APPLICATION OF NETWORK SCHEDULING MODELS IN PLANNING AND CONTROLLING OF BUILDING PROJECTS

(A MANAGERIAL APPROACH TO NIGERIAN CONSTRUCTION COMPANIES)

BY

MOHAMMED GA'AFAR SA'AD

(MBA/ADMIN/0523/93-1994)

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMEDU BELLO UNIVERSITY, ZARIA, NIGERIA,IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN BUSINESS ADMINSTRATION (MBA)

DEPARTMENT OF BUSINESS ADMINSTRATION,
FACULTY OF ADMINSTRATION,
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

1999

DECLARATION

I MOHAMMED GA'AFAR SA'AD hereby declare that this thesis entitled "APPLICATION OF NETWORK SCHEDULING MODELS IN PLANNING AND CONTROLLING OF BUILDING PROJECTS: A MANAGERIAL APPROACH TO NIGERIAN CONSTRUCTION COMPANIES" has been composed by myself and the production of my research finds. It has not been previously presented nor accepted in any previous application for a higher degree. All quotations and sources of information have been acknowledged by means of references.

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CERTIFICATION

This thesis entitled APPLICATION OF NEWORK SCHEDULING MODELS IN PLANNING AND CONTROLLING OF BUILDING PROJECTS : A MANAGERIAL APPROACH TO NIGERIAN CONSTRUCTION COMPANIES, by Mohammed Ga'afar Sa'ad meets the requirements governing the requirements of the degree of masters in business administration of the Ahmadu University, Zaria, Nigeria. And it is approved for its contribution to knowledge and literacy presentation.

Mal. Dalhatu Sabiu	22/9/20
Research Supervisor	Date
Head, Department of Business Administration.	1-3-2004 Date
External Examiner (Prof. U.A. Zakiradden)	25/12/2001 Date
Dean, Postgraduate school PROF. M. A. [illegible]	Date

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DEDICATION

This thesis is dedicated to

My late father

ALHAJ HASSAN SA'AD MOHAMMED

My late mother

ALHAJIA SAKINA ALFADIL ALI

May Allah Ta'ala grants them forgiveness and surrounds their souls with his wide blessing (Amen)

ACKNOWLEDGMENT

My profound gratitude and thanks to Allah Ta'ala for continuous guidance throughout my life, course of study and research.

The successful completion of this program of study and research work has come as the result of combined effort received from many individual and companies; to them I give highest appreciation, gratitude, and thanks.

My research supervisor Dr. (Mrs.) J. Nwasike, who devoted a lot of time to guide my steps throughout the research work. Also all lecturers of program in the department of Business Administration.

Professor Sheik Ahmed Abdullah, Dean Faculty of Administration, Professor Ahmed M. Kani, Dr. Sabo Bako, Mallam Bashier Kurfi, Mallam Nasiru Maitrari, and Mallam Sani Ibrahim, for their help and support throughout the program.

My course mate and friends are always there, Mohamed Omer, Ismail Shareef, Mallam Umer, Dr. Sambo, and Eng. Felicia.

All members of President Kennedy library, and the departmental library for their kind assistance.

All lecturers, staff, and mates in the Department of Architecture for much encourage and support.

My family members; my father, mother, brother, and sisters. Also my friends, Mohammed Hashim, Ashraf Shammat, Hatim Adam, and Taha Mahmoud, for giving me much needed prayers and stimulation.

All the Sudanese families, and brothers in Kano and Zaria, especially Dr. Ahmed Osman and family, Al Haji Osman El Tayeb and family.

All managers and engineers of the construction companies in Kano, Lagos, and Abuja who supported my research with a lot of materials and information.

Thank you very much for your care and concern.

ABSTRACT

Modern society is becoming more technological in nature. Its needs are being met by an industry that is highly technical at a time when the delay lag between scientific discovery and technical implementation of the result of scientific research is diminishing. Today, we are being deluged with and absorbing the fruits of science and technology.

The demands, inventiveness, and consumption of the industrial society react heavily with a service industry such as construction. Consequently, a bewildering array of construction projects, activities, and operations exists todaiy, this array calls for the continuous development of new construction methods and new management approaches. Each new demand and situation requires the design and specification of new construction operation and management system, or the adaptation of existing methods to specify the new problems.

In project management, a model has been used in one form or another to specify what is to be done and in what order to achieve the project objectives. Network scheduling models are one of the latest applications of this useful tool to produce models for planning, scheduling, monitoring, and controlling of the projects. The application potential of this models in the management of building projects show that, the project can be carried out more efficiently and economically than might be expected.

The emphasis of this thesis is to highlight the importance of the network scheduling models as planning and controlling method in building projects, and

the impact of their application in the top management and project management level in construction companies in Nigeria.

In this regard, the thesis work can be divided into two main parts. Part one will focus on the research in the literature which include the concert of model in management, different type of models, models in building projects, the general aspects of planning and controlling, and their application in building projects. Part two concern with the research on the application of network: scheduling models in building projects, and all factors affecting the adaptation and application of the techniques in building projects in general, and in Nigerian construction companies in particular.

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CHAPTER ONE

CONCEPTUAL FRAMWORK

1.1 INTRODUCTION

In management, strategic planning is the establishment of the economic mission of an organization and it is the guide for future decision, a process, and means of linking or structuring the organization.

Production / Operation strategic planning is the part of the overall organization's planning and must be consistent with the over all organization strategies and other functional areas such as finance, marketing, etc. Operational planning is more detailed, short to intermediate range planning of program of action of converting input into outputs, consist of planning the conversion and use of the conversion facilities.

Planning is the outlining of the various actions to be taken by management to achieve certain objectives. These objectives may include:

- Completing contract / project in the shortest possible time compatible with economy.
- Eliminating idle and nonproductive time of labor and plants.
- Anticipating physical difficulties and material shortage in good time for remedial action to be taken.
- Furnishing the managements with likely financial requirements.

Building projects is an undertaking to achieve the desired end of timely completion and economy of operation defined usually in terms of technical performance budget and schedule. It is typified by their complexity, diversity,

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uniqueness, and by non-standardized nature of its production. The management of such projects involves:

- The detailed plan of the construction operations.
- Time scheduling of these operations.
- Time and cost control, through monitoring, periodic correction, and readjustment of the construction plan.
- Administration of the contract, monitoring in this context refers to the process of measuring and reporting job progress and costs.

Project planning is part of the general process of planning that includes goal setting, forecasting, budgeting, and policy-making related to specific project. Project scheduling is more specific than project planning, it establishes times for completing phases of the project, and the activities and tasks are related to each other and to the calendar. Project controlling on the other hand, is concerned with the overall direction of the project, the identification of deviations from planned targets for time, cost, and quality, and the actions necessary to correct or minimize the effect of such deviations.

The modeling school of thought views organization as the system that can be rationally modeled and consist of the decision-making, system theory, and mathematical modeling approaches. The decision-making approach focuses on the importance of information and rational decision process for managing. According to the system theory of management, organization should be managed from a total system of view, which means any decision made from one part of the organization will affect other parts of the organization. Mathematical modeling

approach focuses on the quantifying decision problems and system relationships. Many operations research and management science techniques are widely used to formulate and solve management problems; examples of these techniques are break-even analysis, linear programming, bar chart, and network scheduling models.

Network scheduling models had its origin from 1956 to 1958 in two parallel different problems of planning and control of projects in the United State of America, the first was concerned with the control of contracts for U.S. Navy Polaris Missile Programme, while the second was constructing major chemical plants in America by E.I. du Pont de Nemours Company. It was developed especially to improve the planning and scheduling of single and multiple unit projects, and can help in:

- Giving a realistic forecast of the cost of the project, so alternative decisions involving time/cost trade off can be taken.
- Establishing a reliable planning and close controlling by dividing the project into elements.

The network scheduling technique known as the Critical Path Method (CPM) or Program Evaluation and Review Techniques (PERT), is a powerful tool for planning and management of all types of projects, essentially it is the representation of a project plan by schematic diagram or network that depicts the sequence and interrelation of all the components part of the project, and the logical analysis and manipulation of the network in determining the best overall program of operation. The technique may not be employed only for the planning

and control of construction work, but for research program, maintenance problems, sales promotion, and related operations in other industries. By using this technique, the high and climbing costs of idle equipments, idle manpower, and a lot of time can be reduced.

This thesis is an attempt to highlight the needs of the mathematical models such as network scheduling models as an analytical technique in planning and controlling of building projects, and to examine the working, limitation, and the factors influencing the application of the models in building projects in Nigeria.

1.2 PROBLEM STATEMENT:

One of the remarkable phenomena towards the end of this century is the rapid growth in size and complexity of human organization, which, affects the number, and size of building projects. Therefore, a lot of time, and large amount of capital is invested in these projects.

A project is consider successful if it is completed within the scheduled duration and estimated cost. Sensitivity analysis shows that the most critical parameter that, affecting the cost is the project schedule. To keep the project on schedule it is imperative for the project management to make an accurate forecast of project duration for establishing the pace of performance and also to revise it at regular intervals in view of dynamic environment of the project. Different quantitative techniques were used for this purpose; network-scheduling models is a very useful technique that can keep the projects on schedule. In building projects, there is always a variation between the theoretical and applied part of these techniques,

and each project has its own characteristics and factors that can affects the application of the techniques.

This thesis therefore is directed towards the use of network scheduling models in planning and controlling of building projects in Nigeria and its impact on the duration, performance, and estimated cost on projects.

1.3 AIM AND OBJECTIVES OF THE RESEARCH:

The primary aim of the thesis is to aid the decision makers in the building industry in Nigeria to:

- Realize the importance the importance of the modeling techniques in general, and network scheduling models in particular in planning and controlling of single and multiple unit projects.
- Identify the problems that can be solved by using these techniques.
- Recognize the limitation, variation, and the factors that affect the application of the techniques in planning and controlling of building projects in Nigeria.

The basic objectives of this thesis are:

- To make adequate and realistic decision for each project on hand using quantitative analysis, experience, and personal judgments.
- To help the high management to understand how to keep the project on schedule, and to revise it at regular intervals so as to reduce the risk involved.

- To help the project level management to know to breakdown the project into elements, and to respond to day-to-day conflicts that must be reconciled immediately.

1.4 METHODOLOGY OF THE RESEARCH:

Research methodology is the operation media that, the researcher plans to employ in accomplishing the aim and objectives of the study. It should be readily applied to solve existing problems and should open new directions in the identification of other problems for further research related to the same topic.

Research methodology chosen for this thesis is based on the analysis and synthesis of the following:

- Literature Review: which include data collected from published books, unpublished thesis, journals, newspapers, magazines, and encyclopedia.
- Case Studies: which include data collected from construction companies where the analytical techniques are applied.
- Personal Observation: deductions from personal observation of the environment of the research and response during interview to solicit views groups and individuals.

Data collected from all sources will be properly analyzed, and conclusion will be drawn from it.

1.5 MOTIVATION:

In developing countries, like Nigeria, most of the complex building projects suffer from the delay in completion time or stopped completely. A delay in project completion can cause cost escalation at least equal to the sum of inflation, overhead cost, and additional interest cost for the period of the delay.

This thesis is motivated by the need to search for a realistic solution to this problem. One of the techniques that are widely used for this purpose in planning and controlling of building projects is the network scheduling models, which can help in:

- Provides a means to predict with reasonable accuracy the time required for overall project completion.
- Makes possible the identification of these activities whose expedient execution is crucial to timely project completion.
- Serve as a guide for project shortening when the completion date must be advanced.
- Provide basis for the scheduling of subcontractors and material deliveries to the job site.
- Serve as basis for balanced scheduling of manpower and construction equipments on the project.
- Make possible the rapid evaluation of alternative construction methods.
- Serve as a convenient vehicle for progress reporting and recording.
- Affords a basis for evaluating the time effects of construction changes and delays.

1.6 SCOPE OF THE RESEARCH:

The building industry is the most difficult and persists as well as its greater challenge is the allocation of scarce resources. The essential attention of management of this industry is to make decision on resources allocation. Management is therefore must blend the quantitative techniques of scientific management together with the subjective ingredients of experimental judgments and intuition into an operating procedure to achieve this objectives.

In applying analytical tools in planning and controlling of building projects, this thesis will focus on the network scheduling models with particular reference to its applications in Nigeria.

This thesis work will be limited to the impact of the network models on decision making by top management and project management level, also to the working, limitation, and factors influencing the applications of the techniques in building projects.

1.7 LIMITATION AND CONSTRAINTS:

The limitation and constraints that are apparent in this type of management research work include:

- The shortage in adequate literature related to the application of modeling techniques in the management of projects in Nigeria.
- Lack of historical reference, and adequate day-to-day records of the projects in most construction companies in Nigeria.

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- Constraints related to violet information and poor response by the management of some construction companies.
- Lack of the awareness among the top and project level management in some construction companies in Nigeria to the importance of the network modeling techniques
- In management studies, its difficult to make generalization and a series of feedback studies may reveal direct recurring problems.

CHAPTER TWO

MODELING CONCEPT IN BUILDING PROJECTS

2.1 BUILDING PROJECTS:

2.1.1 DEFINITION:

According to Haynes, M. E. (1993) "A project is an undertaking that has a beginning and an end, and will be carried out to meet established goals within cost, schedule, and quality objectives ". Kelly, J. and Male, S. (1993) defined a project as " A temporary activity with defined goals and resources of its own, delimited from but highly dependent on the regular activity ". Also to them " A project is an undertaking to achieve specific objectives defined usually in terms of technical performance, budget, and schedule ". To Meredith, J. R. and Mantel, S. J. (1989) a project " Is a one time activity with well defined set of desired end results. It can be divided into subtasks that must be accomplished in order to achieve the project goals. The project is complex enough that the subtasks require careful coordination and control in term of timing, precedence, cost, and performance ". Also to Spinner, M. P. (1998) " A project consists of a series of tasks or activities that have several distinguishing characteristics:

- The project has specific starting and ending dates.
- It has well defined objectives.
- It achieves a specific product or result.
- It has unique, no repetitive endeavor.

- Cost, time schedules, and resources (personnel/labor, equipment, and material) are consumed.

Project exist in nearly every field of endeavor, including designing and/or constructing a house, manufacturing facilities, or commercial building, designing a new product, introducing a new product into the market place, installing new facilities for education, banking, health care, commercial, and industrial venture, relocating a business or manufacturing process, relocating offices, and introducing a new business or software product.

In broadest sense, a project is a specific, finite task to be accomplished, whether large or small scale or whether long or short run is not particular relevant, what is relevant is that, the project seen as a unit. There are however some attribute characterized projects:

- Interdependencies: Project often interact with others project being carried out simultaneously by their parent organization, but projects always interact with the parents standard, ongoing operations.
- Uniqueness: Every project has some elements that are unique. No two-construction projects are precisely alike.
- Conflict: the member of the project team is in almost constant conflict for project resources and for leadership role in solving project problems.

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Building projects are complex undertaking that involves many skills, materials, and literally hundred of different operations. The assembly process must constitute a complicated pattern of individual time requirements and restrictive sequential relationships among the many segments of the structure. To some

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degree, every building project is unique, and no two projects are ever quite alike. In its specifics, each structure is an individual, each structure is an individual, tailored to suit its environment, arranged to perform its own particular function, and designed to reflect personal tastes and preference. The vagaries of the construction site and the possibilities for creative and utilitarian variation of even the most standardization-building product combine to make each project a new and different experience.

2.1.2 PROJECT MANAGEMENT:

Project management according to Awani, A. O. (1993) " Is concerned with planning, scheduling, and controlling no routine activities within certain time and resources constraints. It may be broadly described by making and enforcing the necessary decisions related to a project ". To Kerzner, H. (1998) " Project management is the planning, organizing, and controlling of company resources for relatively short time objective that, has been established to complete specific goals and objectives. Furthermore, project management utilize the system approach to management by having functional personnel assigned to a specific project ". Spinner, M. P. (1998) defined project management as " Managing and directing time, material, personnel/labor, and cost to complete a project in an orderly economical manner and to meet the established objectives of time, cost, technical, and/or service results.

In general terms, management might be described as the judicious allocation and efficient usage of resources to achieve a desired end. A successful project using the project management approach will consist of three stages:

i. Planning: Understanding what work to be done, including identifying the individual activities and necessary resources, to complete the project, then developing a plan of action in a logical order that can be displayed graphically as a project planning diagram.

ii. Scheduling: Validation when the work activities need to be done. This stage details the time allowed for the project and each activity when they are to be stated and completed.

iii. Controlling: Monitoring or tracking progress of the project as it is gets under way, analyzing performance, then resolving concerns. It also manages status reporting.

Project management concentrates on a project, it bring together and optimizes the resources necessary to complete the project successfully. These resources include the skills, talent, and cooperative effort of team of people, facilities, tools and equipment, information systems, techniques, and money. Project management emerged because of number of forces in our society required new methods of management, the main two forces are:

i. The growing demand for complex, sophisticated, customized projects and services.

ii. The progress and increase in human knowledge.

Construction projects are involved therefore in strategic project management, which involves:

- Making a number of major decision involving cost and values issues.
- Handling and understanding the creation of information that expands exponentially as the numbers of individual contributing to the construction process increases.

Since 1981 project management has established itself as an independent profession which consisting of nine management functions: scope, cost, time, human resources, communication, quality, contract, procurement, risk, and project integration. These are defined as follows:

- Managing the scope of the project is controlling the project through the aim, goals, and objectives of its sponsor.
- Managing cost, required for financial control of the project is accomplished through accumulating, organizing, analyzing data, and reporting the cost information.
- Managing time is planning; scheduling and controlling a project by achieve the time objectives. Time and cost management may form the very substance of project management.
- Managing human resources, involves directing and coordinating the administration of people involved in the project.
- Managing communications, keeps information flowing among members of project team and management, helping insure successful conclusion of the project.

- Managing the quality, is the fulfillment of the quality standards setup for the performance of the project.
- Managing contract/procurement includes selecting, negotiating, and awarding orders and administration procurement of material equipment and services.
- Managing risk is dealing with the degree of uncertainty of the project through knowledge of experience with the conditions.
- Managing project integration ensures that the various functions of the project are properly coordinated.

Several significant management practices are instinctively used when applying project management methods. A brief description of each of these principles as related to our use is follows:

- Network analysis also called graphic analysis, shows the plan of action through the use of a graphic diagram (used in project planning for preparing the planning diagram).
- Management by objectives is a technique that defines objectives and use disciplined method to measure performance against those objectives (used in project planning and controlling).
- Management by exception is a technique that signals the specific problems by requiring management attention. Studies indicate that management should be involved with no more than 20 percent of the total project at any one time (used extensively in project control).

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Other management practice that are also very important function of project management include:

- Cost minimizing: a procedure used to reduce the time required to complete a project with the least amount of additional cost.
- Resource allocation: assigning resources required to complete each project activity. Resources include personal, labor, cost allocation (assigning costs required to complete each activity), equipment, and material.
- Resource Leveling: a method for scheduling the project activities to keep day-to-day resources requirement even.

Recent years have seen the development and application of a whole new generation of scientific management concepts including a system approach. Application of this approach to construction has resulted in the development of techniques for the time and cost control of projects, treating the entire construction process as a unified system of interrelated and interdependent actions.

2.1.3 PROJECT LIFE CYCLE:

Most projects go through similar stages on the path from the conceptual stage through the completion stage via a project life cycle. The pattern of slow rapid slow progress towards the project goals in common as the result of the changing level of resources used during the successive stages of the project life cycle, figure (2.1) shows the project curve of the project life cycle.

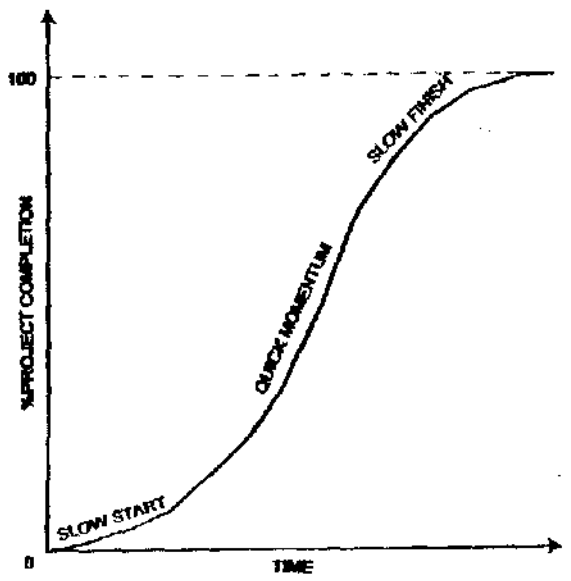


Figure (2.1) **The project curve.**
Source: Ahuja, H. N. and Nadakumar, V. (1985) Simulation Models to Forecast Project completion Time.

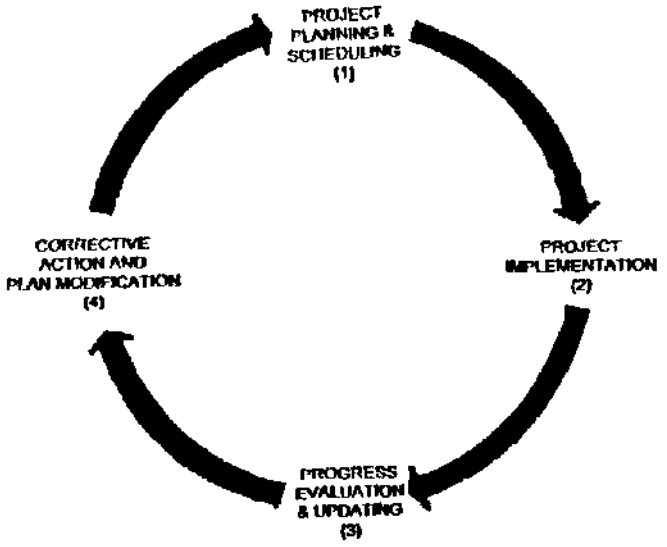


Figure (2.2) **The project life cycle.**
Source: Ahuja, H. N. and Nadakumar, V. (1985) Simulation Models to Forecast Project completion Time.

The project cycle comprises planning and scheduling, implementation, progress evaluation and updating, and correcting action and plan modification, figure (2.2).

During the planning stage, a strategic plan is prepared for the entire duration of a project tactical plan for reporting period is developed on a recurring basis. A provision is made in form of fictitious activity at the end of the strategic plan, with its duration equal to the contingency time that may be required in case of unforeseen occurrences. This contingency time accounts for the impact of the uncertainty variables. Activities at the tactical plan level are schedule after intuitively incorporating the combined impact of the uncertainty variables. During project implementation, progress is monitored, and feedbacks are used to update the plan and prepare reports for progress evaluation. Management evaluate actual against planned progress identifies cause of delay, takes corrective action, and if necessary revise the duration estimates of activities in progress and of those that are yet start in revising the activity duration, the influence of uncertainty variable is taken into account intuitively at best. The strategic plan is revised only when the contingency time allowance is exhausted. The project cycle is repeated until the project is completed.

The ever-present goal of meeting performance, time, and cost are the major considerations throughout the project life cycle. It was generally thought that performance took precedence early in the project life cycle. This is the time when the planner focus on finding the specific methods required meeting the projects

performance goals. We reference to these methods as project technology because they require the application of science or art.

2.2 MODELING CONCEPTS:

A model according to Haplin, D. W. and Woodhead, R. W. (1976) " Is a representation of real-word situation and usually provide a framework within which an investigation and analysis can be made of given situation. Models contain or portray data about a situation that, interpreted according to certain rules or conventions, provide information about the situation relevant to pertinent decision process ". To Buffa, E. S. (1978) " A model is a device for aiding rational thinking, its provide a simplified representation of a complex system or phenomenon and must include the essential, relevant features of the system being studied ". Also he defined a model as " An economizing device that reduce the finite number of possibilities to a much smaller, finite number of categories. It ignore much information potentially available to the problem solver and use categories to collect together many other bits of information that may be considered similar for the process of problem solving ". Riggs, J. L. (1981) consider a model as " A replica or abstraction of essential characteristics of a process. It shows the relationship between cause and effect, and between objectives and constrains. Problem that defy direct solutions because of size, complexity, or structure is often accessible through model simulations ".

Generally, a model is representation of real system, process, or device illustrating its operation and/or its properties. Models must be:

- Can be manipulated, so as to predict the optimal values of the chosen variables.
- Simpler than the reality they represent.
- Easier to manipulate and control.
- Cheaper, so that the failure of the real things can be expensive.

Models may be solved by experimentation or by mathematical analysis, and by them manager can be recognize:

- Variable that can be controlled to affect performance of the system.
- The relevant magnitude of cost required.
- The relationship between cost and variable that include tradeoffs among cost.

2.2.1 CLASSIFICATION OF MODELS:

According to Fabrycky, W. J. Ghare, P. M. And Trogersen, P. E. (1984)

" Models can be classified by distinguishing physical, schematic, and mathematical types. Physical models are the most easily understood since they look like the object under consideration. Schematic models are traditionally used to study organizational and procedural problems. Mathematical models are destruction where symbols rather than physical substitutions are made ".

I. Physical models:

A physical model is a nock-up or scale model of the prototype. Physical models are often used in the preplan analysis of industrial projects, if they are built out of components that equate to individual physical units to be delivered and

connected, they enable a nock-up of the construction or erection sequence to be performed.

Look-alike models derive their usefulness from a change in scale. Microscopic pattern can be magnified for investigation, and huge structures can be scaled down to a manageable size. Flow problems in model plan are studied by easy shifts of scaled down structures and machines, which could not be duplicated with real items because of cost, confusion, or inconvenience. Some details are necessarily lost in models. In a physical replica, this loss may be an advantage where one factor, such as distance is the key consideration but it may render a study futile if the predominant influence is forfeited in the construction of the model.

II. Schematic Models:

Schematic models are representations that to some extent portray a physical situation, so that a physical modeling reaction or perception is induced in the user through a conceptualizing of the situation. Exploded drawings of physical facility can be considered to be schematic models.

The organization chart is a common schematic model. It is a representation of the state of formal relationship existing between various members of the organization. A human-machine chart is another example of a schematic model, it is a model of an event that, the time varying interaction of one or more persons and one or more machines over complete work cycle. A flow process chart is schematic model, which describes the order of occurrence of a number of events,

which constitute an objective such as the assembly of an automobile from many parts.

In each case, the value of the schematic model lies in its ability to describe the essential aspects of the existing situation. It dose not include all extraneous actions and relationship but rather concentrates on a single facet. Thus, the schematic model is not in itself a solution but only facilitates a solution. After the model has been carefully analyzed, a proposal solution can be defined, tested, and implemented.

III. Mathematical models:

A mathematical model employs the language of mathematics, and like other models, may be description and then an explanation of the system it represents. Although its symbols may be more difficult to comprehend than verbal symbols, they do provide a much higher degree of abstraction and provision in their application. Because of the logic it incorporates, a mathematical model may be manipulated in accordance with established procedures.

Almost all mathematical models are used either to predict or to control. The outcome of an alternative course of action may be predicted in terms of a selected measure of effectiveness. For example, a linear programming model may be predicted the profit associated with various production quantities of multi product process. In quality control, a mathematical model may be employed to monitor of defects that will be accepted from a supplier. Such models maintain control over state of reality.

Mathematical models directed to the study of operations differ from those traditionally used in physical science in two important ways. First, since the system being studied usually involves social and economic factors, these models often must incorporate probabilistic element to explain their random behavior. Thus, it is appropriate to distinguish probabilistic models from deterministic models. Second, mathematical models formulated to explain operational system incorporated two classes of variables, those that are directly under the control of a decision maker and those that are not. The objective is to select values from the variables under the decision market control so that some measure of effectiveness is optimized. Thus, these models are directed to decision situations instead of to physical phenomena.

2.3 MODELS IN BUILDING PROJECTS:

Project management generally is hierarchical in nature, focuses on different problem and requires that varying types of models and level of information must be emphasized. The modeling viewpoint is therefore a function of hierarchical level of the manager, the decision process and management function being served by the model, and the project time horizon of the agent involved. As the management hierarchy is descended, the management focus is oriented to the construction operation at the work face, its supply, the problem associated with labor and crews, and the actual performance of the operation technology.

The nature, purpose, and use of a model are highly influenced by the management function addressed by the model and the project life stage involved in its use.

Thus, planning model at the project initiation stage, or even as a planning model on the site at the project implementation. Planning models may not be good reporting models, although estimated cost and deviation statements provide a good format for cost and duration reporting models.

A number of modeling tools have been specifically developed or proposed for project management area. These include network-scheduling techniques with its many variants and computer based information system. Certain modeling tools have been borrowed from other management fields and adapted to the construction environment such as the Gantt or bar chart models originally developed for industrial process area and now commonly used in building field and head offices.

Some of the modeling techniques have a widespread relevant and therefore are used in various construction decision processes and field situations. Others are special purpose techniques relevant only to certain type of building processes and their use depends on opportunity and awareness by management of the modeling techniques and belief that benefits will result from the application of the techniques. In some cases contract terms specifically require the development, use, updating and reporting of the project status based on specific modeling techniques. In others the contractual relationship may render unnecessary the use any model but the simplest modeling concepts such as that of actual and expected cost curve representation of project.

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In this chapter, several modeling concepts widely used in building projects will be discussed that include the bar chart model, line of balance model, multiple activity and crew balance charts, and network scheduling models.

2.3.1 BAR CHART:

The bar or Gantt chart has been originally developed for industrial production area since Henry Gantt invented them around 1917, then the bar chart has been used in construction management as method of portraying a project plan and progress. The basic modeling concept of the bar chart is the representation of a project work item by a time scaled bar whose length represent the planned duration of the project work item, figure (2.3). The bar chart can be located calendar time to indicate the schedule for planned starting, execution and completion of the project work item it models.

Breaking down the project into a number of components develops project bar charts models. In practice the scaled length of the bar is also used as graphical base on which to plot the actual performance towards completion of the project work item. In this way the bar charts model acts both as planning-scheduling and as a reporting-control model.

The information content of the bar chart model can be increased by incorporating planned and actual rates of progress of working the project item onto the bar model itself. Similarly, the actual rate of progress experienced in the field can be assessed and plotted to give the project curve figure (2.4).

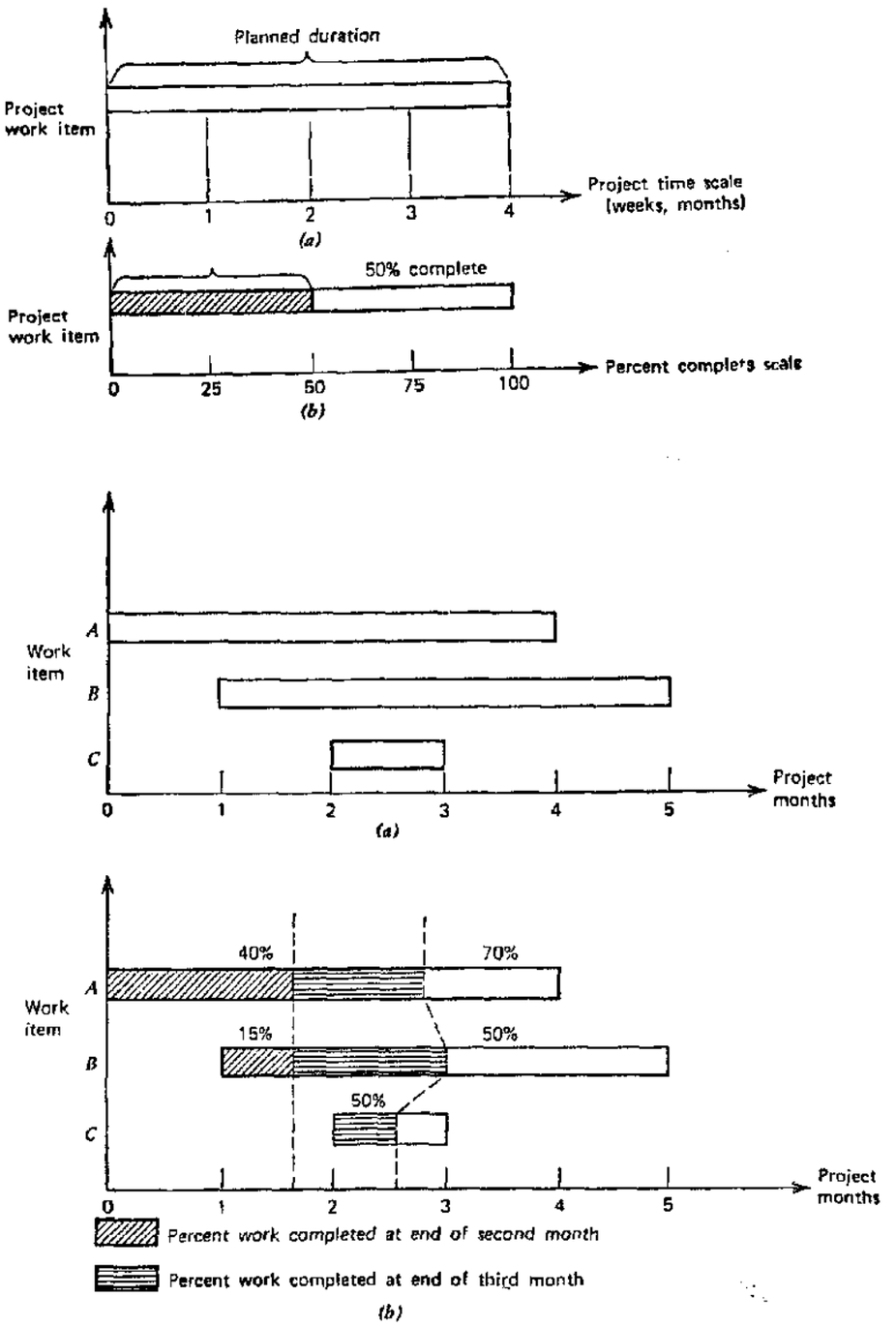


Figure (2.3) **The bar chart model.**

Source: Goldhaber, S. Jack, K. and Macedo, M.C. (1977) Construction Management: Principle and Practice.

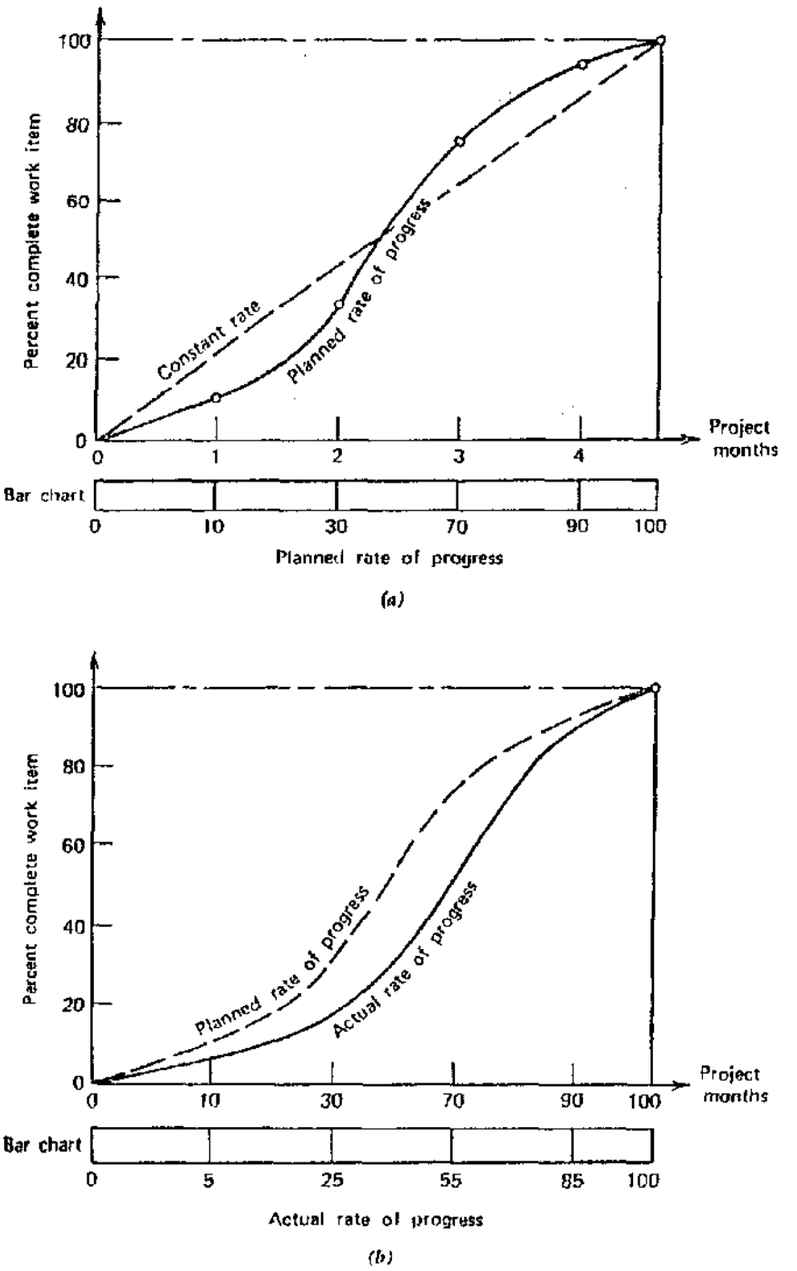


Figure (2.4) **The bar chart model curve.**
Source: Goldhaber, S. Jack, K. and Macedo, M.C. (1977) Construction Management: Principle and Practice.

In large scale system engineering project, the bar chart revealed some fundamental weaknesses as a management tool in an increasingly dynamic and changing management environment, these weakness include:

- The chart cannot show the interdependencies among the activities represented by the bars. This is a serious deficiency when planning a program in which various tasks are scheduled with a large degree of concurrence.
- The inflexibility of bar chart plotted against a calendar scale, which, prevent it from easily reflecting slippage or change in plan.
- The inability to reflect uncertainty or tolerance in the duration times estimated for the various activities.

The modern management environment has tended to eliminate or seriously impair the effectiveness of the Gantt chart as a management tool. Attempt was made to modify the Gantt chart by adding new elements to it, thus extending it capability to meet contemporary needs. One of these attempts is the Milestone system, used extensively in the military and industry for the management of major weapon system programs. Milestones are the key events or points in time, which can be identified when reached as the program progresses. The milestone system provides a sequential list of the various activities to be accomplished in the program. This innovation was important because it recognized the functional elements of the program, reflecting more accurately what is known as the program work breakdown or product indenture structure. The milestone system approaches increase awareness of the interdependencies between activities. The

list of activities and milestone was displayed to a time scale. Symbols on time scale indicated the dates each milestone was scheduled, completed, slipped, etc. The milestone system also made it possible to accumulate these data on data processing equipment, and to code the data for various arrangements. The milestone system proved quite effective and was widely used in solving the problems of different management projects.

2.3.2 LINE OF BALANCE MODEL:

Line of balance model is refinement of bar chart; it used in projects with repetitive sequences of activities develops from the nature of the project and the construction technology adopted. In such a case the individual activities must be properly synchronized in duration and productivity if delays and misuse of resources are to be avoided. Often mishaps and delays in working the activities compound the instability between sequence of activities even in properly balanced situations, with consequent loss of overall productivity and the generation of chain reaction management problem areas.

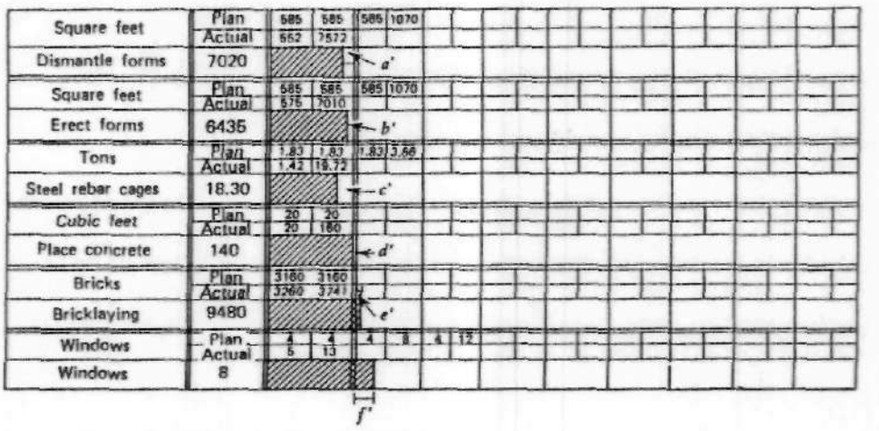
The line of balance model focus on monitoring the current status of an activity relative to it schedule states, incorporates updating as a function of production progress, and enables management decision to be made to maintain or retrieve the balanced progression relationships between project activities by the way it relocate labor resources. The line of balance approach is to determine the technological time and resource relationship between the sequential set of activities involved and by means of this line of balance monitor the relative

departure from the desirable balanced position and thus initiate corrective remedial action by the dynamic allocation of resources. The line of balance model can be considered a means of determining priorities for labor allocation of dragging activities or for the slowing down or stoppage of crowding activities and diversion of their labor, resources crews to other activities.

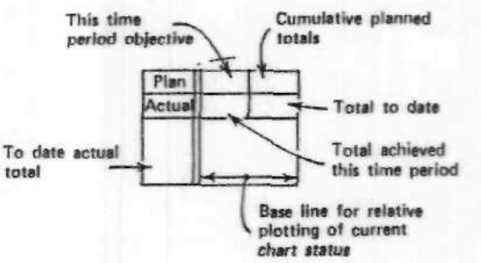
The development of line of balance concepts is illustrated in figure (2.5), each activity has associated with it time dependent reservoir of potential work that is technologically available to it for completion. As a unit of work is completed in one activity, it generate different units of potential work in successive related activities and thus updates their reservoirs of potential work as it decrements its own reservoir. The numbers of units of work that can be completed in a given time on an activity depend on the potential work reservoir available, the crew size allocated, and its resulting efficiency. Different crew sizes produce different rate of progress. The basic problem faced by the superintendent is how to allocate labor resources across activities constrained by both the availability of labor and reservoirs of potential work.

Most building construction superintendents intuitively follow line of balanced concepts. Builders on large multi building projects, where crews can be supplemented or borrowed from neighboring building sites, sometime use the technique formally.

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a' Dismantle forms behind 6% (units working day)
b' Erect forms behind 2%
c' Steel behind 22%
d' Place concrete on schedule
e' Bricklaying 3% ahead
f' Windows 30% ahead



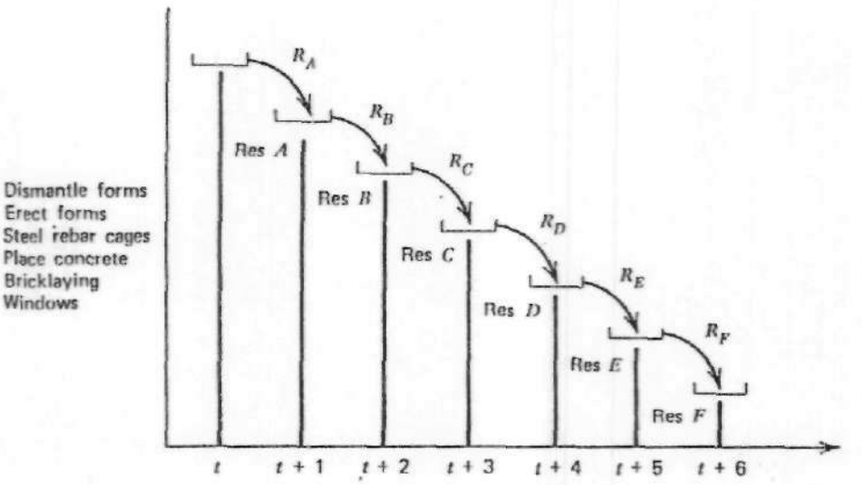


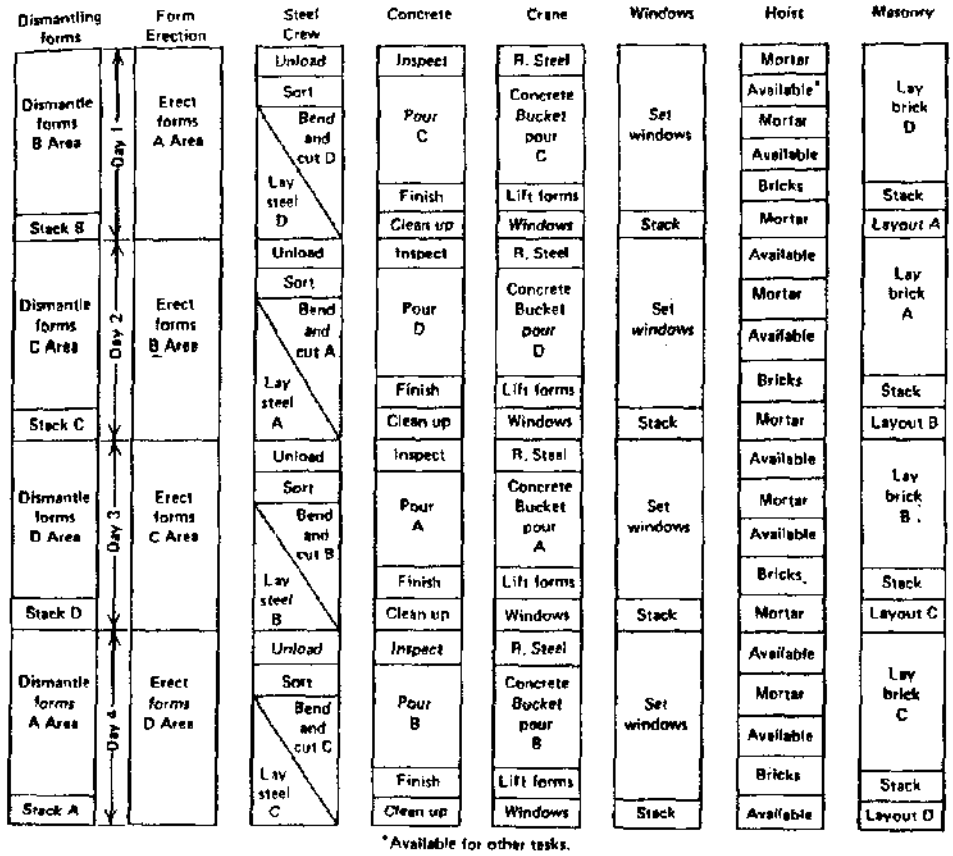
Figure (2.5) The Line of balance model.
Source: Goldhaber, S. Jack, K. and Macedo, M.C. (1977) Construction Management: Principle and Practice.

2.3.3 MULTIPLE ACTIVITY AND CREW BALANCE:

In many situation and especially in high rise building projects using pre-cast units on congested sites, there is need to identify and coordinate many activities with crew allocations and schedule delivery and material handling systems. In this way its possible to analyze and establish the basic building frame cycle duration. A technique in common use in the preplan phase is the multiple-activity or multi-activity chart. It is also often applicable and used in the fieldwork.

The multi-activity chart is a modified bar chart consisting of a series of equal length vertical bars. A vertical bar used for each crew, crane or working unit. The schedule sequence of tasks or activities for each item is then defined and estimates are made for their individual duration. In this way individual crew or equipment cycle times result. There are then all simultaneously analyzed for compatibility, so that two crews are not simultaneously in the same area or do not require the same crane. Finally the bars are adjusted to a common length building cycle duration by equating duration to practical, readily usable part days, hours, and the like. The multi-activity chart thus portrays the planned sequence and schedule for all activities on a building site relevant to the basic frame erection cycle. The vertical bars portray the work assignments, and schedule for each individual crew and major piece of equipment and they can be used as reference in the field to measure current status and as statement of the next work assignment, figure (2.6).

Crew balanced chart are similar to multi-activity charts except that the model focus is internally on a crew operations, and the individual bar are used to model



*Available for other tasks.

Figure (2.6) Multiple activity charts for small building construction.
Source: Goldhaber, S. Jack, K. and Macedo, M.C. (1977) Construction Management: Principle and Practice.

individual crew member work task assignments and sequences. Consequently, crew balance charts have a work improvement usage and are especially useful for situation that involve highly repetitive work such as tunneling, pipe laying, pile driving, and jetty construction. Crew balance charts are useful as field techniques for monitoring crew composition and work assignments, especially in situations that demand changing crew sizes over time.

Typical example are crew build-up situation in masonry and a tunneling where, first, it may be necessary to match masonry output to parallel the steel erection rate of building and second, where the crew composition changes as the driven length increases.

The crew balance chart indicates that individual basis work tasks for each crew member and crane together with their logical interactions, whenever joint work takes are involved, as well as indicating the individual idle times associated with the need to wait until permissive conditions permit resumption of active work tasks. The crew balance chart enables management to establish efficient crew sizes, analyze pipe loading cycle cost, and compare different competing technological methods. If sufficient detail is incorporated into the chart activities, it also is an instructional device for foremen and for capturing field experience, figure (2.7).

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2.3.4 NETWORK SCHEDULING MODELS:

Network analysis has emerged in 1956 when Du Pont, Inc. undertook a through investigation of the extent to which computer might be used to improve the

Figure (2.7) The crew balance chart example.

Source: Goldhaber, S. Jack, K and Macedo, M.C. (1977) Construction Management: Principle and Practice.

planning and scheduling, rescheduling and progress reporting of the company's engineering programs in U.S.A. In late 1957 ran a pilot test of a system using a unique arrow-diagram or network method, which can to be known as Critical Path Method (CPM). Then in 1958 the U.S. Navy Special Project Office in cooperation with Booz-Allen Hamilton and the Lookhead Corporation established a research team. The assignment was Project evaluation research task. The special project office was faced with a development program on Polaris that was a product of time, a huge, complicated, weapon system development program, being conducted at or beyond the state of the art in many areas. With activities proceeding concurrently in hundreds of industrial and scientific organization in different areas, the special project office needed and wanted a new method to provide its management with:

- Information on the progress to date and to outlook for accomplished the objectives of the Fleet Ballistic Missile (FBM) program.
- A measure of the validity of established plan and schedules for optimum accomplish of total program objectives.
- A means of predicting the impact of actual or proposed change done in the plans on the total program objectives.

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What emerged was an original approach to the fast multiplying problems of large-scale system projects in which technical innovation, complex logistics, and concurrent activity must be integrated. Project evaluation research task was employed on the Polaris program and credited with making possible for Navy to produce an operational ballistic missile firing nuclear submarine years a head of

schedule. As the result of the research task, the project evaluation research task became Program Evaluation and Review Technique (PERT). Subsequently, the original network concept has been adopted and extended in hundred of management situations, where it has set the pattern for management information and control systems of the future.

Figure (2.8) illustrate the evolution of the network plan in both CPM and PERT. The difference between the two techniques can be explained by differences in the environment in which each was evolved and applied.

The CPM arrow diagram network developed from more detailed bar charts, which were activity oriented, linking the activities together in a sequence of dependence often without special identification of the connecting points and then produced the arrow diagram. The environmental factors which had an important role in determining the element of CPM techniques, were:

i. Well-defined projects.
ii. One dominates organization.
iii. Small uncertainties.
iv. The project has one geographical location.

The CPM (activity-type network) has been widely used in industrial process, construction, and single project activities.

The PERT (event) network evolved from combination of bar charts and milestone charts, on which milestone were identified as special events, or particular point in time, which were of interest to management. Milestone was useful for progress evaluation, with them it is possible to determine if the job is ahead, behind, or on

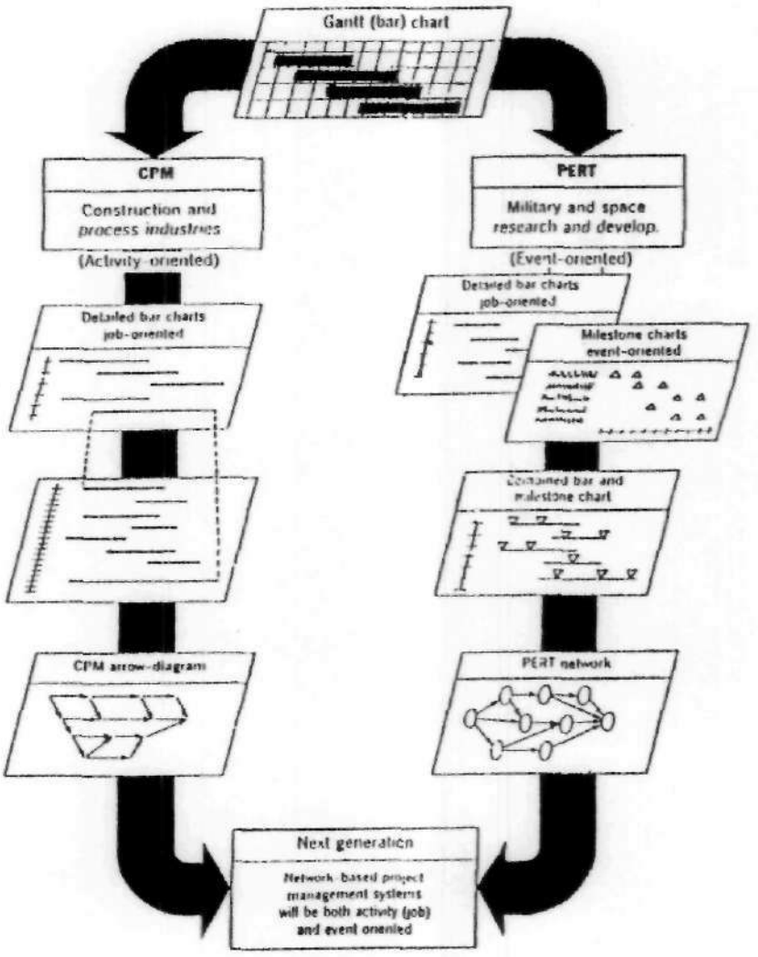


Figure (2.8) Evolution of the network plan.

Source: Goldhaber, S. Jack, K. and Macedo, M.C. (1977) Construction Management: Principle and Practice.

schedule while it is in progress. The influence of milestones caused PERT networks to evolve as heavily event oriented. Some of the environment factors, which affected the development of the PERT technique, were:

i. Massive programs with hard to define objectives.

ii. Multiple and overlapping responsibility divided among organizations.

iii. Large uncertainties of time and cost exist.

iv. The project has wide geographic disposal and complex logistics.

The PERT technique has proved most applicable to large-scale research and development involving a large degree of uncertainty, such as new product development and marketing.

The nodes in the network-scheduling model represent events in the project. An event generally corresponds to the beginning or end of a specific task or activity that must be performed as part of the project. Arcs in the network represent the activities.

The rules of logic in the network are relatively simple. Suppose an activity D can be started only after activities A, B, and C have been completed. This situation can be diagramed as shown in figure (2.9a). Thus, all activities represented by arcs into an event node must complete before an activity represented by an arc out of an event node can begin.

In addition, because of restrictions imposed by most computer routine that, analyze network schedule, two activities cannot have the same beginning and ending event nodes. Thus, if activities B and C can begin after activity A, and activity D can begin after activities B and C have been completed, we might be

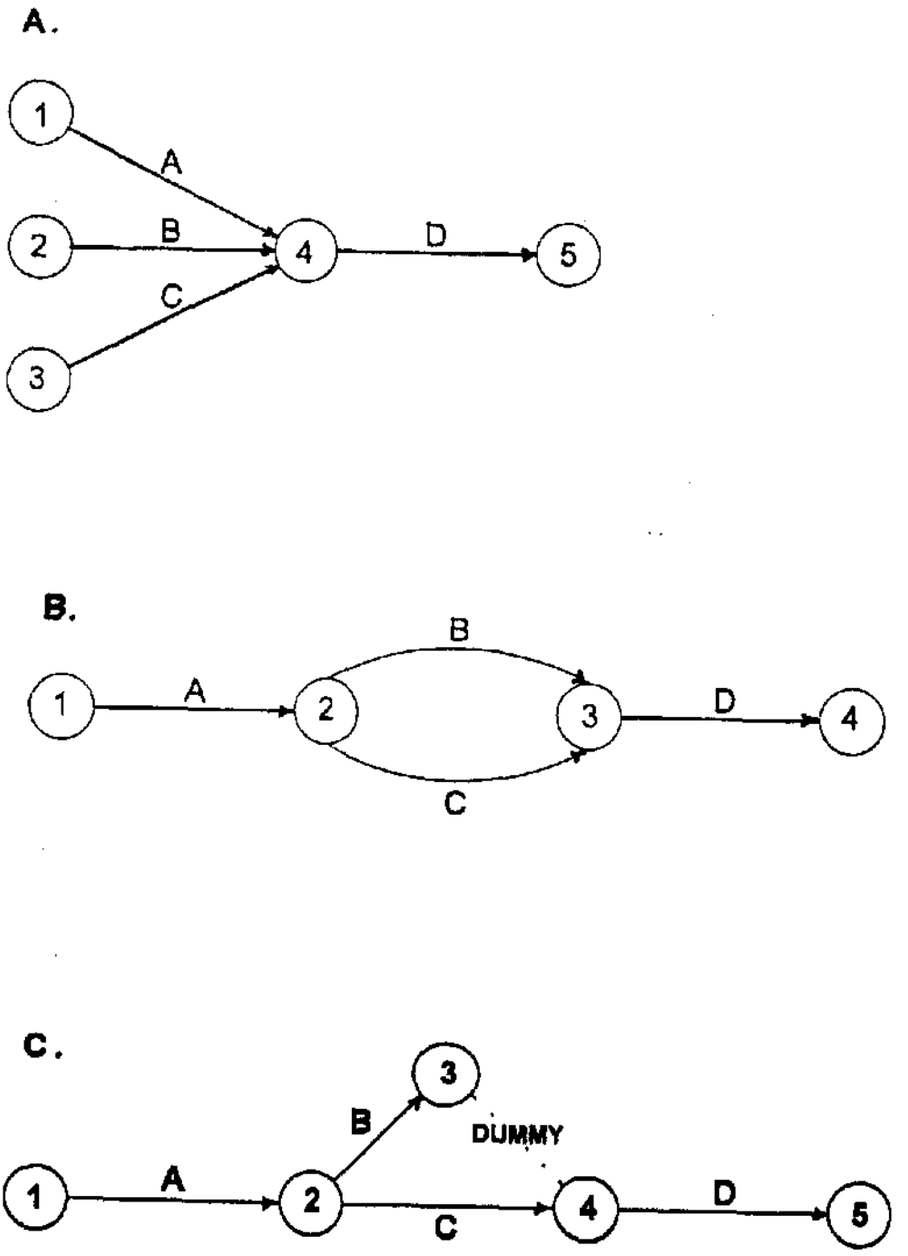
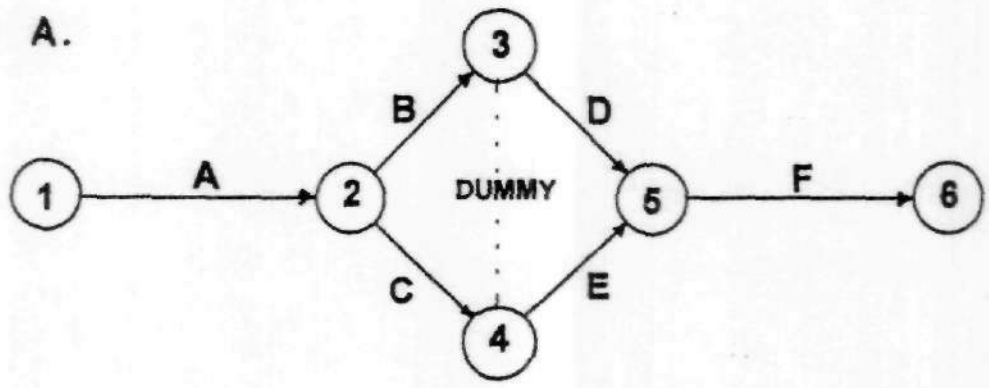


Figure (2.9) **The network diagram rules.**
Source: Wanger, H.M. (1989) Principle of Operation Research: With Application to Managerial Decision.

tempted to diagram this relationship as shown in figure (2.9b). Therefore, a dummy activity is used as shown in figure (2.9c) to distinguish between activities B an activity C. The dummy activity has time duration of zero and used for logical purposes in the network. Now consider a simple example of a project that might be analyzed by using network scheduling. Suppose we wish to conduct a management survey. The first activity A will be to study the purpose of the survey. After completing this task, we can hire data collection personnel B and design the questionnaire C. After both B and C are completed, we can train the personnel D. however, after completing only the design of the questionnaire C, we can begin selecting companies of our survey E, even before the personal has been hired B. Finally, after completing tasks D and E we can take the survey F. these tasks and precedence relationship are shown in table (2.1). The diagram for the management survey can be constructed as shown in figure (2.10a). The construction of such a network could be a significant managerial aid in dealing with a complex problem. In preparing table (2.1), it was necessary to do activity analysis that is the activities required to complete the project had to be identified and the technical precedence relationship among the activities had to be determined. This precedence is the statements of which activities must immediately precede an activity.



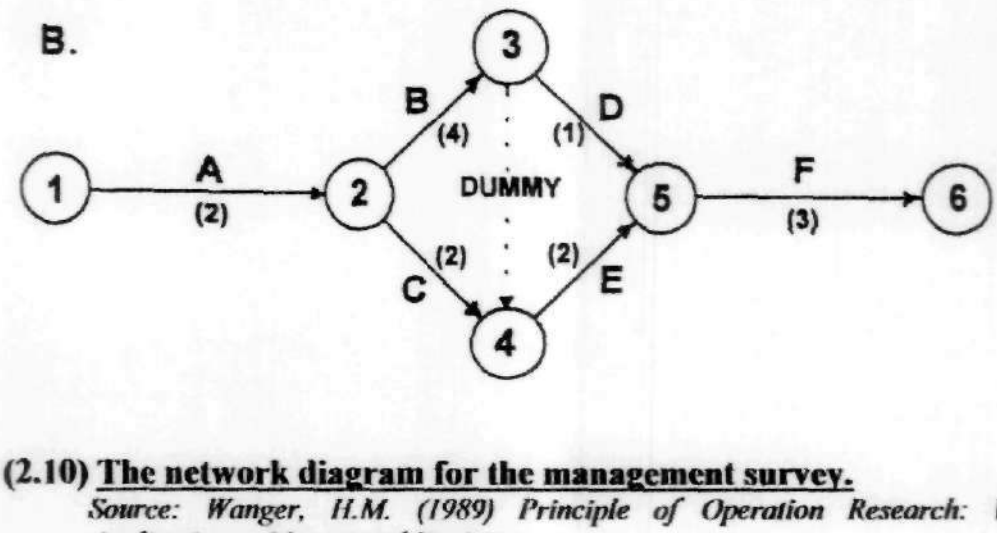


Figure (2.10) The network diagram for the management survey.

Source: Wanger, H.M. (1989) Principle of Operation Research: With Application to Managerial Decision.

ACTIVITY	DESCRIPTIONS	IMMEDIATE PREDECESSORS
A	Study Purpose	-
B	Hire Personnel	A
C	Design questionnaire	A
D	Train personnel	B, C
E	Select companies	C
F	Survey	D, E

Table(2.1) **Activities required and immediate processors for the management survey.**

Source: Wanger, H.M. (1989) Principle of Operation Research: With Application to Operation Research.

The value from the network can be enhanced if the activity analysis also uses estimates of time required to complete each activity, and these are included in the network. In order to determine the time estimates, decisions must be made regarding the methods and tools to be used in completing each activity. Again, this forces the manager to breakdown the project into its individual tools, and to plan each of these in details before beginning the project. Given these time estimates as shown in figure (2.10b), the network may be analyzed to provide additional information of importance to managers. The most obvious information of interest is the total length of time required for the project. Since we are interested in completing each of the activities, the total time for the project will be equal to the length path through the network. Thus, we apply a simply algorithm to obtain the estimate. This algorithm computes the earliest and latest start and finish times for each activity. The early start and finish times are simply the earliest that each activity can be started and finished respectively, given the technical precedence relationships in the network. The latest start and finish times are the latest that an activity can be started and finish respectively, without

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delaying the total time to complete the project. The difference between the early and late start (finish) times is the slacking associated with an activity. The slack is the amount of time that a particular activity could be delayed without delaying the completion of the project. This information can be very useful to managers in scheduling work and the use of equipment. The activities with zero slack cannot be delayed without delaying the entire project. These activities are on the longest path through the network, which is called the critical path.

Network analysis methods, when used for planning and controlling a project, may be said to have the following advantage:

i. The systematic approach to planning encourages a logical discipline in the overall process.

ii. It allow the practice of management by exception, in as much as it concentrates attention on critical activities rather than those, which have abundance of float.

iii. It allows the considered adjustment of scarce resources by taking into account the float of each activity.

iv. It provides a model of the project, which can be tested in many ways before the commencement of the work.

v. It allow the true effect of variations in the work to be calculated, particularly in so far the variations effect other activities, perhaps remotely and not obviously connected to the ones being varied.

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vi. It provides a standard method of planning and control which itself lead to standard documentation. As a result, the communication of the plan as an organization becomes easier and more effective.

vii. It facilitates the preparation of a precise materials delivery schedule.

viii. It portrays clearly the interrelationship between one activity and the other.

ix. It facilitates a change of supervision in the work during its progress.

x. It allows the separate consideration of the function of planning and scheduling.

xi. It pinpoints the responsibilities of individuals within the organization.

xii. It harnesses the facility of the computer to make quick and accurate calculations and presentation.

From these many advantages, it will appear that network analysis methods of programming are likely to be more effective in use in many projects than the traditional methods already described.

The use of network analysis is not, however, without its drawbacks, they tend to arise because the programming of projects is largely concern with the direction and control of human beings. The drawback may be summarized as follows:

i. There is the temptation to create large organizational empire and to over produce paper work.

ii. Attempt is to use the system as a decision-taker rather than as an aid to decision-maker.

iii. The technique tends to cut across existing system of the organization.

iv. There is a marked reluctance through unsuitability, unfamiliarity, and the fear of exposure to move from the static traditional methods to the dynamic methods of network analysis.

v. The method cannot be exploited to the full unless it is integrated with the other management systems.

vi. In certain circumstances the method may be too inflexible. The setting-up of one particular rigid network of activity sequence may be obscure, for the time being, the existence of other possible methods and sequences.

vii. If the network analysis is used on a time only basis uneconomic use of resources mar result.

viii. The establishment of float may result in the premature slacking of effort.

ix. A widely based training program must be undertaken in the use of the method.

x. Greeter planning effort and therefore greater cost is necessitated by the use of the tool.

Network scheduling models, especially for the control of a project can be relatively costly; the cost of obtaining information and updating the network may not justify the benefits of the methods in relatively small project, which may consider as disadvantage of the models.

The PERT/Cost system was developed in 1962 for the specific cost overruns of many project had made it necessary to add the resources dimension (manpower, material, and machines) to the network diagram. PERT/Cost also aids in conceptual planning by financially quantifying the project tasks to be performed

and by assessing the adequacy of funding requirements for meeting total project cost. It provides a means for comparing time schedules and resources estimates of different departments or different contractors.

The use of the PERT/Cost system enables the manager to:

- Ensure that all estimate of cost are related to the practical and accepted proposals for carrying out the work, having special regard to the resources that will be used.
- Check whether the reminder for the contract program can be carried out for the estimated costs and the magnitude of any errors, which may result from the work.
- Locate areas in which spending in excess of the budget or estimate is taking place.
- Check weather the best use is being made of those resources, which are planned and made available for the work.
- Evaluate alternatives method carrying out the work before committing himself to any one method.

The Graphical Evaluation and Review Technique (GERT) is a network model developed to deal with more complex modeling situation than can be handled by PERT/CPM. GERT combines signal flow graph theory, probabilities network, PERT/CPM, and decision trees all in a single framework. Its components consist of logical nodes and directed arcs with two parameters, the probability that a given arc is taken or realized and distribution function describing the time by the activity. Evaluation of the GERT network yields the probability of each node

being realized and the elapsed time between all nodes. It is useful to compare GERT and PERT/CPM in order to focus on what is different about GERT.

GERT	PERT/CPM
Branching from node is probabilistic.	Branching from a node is deterministic.
Various possible probability distributions from time estimate.	Only the beta distribution form time estimates.
Flexibility in node realization.	No flexibility in node realization.
Looping back to earlier events is acceptable.	Looping back is not allowed.
Difficult to use as a control.	Ease to use for control.
Arcs may represent time, cost, reliability, etc.	Arc represents time only.

Table (2.2) **Comparison between GERT and PERT/CPM**
Source: Merdith, J.R. and Mantel, S.J.(1989) Project Management: A Managerial Approach.

The steps employed in using GERT are as follows:

- Convert the qualitative description of the project action plan into a network just as in the use of PERT/CPM.
- Collect the necessary data to describe the arcs of the network. Focusing not only on the specific activity being modeled, but also on such characteristic of the activity as the likelihood it will be realize, the chance it might fail, any alternative activities that exist, and the like.
- Determine the equivalent function of the network.
- Convert the equivalent function of the network into the following two performance measures:
    - The probability that specific node realized.
    - The moment of the generating function of the arc times.

- Analyze the results and make inferences about the system.

The list of common GERT symbols, together with a few examples is given in figure (2.11), also figure (2.12) describe a small project situation developed through GERT approach.

Symbol	Name	Explanation
		INPUT
	Exclusive—or	Any branch leading into the node causes the node to be realized, but only one branch can occur.
	Inclusive—or	Any branch causes the node to be realized and at the time of the earliest branch.
	And	The node is realized only after ALL branches have occurred.
		OUTPUT
	Deterministic	All branches out must occur if the node is realized.
	Probabilistic	Only one of the branches may occur if the node is realized.
		EXAMPLES
	Beginning node with branches that must occur.	
	Ending node that occurs whenever **a** or **b** occurs.	
	Intermediate node that occurs if **a** occurs with either **b** or **c** following.	
	Intermediate node that occurs when all **a**, **b**, and **c** occur with either **d** or **e** following.	

Figure (2.11) The GERT symbols.

Source: Merdith, J.R. and Mantel, S.J. (1989) Project Management: A Managerial Approach

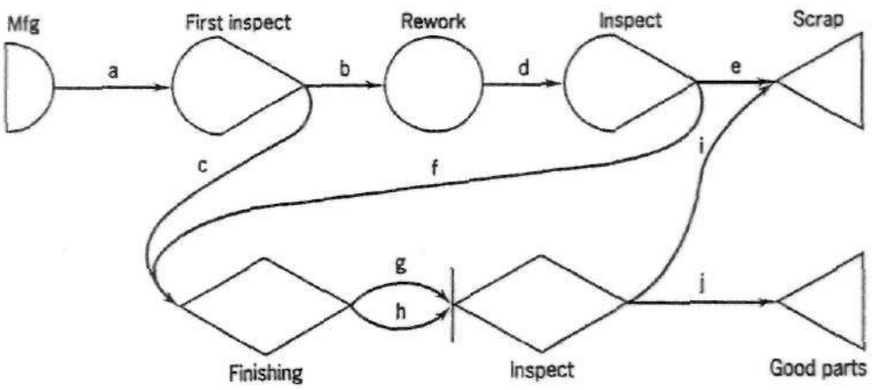


Figure (2.12) Sample GERT network.

Source: Merdith, J.R. and Mantel, S.J. (1989) Project Management: A Managerial Approach

CHAPTER THREE

PLANNING AND CONTROLLING OF BUILDING PROJECTS

3.1 PLANNING:

3.1.1 DEFINITION:

Planning according to Fulmer, R. M. (1978) " Is the primary task of management, it must occur before any of the other managerial functions because it determine the nature of these functions. Planning is more than forecasting, it involves the processes of choosing objectives, charting a course and moving along that course to the attaining of the objective. Planning make things happen that would not otherwise occur, it is a mean by which successful executives bridge the gap to the future ". To R.O. and Christie, N. D. (1974) " Planning sets the objectives and polices both in an overall sense and on a divisional basis. It determines detailed budgets, schedules and procedure, to guide achievement of objectives. It provides also the grouping of activities and the essential staffing to cover the tasks of the undertaking, as well as other resources and facilities essential for operation ". Aluko, M. (1998) defined planning as " The process of deciding what objectives to pursue during the future time period and what to do in order to achieve objectives. Thus, planning process comprises setting objectives and determining the course of action to be used in achieving the objectives. Also it is the function that produces and integrates objectives, strategies, and policies ".

Generally planning is the most basic of all management functions and organizations to define its purpose and objectives. It enables performance

standards to be set and result can be therefore compared with the standards to enable company managers to see how the organization is progressing towards its goals. In planning, several areas must be considered such as:

- Plans should be based upon clearly defined objectives and make use of all available information and data.
- Plans should be flexible and has the ability to adjust to changing business environment.
- Plan should consider factors in environment, which help or hinder the organization in reaching its goals.
- Plans should take account of existing organizations and provide for control, so that performance can be checked with established standards.
- Plans should be precise, practicable and simple to understand and operate.

3.1.2 PLANNING FUNCTION:

Planning process within an organization is dynamic and continuous; it has to be in order for the company to successfully meet the ever-changing conditions both from within and without its own walls. The planning function provides the necessary guidelines for the direction and channeling of activities so that, decision making may form a logical sequence aimed at achieving some known and specific objectives.

The basic differences in planning activity carried out at various levels in an organization may be categorized in terms of three parameters:

i. The time span affected by the decision.

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ii. The level of resources committed by the company.

iii. The degree of risk arises.

There is a wide spectrum of planning activity within an organization, and we will be concerned here with those aspects, which are the responsibility of the top and senior level of management, which can be defined as:

- Strategic Planning.
- Corporate Planning.
- Operational Planning.

I. Strategic Planning

Strategic planning is a top management function that is concerned with decisions about the future form, role, and posture of the organization, particular in relation to the environment external to the company. It is the process of the defining the overall company objectives and goals and the way in which they are to be achieved.

The strategic planning needs more than any planning activities a good deal of informed but quantitative business judgment. It is also requires an awareness to possible threats and danger to the existence of the company from outside sources. The specification of objectives, both explicitly and implicitly, is an integral part of strategy formulation. Company objectives form the direction signposts for all ventures into the unknown future at all levels of decision making within the organization.

Company goals, on the other hand, are based on the strategic plan at specified points in time, against which actual corporate performance at that time can be measured and assessed, and then controlling action that to be taken.

Strategic planning involves reassessment and redirection rather than projection of the present into the future. It is the basic for making things happen. Strategic plan is principally concern with the company's relationship with the outside environment; it is also define the limiting boundaries within which all the other planning activities take place.

II. Corporate Planning

Corporate planning is the process of translating the aims, objectives, and goals as set out in strategic plan into a workable program suitable for practical implementation. It determines the actual allocation of resources to be made. As strategic plan sets the boundaries within which cooperate planning can take place, so the corporate plan form the framework within which operation plan covering the various sections of the company can be carried out. Also the constraints between the sections can be adjusted in the process of establishing a composite plan that is compatible both within and between its component parts.

Planning is continuous activity involving a recycling process in which the various section of the plan are progressively modified, reassessed, and refined until a composite plan is achieved which is compatible in all aspects with the objectives and goals that it seeks to achieve.

III. Operational Planning:

Operational planning is concerned with allocation of available productive resources to the production requirements as determined demand forecasting. It must convert the demand forecasts into a complete production program. The purpose of operational planning is to ensure that all resources needed to produce the required items are at the right place, at the right time, and in the needed quantities, and therefore, the waste resources are minimized. All this must be accomplished within the overall constraints and policies imposed by higher management. These tasks also be accomplished with the existing or obtainable resources, with consideration given such factors as previous commitment of resources, seasonally of resources and demand, quality factors, lead item of purchased items, in-transit time, quantities required in process, and production lead time.

The operational plan provides only the general framework within which specific activities are to be performed. It dose not specify that a particular activity must be performed on a particular facility at a particular time. Details such as these are determined in operation scheduling. The operational plan, however, specify that during certain time period a particular facility must be operated an extra shift in order to handle all the activities assigned to it during that period.

Generally operational plan allocated available resources to several production requirements but in general way. The plan contains reasonable flexibility, so that detailed task assignment can be made within the general framework.

Operational planning needs to be carried out on different time spans;

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i. Long term Operational Planning: Which really is the translation of corporate objectives and goals into operation terms, is essential for all decisions that involve long lead times such as plant construction, equipment and facility acquisition, and training of personnel. It requires large commitment of capital and high risk and usually covers from 5 to 20 years. In the long-term operational plan, flexibility is required to enable changes to be readily incorporated.

ii. Intermediate term Operational Planning: Concerned with allocating financial resources to the need of any company, such as the requisition of capital equipment, minor construction programmer, the building of new plants, and equipment programs and usually cover from 1 to 5 years.

iii. Short term Operational Planning: Established production programs that allocate existing or due in resources to current production requirements. This type of plan, which usually covers from 2 months to 2 years, establishes the overall activity level of the company by making such decisions as the number of shifts of the operation, work force size, additional equipment requirements, material requirements, and amount of subcontracts support. It may also indicate the need for improved facility arrangement and for a new balance on the production.

2.1.2 PROJECT PLANNING:

Martino, R. L. (1968) defined project planning as " The determination of the tasks to be done, their necessary sequence, and their resources requirement to

achieve the project objectives ". According to Clough, R. H. (1972) " Project planning is the devising of workable scheme of operations which is established to accomplish a defined objectives when put into action ". To Spinner, M. P. (1998) " project planning is understanding what work to be done, identifying the individual activities and necessary resources, to complete the project, then developing a plan of action in a logical order that can be displayed graphically as a project planning diagram.

Generally, there are two board divisions of planning by management, both of which are necessary for the successful operation of the construction companies:

i. Strategic Planning: Which is concerned with the operation of a company as commercial undertaking. It is the policy of planning and is concerned with the overall means of achieving objectives of a company, which is defined by the board of directors.

ii. Operation Planning: It is associated with the technical processes of that company, and concerned with the various methods of arranging and employing resources such as money, materials, men, and plants to carry out the day to day operations of the company.

Construction planning is concerned primarily with establishing the sequential order in which various operations will be carried out on the job site. Operation planning is the most time consuming and difficult phase, as well as being the most important of the job management systems. It requires an intimate knowledge of construction methods combined with an ability to visualize discrete work elements and to establish their mutual interdependencies.

Most construction projects are much extensive, involving large number of job activities whose interrelationships are intricate and complex. When such job equipment availability and material delivery times are also considered, job planning becomes an arduous management function.

As a consequence of its complicated nature, construction has long needed planning method that it possible for the project manager to manipulate large numbers of job activities and complex sequential relationship in a simple and understandable scheme.

The network model is just a tool, and is the basis for planning, scheduling, and controlling methods in building projects. These methods apply equally well to all construction projects, large and small, intricate and straightforward. Network models planning involve a depth and thoroughness of study that gives the contractor an invaluable understanding and appreciation of job requirements. It indicates to field supervisors, awareness, and engineers that the company is vitally concerned with the progress of the work and has taken steps to ensure efficient operations and timely completions.

More specifically, project operations planning consist of the following steps:

i. Creating a work breakdown structure.
ii. Dividing the project into job activities that can be performed in order to construct the project plan.
iii. Determining the sequential relationships among the activities.
iv. Specifying the resources required for each activity.
v. Creating scheduling and analysis of the project.

Step 1: Work breakdown structure:

A work breakdown structure is the starting place for planning all parameters of project quality, cost, and time. It is a technique based on dividing a project into sub-units or work packages. All units or elements required to complete the project must be identified to reduce the chances of neglecting or overlooking an essential step.

