withheld under the FOIA.

5.2.1 Definitions

- The estimate consists of a title page, signature page, and price schedule.
- The cost estimate back-up data is the detailed cost data which includes production and crew development methodology, labor, equipment and crew backup files, subcontractor quotes and all other data identified on agency approved estimating software as detail sheets.

- Supporting documents that are publicly available as part of the solicitation, such as plans, specifications and project description, or that which contains no cost information, such as sketches, soil borings and material classifications, are not part of the cost estimate or back-up.

5.2.2 Requests for Clients Estimates and Back-Up Data

Clients estimates and the estimate back-up data are intra-agency memoranda, which may be withheld under a "confidential commercial information" and "deliberative process" privileges. Requests for clients estimates and back-up data will be reviewed on a case-by-case basis, based on the following guidance, to determine whether release will harm the interests of the parties.

5.2.3 Sealed Bid Procurement

When sealed bidding is used, neither the client estimate nor the estimate back-up data should be released prior to bid opening. It is well established that release of client's estimates and back-up data before contract award would harm the interests of the parties.

5.2.4 Post Bid

The client estimate will normally be released when bids are opened. In some instances, however, the client estimate will not be released at that time, such as when all bids received are non-respons ve and a re-procurement is envisioned.

5.2.5 Negotiated Procurement

Negotiated procurement for construction estimate should not be released prior to contract award, except in negotiating for a fair and reasonable price.

5.2.6 Back-Up Data

The cost estimate back-up data should not be released. Release of estimate back-up data after contract award and before completion of a construction contract may also result in harm to the client. The client estimate back-up data is used to develop cost estimates for modifications and claims. Release of the backup data prior to contract completion provides the contractor with the details of the Clint's position and would allow the contractor to develop a biased price proposal. This could harm the Clint's ability to negotiate for a fair and reasonable price for the modification or claim, putting the client at a serious commercial disadvantage. Moreover, knowledge of the construction methods contemplated by the client might reduce the contractor's incentive to discover less expensive methods. This could also reduce the contractor's incentive to locate and charge out materials at a lower cost, or to achieve project goals using less labor and equipment.

5.3 TEAM INVOLVEMENT

Cost engineers are an important member of the project delivery team. The cost engineer is expected to have a clear understanding of those responsibilities and areas where contributions can be made. It is imperative that the team concept be enhanced and supported by each member. As such, the cost engineer is encouraged to lead in cost issues and provide ideas for cost control and sharing measures.

5.4 LIFE CYCLE COST (LCC) STUDY SUPPORT

Quality management policy requires life cycle cost (LCC) studies to be performed to evaluate system alternatives. These analyses are the responsibility of the design team. The cost engineer may be called upon to support the analysis by providing cost input. As preparation to such responsibility, the cost engineer should be familiar with the LCC procedures.

5.5 WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure (WBS) provides a common framework for preparing cost estimates, developing models, and collecting cost data for construction projects. It is to be used for categorizing facility costs and associated supporting facility costs for all conventional construction projects. This WBS is comprised of 15 primary facility systems and four supporting facility systems. Each system is divided into one or more subsystems, which are further divided into assemblies made up of construction line items. An example of WBS levels numbering is as follows:

Level 1	Scope
Level 2	Facility (Building)
Level 3 (System)	Superstructure
Level 4 (Subsystem)	Floor Construction
Level 5 (Assembly	Floor Decks and Category)

Slabs
Level 6 (Assembly) Precast Concrete Slab
Level 7 (Detail Line Item) Erection, Precast Slab

a. Measure

A unit of measure is associated with each level of the WBS and should be followed to facilitate the estimating review process. This will allow estimates to be compared to other similar project estimates.

b. Numbering Structure

The standard numbering structure and description manual is available and referred to as Data Dictionary." The dictionary includes description of building functional components and associated supporting facilities.

5.6 PROGRAM SPECIFIC REQUIREMENTS

Construction cost estimates are prepared throughout the planning, design, and construction phases of a construction project. These construction cost estimates may be categorized as follows: programming estimate, concept estimate, final estimate, and private or public estimate.

a. Programming Estimate

In the planning phase, the cost estimate is called programming estimate and is prepared on stage by stage basis. The development of this programming estimate is based on preliminary project scope or mission requirements which form the criteria and standards for development and preparation of cost estimates for constructing facilities.

b. Design Estimate

Design estimates for Design-Bid-Build (DBB) projects may be categorized as 15%, 35%, or 65% stages of design. The estimates are refined more during these phases since the design criteria and project requirements have been further defined. The 15% design estimate may be prepared by a variety of methods, such as conducting a Design utilizing parametric estimating procedures, detailed quantities take-off, or a combination of detailed quantities take-off with parametric estimating procedures. There may be instances when a 35% and a 65% design estimate would be prepared, which would be a further refinement of the project cost at this phase to be as a guide in comparison to the programmed amount. Design estimates for Design-Build (DB) projects are based upon draft performance and prescriptive specifications(DPPS).

c. Pre-Final Estimate

The next stage of development is the pre-final estimate. DBB and DB projects are each developed differently due to these two project delivery methods.

d. Design Build

Pre-final estimates for DB projects are based upon the 100% performance and prescriptive specifications stage.

e. Design Bid Build

Pre-final estimates for DBB projects are based on the 90% design phase. This estimate is the detailed bottom-up cost estimate based on the final plans and specifications.

f. Independent Government Estimate

The last stage of development is the IGE For DBB projects. The IGE is based on the 100% design phase of the plans and specifications. For DB projects the estimate is based upon the final performance and prescriptive specifications. The estimate that is provided to the Contracting Officer serves as the IGE.

CHAPTER SIX

PROJECT COST MANAGEMENT

6.0 INTRODUCTION

Project Cost Management includes the processes involved in estimating, budgeting, and controlling costs so that the project can be completed within the approved budget. An overview of the Project Cost Management processes include the following:

a. Estimate Costs: The process of developing an approximation of the monetary resources needed to complete project activities.

b. Determine Budget: The process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline.

c. Control Costs: The process of monitoring the status of the project to update the project budget and managing changes to the cost baseline.

These processes interact with each other and with processes in the other Knowledge Areas as well. Each process can involve effort from one group or person, based upon the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases.