SCHEDULING THE CONSTRUCTION OF KASOA GOVERNMENT HOSPITAL WORKS USING PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT)

By

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge it contains no material previously published by another person nor material which has been accepted for award of any degree in the University , except where due acknowledgement has been made to the test.

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ABSTRACT

The thesis is aimed at scheduling and controlling the construction of Kasoa Government Hospital in Central Region, Ghana, using the Program Evaluation and Review Technique (PERT) as the planning tool.

Program (Project) Evaluation and Review Technique (PERT) is a project management tool used to schedule, organize, and coordinate tasks within a project. It is basically a method to analyze the tasks involved in completing a given project, especially the time needed to complete each task, and to identify the minimum time needed to complete the total project. PERT planning involves the following steps:

- Identify the specific activities and milestones.
- Determine the proper sequence of the activities.
- Construct a network diagram.
- Estimate the time required for each activity.
- Determine the critical path.
- Update the PERT chart as the project progresses

The three time estimates used in this thesis were taken from constructors who have been engaged in such jobs and are abreast with the challenges and skills.

The normal days of completion as found from the calculation and analysis with the acquired data is 504 days with a standard deviation of 25.9. The probabilities of project completion times were also found.

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God bless you all….Amen.

DEDICATION

To God be the Glory, great things He has done. I dedicate this thesis to the Almighty God, my parents Mr and Mrs Owusu-Boakye and my siblings Afia, Kwasi, Nana Ama, Ama Akyaa, Kwame and Kwadjwo Nyame for all the support they have given me.

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Health is the level of functional or metabolic efficiency of a living being. In humans, it is the general condition of a person's mind, body and spirit, usually meaning to be free from illness, injury or pain (as in "good health" or "healthy"). The World Health Organization (WHO) defined health in its broader sense in 1946 as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity". Although this definition has been subject to controversy, in particular as having a lack of operational value and the problem created by use of the word "complete", it remains the most enduring.[4][5] Classification systems such as the WHO Family of International Classifications, including the International Classification of Functioning, Disability and Health (ICF) and the International Classification of Diseases (ICD), are commonly used to define and measure the components of health.

The maintenance and promotion of health is achieved through different combination of physical, mental, and social well-being, together sometimes referred to as the "health triangle". The WHO's 1986 Ottawa Charter for Health Promotion furthered that health is not just a state, but also "a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities". Systematic activities to prevent or cure health problems and promote good health in humans are delivered by health care providers. Applications with regard to animal health are covered by the veterinary sciences. The term "healthy" is also widely used in the context of many types of non-living organizations and their impacts for the benefit of humans, such as in the sense of healthy communities, healthy cities or healthy environments. In addition to health care interventions and a person's surroundings, a number of other factors are known to influence the health status of individuals, including their background, lifestyle, and economic and social conditions; these are referred to as "determinants of health".

In Ghana, the Ghana Health Service is a Ghanaian government body established in 1996 as part of the Health Sector Reform of Ghana. The Health Service is under the Ministry of Health. The Health service primarily administrates the health services provided by the government and in implementing government policies on healthcare. They are also responsible for the grading of Health facilities in the country.

Kasoa (Oduponkpehe) is located in the Awutu Bereku Districts of Ghana, in the Central Region of Ghana. The town is situated along the Accra-Cape Coast Road, approximately 36 kilometres by road, west of Kotoka International Airport, the International Airport that serves Ghana's capital city of Accra. This location lies approximately 28 kilometres (17 mi), by road, west of the central business district of the city of Accra. The coordinates of the town are:05 31 12N, 00 28 48W (Latitude:5.5200; Longitude:-0.4800). Kasoa has a population of over 50,000 people with a growth rate, in the city, of 3.8% per annum.

Kasoa has been earmarked for municipality status. It municipality status has been given a presidential approval and currently waiting parliamentary approval. Interestingly, Kasoa can not boast of any hospital apart from its numerous clinics and health centres thereby jeopardizing the health of the citizenry in the town. The Government of Ghana in collaboration with Ghana Health Services and District Assembly has allocated monies for the construction of Kasoa Government Hospital near Kasoa new market and will start in starting in the last quarter of the year.

With the backdrop of the above situation, a contract has been awarded to construct a government hospital for the people of Kasoa.

1.2 Statement of the problem

Ghana Health Services does not have a project management model to monitor the projects undertaken by both the company or third party contractors. Hence, the cost of delays and poor scheduling has not been quantified. This project work shall use Program Evaluation and Review Technique (PERT) to manage the scheduling and construction of Kasoa Government Hospital.

1.3 Research Questions

- What is the start activity?
- How does each activity precede the other?
- Which activities are concurrent?

- What is the completion time?
- What are the probabilities of completing at other time durations?

1.4 Objectives

The objectives of this work are to;

(i) help assess a basis to monitor and control the project activities

(ii) provide a basis to help track project progress.

(iii) help assess all probabilities to complete the project within specific times

(iv) help assess how time delays will impact on the project.

(v) be used as basis to schedule other related job.

1.5 Methodology

The methods involved to achieve the objective of this thesis include;

(i) the times used in this project were taken from different contractors on similar projects

(ii) the data on the materials and nature on job were acquired from the building contractors.

(iii) other researches were done on the internet and other academic materials.

(iv) PERT method shall be used to schedule the project

1.6 Justification

Projects of such magnitude need to be properly managed to save time, money and other scarce and expensive resources. PERT is being adopted as the preferred model because of the flexibility in using three sets of time since different contractors undertake similar projects with different manpower and skill. Also since it is the first time it is being applied on such a project in the health sector.

1.7 Limitation

It is assumed that the project has passed the research and development, bidding and awarding of contract and procurement stages. It is limited to the scheduling of the construction of the hospital using PERT as the project management modeling tool considering only the time and not the cost aspects of the project.

1.8 Organization of the thesis

This thesis consists of five (5) chapters.

Chapter 1 gives the overview of health services and a profile of Ghana Health Services. It further on introduces the nature of the construction work and the scheduling model to be used. The scope is described and the limitation discussed in chapter 1. Chapter 2 reviews some pertinent literature on PERT. Chapter 3 gives the overview of project management techniques and explains the PERT model whiles in chapter 4, the data collected are analyzed using PERT method. Chapter 5 presents the results and recommendations of this work.

CHAPTER 2

LITERATURE REVIEW

This chapter puts forward pertinent literature on Program Evaluation And Review Technique (PERT).

The concept of work breakdown structure was developed with the Program Evaluation and Review Technique (PERT) in the United States Department of Defense (DoD). PERT was introduced by the U.S. Navy in 1957 to support the development of its Polaris missile program. While the term "work breakdown structure" was not used, this first implementation of PERT did organize the tasks into product-oriented categories.

By June 1962, DoD, North American Space Agency (NASA) and the aerospace industry published a document for the PERT/COST system, which described the work breakdown structure approach. This guide was endorsed by the Secretary of Defense for adoption by all services. In 1968, the DoD issued "Work Breakdown Structures for Defense Materiel Items" (MIL-STD-881), a military standard requiring the use of work breakdown structures across the DoD. This standard established top-level templates for common defense materiel items along with associated descriptions (WBS dictionary) for their elements. The document has been revised several times, most recently in 2005. The current version of this document can be found in "Work Breakdown Structures for Defense Materiel Items" (MIL-HDBK-881A). It includes instructions for preparing work breakdown structures, templates for the top three levels of typical systems, and a set of "common elements" that are applicable to all major systems and subsystems.

In 1987, the Project Management Institute (PMI) documented the expansion of these techniques across non-defense organizations. The Project Management Body of Knowledge (PMBOK) guide provides an overview of the WBS concept, while the "Practice Standard for Work Breakdown Structures" is comparable to the DoD handbook, but is intended for more general application.

Since the development of Critical Path Method (CPM) and PERT in the 1950's, the techniques have been the subject of hundreds of research papers. Research has generally been focused on PERT, since the deterministic CPM presents few problems of interest. The research on PERT can be organized into five general categories. The first category includes research on the error and bias due to PERT assumptions made. The second category involves finding the distribution function F(T) of project completion times through exact analysis, approximation, and bounding methods. Third, Monte Carlo sampling has been used to study the distribution of PERT networks. The fourth category involves resource allocation problems and load leveling. The fifth area of research is the crashing of PERT networks. This literature review will focus on the research most directly related to this study; Monte Carlo simulations and crashing of PERT networks.

Van Slyke (1963) was the first of many researchers to apply Monte Carlo simulations to study PERT. Van Slyke demonstrated several advantages of using simulation including more accurate estimates of the true project length, flexibility in selecting any distribution for activity times, and the ability to calculate "criticality indexes" which are the probability of various activities being on the critical path. (Pritsker et al., 1966) developed a modification of PERT called the Graphical Evaluation and Review Technique (GERT). GERT allowed activity times to follow several different distributions. Project completion time distributions were computed through Monte Carlo simulation. (Kennedy et al., 1976) developed a modification of GERT called Project Length Analysis and Evaluation Technique (PLANET). PLANET added the ability to calculate the probability of activities being critical and find the distribution of completion times for each activity.

Ameen (1987) developed Computer Assisted PERT Simulation (CAPERTSIM), a simulation program developed as a teaching tool to teach project management techniques. Students used the program to evaluate decision making under uncertainty and cost-time relationships and trade-offs. Ameen reported students reacted very favorably to participating in the computer-assisted PERT simulation project.

Badiru (1991) reported development of another simulation program for project management, called STARC. STARC allows the user to calculate the probability of completing the project by a specified deadline. It also allows the user to enter a "duration risk coverage factor". This is a percentage over which the time range of activities are extended. This allows there to be some probability of generating activity times above the pessimistic time and below the optimistic time.

Additional authors who have studied various PERT problems via simulation include Klingel (1966), Gray (1969), Burt (1971), Herbert (1979), Schonberger (1981), Dodin (1984) and Kidd (1986).

The traditional method of crashing PERT networks has been to convert the model to a deterministic model by using the means of the activity times. The network is then crashed in a series of iterative steps until the expected completion time of the project is acceptable, the cost of crashing exceeds the benefits, or all activities have been crashed as much as possible. Benson et al., (1972) reported on FASNET, a program which uses the CPM model and allows data to be entered as the project progresses. The network is re-analyzed each time new data is entered.

(Moore et al., 1978) and Hannan (1978) reformulated the problem using goal programming. Goal programming is a modification of linear programming which can solve problems with multiple objectives. This allows goals in addition to cost minimization to be added to the problem. Because of conflicting objectives, not all goals are achieved completely.

Foldes et al., (1993) presented a reformulation of crashing networks when the cost-time tradeoff is represented by a non-linear, non-differentiable convex function. Very little research has been conducted which addresses crashing in a stochastic environment.

Herbert (1979) suggested that the reason for the lack of such research stems from the fact that it "seems unlikely that the effort required to gather the data and this only estimate data needed to specify stochastic tradeoff functions for each activity in a large project could be justified on the basis of anticipated improvement in performance."

Antill et al., (1982) suggested a different reason. It is obvious that PERT compression yields indefinite results, indicating only the areas within the project that can be considered for probable compressions. In effect, the overall compression characteristics of the network model are too vague to provide other than an approximate forecast of the time-cost behavior. Compression therefore cannot be applied with confidence to PERT networks as it can to a CPM model.

The first approach to address the problem of crashing under stochastic conditions was made by Coskun (1984). Coskun formulated the problem as a Chance Constrained Linear Programming (CCLP) problem. CCLP is a method of attempting to convert a probabilistic mathematical programming formulation into an equivalent deterministic formulation. Coskun's formulation ignored the assumed beta distribution of activity times. Instead activity times were assumed to be normally distributed with the mean and standard deviation of each known. The formulation allows a desired probability of completion within a target date to be entered. Coskun concluded that "While the solution of the CLLP formulations of the optimal PERT compression problem provides a wealth of information with significant managerial implications, the computational efforts necessary to solve the CCLP are no greater than those necessary to solve the deterministic compression problem."

Johnson et al., (1990) used simulation to compare three rules for crashing stochastic networks:

(i). Select the lowest cost slope activity or activities that will shorten the critical path(s). Rule1 is the CPM developed rule for crashing a project. It reflects the common approach taken to expediting in the literature.

(ii). Select the activity with the highest criticality index. In the case of ties, choose the alternative that costs least per unit of time to reduce. The criticality index should ideally be recomputed at each step in crashing a project.

(iii). Select the least cost/day activity first. This rule is a combination of the first two rules. It reflects the idea of selecting the least cost expected value. The procedure follows Rule 2 in the calculation of criticality index. The criticality index would then be multiplied by the number of days the expected time of an activity can be reduced. This yields an expected number of days that the critical path can be shortened. This expected value is then divided into the total incremental cost of expediting the activity. Theoretically, the criticality index should be regenerated and the computations repeated at each step in crashing the project. The authors concluded that Rule 3 provided the lowest cost of crashing the network. Although the differences in cost were small in the examples, the authors argued that "the greater size of 'real life' problems and the likelihood of multiple critical paths would likely lead to larger differentials in the expected cost of different rules."

Ramini (1986) also proposed an algorithm for crashing PERT networks incorporating the use of criticality indices. Apparently he did not implement the algorithm, as no results are reported. Other authors believe that his method does not take into account bottlenecks.

Klosterman (1979) used the PERT to assess the program of the vocational training unit at a large institution for the retarded. The program objective was to train and place 82 retarded residents into various community settings during the 1975-1977 biennium, since the existing situation indicated a need for more information about the applied procedures that needed procedural changes. The study ascertained the steps taken by residents from entrance into the unit to entrance into the community. PERT networks for vocational steps and living (cottage) steps were made for two resident population samples: (i) residents placed into the community and monitored by the unit, and (ii) residents randomly selected from the persons assigned to the unit on August 31, 1975.

The literature recommended the use of pert for any new or novel project having limited time or money resources. Based upon the results on this study, two additional applications seem appropriate: (i) the large number of recommendations generated indicates that pert can be helpful for defining poorly understood processes and evaluating the capability of those processes to meet time-limited objectives; and (ii) pert-derived information has considerable value at the case review level, as knowledge of ways in which clients obtain services can provide data for analyzing progress of individual clients.

Krogstad et al., (1977) applied PERT in scheduling audit work, in allocating personnel resources, in predicting engagement completion time, in estimating audit costs, in anticipating work bottlenecks, and in guiding audit acceleration. A simplified, hypothetical audit engagement was presented to demonstrate the principal features and advantages associated with the application of pert in auditing, with extensive diagrams to illustrate the network of activity and time estimates. A model for the pert cost method shows how it adds to pert the capability for planning, monitoring, and controlling audit costs, and for analyzing time and cost tradeoffs. These managerial tools were intended for auditors who needed to improve audit planning and control assignments.

Hemphill et al., (1975) indicated that a full description of PERT and its applications to Occupational Field (OF) studies would be of operational value to the Office of Manpower Utilization (OMU). This report on PERT is designed to serve two purposes. First, it can be used as training material for new personnel to introduce them to techniques of planning and control in OF studies. Second, it can provide ready reference materials for individuals directly involved in designing, directing, planning, and controlling of Occupational Field (OF) studies. Accordingly, the various steps, events and activities used as illustrations in the application of PERT employed the terminology of the different phases of OMU's Task Analysis process.

Woolf et al., (1968) applied PERT to a medical research project, “The Surgical Treatment of Emphysema, the Selection of Patients and the Evaluation of Results” at the Toronto General Hospital. In order to use PERT, the project was broken down into the individual tasks that must be performed. A network was drawn showing the sequence of activities from start to final completion, thus defining the work to be done. Time estimates were given to each of these activities and entered into an IBM 1130 computing system together with a network description. The computer defines the “critical path” and produces a schedule report showing the estimated overall duration of the project and a schedule for completing each of the separate activities. As each activity was completed, an IBM card is sent to the project director who compares the actual completion date with the date on the schedule report. In this way it was possible to determine whether the project was on time, behind or ahead of schedule. The PERT technique significantly helped to organize the project and maintain progress toward its conclusion. The researchers suggested the use of PERT technique in complex medical research work.

Kwak et al., (1976) did an extensive work in the application of PERT to R and D scheduling for the National Center for Drug Analysis, United States Food and Drug Administration. The Center is a pharmaceutical-chemistry laboratory having specialized functional responsibilities for research and development of analytical chemical procedures. The model was constructed based on the empirical data obtained at the Center for a five-year period. The model has been statistically tested and interpreted. It was used to assist the management of the center in developing a complete work-planning process and in controlling project tasks, thus achieving the effective utilization of human and physical resources.

Kirl et al., (1966) applied PERT on the logic designer who could circumvent usually unrealistic worst-case criteria. They substituted a formalized statistical method, which determines: (i) expected or most probable delays, (ii) critical timing paths, (iii) timing slack allowable between various inputs and (iv) probability of achieving an output by a certain time. From these data the designer can make a meaningful judgment regarding the reliability of his system. Significantly, he may achieve high reliability without being forced to resort to worst-case design.

Kost et al., (1986) conducted a case study on the use of the Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) in planning and managing premature infants with respiratory disease in a laboratory. The researchers illustrated the utility and efficiency of these networks planning techniques by means of iterative PERT analyses, the project was kept on track, despite an overly optimistic estimate of the completion date. In spite of the initial and intense demands by clinicians about the use of the new monitoring techniques for management of premature infants with respiratory disease. Additionally, the iterative management approach improved project participants' expertise in estimating and meeting deadlines.

Hatush et al., (1997) used the PERT model as a methodology for assessing and evaluating contractor data for the purpose of prequalification and bid evaluation presentation. The PERT approach is used to develop a linear model for the assessment of contractor data. The model incorporates a multiple ratings permitting the uncertainty in contractor data to be evaluated.

An empirical study investigating the importance of different contractor criteria is described. A lexicographical ordering with aspiration levels and risk analysis with sensitivity methods are used to evaluate and select or rank-order contractors against the main client goals of time, cost, and quality.

Gilless et al., (2000), published a practical and inexpensive technique, illustrated by application to a wildfire protection planning problem, estimating the time required to produce a given length of fire line by different firefighting resources under diverse conditions with the model of PERT. The researchers found that estimated production times are essential input for the planning model of initial attack on wild land fires used by the California Department of Forestry and Fire Protection. The technique provided that agency with useful “rules-of-thumb” for use in firefighter training.

Applbaum et al., (1971) put forward an article which illustrates the use and significance of PERT (Program Evaluation Review Technique) as a tool for communication research. Five operational steps are proposed to “PERT out” a communication research project: (i) Determine primary and secondary project tasks; (ii) List the plan of action for accomplishing each task; (iii) Pictorially represent the events and activities; (iv) Calculate the time estimates for the activities; and (v) Adjust the PERT network to conform to the ongoing project. Advantages of PERT in planning communication research are described. These were that it allowed the researcher to predict time sequences, to illustrate potential problems, to focus upon proper utilization of resources, to provide status reports, to clarify design and statistical questions, to permit self-correction, and to allow for more accurate experimental replications.

Honsinger (1968) used the PERT/CPM as a network technique for planning, scheduling, and controlling the progress of a project, usually a large and complex project such as the construction, conversion, or overhaul of a ship.

Bandyopadhvay et al., (2002) described the use of CPM/PERT approach to QS-9000 registration and the experience of QS-9000 registration process at a United States auto parts company. They also discussed the key planning activities and key criteria of success for the QS-9000 registration process. QS-9000 has been developed and mandated by the big three auto makers: General Motor, Ford and Chrysler and some of the truck manufacturers as the new quality systems requirement for all their tier one suppliers. Consequently, many of their tier one suppliers have been hurdling through the implementation of QS-9000 as their survival strategy.

Luttman et al., (1995) studied the recent changes in health care and focused their attention on new tools for planning and managing clinical processes. The researchers adopted the use of one tool in particular, clinical pathways in their clinical planning and management processes and this has shown tremendous results.Pathways employ a concept long used in other industries: the explicit design and documentation of a process. Until their research however, the most common tools used in other industries to perform process design, the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM), have not migrated to health care. Luttman et al., (1995) presented a methodology for incorporating PERT/CPM into the design and management of clinical processes.

Main et al., (1989) discussed the two techniques of systems analysis Critical Path Method (CPM) and Program Evaluation Review Techniques (PERT) in management. They represented a complete documentation of an automated PERT/CPM production scheduling applications. These applications have been designed to be a complete and automated, time scheduling system for use in a large-scale production environment such as the U.S. Naval Shipyards. This scheduling system has been designed to function as an integrated part of the shipyards' Management Information System. This manual has two major parts. The first part of the manual presents detailed information related to the techniques and methods utilized within the application. The manual also provides detailed information on the computer aspects of the system, including the individual programs. In addition, the manual contains a complete set of formulae which have either been utilized by the system or developed for it.

Mota et al., (2007) analysed the risk of blackouts inherent in complex power systems, despite all efforts to prevent their occurrences. To mitigate the consequences of major blackouts, better restoration plans had been demanded. Commonly, these plans consist of a set of actions textually described. In order to enhance the operating staff comprehension about the restoration plan, their paper proposes a methodology, based on CPM/PERT graph theory, that allows power system restoration plans to be graphically visualized. This approach permits to clearly see the precedence relations among activities and to graphically follow the restoration process during its execution. The methodology can also take advantage of calculations involved with CPM/PERT methods to evaluate the restoration duration and the plan critical path.

Irawati (1997) during a house renovation project applied the PERT as the most appropriate model to successfully complete it with much efficiency. Jones (2009) proposed PERT as an effective tool for Hospital pharmacists to integrate their departmental planning process with strategic plans for the institution. This will necessitate the development of more sophisticated procedures for planning, scheduling, and controlling in order to meet deadlines imposed by the master plan. Program Evaluation and Review Technique/Critical Path Method (PERT/CPM), a network analysis instrument, can be a valuable planning tool. It allows the pharmacist to: (i) visualize the sequence of activities and events (network) in the development of a new service; (ii) evaluate activity times; (iii) determine those activities which are critical to the completion of the plan and (iv) apply statistical analysis to the anticipated completion date. A PERT/CPM network analysis is described in a format which allows the reader to visualize the use of this tool in the strategic planning process. The case study plan was actually carried out in a 203-bed, acute care hospital. The completion date was within 10 days of the date projected at probability equals 0.05.

Proctor (1995) argued that planning, scheduling and control can be enhanced greatly in Marketing planning which is a key area of marketing management. Planning activities have become extremely complex and demand systematic and effective techniques, which can help optimize the efficiency of executing such activities. Efficiency amounts to bringing about the greatest reductions in time to complete the scheduled activities while taking into account the economic feasibility of using available resources with the use of project evaluation and review technique (PERT). He claims that PERT helps to monitor and organize resources to enable activities to be completed on time and within budget limits. Describing time line for windows, a computer software, he used a PERT package which is designed specifically for the end-user and which can be run on a desktop computer to facilitate the marketing planning process.

Peng et al., (1993) scheduled cooperative tasks that have been reassigned to a set of processing nodes in a distributed system, when each task is assumed to consist of several modules. During the course of their execution, the tasks communicate with each other to collectively accomplish a common goal. Such intertask communications lead to precedence constraints between the modules of different tasks. The objective of this scheduling is to minimize the maximum normalized task response time, called the system hazard. Real-time tasks and the precedence constraints among them are expressed in a PERT/CPM form with Activity On Arc (AOA), called the Task Graph (TG), in which the dominance relationship between simultaneously schedulable modules is derived and used to reduce the size of the set of active schedules to be searched for an optimal schedule. Lower-bound costs were estimated and used to bind the search

Lee et al., (1999) used a framework to establish an effective clinical pathway for open-heart surgery patients and have been shown to improve patient's length of stay, cost, and quality of care. This study investigated whether PERT/CPM can be used to realize similar projects with pulmonary labectomy pathway and the results indicated a comparative earlier discharge and reduction in readmission rates.

Coleman (2009) used the PERT/CPM to analyze warehouse expansion project. The objective of the report was to analyze the relationship between these A-K activities. He developed a report that presents the activity schedule and expected project completion time for the warehouse expansion project. Then, he analyzed the questions from some specific data and diagrams. He discussed the feasibility and probability of requirement which is 40-week completion time for the project and supposes that activity times be shortened to provide an 80% chance of meeting the 40-week. He finally, revised activity schedule by known crashing cost which enabled him to meet the deadline.

Fischer et al., (1996) stated that the existing scheduling tools at the time required the manual translation of design information to activities and typically did not provide dynamic links between cost estimates and corresponding schedules. They indicated that to take advantage of the increasingly electronic and object-based descriptions of designs, schedules, and estimates, integration mechanisms that translate design descriptions into schedule and cost views of projects are needed. They have presented computer-interpretable models for the representation of construction methods as one such mechanism. These models support the automated generation of realistic construction schedules.

Cottrell (1999) has developed and tested a simplified version of PERT for project planning. The simplification has been understood to reduce the number of estimates required for activity durations from three, as in conventional PERT, to two. This is accomplished by applying the normal distribution, rather than the beta distribution to activity duration. The two required duration estimates are the 'most likely' and the 'pessimistic.'

Dawson et al., (1998) found the standard planning techniques, such as PERT, and the popular software tools that support them, are inadequate for projects involving uncertainties in the project direction and task durations. Probability distributions for task durations and generalized activity networks with probabilistic branching and looping have long been established as viable techniques to manage these project uncertainties. Unfortunately, their complexity has meant that their use in industry is minimal. They have proposed extensions to existing software tools to specify and manage such uncertainties that would be easy to learn and use.

CHAPTER 3

METHODOLOGY

3.1 Overview of Project Management

Project management is the discipline of planning, organizing, securing and managing resources to bring about the successful completion of specific project goals and objectives. It is sometimes conflated with program management, however technically that is actually a higher level construction: a group of related and somehow interdependent engineering projects.

A project is a temporary endeavor, having a defined beginning and end (usually constrained by date, but can be by funding or deliverables), undertaken to meet unique goals and objectives, usually to bring about beneficial change or added value. The temporary nature of projects stands in contrast to business as usual (or operations), which are repetitive, permanent or semi-permanent functional work to produce products or services. In practice, the management of these two systems is often found to be quite different, and as such requires the development of distinct technical skills and the adoption of separate management.

The primary challenge of project management is to achieve all of the project goals and objectives while honoring the preconceived project constraints. Typical constraints are scope**,** time**,** and budget. The secondary and more ambitious challenge is to optimize the allocation and integration of inputs necessary to meet pre-defined objectives.

3.2 Project Management Processes

Traditionally, project management includes a number of elements: four to five process groups and a control system. Regardless of the methodology or terminology used, the same basic project management processes will be used.

Figure 3.0: Project Management Processes

The project development stages

Major process groups generally include:

(i) Initiation
(ii) Planning or development
(iii) Production or execution
(iv) Monitoring and controlling
(v) Closing

In project environments with a significant exploratory element (e.g., Research and development), these stages may be supplemented with decision points (go/no go decisions) at which the project's continuation is debated and decided.

3.2.1 Initiation

The initiation processes determine the nature and scope of the project. If this stage is not performed well, it is unlikely that the project will be successful in meeting the business' needs. The key project controls needed here are an understanding of the business environment and making sure that all necessary controls are incorporated into the project. Any deficiencies should be reported and a recommendation should be made to fix them.

The initiation stage should include a plan that encompasses the following areas:

(i) analyzing the business needs/requirements in measurable goals

(ii) reviewing of the current operations

(iii) financial analysis of the costs and benefits including a budget

(iv) stakeholder analysis, including users, and support personnel for the project

(v) project charter including costs, tasks, deliverables, and schedule.

3.2.2 Planning and design

Planning Process Group Activities

After the initiation stage, the project is planned to an appropriate level of detail. The main purpose is to plan time, cost and resources adequately to estimate the work needed and to effectively manage risk during project execution. As with the Initiation process group, a failure to adequately plan greatly reduces the project's chances of successfully accomplishing its goals.Project planning generally consists of

(i) determining how to plan (e.g. by level of detail or rolling wave);
(ii) developing the scope statement;
(iii) selecting the planning team;
(iv) identifying deliverables and creating the work breakdown structure;
(v) identifying the activities needed to complete those deliverables and networking the activities in their logical sequence;
(vi) estimating the resource requirements for the activities;
(vii) estimating time and cost for activities;
(viii) developing the schedule;
(ix) developing the budget;
(x) risk planning;
(xi) gaining formal approval to begin work.

Additional processes, such as planning for communications and for scope management, identifying roles and responsibilities, determining what to purchase for the project and holding a kick-off meeting, are also generally advisable.

For new product development projects, conceptual design of the operation of the final product may be performed concurrent with the project planning activities, and may help to inform the planning team when identifying deliverables and planning activities.

3.2.3 Executing

Executing Process Group Processes

Executing consists of the processes used to complete the work defined in the project management plan to accomplish the project's requirements. Execution process involves coordinating people and resources, as well as integrating and performing the activities of the project in accordance with the project management plan. The deliverables are produced as outputs from the processes performed as defined in the project management plan.

3.2.4 Monitoring and Controlling

Monitoring and controlling consists of those processes performed to observe project execution so that potential problems can be identified in a timely manner and corrective action can be taken, when necessary, to control the execution of the project. The key benefit is that project performance is observed and measured regularly to identify variances from the project management plan.

Monitoring and Controlling includes:

(i) measuring the ongoing project activities ('where we are');

(ii) monitoring the project variables (cost, effort, scope, etc.) against the project management plan and the project performance baseline (where we should be);

(iii) identify corrective actions to address issues and risks properly (how can we get on track again);

(iv) influencing the factors that could circumvent integrated change control so only approved changes are implemented

In multi-phase projects, the monitoring and control process also provides feedback between project phases, in order to implement corrective or preventive actions to bring the project into compliance with the project management plan.

Project Maintenance is an ongoing process, and it includes:

(i) continuing support of end users
(ii) correction of errors
(iii) updates of the software over time

Over the course of any construction project, the work scope may change. Change is a normal and expected part of the construction process. Changes can be the result of necessary design modifications, differing site conditions, material availability, contractor-requested changes, value engineering and impacts from third parties, to name a few. Beyond executing the change in the field, the change normally needs to be documented to show what was actually constructed. This is referred to as Change Management. Hence, the owner usually requires a final record to show all changes or, more specifically, any change that modifies the tangible portions of the finished work. The record is made on the contract documents – usually, but not necessarily limited to, the design drawings. The end product of this effort is what the industry terms as-built drawings, or more simply, "as built." The requirement for providing them is a norm in construction contracts.

When changes are introduced to the project, the viability of the project has to be re-assessed. It is important not to lose sight of the initial goals and targets of the projects. When the changes accumulate, the forecasted result may not justify the original proposed investment in the project.

3.2.5 Closing

Closing includes the formal acceptance of the project and the ending thereof. Administrative activities include the archiving of the files and documenting lessons learned.

This phase consists of:

(i) project close: finalize all activities across all of the process groups to formally close the project or a project phase

(ii) contract closure: complete and settle each contract (including the resolution of any open items) and close each contract applicable to the project or project phase.

(iii) project control systems

Project control is that element of a project that keeps it on-track, on-time and within budget. Project control begins early in the project with planning and ends late in the project with post-implementation review, having a thorough involvement of each step in the process. Each project should be assessed for the appropriate level of control needed: too much control is too time consuming, too little control is very risky. If project control is not implemented correctly, the cost to the business should be clarified in terms of errors, fixes, and additional audit fees.

Control systems are needed for cost, risk, quality, communication, time, change, procurement, and human resources. In addition, auditors should consider how important the projects are to the financial statements, how reliant the stakeholders are on controls, and how many controls existing. Auditors should review the development process and procedures for how they are implemented. The process of development and the quality of the final product may also be assessed if needed or requested. A business may want the auditing firm to be involved throughout the process to catch problems earlier on so that they can be fixed more easily. An auditor can serve as a controls consultant as part of the development team or as an independent auditor as part of an audit.

Businesses sometimes use formal systems development processes. These help assure that systems are developed successfully. A formal process is more effective in creating strong controls, and auditors should review this process to confirm that it is well designed and is followed in practice. A good formal systems development plan outlines:

(i) a strategy to align development with the organization's broader objectives
(ii) standards for new systems
(iii) project management policies for timing and budgeting
(iv) procedures describing the process
(v) evaluation of quality of change

3.3 A successful project

There are three main points that are most important to a successful project:

(i) a project must meet customer requirements.

(ii) a project must be under budget.

(iii) a project must be on time

3.4 The Role of the Project Manager

The role of the project manager in project management is one of great responsibility. It's the project manager's job to direct and supervise the project from beginning to end. Here are some other roles:

(i) the project manager must define the project, reduce the project to a set of manageable tasks, obtain appropriate and necessary resources, and build a team or teams to perform the project work

(ii) the project manager must set the final goal for the project and must motivate his workers to complete the project on time.

(iii) a project manager must have technical skills. this relates to financial planning, contract management, and managing creative thinking and problem solving techniques are promoted.

(iv) no project ever goes 100% as planned, so project managers must learn to adapt to change.

3.5 Common Barriers to Successful Project

There are many things that can go wrong with project management. These are commonly called barriers. Here are some possible barriers:

(i) poor communication

- many times a project may fail because the project team does not know exactly what to get done or what's already been done.

(ii) disagreement

- project must meet all elements in a contract.
- customer and project manager must agree on numerous elements.

(iii) failure to comply with standards and regulations.

(iv) inclement weather.

(v) union strikes.

(vi) personality conflicts.

(vii) poor management

(viii) poorly defined project goals

3.6 Goal of Project Management

According to the New Comprehensive International Dictionary of the English Language a goal is a point toward which effort or movement is directed. The objective point that one is striving to reach should be smart goals

(i) specific

- well defined
- they are clear to anyone that has a basic knowledge of the project

(ii) measurable

- have some means to be able to know if the goal is obtainable or how far away completion is.

(iii) agreed upon

- have agreement between the users and the project team on what goals should be

(iv) realistic

- looking at the resources, knowledge, and time available can the goal be accomplished

(v) time-framed

- how much time is needed to accomplish the goal
- having too much time can affect the project performance

3.7 Project Management Tools

Good project management deals with three factors: time, cost and performance. Projects are successful if they are completed on time, within budget, and to performance requirements. In order to bring the many components of a large project into control there is a large toolkit of techniques, methodologies, and tools. These techniques provide the tools for managing different components involved in a project: planning and scheduling, developing a product, managing financial and capital resources, and monitoring progress. However the success of a project will always rest on the abilities of a project manager and the team members.

3.7.1 Work breakdown structure

A work breakdown structure (WBS) in project management and systems engineering, is a tool used to define and group a project's discrete work elements in a way that helps organize and define the total work scope of the project.

A work breakdown structure element may be a product, data, a service, or any combination. A WBS also provides the necessary framework for detailed cost estimating and control along with providing guidance for schedule development and control. Additionally the WBS is a dynamic tool and can be revised and updated as needed by the project manager.

3.7.1.1 WBS design principles

A. The 100% rule

One of the most important Work Breakdown Structure design principles is called the 100% Rule. The 100% Rule states that the WBS includes 100% of the work defined by the project scope and captures all deliverables internal, external and interim in terms of the work to be completed, including project management. The 100% rule is one of the most important principles guiding the development, decomposition and evaluation of the WBS. The rule applies at all levels within the hierarchy: the sum of the work at the "child" level must equal 100% of the work represented by the "parent" and the WBS should not include any work that falls outside the actual scope of the project, that is, it cannot include more than 100% of the work. It is important to remember that the 100% rule also applies to the activity level. The work represented by the activities in each work package must add up to 100% of the work necessary to complete the work package.

B. Mutually exclusive elements

Mutually exclusive: In addition to the 100% Rule, it is important that there is no overlap in scope definition between two elements of a Work Breakdown Structure. This ambiguity could result in duplicated work or miscommunications about responsibility and authority. Such overlap could also cause confusion regarding project cost accounting. If the WBS element names are ambiguous, a WBS dictionary can help clarify the distinctions between WBS elements. The WBS Dictionary describes each component of the WBS with milestones, deliverables, activities, scope, and sometimes dates, resources, costs, quality.

3.7.1.2 Planned outcomes, not planned actions

If the Work Breakdown Structure(WBS) designer attempts to capture any action-oriented details in the WBS, he/she will likely include either too many actions or too few actions. Too many actions will exceed 100% of the parent's scope and too few will fall short of 100% of the parent's scope. It is considered that the best way to adhere to the 100% Rule is to define WBS elements in terms of outcomes or results. This also ensures that the WBS is not overly prescriptive of methods, allowing for greater ingenuity and creative thinking on the part of the project participants. For new product development projects, the most common technique to ensure an outcome-oriented WBS is to use a product breakdown structure. Feature-driven software projects may use a similar technique which is to employ a feature breakdown structure. When a project provides professional services, a common technique is to capture all planned deliverables to create a deliverable-oriented WBS. Work breakdown structures that subdivide work by project phases (e.g. Preliminary Design Phase, Critical Design Phase) must ensure that phases are clearly separated by a deliverable also used in defining Entry and Exit Criteria (e.g. an approved Preliminary Design Review document, or an approved Critical Design Review document).

3.7.1.3 Level of detail

A question to be answered in determining the duration of activities necessary to produce a deliverable defined by the WBS is when to stop dividing work into smaller elements. There are several heuristics or "rules of thumb" used when determining the appropriate duration of an activity or group of activities necessary to produce a specific deliverable defined by the WBS.

(i) The first is the "80 hour rule" which means that no single activity or group of activities to produce a single deliverable should be more than 80 hours of effort.

(ii) The second rule of thumb is that no activity or series of activities should be longer than a single reporting period. Thus if the project team is reporting progress monthly, then no single activity or series of activities should be longer than one month long.

(iii) The last heuristic is the "if it makes sense" rule. Applying this rule of thumb, one can apply "common sense" when creating the duration of a single activity or group of activities necessary to produce a deliverable defined by the WBS.

A work package at the activity level is a task that:

(i) can be realistically and confidently estimated;

(ii) makes no sense practically to break down any further;

(iii) can be completed in accordance with one of the heuristics defined above;

(iv) produces a deliverable which is measurable; and

(v) forms a unique package of work which can be outsourced or contracted out.

3.7.1.4 Terminal element

A terminal element is the lowest element (activity or deliverable) in a work breakdown structure; it is not further subdivided. Terminal elements are the items that are estimated in terms of resource requirements, budget and duration; linked by dependencies; and scheduled.

A terminal element is sometimes called a work package, although the two terms are not synonymous.

3.7.1.5 Misconceptions

A WBS is not an exhaustive list of work. It is instead a comprehensive classification of project scope.

(i) A WBS is neither a project plan, a schedule, nor a chronological listing. It specifies what will be done, not how or when.

(ii) A WBS is not an organizational hierarchy, although it may be used when assigning responsibilities.

3.8 GANTT Charts

Developed by Harry Gantt in 1916, these charts give a timeline for each activity. They are used for planning, scheduling and then recording progress against these schedules. A Gantt chart showing three kinds of schedule dependencies (in red) and percent complete indications. A Gantt chart is a type of bar chart that illustrates a project schedule. Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a project. Terminal elements and summary elements comprise the work breakdown structure of the project.

Although now regarded as a common charting technique, Gantt charts were considered revolutionary when they were introduced. In recognition of Henry Gantt's contributions, the Henry Laurence Gantt Medal is awarded for distinguished achievement in management and in community service. This chart is used also in Information Technology to represent data that have been collected.

3.8.1 Advantages and limitations

Gantt charts have become a common technique for representing the phases and activities of a project Work Breakdown Structure (WBS), so they can be understood by a wide audience all over the world.

A common error made by those who equate Gantt chart design with project design is that they attempt to define the project work breakdown structure at the same time that they define schedule activities. This practice makes it very difficult to follow the 100% Rule. Instead the WBS should be fully defined to follow the 100% Rule, and then the project schedule can be designed.

Although a Gantt chart is useful and valuable for small projects that fit on a single sheet or screen, they can become quite unwieldy for projects with more than about 30 activities. Larger Gantt charts may not be suitable for most computer displays. A related criticism is that Gantt charts communicate relatively little information per unit area of display. That is, projects are often considerably more complex than can be communicated effectively with a Gantt chart. Gantt charts only represent part of the triple constraints (cost, time and scope) of projects, because they focus primarily on schedule management. Moreover, Gantt charts do not represent the size of a project or the relative size of work elements, therefore the magnitude of a behind-schedule condition is easily miscommunicated. If two projects are the same number of days behind schedule, the larger project has a larger impact on resource utilization, yet the Gantt does not represent this difference. Although project management software can show schedule dependencies as lines between activities, displaying a large number of dependencies may result in a cluttered or unreadable chart. Because the horizontal bars of a Gantt chart have a fixed height, they can misrepresent the time-phased workload (resource requirements) of a project, which may cause confusion especially in large projects. In the example shown in this article (figure 3.1). Activities E and G appear to be the same size, but in reality they may be orders of magnitude different. A related criticism is that all activities of a Gantt chart show planned workload as constant. In practice, many activities (especially summary elements) have front-loaded or back-loaded work plans, so a Gantt chart with percent-complete shading may actually miscommunicate the true schedule performance status.

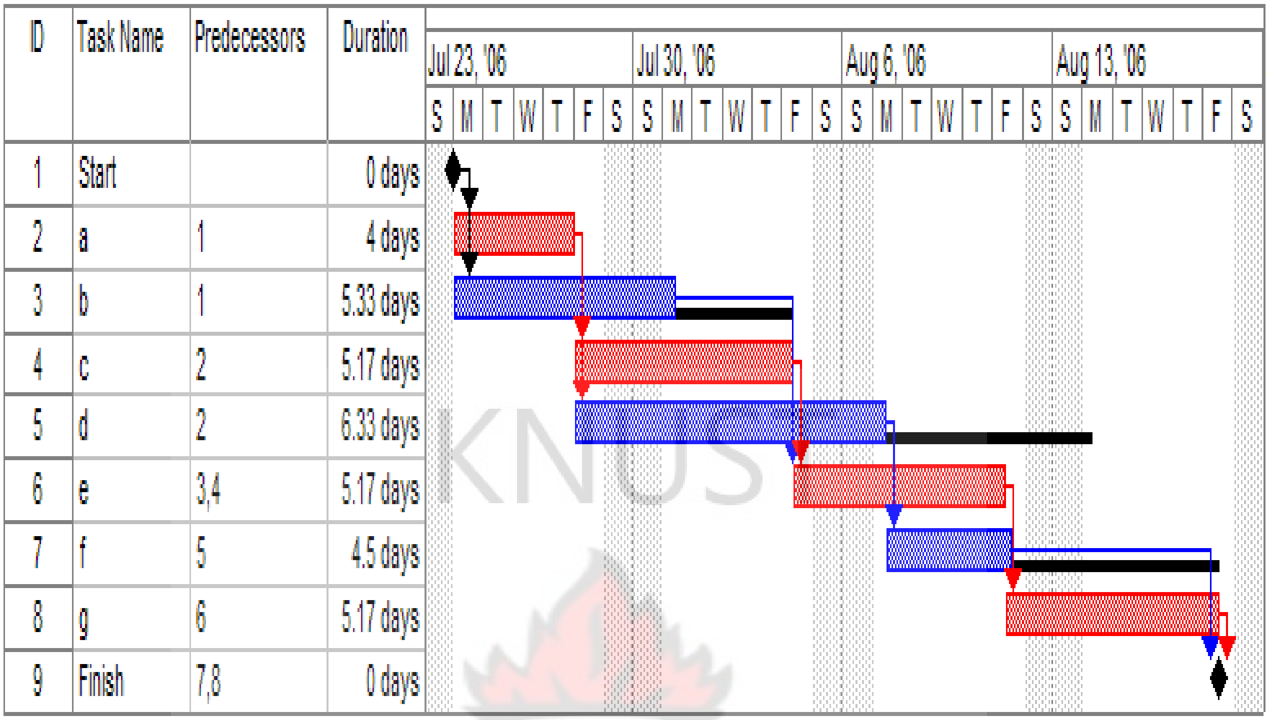


Figure 3.1: A Gantt chart created using Microsoft Project (MSP).

Note (1) the critical path is in red, (2) the slack is the black lines connected to non-critical activities, (3) since Saturday and Sunday are not work days and are thus excluded from the schedule; some bars on the Gantt chart are longer if they cut through a weekend.

3.8.1 CPM (Critical path Method)

Critical path method

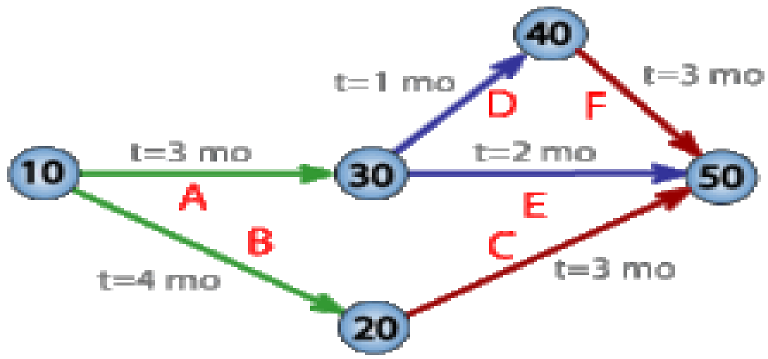


Figure 3.2: A network diagram demonstrating the critical path

The critical path method (CPM) is an algorithm for scheduling a set of project activities. It is an important tool for effective project management.

3.8.2.1 Basic technique

The essential technique for using CPM is to construct a model of the project that includes the following:

(i) A list of all activities required to complete the project (typically categorized within a work breakdown structure),

(ii) The time (duration) that each activity will take to completion, and

(iii) The dependencies between the activities

Using these values, CPM calculates the longest path of planned activities to the end of the project, and the earliest and latest that each activity can start and finish without making the project longer. This process determines which activities are "critical" (i.e., on the longest path) and which have "total float" (i.e., can be delayed without making the project longer). In project management, a critical path is the sequence of project network activities which add up to the longest overall duration. This determines the shortest time possible to complete the project. Any delay of an activity on the critical path directly impacts the planned project completion date (i.e. there is no float on the critical path). A project can have several, parallel, near critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.

These results allow managers to prioritize activities for the effective management of project completion, and to shorten the planned critical path of a project by pruning critical path activities, by "fast tracking" (i.e., performing more activities in parallel), and/or by "crashing the critical path" (i.e., shortening the durations of critical path activities by adding resources).

3.8.2.2 Expansion

Originally, the critical path method considered only logical dependencies between terminal elements. Since then, it has been expanded to allow for the inclusion of resources related to each activity, through processes called activity-based resource assignments and resource leveling. A resource-leveled schedule may include delays due to resource bottlenecks (i.e., unavailability of a resource at the required time), and may cause a previously shorter path to become the longest or most "resource critical" path. A related concept is called the critical chain, which attempts to protect activity and project durations from unforeseen delays due to resource constraints.

Since project schedules change on a regular basis, CPM allows continuous monitoring of the schedule, allows the project manager to track the critical activities, and alerts the project manager to the possibility that non-critical activities may be delayed beyond their total float, thus creating a new critical path and delaying project completion. In addition, the method can easily incorporate the concepts of stochastic predictions, using the Program Evaluation and Review Technique (PERT) and event chain methodology.

Currently, there are several software solutions available in industry that use the CPM method of scheduling. The method currently used by most project management software is based on a manual calculation approach developed by Fondahl of Stanford University.

3.8.2.3 Flexibility

A schedule generated using critical path techniques often is not realised precisely, as estimations are used to calculate times: if one mistake is made, the results of the analysis may change. This could cause an upset in the implementation of a project if the estimates are blindly believed, and if changes are not addressed promptly. However, the structure of critical path analysis is such that the variance from the original schedule caused by any change can be measured, and its impact either ameliorated or adjusted for. Indeed, an important element of project postmortem analysis is the As Built Critical Path (ABCP), which analyzes the specific causes and impacts of changes between the planned schedule and eventual schedule as actually implemented

3.8.2.4 Terminologies in PERT modeling

(i) PERT event: a point that marks the start or completion of one or more activities. It consumes no time and uses no resources. When it marks the completion of one or more tasks, it is not “reached” (does not occur) until all of the activities leading to that event have been completed.

(ii) Predecessor event: an event that immediately precedes some other event without any other events intervening. An event can have multiple predecessor events and can be the predecessor of multiple events.

(iii) Successor event: an event that immediately follows some other event without any other intervening events. An event can have multiple successor events and can be the successor of multiple events.

(iv) PERT activity: the actual performance of a task which consumes time and requires resources (such as labour, materials, space, machinery). It can be understood as representing the time, effort, and resources required to move from one event to another. A PERT activity cannot be performed until the predecessor event has occurred.

(v) Optimistic time (O): the minimum possible time required to accomplish a task, assuming everything proceeds better than is normally expected

(vi) Pessimistic time (P): the maximum possible time required to accomplish a task, assuming everything goes wrong (but excluding major catastrophes).

(vii) Most likely time (M): the best estimate of the time required to accomplish a task, assuming everything proceeds as normal.

(viii) Expected time (T_E): the best estimate of the time required to accomplish a task, assuming everything proceeds as normal (the implication being that the expected time is the average time the task would require if the task were repeated on a number of occasions over an extended period of time).

$$\mathbf{T_E = (O + 4M + P) / 6}$$

(ix) Float is the amount of time that a task in a project network can be delayed without causing a delay - Subsequent tasks – (free float) or Project Completion – (total float)

(x) Critical Path: the longest possible continuous pathway taken from the initial event to the terminal event. It determines the total calendar time required for the project; and, therefore, any time delays along the critical path will delay the reaching of the terminal event by at least the same amount.

(xi) Critical Activity: An activity that has total float equal to zero. Activity with zero float does not mean it is on the critical path.

(xii) Lead time: the time by which a predecessor event must be completed in order to allow sufficient time for the activities that must elapse before a specific PERT event reaches completion.

(xiii) Lag time: the earliest time by which a successor event can follow a specific PERT event.

(xiv) Slack: the slack of an event is a measure of the excess time and resources available in achieving this event. Positive slack would indicate ahead of schedule; negative slack would indicate behind schedule; and zero slack would indicate on schedule.

(xv) Fast tracking: performing more critical activities in parallel

(xvi) Crashing critical path: Shortening duration of critical activities on arc network, in which the activities are represented on the lines and milestones on the nodes. Over time, some people began to use PERT as an activity on node network.

3.8.2.5 Steps in PERT

PERT planning involves the following steps

(i) identify activities and milestones

the activities are the tasks required to complete the project. the milestones are the events marking the beginning and end of one or more activities. it is helpful for list the tasks in a table that in later steps can be expanded to include information on sequence a duration.

(ii) determine activity sequence

this step may be combined with the activity identification step since the activity sequence is evident for some tasks. other tasks may require more analysis to determine the exact order in which they must be performed.

(iii) construct the network diagram

using the activity sequence information, a network can be drawn showing the sequence of the serial and parallel activities. for the original activity –on-arc model, the activities are depicted by arrowed lines and milestones are depicted by circles.

(iv) estimate activity times

Weeks are a commonly used not of time for activity completion, but any consistent unit of time can be used. PERT has the ability to deal with uncertainty in activity completion times. For each activity, the model usually included three time estimates:

(i) Optimistic time: generally, the shortest time in which the activity can be completed. It is common practice to specify optimistic times to be three standard deviations from the mean so that there is approximately a 1% chance that the activity will be completed within the optimistic time.

(ii) Most likely time: The completion time having he highest probability. Note that this time is different from the expected time.

(iii) Pessimistic time: The longest time that an activity might require. The standard deviation from the mean is commonly used for the pessimistic time.

PERT assumes a beta probability distribution for the time estimates. For a beta distribution, the expected time for each activity can be approximated using the following weighted average:

Expected time= [(Optimistic + 4 x Most likely + Pessimistic)/6]

This expected time may be displayed on the network diagram.

To calculate the variance for each activity completion time, if three standard deviation times were selected for the optimistic and pessimistic times, then there are six standard deviation between them, so the variance is given by:

Variance= [(Pessimistic – Optimistic)/6]^2

(v) Determination of the critical path

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

ES – Earliest Start time

EF – Earliest Finish time

LS – Latest Start time

LF – Latest Finish time

These times are calculated using the expected time for the relevant activities. The earliest start and finish times of each activity are determined by working forward through the network and determine the earliest time at which an activity can start and finish considering its predecessor activities . The latest start and finish times are the latest times that an activity can start and finish without delaying the project. LS and LF are found by working backward through at the network. The difference in the latest and earliest finish of each activity is that activity‘s slack. The critical path then is the path through the network in which none of the activities have slack.

The variance in the project completion time can be calculated by summing the variances in the completion times of the activities in the critical path. Given this variance, one can calculate the probability that the project will be completed by a certain date assuming a normal probability distribution for the critical path. The normal distribution assumption holds if the number of activities in the path is large enough for the central limit theorem to be applied.

Since the critical path determines the completion date of the project, the project can be accelerated by adding the resources required to decrease the time for the activities in the critical path. Such a shortening of the project sometimes is referred to as project crashing. The under listed times are needed to analyze the critical path;

(i) $ET(i)$, the **early event time** for node i, is defined by

a) Determining all immediate predecessors j for node i, and

b) Setting $ET(i) = \max_{all_j}(ET(j) + t_{ij})$

(ii) $LT(i)$, the **late event time** for node i is defined by

a. Determining immediate successors j to node i, and

b. Setting $LT(i) = \min_{all_j}(LT(j) + t_{ij})$

(iii) $TF(i, j)$, **the total float time**, is allowed increase in t_{ij} without delaying project: $TF(i, j) = LT(j) - ET(i) - t_{ij}$

(iv) The critical path is a path from start to finish through activities (**critical activities**) with $TF(i, j) = 0$

(v) $FF(i, j)$, the **free float time**, is allowed to increase in the starting time for (i, j) without delaying project: $FF(i, j) = ET(j) - ET(i) - t_{ij}$

(vi) LP Formulation:

Let x_j be the time for j event.

$Min\ \ z = x_j - x_1$, subject to $x_j \geq x_i + t_{ij} \forall (i, j)$, and all x_i's

(vii) Crashing the project: re-solving the problem with additional costs and constraints on t_{ij}'s

(viii) Update as project progress

Make adjustments in the PERT chart as the project progresses. As the project unfolds, the estimated times can be replaced with actual times. In cases where there are delays, additional resources may be needed to stay on schedule and the PERT chart may be modified to reflect the new situation.

3.8.2.6 Benefits of PERT

PERT is useful because it provides the following information:

(i) Expected project completion time

(ii) Probability of completion before a specified date

(iii) The critical path activities that directly impact the completion time

(iv) The activities that have slack time can lend resources to critical path activities.

(v) Activity starts and end dates.

3.8.2.7 Limitations of PERT

(i) The activity time estimates are somewhat subjective and depend on judgment. In cases where there is little experience in performing an activity, the numbers may be only a guess. In order cases, if the person or group performing the activity estimates the time there may be bias in the estimate.

(ii) Even if the activity times are well estimated, PERT assumes a beta distribution for these time estimates, but the actual distribution may be different.

(iii) Even if the beta distribution assumption holds, PERT assumes that the probability distribution of the project completion time is the same as that of the critical path. Because other paths can become the critical path if their associated activities are delayed, PERT consistently underestimates the expected project completion time.

3.8.3 The Network Diagram

In a project, an activity is a task that must be performed and an event is a milestone marking the completion of one or more activities. Before an activity can begin, all of its predecessor activities must be completed. Project network models represent activities and milestones by arcs and nodes.

3.8.3.1 Characteristics of the network diagram

The network diagram needs a list of **activities** for some project.

(i) each activity has list of predecessors activities.

(ii) an AOA (activity on arc) network represents the project.

(iii) start node 1 has arcs for all activities with no predecessors.

(iv) finish node f has no successors.

(v) start node is numbered with lower number than finish node.

(vi) each arc is labelled with an activity and an activity time.

(vii) two nodes can be connected by at most one arc.

(viii) dummy activities are added to avoid rule 5 conflicts.

3.8.3.2 Probabilistic Time Estimates

PERT-type approach uses 3 time estimates for each activity

(i) most likely time (m):subjective estimate of most frequent time

(ii) optimistic time (a):shortest possible time (ideally)

(iii) pessimistic time (b):longest time possible if everything went wrong

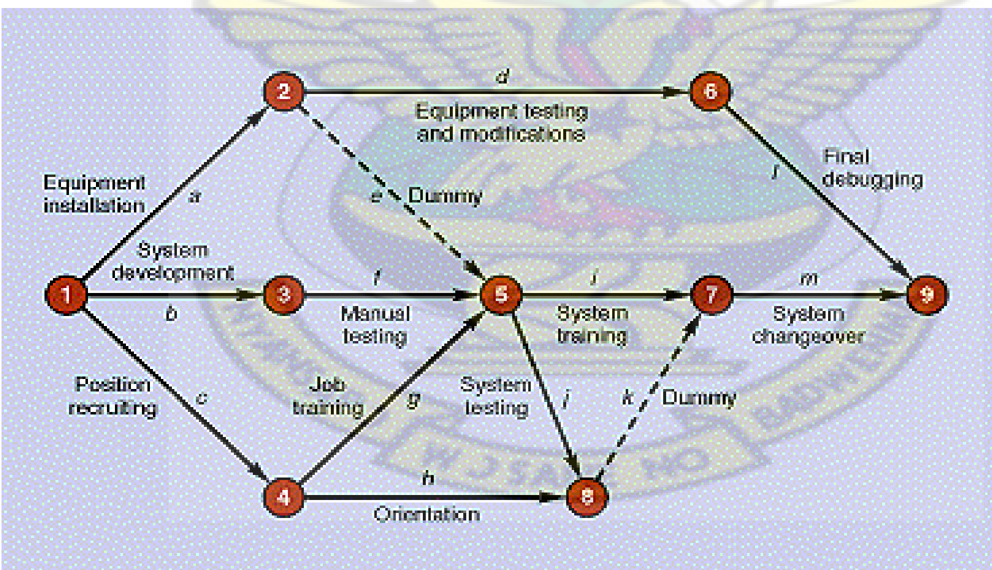


Figure 3.3: A typical network diagram

There are two types;

(i) **Activity-on-node (AON) --** nodes represent activities and arrows show precedence relationships.

(ii) **Activity-on-arrow (AOA) --** arrows represent activities and nodes are events for points in time.

A Dummy inserted into the network to show a precedence relationship, but it does not represent any actual passage of time.