A work breakdown structure is typically constructed with two or three levels of detail, although more levels may be required for very large and complex projects. Identifying logical subdivisions of the project, then breaking each of these down further, will do this. The main goal here is to identify a unit of work that is discrete and that advances the project towards its completion.

Step 2: Job Activities:

The segments into which a project is subdivided for planning purposes are called activities. An activity is a single work step that has a recognizable beginning and end, and requires time for its accomplishment. The extent to which a project is divided into activities depends upon a number of practical considerations such as the stages of planning i.e. pretender, pre-contract, or short term. Others are:

i. The area of responsibility required, such as the general contractors and subcontractor's work.
ii. The craft or crew requirements distinguish category of work.
iii. The category of work as distinguished by equipment that may require.
iv. The category of work as distinguished by materials required such as concrete, timber, or steel.

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v. The distinct structural element required, such as walls, beams, columns, slabs, or fittings.

vi. According to the owner's breakdown of the work for the binding or payment purposes.

vii. With regard to contractor's breakdown for estimating and cost accounting purposes.

According to the location on the project, which different times or different crews will be involved.

The activities need may represent relatively large segments of a project or may be limited to small steps. What is suitable for one project may not be appropriate for another. Too little detail will limit planning and control effectiveness. Too much will inundate the project manager with detail that lends to obscure the really significant factors and needlessly increase the cost of the management system.

Step3: Dependency Relationship

All activities in a project program are related to each other in various ways. These relationships are called dependencies; activities can be related to one another because of the common resources such as:

i. Facilities and Equipment: Activities, which must employ common facilities or equipment and cannot do so concurrently are dependent upon one another, one must be completed before the next can start.

ii. Funding: Activities, which cannot start until certain funding activities have been accomplished, are dependent upon the completion of those activities.

iii. Manpower: Activities, which must use the same manpower, are dependent upon the completion of the other.

Most dependency relationships result simply from the fact that an activity cannot begin until the preceding activity is completed. On the other hand many activities in a building projects can overlap on activity starting before previous activity is completed. There are number of ways in which this relationship can be expressed such as a listing that shows for each activity those activities that can start immediately after and only after that activity. Also can be presented on a graphical display of activity relationship, showing in pictorial form all of the dependencies among activities.

Step4: Resources Allocation:

A schedule on a calendar timetable is the result of allocating or committing resources to project activities from the limits available. Resources allocation involves the leveling or smoothing of resources requirements, the aim being to keep fluctuating requirements for labor and plant to a minimum and in doing this, the plan will be transformed into a work schedule.

When drawing the arrow diagram and estimating the activity time, the availability of resources for different activities was not limited, and it was therefore assumed that they would be available as required. In some cases, however, the same resources may be required as different activities, which fall on parallel path in the arrow diagram.

When allocating resources and smoothing requirements, activities can be moved within their float, but if after doing this demand for resources still exceeds

availability of project duration's will have to be lengthened or some alternative method considered, e.g. work overtime.

Step5: Scheduling and Analysis:

I. Scheduling:

A schedule is the conversion of a project action into an operation timetable. As such, it serves as a fundamental basis for monitoring and controlling project activity, and taken together with the plan of the project. In the project environment, the scheduling is more important than it would be in an ongoing operation because project lack the continuity of day to day operation and often present much more complex problems of coordination. Indeed, project scheduling is so important that a detailed schedule is sometimes a customer specified requirement.

A project schedule is simply a projected timetable of construction. There are several steps involved in the division of an efficient and workable job schedule, the following list is offered as a procedural guide in this regard:

i. Estimate the time required to carry out each network activity.
ii. Using this time estimate to compute the time period required for overall project completion.
iii. Establish time intervals within which each activity must start and finish to satisfy the completion date requirement.
iv. Identify those activities whose expedient execution is crucial to timely project completion.

v. If the project completion date is not consonant with contract or other requirement, shorten the project duration at least possible cost.

vi. Utilizing surplus or slack times that most activities adjust the start and finish times of selected activities to minimize resources conflicts and smooth out demands on manpower and equipment.

vii. Makeup working project schedule that shows anticipated calendar dates for start and finish of each network activity.

To illustrate the network planning technique, let us consider a small Design/Build project which will follow six procedural steps: establishing objectives, defining the required activities, dividing those activities, constructing the work breakdown structure, drawing the sub-diagrams, and developing the project planning diagram.

i. Establishing Objectives: usually set by higher management, the major objectives are the project start and completion dates, project cost budgets, and the expected product or result. The timing objective may also contain interim timing objectives (generally known as milestone) that must be met to achieve the completion date.

ii. Define the required activities: once the objectives are authenticated, the next step is to identify the jobs or activities needed to complete the project. Identifying the activities will be done those persons and/or divisions who have the most knowledge and experience of the work to be done to achieve the established objectives.

iii. Dividing the activities: the activities then can be divided into a group of interrelated jobs according to the specialization or professions. For the Design/Build project, the activities are divided into the following groups:

- Building work.
- Structural work.
- Mechanical work.
- Electrical work.
- Architectural work.

iv. Constructing the work breakdown structure: the activities within each group of work must be identified, and then the work breakdown structure can be prepared. Figure (3.1) shows the work breakdown structure of the Design/Build project.

v. Drawing the sub-diagrams: the sub-diagrams are a valuable aid to reduce the work involved in preparing the final step, the project-planning diagram. Once the sub-diagrams are completed, the project team will have reached the fairly good understanding of the entire project. The first and final sub-diagrams of the Design/Build project are shown in figure (3.2). In addition to this approach for diagramming a project plan, the precedence diagramming method is a worthwhile to consider, it gained considerable popularity and acceptance among project management software manufactures and establishments that are engaged in very large and complex projects. Figure (3.3) shows the precedence diagram of the Design/Build project.

Figure (3.1) The work breakdown structure of the Design/Build project.
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

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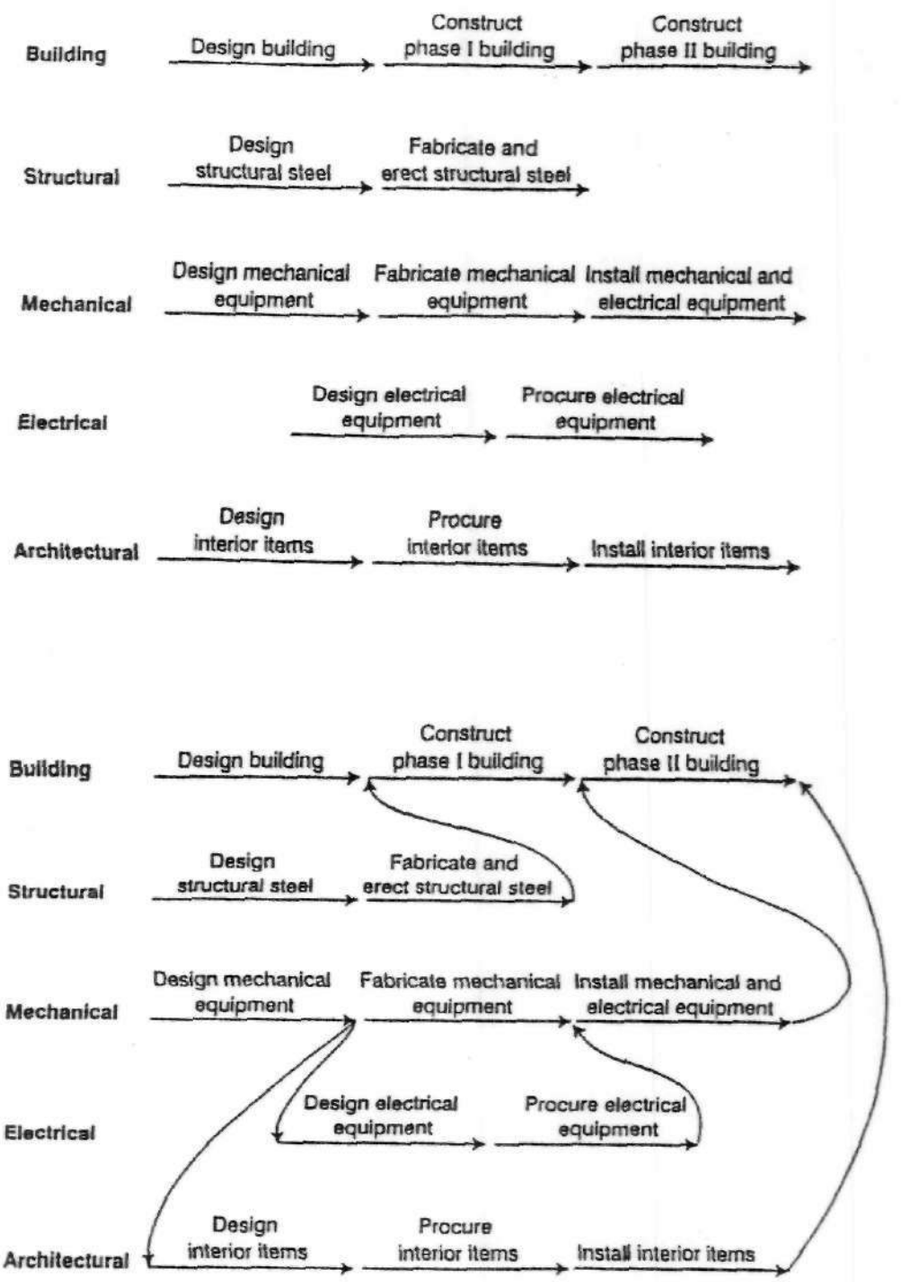


Figure (3.2) The first and final sub-diagram of the Design/Build project.
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

Figure (3.3) The precedence diagram of the Design/Build project.
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

vi. Develop the project-plan diagram: finally, the project plan diagram is developed showing the relationship of all activities. If the immediate steps are followed especially in large and/or complex projects, then this step is essentially a refinement of the final step of the sub-diagram. Figure (3.4) shows the first and final planning diagram of the Design/Build project. By adding the node symbols and numbering identifications, the basic planning diagram for scheduling purpose is complete.

To calculate the expected activity completion times, determining the probability of meeting a schedule is helpful for resolving problems caused by uncertainty. It is only, however, and the real issue is determining what problems made a schedule less probable of being met. With three times estimated method, statisticians have provided formulas for calculating the probability of meeting the project duration or even meeting the scheduled finish date of any specific activity.

The expected time estimate TE is given by

TE = (a+4m+b)/6

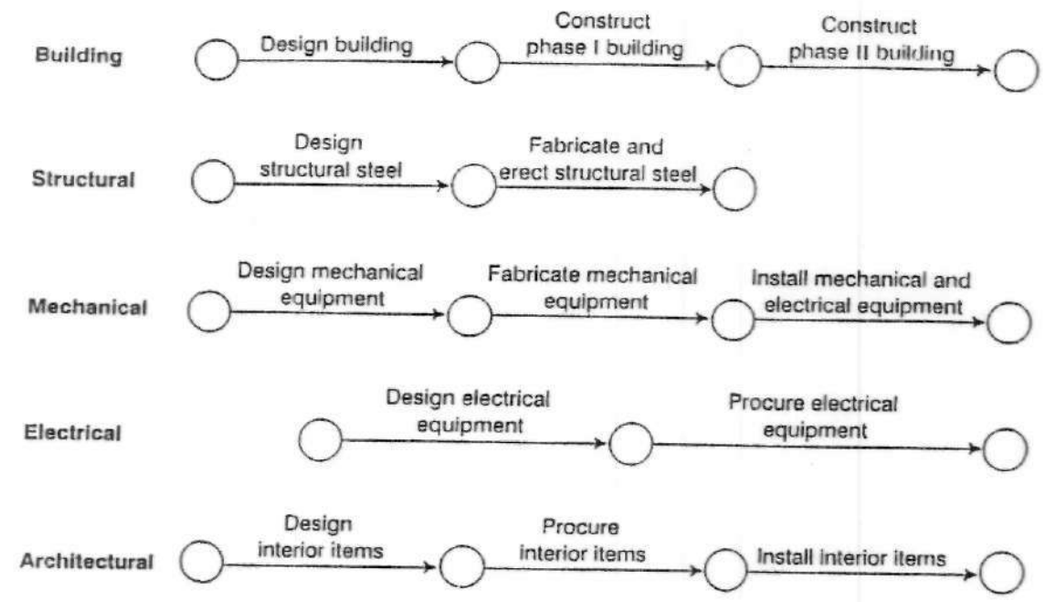
Where

a = the optimistic time estimate.

b = the pessimistic time estimate.

m = the most likely time estimate (average).

The formula for calculating expected times are to be based on the data statistical distribution. This distributing is based rather than the more common normal distribution because it is highly flexible in form and can take into account such extremes as where a=m or b=m.



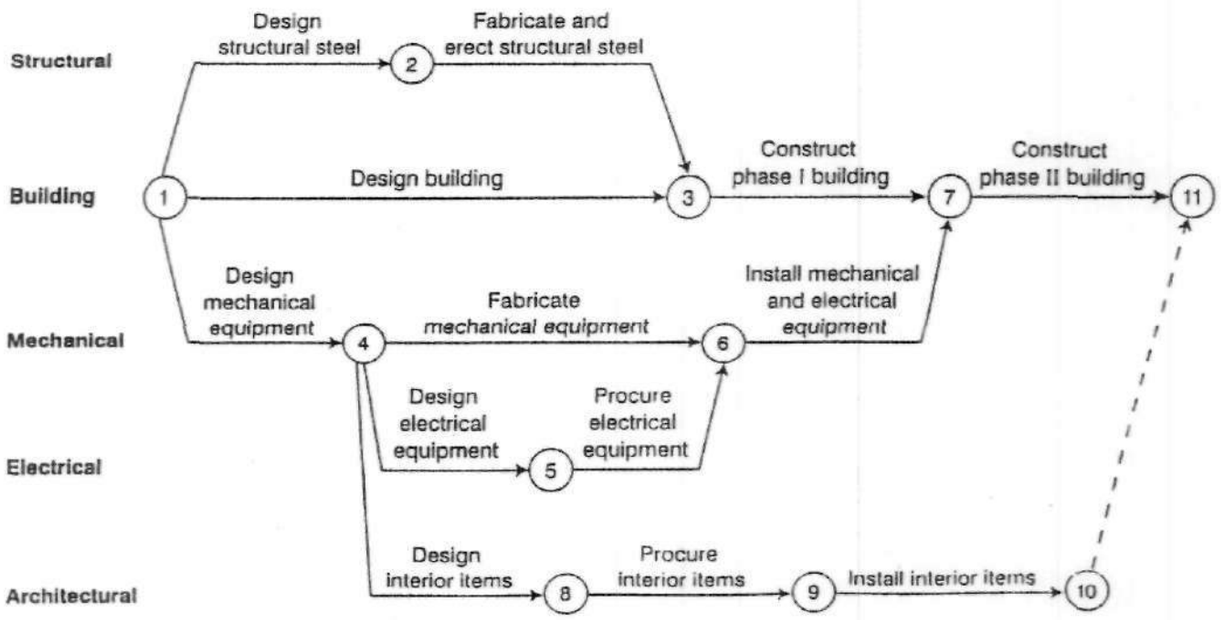


Figure (3.4) **The first and final plan diagram of the Design/Build project.**
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

The three times estimate and the results of the expected value calculations for the Design/Build project are shown in figure (3.5) and table (3.1).

The next step in determining the probability is to calculate the variance, which, is the term that describe the uncertainty associated with the time required to complete an activity.

The variance $\sigma^2 = \{(b - a)/6\}^2$

Standard deviation $\sigma = \sqrt{\sigma^2}$

Table (3.1) shows expected activity times (TE), variance (σ^2), and standard deviation (σ).

II. Network analysis:

Critical Path Time: To calculate the total duration for the project, let us consider the units are weeks and the project on week zero. According to figure (3.6), there are five activity paths leading to event they are:

Path 1 = 2+10+6+6 = 24 weeks

Path2 =13+6+6 = 25 weeks

Path3 =6+9+6+6 = 27 weeks

Path 4 =6+4+7+6+6 = 29 weeks

Path 5 =6+2+4+10 = 22 weeks

The longest of these paths is path 4 using twenty-nine weeks, which means those twenty-nine weeks, is the shortest time in which the entire network can be completed. This is called the critical time of the network, and path 4 is the critical path, usually shown in a heavy line. In a simple network such as this example it is

I-J	DESCRIPTION	OPTIMIS. TIME	AVER. TIME	PASSIM. TIME	EXPEC. TIME	VARIA.	STAND. DEV.
1-2	Design Structural steel	2	2	2	2	0	0
1-3	Design building	13	13	13	13	0	0
1-4	Design mechanical equipments	5	6	9	6	0.44	0.67
2-3	Fabricate and erect structural steel	10	10	10	10	0	0
3-7	Construct phase 1 building	6	6	6	6	0	0
4-5	Design electrical equipments	2	4	8	4	1	1
4-6	Fabricate mechanical equipments	9	9	9	9	0	0
4-8	Design interior items	2	2	2	2	0	0
5-6	Procure electrical equipments	4	7	9	7	0.69	0.83
6-7	Install mechanical & electrical equipment	5	6	7	6	0.33	0.11
7-11	Construct phase II building	5	6	7	6	0.33	0.11
8-9	Procure interior items	4	4	4	4	0	0
9-10	Install interior items	10	10	10	10	0	0
10-11	Dummy	0	0	0	0	0	0

Table (3.1) Time estimate, variance, and standard deviation for the Design/Build project.

Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

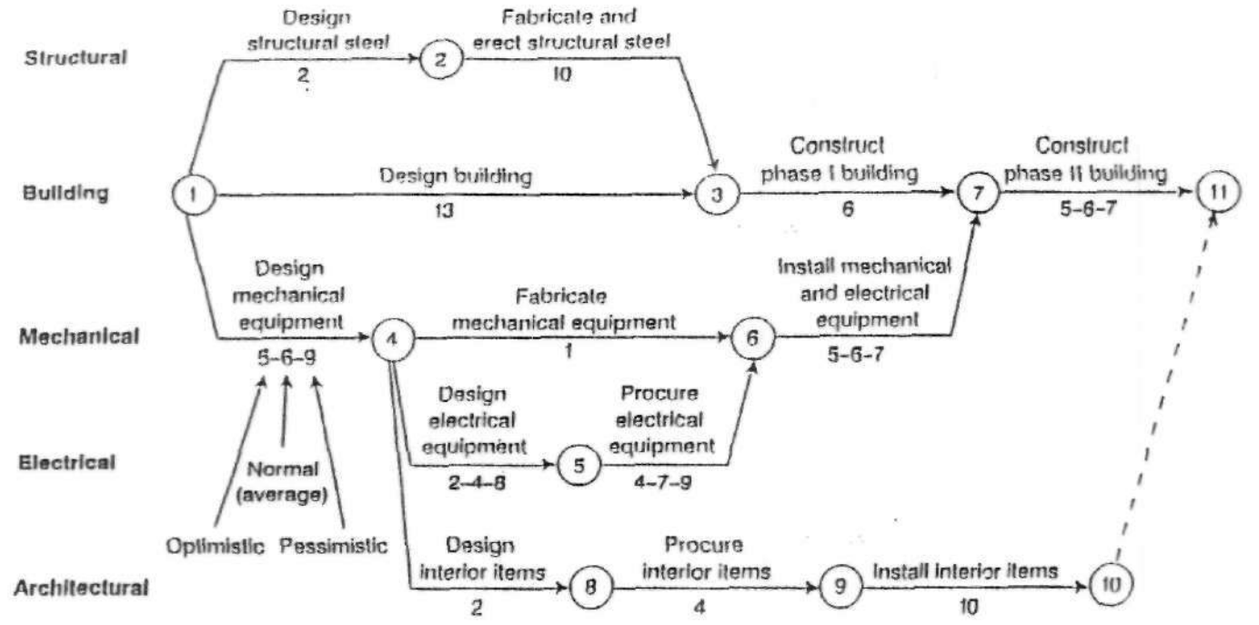


Figure (3.5) The three time estimates applied to the Design/Build project.
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

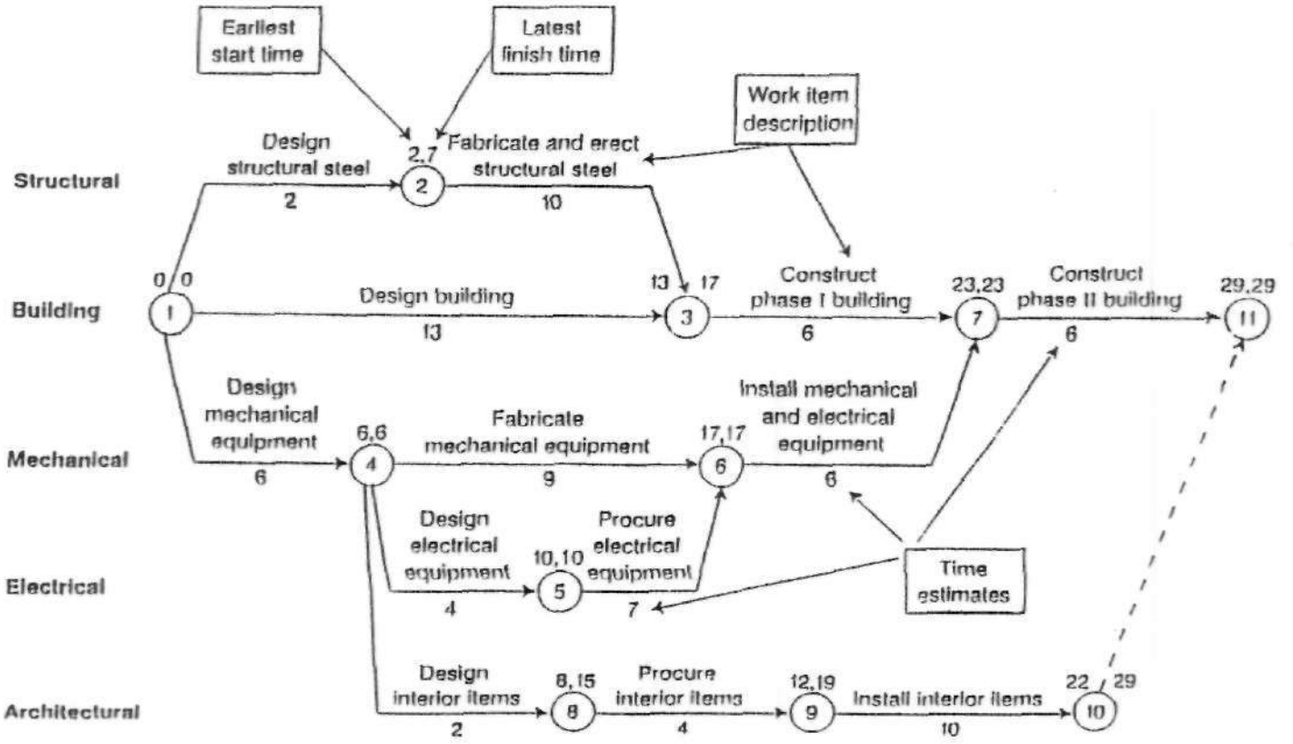


Figure (3.6) Time estimates, earliest start, and latest finish times for the activity of the Design/Build Project.
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

easy to find and evaluate every path between stat and finish, many real networks are considerably more complex, and finding all paths can be taxing.

Earliest Start and Finish times and Latest and Finish times: The early start and finish times are the earliest that each activity can be started and finished respectively. Given the starting times as zero and the earliest start time (EST) for each activity, the earliest finish time (EFT) is simply (EST + Activity time). Table (3.2) shows the EST and EFT for each activity.

The latest start and finish times are the latest that an activity can be started and finished respectively without delaying the total time to complete the project. Given the latest finish time (LFT) for the project as a whole, therefore, the latest start time (LST) for each activity is (LFT – Activity time). Table (3.2) shows the LST and LFT for each activity.

Slack: Total slack (TS) for an activity is the maximum time that the activity can be delayed beyond its EST without delaying the project completion time. The critical activities are those that are in the sequence of the longest time path through the network and therefore, the activities on this path all have minimum possible TS which is the difference between LST and EST for an activity as shown in table (3.2).

Free slack (FS) is the amount of time that an activity can be delayed without delaying the EST of any other activity. Free slack for an activity will never exceeds its TS. Free slack is computed as the difference between the EFT for an activity and the EST of all of its immediate successors.

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I-J	DESCRIPTION	TIME (WEEKS)	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT
1-2	Design Structural steel	2	0	2	5	7	5
1-3	Design building	13	0	13	4	17	4
1-4	Design mechanical equipments	6	0	6	0	4	0
2-3	Fabricate and erect structural steel	10	2	12	7	17	5
3-7	Construct phase 1 building	6	13	19	17	23	4
4-5	Design electrical equipments	4	6	10	6	10	0
4-6	Fabricate mechanical equipments	9	6	15	8	17	2
4-8	Design interior items	2	6	8	13	15	7
5-6	Procure electrical equipments	7	10	17	10	17	0
6-7	Install mechanical & electrical equipment	6	17	23	17	23	0
7-11	Construct phase II building	6	23	29	23	29	0
8-9	Procure interior items	4	8	12	15	19	7
9-10	Install interior items	10	12	22	19	29	7

Table (3.2) Tabulated schedule for the Design/Build project.

Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

Interfering slack is the amount of spare time available, which if used, will affect subsequent activities, and can be calculated by (TS – FS).

Independent slack is the amount of spare time available, which can be used without affecting any succeeding activity and not be affected by any preceding activity. It is calculated by (Earliest Succeeding Time – Latest Preceding Time – Activity Duration).

Reduction of Projects Time Duration: This can be accomplished by shifting resources from other activities or by obtaining additional resources and thus, adding to the cost of the project. Normally, this can be achieved by crashing one or more activities on the critical path.

Crashing non-critical activities could not help reduce the project completion date since these activities already have positive slack. When the critical path contain many activities, it may not be obvious which activities should be crashed. Often crashing is available only in discrete amounts and at considerable cost. Candidate activities should be compared on the basis of their crashing cost as well as the amount by which they reduce project completion time. Moreover, crashing decision should not be made without assessing their potential impact on various non-critical paths in the network. If the length of the critical path reduced enough, some other path may become critical. Thus, part of the cost incurred to reduce the length of the critical path may be wasted.

3.2 CONTROLLING:

3.2.1 DEFINITION:

Controlling according to King, J. R. (1975) " Is concerned with the direction, rate of progress, and quality of achievement. It depends on having quantity and quality targets for the aspects of the job that have to be controlled, and a means of measuring past and current performance and estimating what still has to be done. It is also implies control of deviations from the planned path, to keep them within the agreed degree of tolerance ". To Oxley, R. and Poskitt, J. (1976) " Controlling is complementary to planning. It involves comparing at regular interval, the achievement with the plans and then taking any necessary correction action to bring things back to schedules ". Also Aluko, M. (1998) defined controlling as " Implies accomplishment of event against set standards and the correction of deviations to ensure attainment of objectives according to set plans ".

Generally, controlling is an element of management tasks, and involves the measurement and correction of performance of subordinates to make sure that the objectives of the organization and the plans devised to achieve them are accomplished efficiently and effectively.

Controlling involves:

i. Setting standard.

ii. Measuring performance against standard.

iii. Getting the feedback result.

iv. Correcting deviation from standards.

To maintain effective controlling in modern organizations, certain principles must be ahead to, and these include:

i. Controlling must be set according to the nature of job to be performed.
ii. Deviations should be reported immediately. In ideal situations, notification is made before deviation occurs.
iii. Control must conform to the pattern of the organization in term of definition and responsibility.
iv. Controlling should be flexible and economical in operation to provide for alternative remedies where failure.
v. Controlling should show exceptions at selected points. The principle is that, where by only exception to the standard are notified, should be adopted.

3.2.2 PROJECT CONTROL:

Project control according to Martino, R. L. (1969) " Concerned with rate of output in order to meet program dates, and with quality and cost, in order to meet client requirements. Many different techniques have devised to assist in various form of control ". To Merdith, I. R. and Mantel, S. J. (1989) " Project control is the act of reducing the difference between plan and reality, it involves collection of information about the system performed, comparison with the desired level, and action to be taken to attain the desired performance ". Spinner, M. P. (1998) defined project control as " Monitoring or tracking progress of the project as it

gets under way, analyzing performance, then resolving concerns. It also manages status reporting ".

Project control is an early warning system to resolve problem in the earlier stage of the project and thus avoid panic situation when the project nears completion. It compares the early start/finish schedule, based on the original plan with the actual performance of the project. Figure (3.7) summarizes the steps in the planning and control process.

Several factors related to performance, time, or cost causes a project to require the such as:

i. Performance Factors:
    - Unexpected technical problems arise.
    - Insufficient resources are available when needed.
    - Insurmountable technical difficulties are present.
    - Quality or reliability problems occur.
    - Client requires changes in system specifications.
    - Inter functional complications arise.
    - Technological breakthroughs affect the project.

ii. Cost Factors:
    - Technical difficulties require more resources.
    - The scope of the work increases.
    - Initial bids or estimated were too low.
    - Reporting was poor or untimely.
    - Budgeting was inadequate.

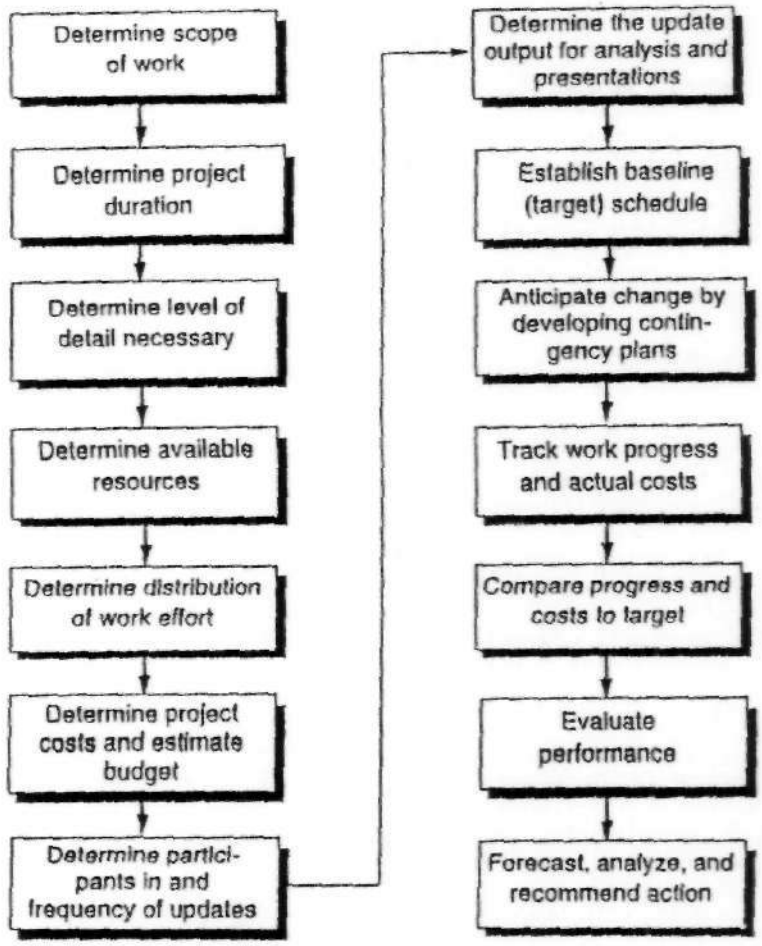


Figure (3.7) **The planning and control process.**
Source: Primavera (1999) Primavera Project Planner: Planning and Control Guide.

- Corrective control was not exercised in time.
- Input price change occurred.

iii. Time Factors

- Technical difficulties took longer than planned to solve.
- Initial time estimates were optimistic.
- Task sequencing was incorrect.
- Required inputs of material, personal, or equipment were unavailable when needed.
- Necessary preceding lacks were incomplete.
- Customer generated change orders required network.
- Governmental regulation was altered.

Once the program plan or network has been prepared, the initial schedules established, the next four distinct control stages are characterized as follows:

i. Monitoring the project: monitoring project activities is a continuous checking of their performance. It consists of reporting the date of actual completion of activities plus any revisions in the plan. Management then makes a schedule forecasts based on the last completion date. This updated program information is feedback on regular schedule for processing, evaluating, and translation into management action. Such periodic evaluation of existing plans by comparison with actual, current, and operating condition give the program manager a continual check on the critical areas of this program. If there are disturbing signs that the project may be heading for difficulties, formal monitoring and reporting will be

more frequent. The present status of each project activity is noted and recorded. The frequency of this monitoring varies from daily to monthly or quarterly. In most engineering and construction situation, it is either weekly or monthly. Figure (3.8) shows the progress schedule for the Design/Build project.

ii. Assessing the project: The next stage, assessing what the, determines what effect the changes have on the project schedule, particularly on the project completion date. With the revised duration, new calculations are made for the earliest start times and latest finish times of all the project activities. To observe the total effect, a completely new schedule is to be prepared, requiring recalculation of the total float for each activity. The new total float table will show some dramatic changes on some activities, which is sign that a new schedule needs to be recalculated. The schedule gives more attention to those activities to present further potential delays and to reduce there durations as a possible way to restore the project to its original completion date. The revised schedule is quite complete, showing early and latest start times, early and latest finish times, duration and float. It is very helpful in reviewing the entire to help resolve the scheduling problems.

iii. Resolving Problems: Certain questions must be answered to help solve the planning and scheduling concerns and or problems of the project.

- Which specific activities are behind schedule? How much will they delay the project date if not corrected?

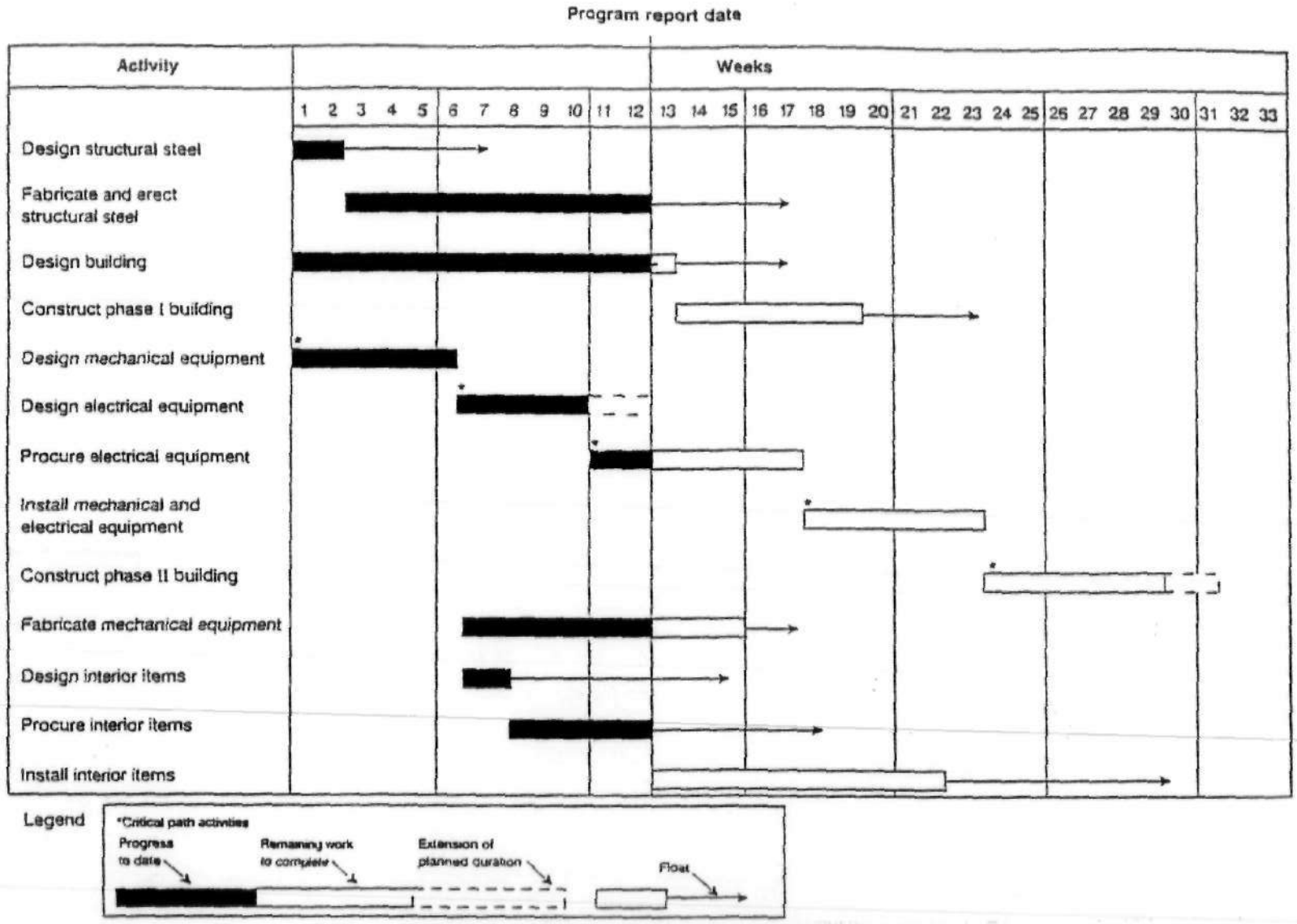


Figure (3.8) The progress schedule of the Design/Build project.
Source: Spinner, M. P. (1997) Project Management: Principle and Practice.

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- What are the reasons for the delay that have caused the project to fall behind schedule?
- What steps have been or are being taken or should be taken to get back on schedule, and what results have been achieved or are expected?
- Will any other specific recommendations for further action restore the schedule and prevent further concerns?

iv. Communicating: It is important to communicate the project status to management, suppliers, vendors, contractors, and project team members. While a written report is possibly one of the most valuable communication devices, other include phone calls, e-mails, personal contact, and meeting formally as well as continuously throughout the project. A written periodic project status report, weekly or monthly, should be distributed to all those who want to see the project reach a successful conclusion. The status report represent a view of what is happening in the project, offering readers an opportunity to suggest improvements early enough to make an impact on the project progress. The status report is essentially a summery; it includes a brief background of the project, highlights critical areas, and outlines the resolutions and improvement planned. The status report is based on the progress schedule, which is a graphic presentation of the project schedule revised to show actual progress.

The process of controlling involves all phases of the project from conception to completion. It is a cycles that brings with the setting of project objectives and end only when the last activity has been completed. Throughout each phase of the

operation, the system must provide management with the ability to respond to any situation, which might arise.

3.3 PLANNING AND CONTROLLING SOFTWARE:

Project management software provides an easy to use approach to project planning with an intuitive that makes project planning and control easy and fun. Using project management software can organize the thinking and identify potential problems, and following established project procedures ensure that:

- Informing the team about options, alternatives, and workaround efficiently.
- Presenting the project to upper management clearly and convincingly make it easier to obtain the required support when needed.

These are the most important reasons that created the software managing projects easier especially when encounter difficulty.

Before implementing project software such as Microsoft Project or Primavera to schedules projects, it is important to understand the processes involved and the associated recommendation that help smooth implementation of the software and then reach the project goals. If the project have already started, there is need to incorporate or adjust the existing methodology for planning new project or updating the existing ones. In the various stages of project life cycle, the key elements that should guide the decisions are planning, controlling, and managing communications.

The following features are being offered by most project management software packages:

- Planning, tracking, and monitoring: Those most common features provide for planning and tracking of the project tasks, resources, and cost. The data format for describing the project to the computer is usually based on standard network typologies such as the CPM or PERT method. Task elements with their estimated start and finish times, they're assigned resources, and actual cost data can be entered and updated as the project progresses. The software provides an analysis of the data and documents the technical and financial status of the project against its schedule and original plan. Usually, the software also provides impact assessment of plan deviations and resource, and schedule projections. Many systems also provide resources leveling.
- Reports: project reporting is usually achieved via a menu driven report writer system that allows the user to request several standard reports in a standard format the user can also modify reports or creates new ones. Depending on the sophistication of the system and its peripheral hardware, these reports are supported by full range of Gantt charts, network diagrams, tabular summaries, and business graphics. A sample of reporting capabilities available today includes:
    - Budget cost of work scheduled report.
    - Budget cost of work performed report.
    - Actual versus planned expenditure report.

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- Earned value analysis.
- Indices of cost and performance scheduled.
- Cash-flow report.
- Critical-path analysis.
- Change order report.
- Standard government reports, formatted for the performance monitoring system.

In addition, many software packages feature a user oriented, free format report writer for styled project reporting.

- Project Calendar: This feature allows the user to establish workweeks based on actual workdays. The project calendar can be printed out in detail or in a summery format and is automatically the basis for computer-assisted resources scheduling.
- What if analysis: Some software is designed to make what if analysis easy. A separate, duplicate project database is established and the desired changes are entered. Then the software performs a comparative analysis and displays new against the old project plan in tabular or graphical form for fast and easy management review and analysis.
- Multi project analysis: Some of the more sophisticated software packages feature a single, comprehensive database that facilitates cross project analysis and reporting. Cost and schedule modules share common files that allow integration among projects and minimize problems of data inconsistencies and redundancies.

For the purpose of easy classification, project management software products have been divided into three categories based on the type of functions and features they provide:

i. Software I: Designed for single project planning, and they are simple, easy to use and understand. They do provide, however, only a limited analysis of the data. They do not provide automatic scheduling based on specific changes. Therefore, deviations from the original project plan require complete re-planning of the project and a complete new data input to the computer.

ii. Software II: Designed for single project management, these software package aid projects leaders in planning, tracking, and reporting of the projects. They provide a comprehensive analysis of the project, progress reports, and plan provisions based on actual performance. This type of software is designed for managing projects beyond the planning stage, and for providing semiautomatic project control.

iii. Software III: These packages for multi project planning, monitoring, and control by utilizing a common database and sophisticated cross project monitoring and reporting software.

Most software packages at type II and III have the following extensive capabilities for project monitoring and control:

i. System Capacity: The number of activities and/or number of sub-networks that may be used.

ii. Network schemes: The network schemes are activity diagram and/or precedence relationship.

iii. Calendar dates: An internal calendar is available to schedules the project's activities. The variations and options of different calendar algorithms are numerous.

iv. Gantt or bar charts: A graphic display of the output on a time scale is available if desired.

v. Flexible report generation: The user can specify within defined guidelines the format of the output.

vi. Updating: The program will accept revised time estimate and completion date and the revised schedule.

vii. Cost control: The program accept budget cost figures for each activity and then the actual cost incurred, and then summarized the budgeted and actual figures on each updating run. The primary objective is to help management produce a realistic cost plan before the project is started and to assist in the control of the project expenditures as the work progresses.

viii. Scheduled dates: A date is specified for the completion of any of the activities for the purpose of planning and control. The calculations are performed within these dates as constraints. Figures (3.9a), and (3.9b) shows the schedule layout of the Design/Build project using Primavera P3.

ix. Sorting: The program lists the activities in a sequence specified by the user.

x. Resources allocation: The program attempts to allocate resources optimally using one of many heuristic algorithms.

xi. Plotter availability: A plotter is available to plot the network diagram.

xii. Machine requirements: This is minimum hardware memory requirement for the program (in units of bytes).

xiii. Cost: Indicates whether the program is sold and/or leased and the purchase and/or lease price (where available).

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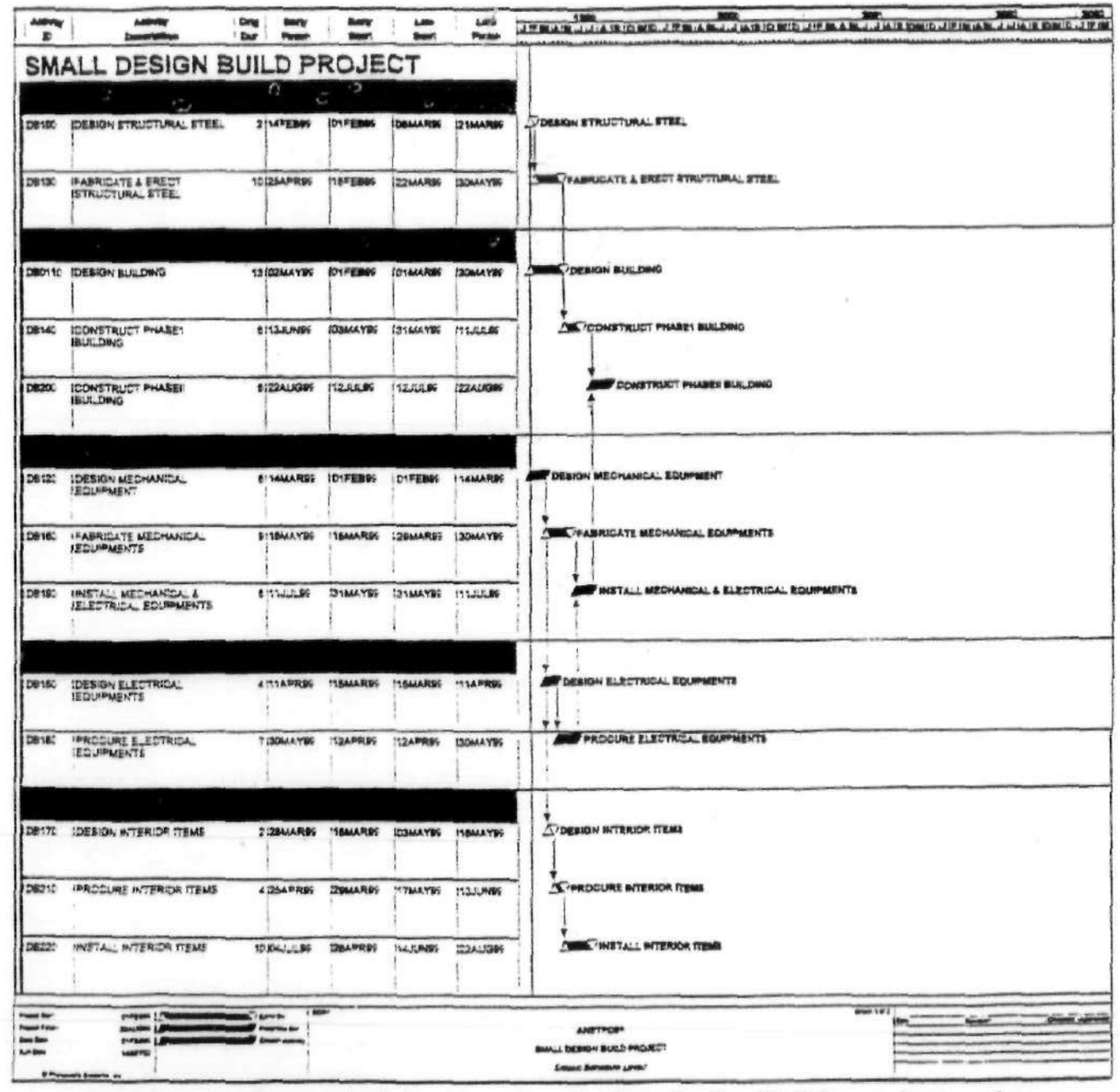


Figure (3.9A) <u>The schedule layout of the Design/Build project using Primavera program (Activity Form).</u>

Source: Author (1999) Using Primavera 0.3 Program.

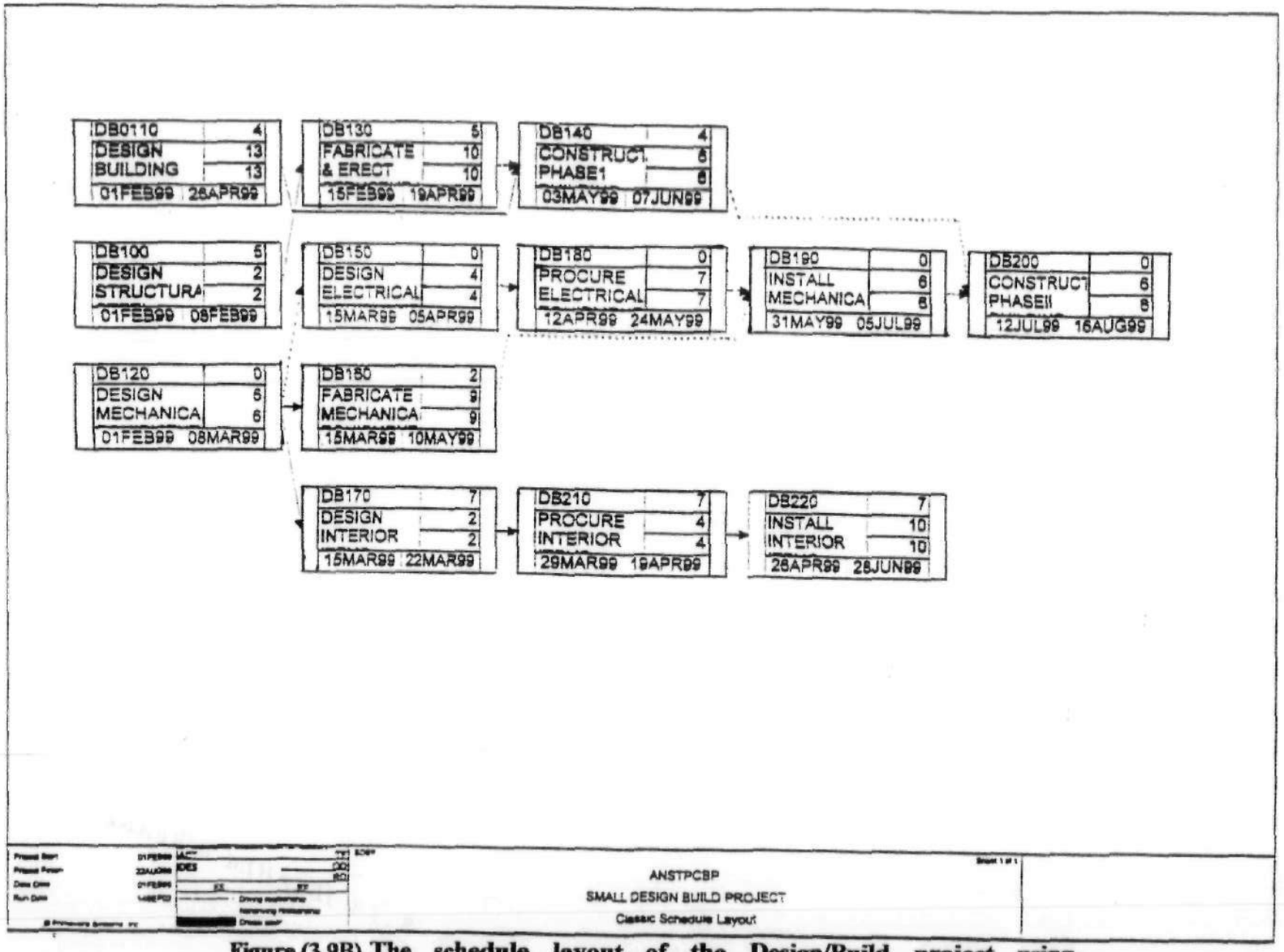


Figure (3.9B) The schedule layout of the Design/Build project using Primavera program (PERT view).

Source: Author (1999) Using Primavera 0.3 Program.

CHAPTER FOUR

APPLICATION OF NETWORK MODELS IN BUILDING PROJECTS

4.1 INTRODUCTION

Network analysis management technique designed for use in planning, scheduling, monitoring, and controlling of projects. The application potential is much larger than might be expected because management operates basically on the project concept. In some operations, such as refining petroleum or assembling automobiles, the production cycle is continuous, but in the other operations, such as constructing a building or a bridge, the project is one time job. Both types, however, can be classified as projects, the first can be considered a continuous project, and the second a static project. Network analysis is best suited to the static type. The status type of project, therefore, is basically one has a definite beginning and a definite end. It consists of a number of interrelated and interdependent activities, all of which utilize resources and upon which there are imposed internal and external conditions. The ultimate aim of course, is to achieve the objective for which project was instituted in the best cost-time at least cost at least risk.

4.2 GENERAL APPLICATION OF NETWORK IN CONSTRUCTION:

The application of network analysis in the management system of the construction companies relates not only to this particular activities each taken separately, but also to their unity within the framework of the company's

organization units such as the top managers section or their integration. Generally in construction companies the network scheduling models, are being applied in:

- The planning and control program required for the operations on building projects. The network extends to the entire construction program and the compacting is centered upon the timing of the job.
- Timing the construction plan for each particular project as a result of the process of establishing the organizations and the technology for the building operations. It form an integral part of the contractor preparations prior commencement. The network is prepared for the whole project and whilst it adheres strictly to the terms agreed upon respecting the duration of works, it concentrates their timing and coordinating the company's resources, i.e. ganged and machines. The resources requirements are summed up at regular intervals for selecting the optimum organizational and technological alternatives. The time schedule of the project is a tool in hand of the contractor and it set down the actual optimum plan of the construction program.
- A detailed contractor's control of the construction program on each particular building project that, can be carried out by means of similarities on the network graph. It is control instrument over the company's own working forces (for site managers). Computation centers upon the timing of the building operations.

- The planning and control program made for the actual civil engineering work such as the construction of dams, bridges, roads, and sanitation facilities.
- The planning and control of the main repair and maintenance work in buildings.
- Using the network plan as integral part of management system of the construction companies.

The first task of the network analysis to specify and control such a time schedule of construction exploiting both of the company's own resources at optimum rate and the extraneous ones that had been based on cooperative basis. The input of the computing consists of the program of each particular organization unit. The computation is centered on the optimum resources allocation.

The network analysis fulfills simultaneously two functions:

i. Specify the time rector of building production, which adapts itself to the continuous and well-balanced utilization of the building company's resources.

ii. Sum up the selected requirement for the optimally selected time intervals and for the selected organizational levels (building site manager, top managers section and their integration).

Therefore the network analysis is so helpful to the construction companies management system because it offers quite number of advantages that no other operation research method can offer it. It's particular advantageous that the fundamentals are the network graphs of different building activities they are

objectively elaborated beforehand and utilized in preparation of the construction programs and consequently available to the construction company for its free use. This systematic utilization of network analysis is worked out in detail and has been used for some time past in the construction companies.

43 APPLICATION TO SINGLE AND MDLTI UNIT PROJECTS:

The basic principle of network planning, scheduling, and control are as applicable to multiple unit projects as they are to single unit one. However, network techniques must be modified in certain way to apply the principle to a multiple unit problem in a practical way. When the techniques are applied to such a problem proven production control techniques are sample added to the basic principles. The following are the basic guidelines to be applied to single and multiple unit projects:

i. Establish what work to be done, here, determine the different type of products to be produced such as living rooms, bedrooms, toilets and landscaping,

ii. Separate the main building operations from the finishing operations also separate the internal work from the external for practical reason,

iii. Determine the activities or tasks, and the relationship between them for each product and operation,

iv. Prepare the network for each product and operation independently. In the case of multiple units, prepare the similar network with variations for each product in the similar units.

v. In the scheduling phase, determine the expected time for each activity, here; consider the additional time and the lead-time for each activity.

vi. Review the network topography without expending any additional time, and then determine the length of the critical path for various networks using the computer program.

vii. Determine the unusual type of activities, which were liberally, used both in phasing the network together and in constructing some of the networks.

viii. Develop the total network plan by relating each network to the other; also calculate when each network should begin so that networks ties into one another properly.

ix. Prepare the final scheduling calendar for the total network and for each unit or product network. Print them in a form of useful to subcontractors.

x. Prepare an additional piece of information, which include the designation of what goes on every product, the designation of each unit, and the start date of the project.

xi. Prepare a sub-schedule for every real activity on the network, and therefore, for every subcontractor or trade working on the site. The location column on this sub-schedule specifies the building unit and the floor plan for each unit listed.

xii. Prepare for each subcontractors or trade working on the project a report that shows all the operations for every particular unit.

xiii. Develop a control card for each network, the control card describe the building number, the unit number, and the particular unit floor plan. Also include the lead-time, the base date, and the starting date.

xiv. Add the general cost including the overhead and any other miscellaneous items to the network for appropriate cost.

xv. Specify the timing and payment for each subcontractor depending upon the completion of various items in the network.

xvi. Design a system by which the field superintendent is required to report on the project status based on the scheduled program. The final record will include both scheduled and the completion date.

xvii. Access this information obtained from the project status and produce an updated schedule for each activity, listing only the uncompleted items.

xviii. This will be carried out until the final completion of the project.

This guideline demonstrates that, network-planning technique is a tool which management can use to carry on the building projects more efficiently and more economically than its possible without it. It is also clearly illustrates that, in certain environment, the linking of costs to activities in the network is practical and desirable. Other benefits enjoyed by using the system result from improved communication, reduced paper work and increase attention to quality.

4.4 MANAGERIAL APPROACH TO NIGERIAN CONSTRUCTION COMPANIES:

The system and methods used to formulate and implement construction program and projects and their achievement in terms of development, are closely related to

a company's political, economic, and social achievement, which differ from one country to another. In Nigeria, there are several problems and shortcoming in the course of implementing construction development projects in general and in introducing and applying network analysis technique in this field in particular. Network analysis so far, a rather limited application in Nigerian construction companies, as a very useful program and control tool, one would have expected a wide acceptance and application of these technique. These stems from a number of factors, which discredit these techniques and impede further application. Main factors may be listed into two groups:

i. Factors associated with the ability of construction companies to adopt the network technique as a planning and control methods in building projects.
ii. Factors associated with application of the network techniques in programming and controlling of the projects.

4.4.1 FACTORS INFLUENCING THE APPLICATION OF THE NETWORK TECHNIQUE:

Based on the literature survey, the construction companies especially the small and medium size ones in Nigeria are faced with several factors that limit the adaptation of the network techniques as planning and control method in building projects. Main factors may be briefly stated as follows:

i. Rapid postulated rates of construction growth are frequently, for some reason or another, not backed by well studies and prepared projects to achieve these targets for which network analysis techniques are to be used to program, coordinate, and control their implementation. In this regard the

only consequence is that, project would be based on sketchy estimates on market size, location, capital output and capital labor ratio, foreign exchange component of investment, the forward and backward linkage, skill manpower, time duration, and infrastructure requirements which differ from actual performance and hence entail interruption of work, alterations, and increase in costs. Even with well-conceived projects and well-prepared feasibility studies, time may have elapsed for some reasons or other, such as in seeking financiers, between the completion of study and commencement of the execution of the project during which many relevant circumstances are likely to have changed, and thus project implementation is based on unrealistic technical parameters and estimates.

ii. Lack of company's well organization that includes staffing and equipments, and affect the coordinating and monitoring of the project during the implementation stage. What is evident in most of the cases is mal-organization, improper assignment of the responsibilities, duplication of functions, lack of coordination between the parties participating in implementing the project and inadequate progress reporting and follow up. Only too often do the individuals, groups, or departments. Although at work in the same project, operate in almost complete different isolation from the others; with no coordination between their work schedules, this problem is further aggravated by those projects having inter-linkages. In the absence of coordination, delays encountered in implementing one project result in further delay and burgeoning cost in the others.

iii. Lack of well qualified personal in this field capable of developing the right logic of the strategy of the projects and providing reliable estimates for the activity program. The problem here is that, these techniques are new to Nigerian environment and the relevant data and previous experience are scarce. For this reason foreign consultants from the advanced countries are being called upon for short assignments to assist in preparing and programming projects implementation. As many of them are not well acquainted with the local conditions and work pace in Nigeria concerned, the schedules they develop are for the most past based on unrealistic estimates of time duration, resources, and cost.

iv. The power tool and detailed programming achieved by these techniques may be reason for these who have not been used to it before to fear that the top management may use it for tight control and hence be reluctant to apply these techniques.

v. The top management might claim that the current programming and control practices so fare used in project implementation are satisfactory. This might be attributed to either lack of reliable information, which would otherwise have identified and determined exiting problems and their order magnitude. Or the fact that project management may as in often the case, is unaware of the potentialities of these techniques and the saving in time, resources, and costs that will result in applying them. Furthermore, project management on the approval of a project for implementation, may develop

an aggregate project implementation network, after which its put the project into execution with no further detailed programming.

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4.4.2 FACTORS INFLUENCING THE APPLICATION OF NETWORK TECHNIQUES:

In large construction companies in Nigeria, the application of network scheduling models is limited due to several factors that, in many projects may lead the work to stop completely. These problems are associated with the determination of job activities, activity time estimate, and activity cost estimate.

i. Determination of job activities: It is related with the works that must be performed to meet the project objectives. Activities must be determined without omission because the sequence or order in which is to be performed is of vital importance. In the implementation program of these activities, the site manager can be faced with several factors affecting the scheduling program of the project such as:
    - Unplanned activities: These are the activities arise during the design change or network and can affect the project duration and cost.
    - Unusual activities: These are activities used to show certain relationship between two other activities and it always consumes time but no resources.

ii. Activity time estimate: To estimate duration of an activity, the resources normally used on such activities, the work content of the activity and the average productivity on similar activities from historical record are considered. This estimate will hold, if during its life the project

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environment remains the same as envisaged at the time of planning. But in real life as the project progress, its activities encounter many problems that may impinge upon their duration. The cause of these problems is mostly uncertain yet predictable variables that dynamically affect the activity duration. The assessment of their impact is a complex problem since the variable are dynamic and depend on project condition and the time of year when the activity will be worked on. For example a concerning activity is more susceptible to weather compared to activities such as interior drywall or indoor equipment installation. Some of the variable that cause uncertainty in activity duration estimate are: learning curve, weather, space congestion, crew absenteeism, regularity requirements, design changes and work, economic activity level, labor unrest, crew interfacing, project complexity, foundation conditions, design delta collection schedule, ineffective supervision, inefficient consultant, building code, transportation schedule, construction materials delivery schedule, legal problems and union problems. Based on the literature survey and field experience, certain uncertainty variables are considered more significant depend on the project under consideration such as:

- Weather: The effect of natural environment in Nigeria strongly influences the progress of construction. The uncertainty in activity duration estimate due to weather is dependant upon the time of the year the activity performed. Weather condition affect labor productivity as well as activity duration. Excavation in rain season

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is done at a different rate than under normal conditions. The uncertainty in weather conditions causes major delays in certain activities.

- Economic activity level: There is relation between the number of ongoing projects and labor productivity based on the ratio of demand to the available skilled labor, as the number of projects increases, there is abound to be more demand for labor. If the labor is in short supply, it mars result in recruitment of marginally qualified crew thereby reducing the overall productivity.
- Design change and rework: These are inevitable on any project and become unavoidable on project when the design and construction phases overlap. Factors such as errors and omissions in the original design, incorporation of latest improvements, continuous change in safety and legal requirements, necessitate change resulting in extended duration for certain activities. As experienced on several projects change orders are deleterious to the project schedule.
- Regularity requirements: Many projects must proceed under the continued threat of shutdowns, delay harassment and court challenges due to regularity requirements. It recognized that there would be more and more government regulations on safety of design and field construction methods and environmental consequences of project. There are expected to have a significant impact on activity duration.

- Crew absenteeism: Crew absenteeism can be major menace on some projects. It is impact is well pronounced during raining season when absenteeism is expected to be erratic and high. Depending on crew formation, absenteeism of crucial tradesmen may even make it necessary to stop work on an activity. Labor unrest: Labor unrest has many reasons such as symptomatic among them is current contact expiry management attitude overtime problems disciplinary action. An environment of labor unrest bodes downturn in productivity varying with type of activity union's etc.

iii. Activity cost estimate: The cost of an activity in construction project is comprises of two main types of cost, the direct cost, which include the cost of the contractor of labor, plants, and material to carryout the activity. Indirect cost which consist of these costs that incurred indirect proportion to the length of time that of the contract, such as the wages of the site staff or the head office expenses. The job costing structure on such programs need a great deal of interpretation to relate the actual costs to actual progress, and there are many problems associated with the manpower and costs in this program such as:

- Change in estimate: As a project develop, changes are made in the product or system under design because unforeseen technical difficulties are encountered or it become evident that certain modifications would increase the stability, reliability or economy of the product or system.

- Cost uncertainties: Even if change in cost estimate are not forced by external or project change, they are likely to become necessary as a project moves along and estimating errors become apparent. Thus the assumption that a particular course of action will result in a least cost situation may prove highly unrealistic. In actual applications, however, many of these costs are so difficult to estimate that, the optimum allocation of resources remains a guess.
- Cost-plus Psychology: This tendency to understate costs seems to be the rule rather than the exception. Report of final incurred costs tends to play down or omit earlier cost estimates, thus making it difficult to verify the original estimates. Revisions partially absolve the individual responsible for the original estimate since the final cost estimate is formulated. Furthermore, by the time the project is completed, it is usually impossible to demonstrate what the original program would have cost if it had not been altered.

CHAPTER FIVE

SUMMERY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARIES AND CONCLUSION

The last forty years have seen the expressive and development of new family of planning and control modeling techniques adapted to the management system of projects. Much of the development work has been done in the defense industry but the construction, chemical, and other industries have played an important role in the application of the techniques. The network scheduling models are universal since of their range of applications both by type and size of the project, and there is no doubt that the techniques are revolutionizing the concepts and methods of projects management and control.

Applications of the network techniques beyond the original engineering oriented program for which they were developed are increasing every day. The approach is usefully introduced in such diverse situations as planning the economy of an undeveloped nation or establishing the sequence and timing of actions to effect a complex merger. Network models are much needed today because of the hard work and easements of the pioneer and have several distinguishing characteristics:

i. They give the management the ability to plan the best possible use of resources to achieve a given goal within overall time and cost limitations.

ii. They enable the executives to manage projects with repetitive situations. The importance of this kind of programs in the national and world economy has become increasingly clear.

iii. They help management to handle uncertainties involved in the program where no standard cost and time data are available.

iv. They utilize the time network analysis as basic method of approach and as a foundation for determining manpower, material, and capital requirements.

Network method is only effective as the ability and experience of the user permit. The rules of using them are simple, their application, however, is not simple because they require an analysis of what is to be done. According to that the technique has the following requirements:

i. All of the individual tasks to complete a given program must be visualized in a clear to be putdown in a network, which comprised of events and activities.

ii. Events and activities must be sequenced on the network under highly logical set of ground rules, which allow the determination of important critical and sub-critical paths.

iii. Expected time estimate and statistical variance for each activity in the network must be calculated from the three time estimates, i.e. optimistic, most likely, and pessimistic elapsed time.

iv. Depending on the size and complexity of the network, computer routines are available to calculate the critical path through it. Computer can also

calculate the amount of slack for all events and activities not on the critical path. A negative slack condition can prevail when a calculated date not achieve a program date objectives, which has been estimated on a prior basis.

In building projects, network model is very effective where; the time and cost of various activities could be estimated with a reasonable amount of accuracy. The following concepts must be considered in the application of the technique:

i. Planning must be geared to the operation to be performed that is, oriented around what is being done.

ii. Scheduling must be a separate task and must be based on a number of people available.

iii. Reporting can be geared to completion (entire or in part) of the activities or it can be geared to the arrival at a milestone in the project that is oriented around either what is being done or around what is to be accomplished.

iv. Whatever the method of selecting a range of activity times is used in the final analysis only one number is used as expected duration of activity.

v. Probability analysis can make possible the logical construction of a confidence interval for the project duration. However, no matter how meticulously qualified or statistically derived an estimate may be it is only a forecast of future action and as much susceptible to infinite possibilities of variation. Our major concern then, is a control system to cope with changes, to enable use to react quickly.

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The application of the network analysis is the management system of the construction companies in general that, include the planning and control of single and multiple unit projects, civil engineering work, maintenance and repair work in buildings, and the whole management system of the organizations.

In Nigerian construction companies, the application of the technique is limited to several factors related to the organization system of these companies. The implementation of the technique in some companies also faced with several problems concerned with the time and cost estimate of the tasks or activities which affected seriously by the economic situation in the country and make most of the building projects to suffer from much delay or stop completely.

5.2 RECOMMENDATIONS:

In the adaptation of network scheduling models in Nigerian construction companies as planning and controlling techniques, the following recommendations are to be considered:

i. Projects to be planned and controlled by network techniques should be those well conceived and well prepared. In a case where considered time has elapsed from the moment of feasibility study is finalized to the moment where project implementation is to start, changing conditions should be defined and determined and the feasibility study is adapted accordingly.

ii. Before the application of the technique, the top management should be oriented and become acquired with them and with their capabilities in

saving time resources and costs. This is of vital importance since experience indicates that, without the top management appreciation of and enthusiasm for the system and methods used, no worthwhile result could be achieved.

iii. Training of project personnel at the various levels in these techniques should be provided. This could be in the form of formal training program held in one of the training institutions in Nigeria or abroad. Training May considered both manual as well as computer oriented techniques.

iv. Organization for project implementation should be improved with better staffing and facilities for proper use of the network analysis technique in the planning project implementation realistically. Coordination of effort expended in this project, collection of relevant and reliable information to control project progress and taking of corrective actions to realign these efforts to meet pre-stated objectives.

In the application of the network techniques in the building projects the following main recommendation can be taken into account:

i. Determination of the project activities is the basic in the network analysis and must be specified without omission, also with consideration to uncertain and unusual type of activities in each project.

ii. The forecast of project duration and cost and their effectiveness and impact on the project depend mainly on the skill and experience of the scheduling engineer.

iii. Computer models can be used to simulate the expected occurrence of the uncertainty variables and their impact, and then incorporate it in the time and cost estimates of an activity. Such a model can generate additional information such as a critically index for each activity, the need for schedule revision, and level of sensitivity of an activity to specific uncertainty variables.

For successful implementation of the above-mentioned recommendation, it is vital importance to study the impact of each of them during the implementation stage, which will ensure the integrated approach of network models in planning and controlling of building projects.

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APPENDIX

GLOSSARY

Accrued Cost: A cost that is charged all at once, either at the start or finish of a task, or gradually over the duration of a task.

Action plan: A detailed plan of what need to be done and where.

Activity: In PERT, project needed to be accomplished, symbolized by an arc.

Activity Chart: A graphic tools to analysis and times the small, physical actions of worker and machine in planning a routine, repetitive, worker-machine task so that idle time can be identified.

Actual: Factual information about a project quantity as opposed to estimated information. For example, when you create a task, you enter its estimated duration, later on, if you are tracking task progress, you can enter the task's actual duration.

Analytic Approach: Breaking problems into their constituent parts to understand the parts better and there by solve the problem.

Applied Research: Research for the advancement of scientific knowledge that has specific commercial uses.

Arc: In network modeling, an arrow line segment that symbol for a project activity.

Assignment: A task that is been assigned to a resources.

Assumption: An estimate or guess about what you expect will be true during a project, like the cost of particular material.

Backward Scheduling: Determining the start and finish times for waiting jobs by assigning them to the latest available time slot that will enable each job to be completed just when its due, but not before.

Bill of Materials: A document describing the details of an item's product builds up including all components items, their build up sequences, the quantity needed for each and the work centers that perform the build up sequence.

Constraint: A restriction you place on task's start or finish date. For example, you can specify that a task must start on a certain date or start no earlier than a certain date.

Controlling: Activities that assure that the actual performance is in accordance with planned performance.

Control Chart: A graph showing how statistic is changing overtime compared to its average and extreme values.

Cost: The total cost of a task, resource, assignment, or project.

Cost Time Slope: The ratio of the increased cost of expediting to the decreased amount of time for the activity.

Critical Path: In PERT, a path whose activities are expected to consume the most time.

Database: The central storage area of all project information in Microsoft project. When you display a view, you are looking at a portion of the information contained in the database.

Decision Tree: A diagram used to structure and analysis decision problem, systematic sequential laying out of decision point's alternative and chance events.

Delay Time: The amount of time inserted between overlapping tasks to resolve resources over allocations.

Deliverables: The physical items to be delivered from projects. This typically includes reports and plants as well as physical objects.

Dependency: A condition that specifies the start or finish of one task relative to the start or finish of its predecessor task. For example, if two tasks are linked with a finish to start dependency, the condition is that, one task can start only after its predecessor task is completed.

Detailed Scheduling: Determining starts, finish times, and worker assignments for all jobs at each work center.

Deterministic: Predetermined with no possibility of an alternate outcome, compare with stochastic.

Deterministic Model: A model in which variable values are known with certainty.

Development: In models, technical activities concerned translating basic applied research into products or processes.

Dummy Activity: In PERT, a fictitious activity consuming no time, symbolized by a dashed arc.

Duration: The length of time it takes to complete task duration during the normal working hours.

Earliest Beginning Time (Ti): In PERT, the minimum amount of time that must be consumed before an activity can begin.

Effectiveness: A chewing the objective set before hand, to be distinguished from efficiency, which is measured by output realized for the input used.

Event: In PERT, the beginning or ending of an activity, symbolized by a node.

Expected Beginning Time (Tb): In PERT, the amount of time that can be consumed before an activity can begin.

Expected Completion Time (Tc): In PERT, the amount of time an activity will be expected to consume once an activity begins.

Expected Time (Ts): In PERT, the amount of time an activity is expected to consume.

Feed Back: Information in the control process that allow management to decide whether organizational activities need adjustment.

Fixed Cost: A cost that dose not change regardless of the task duration or how much work a task requires.

Fixed Duration Scheduling: A way to specify that the duration of a task remains the same regardless of how many resources are assigned to it.

Fixed Duration Task: A task whose duration is set to remain constant. Changes to the work or assigned resource units won't change the duration.

Forecast: Use of past data to determine further events, an objective computation.

Forward Scheduling: Determine the start and finish times for waiting jobs by assigning them to the earliest variable time slots at the work center.

Free Slack: The amount of time a task can slip without delaying another task.

Gantt Chart: A bar chart showing the relationship of project activities in time.

Gantt Scheduling Chart: A graph showing the time requirements of waiting jobs scheduled for production at machines and work centers.

Implementation: Activities concerned with designing and building a production or services models emerging from research and development.

Input/Output Control: Activities to monitor actual verses planed utilization of a work center's capacity.

Inputs: Labor, capital, land, or management resources changed by a conversion process into goods or services.

Job: A group of related task or activities that needs to be performed to meet organizational objectives.

Job Design: Activities that specify the content of each job and determine how work is distributed within the organization.

Lag Time: The amount of time added between completion of one task and the start of its successor task.

Latest Beginning Time (Tl): In PERT, the maximum amount of time that can be consumed before an activity begins if the project is to be completed on time.

Lead-time: The time passing between ordering and receiving goods or services.

Least Slack Rules (Ls): priority rules that gives top priority to the waiting job whose slack time is least slack.

Leveling: Getting rid of resources over allocations by either delaying or splitting tasks that have over allocated resources assigned to them.

Line Balancing Model: Assigning tasks among workers at assembly line station so that performances time are made as equal as possible.

Material Management: Activities relating to managing the flow of materials into and through an organization.

Mathematical Modeling: Creating and using mathematical representations of management problems and organizations to predict outcomes of proposed courses of action.

Model: A way of looking at reality, usually for the purpose of abstracting and simplifying it to be understandable in a particular context.

Modeling Management: One of the three primary theories of management emphasizing decision-making, systems and mathematical modeling.

Most Likely Time (Tm): In PERT, the single best guess of the amount of time an activity is expected to consume.

Network: A group of items connected by some common mechanism.

Network Modeling: Analyzing the precedence relationship of project activities and depicting them graphically.

Node: In network modeling, it is a circle at one end of an arc that represents the symbol for the beginning or ending of a project activity.

Operation Management: Management of conversion process, which converts land, labor, capital, and management inputs into desired outputs of goods or services.

Optimistic Time (To): In PERT, the least amount of time an activity is expected to consume.

Path: In PERT, a portion of the network, including the first and last activities for which each activity has a single immediate successor.

Path Time: In PERT, the amount of time that will be expected to consume by activities on a path.

PERT Languages: The terms and symbols specific to PERT.

Pessimistic Time (Tp): In PERT, the greatest amount of time an activity is expected to consume.

Phase: A group of tasks required to complete a major step in a project.

Planning: Activities that establish a course of action and guide future decision-making.

Planning for Operations: Establishing a program of action for acquiring the necessary physical facilities to be used in the conversion process.

Planning the Conversion System: Establishing a program of action for acquiring the necessary physical facilities to be used in the conversion process.

Predecessors: The tasks that logically precede a particular task in time.

Probabilistic: PERT, a modification of PERT to consider the variance and the mean of the expected times.

Procurement Costs: Costs of placing an order, or set up costs if ordered the firm manufactures items.

Programming: An algorithmic methodology for solving particular type of complex problem, usually conducted on a computer.

Program Evaluation and Review Technique (PERT): An application of network modeling originally designed for planning and controlling the U.S. Navy's Polaris nuclear submarine project.

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Progress Bar: On the Gantt chart view, a horizontal line drawn in the center of a Gantt bar to indicate the percent that a task is complete.

Progress Line: On the Gantt chart view, a vertical zigzagging line that represent the degree to which tasks are ahead or behind schedule.

Project: A one time only set of activities that have a definite beginning and ending point in time.

Project Calendar: A calendar of working and non-working times used by the entire project, it is the base calendar. The defaults project calendar is the standard calendar.

Project Planning: Activities that establish a course of action for a project.

Project Scheduling: Is the representation of the activities that establish the times and sequence of project tasks.

Quality: The degree to which the design specification for a product or service are appropriate to its function and use, and the to which a product or service conforms to its specifications.

Resource allocation: The assignment of resources to tasks in a project.

Resource Calendar: A calendar showing the working and non-working times for individual resources.

Resource Group: A set of resources that is usually grouped by type and given a group name.

Resource List: A list of the resources that is available to be assigned to tasks in a project. A resource list can include people, equipments, and supplies.

Resources: The people, equipments, supplies, and services required to complete the tasks in a project.

Resources level: Approaches to even out the peaks and valleys of resources requirements so that a fixed amount of resources can be employed over time.

Resources Loading: The amount of resources of each kind that are to be devoted to specific activity in a certain time period.

Research and development (R&D): Organization effort directed towards product and process innovation includes stages of basic research, applied research, development and implementation.

Schedule: A plan showing the sequence, start dates, finish dates, and durations of tasks in a project.

Scientific Management: One of several theories of classical management emphasizing economic efficiency at the production core through management rationality, the economic motivation of workers and the separation of planning and doing work.

Sensitivity Analysis: Investigation of the effect on the outcome of changing some parameters in the procedure or model.

Simulation: A Technique for emulating a process, usually conducted a considerable number of times to understand the process better, and measure its outcome under different policies.

Slack Time: The difference between the length of time remaining until a job is due and the length of its operation time. In PERT, the amount of leeway time an activity can consume and still allow the project to be completed on time.

Slippage: The difference between a task's scheduled start or finish date and its baseline start or finish date, when the scheduled dates occur later than the baseline dates.

Stochastic: Probabilistic, or not deterministic.

Subtask: A task that is indented under and is part of a summery task.

Successor Task: A task whose start or finish date depends on the start or finish date of another task. A successor task cannot start or finish before its predecessor task has started or finished.

Systematic Approach: A wide ranging, synthesizing method for addressing problems that considers multiple and interacting relationships. Commonly contrasted with the analytic approach.

Strategic Planning: A process of thinking through the organization's current mission and environment and then setting forth a guide for tomorrow's decisions and results.

Task: The smallest group of work that can be assigned to a workstation.

Trade off: allowing one aspect to get worse in return for another aspect getting better.

Total Slack: The amount of time a task can slip without delaying the project end date.

Work Breakdown Structure: A basic project documents that describes all the work that must be done to complete the project and form the basic for costing, scheduling, and work responsibility.

Work Statement: a description of a task that defines all the work required to accomplish it including inputs and desired outputs.