3.9 Activity Slack

Slack is computed by:

$$S_{ij} = LS_{ij} - ES_{ij} \quad \text{or } S_{ij} = LF_{ij} - EF_{ij}$$

Slack enables resources to be temporarily diverted to other activities:

(i) avoid delays

(ii) compensate for an inaccurate time estimate

3.9.1 Activity Scheduling

(i) **Earliest Start time (ES):** the earliest time an activity can start

(ii) **Forward pass:** start at the first node and move forward through the network to determine the earliest start time for an activity

(iii) **Earliest Finish time (EF):** the earliest start time plus the activity time

$$EF_{ij} = ES_{ij} + t_{ij}$$

(iv) **Latest Start time (LS):** the latest time an activity can start without delaying the completion of the project beyond the critical path time.

$$LS_{ij} = LF_{ij} - t_{ij}$$

(v) **Latest Finish time (LF):**the latest time an activity can be completed and still maintain the

(vi) **Critical path time**

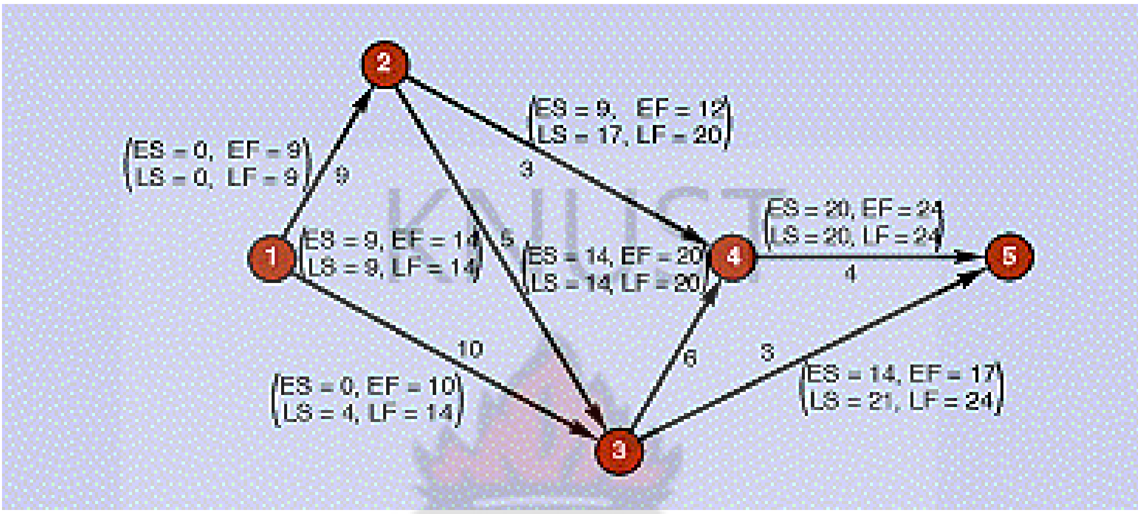


Figure 3.4: A network showing ES, EF, LS, LF

3.9.2 Critical path

In project management, a critical path is the sequence of project network terminal elements with the longest overall duration, determining the shortest time to complete the project.

The duration of the critical path determines the duration of the entire project. Any delay of a terminal element on the critical path directly impacts the planned project completion date (i.e. there is no slack on the critical path).

CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.1 Introduction

This chapter presents data collection and analysis of the study. As mentioned earlier, networks form the basis of the analysis in order to find and estimate both the critical path and critical activities of the project.

Table 4.1: Project Activities

Activity	Description	Predecessors
A	Select administrative and medical staff.	-
B	Select site and do site survey.	-
C	Select equipment.	A
D	Prepare final construction plans, foundation and lay out.	B
E	Bring utilities to site.	B
F	Interview applicants and fill positions in medical field, maintenance and security.	A
G	Purchase and take delivery of equipment	C
H	Construct the hospital.	D
I	Develop an information system.	A
J	Install the equipment.	E,G,H
K	Train medical and other support staff.	F,I,J

4.2 Time Estimates

Three time estimates are sampled from individual contractors on every activity and are used to draw the network diagram. They are the

(i) pessimistic time

(ii) optimistic time

(iii) most likely time

From the survey, the contractor with the most advanced technology available is most likely to finish earlier and is assigned the Optimistic time. The pessimistic times were assigned to the contractors who use a lot of manpower (least machinery) and the most likely time were proposed by the contractors with the blend on machinery and manpower.

Out of the three (3) time estimates the expected time (mean) is calculated from the formula

Expected time= [(Optimistic + 4 x Most likely + Pessimistic)/6]

Table 4.2: Showing the succession of project and the optimistic, pessimistic and most likely times in days from survey carried out

Activity	**Description**	**Optimistic time (O)**	**Pessimistic time (P)**	**Most likely time (M)**	**Expected time**
A	Select administrative and medical staff.	56	112	84	84
B	Select site and do site survey.	35	91	63	63

C	Select equipment.	49	91	70	70
D	Prepare final construction plans, foundation and lay out.	49	119	63	70
E	Bring utilities to site,	119	245	161	168
F	Interview applicants and fill positions in medical field, maintenance and security.	63	105	63	70
G	Purchase and take delivery of equipment	210	280	245	245
H	Construct the hospital.	238	350	273	280
I	Develop an information system.	84	126	105	105
J	Install the equipment.	21	63	21	28
K	Train medical and other support staff.	42	84	63	63

4.3 The Network Diagram

A project network enables answering all above questions by providing two crucial pieces of information, namely the order in which certain activities must be performed and the (estimated duration of each activity.

The network consists of a number of nodes (rectangles) and straight lines (arrows) that lead from some node to another. Three types of information are needed to describe a project.

(i) Activity information

(ii) Precedence relationships

(iii) The expected (mean) times of each activities.

4.4 Forward Pass

The starting and finishing times of each activity if no delays occur anywhere in the project are called the earliest start time and the earliest finish time of the activity. These are presented by the symbols

Earliest Start time (ES) =earliest start time for a particular activity

Earliest Finish time (EF) =earliest finish time for a particular activity, where

EF=ES + expected (mean) duration of the activity

If an activity has more than one predecessors, then

ES for the activity=MAX (EF for the immediate predecessors)

This process of starting with the initial activities and working forward in time toward the final activities to calculate all the ES and the EF values is referred to as making a forward pass through the network.

4.5 The Backward Pass

An activity‘s immediate successors cannot start until the activity finishes. This rule is saying that the activity must finish in time to enable all its immediate successors to begin by their latest start times.

Latest Start time (LS) =latest start time for a particular activity without delaying critical path time.

LS=LF-Expected (mean) time

Latest Finish time (LF) =latest finish time for a particular activity without delaying critical time.

LS=Minimum LS of immediate successors

Table 4.3: Showing the Earliest Start, latest start time and the Earliest Start and latest finish times in days

Node	Expected Time	ES	EF	LS	LF	Slack
A	84	0	84	14	98	14
B	63	0	63	0	63	0
C	70	84	154	98	168	14
D	70	63	133	63	133	0
E	168	63	231	245	413	182
F	70	84	154	371	441	287
G	245	154	399	168	413	14
H	280	133	413	133	413	0
I	105	84	189	336	441	252
J	28	413	441	413	441	0
K	63	441	504	441	504	0

The procedure illustrated above is to start with the final activities and work backwards in time toward the initial activities to calculate all the LF and the LS values.

4.6 The Critical Path

The critical path is determined by adding the times for the activities in each sequence and determining the longest path in the project. The critical path determines the total calendar time required for the project. If activities outside the critical path speed up or slow down (within limits), the total project time does not change. The amount of time that a non- critical path activity can be delayed without the project is referred to us slack time. The critical path then is the path through the network in which none of the activities have slack, in other words have a slack of Zero.

The slack of an activity is the difference between its Latest Finish Time and its Earliest Finish Time. In symbols Slack=LF-EF

The critical path in this project is therefore

B ⟶ D ⟶ H ⟶ J ⟶ K

Hence if no delay occurs the project has to be completed in 504 days.

4.7 Activity Scheduling

Meeting project duration depends also on how schedules are made on individual activities. Having no delays means that:

(i) The actual duration of each activity turns out to be the same as its estimated duration and

(ii) Each activity begins as soon as all its immediate predecessors are finished.

4.8 Probability of Project Completion by Due dates-Discussion

The standard deviation of the project duration probability distribution is computed by adding the variances of the critical activities (all the activities that make up the critical path) and taking the square root of that sum. The variance is calculated from the formula

VARIANCE= (Pessimistic time – Optimistic time) ^{2} / 36

Table 4.4: Showing the various time estimates and the variance

Activity	Description	Optimistic time (O)	Pessimistic time (P)	Variance
A	Select administrative and medical staff.	56	112	87.1
B	Select site and do site survey.	35	91	87.1
C	Select equipment.	49	91	49
D	Prepare final construction plans, foundation and lay out.	49	119	136.1
E	Bring utilities to site,	119	245	441
F	Interview applicants and fill positions in medical field,	63	105	49

	maintenance and security.			
G	Purchase and take delivery of equipment	210	280	136.1
H	Construct the hospital.	238	350	348.4
I	Develop an information system.	84	126	49
J	Install the equipment.	21	63	49
K	Train medical and other support staff.	42	84	49

The project variance (σ^2_p) is however the sum of the variances of individual activities on the critical path.

Sum of variances of critical activities

$\boldsymbol{\sigma^2_p = 87.1 + 136.1 + 348.4 + 49 + 49 = 669.6}$

The standard deviation (σ_p) =**SQRT (669.6) = 25.9**

Although the project is estimated to be completed within 504 days, there is a tendency that the project may be completed ± 25.9 days. Thus there is the need to find probabilities that it may or may not be completed on the specific time or it may be completed within other proposed times.

To determine the probability that the project will be completed within specified time, the formula applied is

$\boldsymbol{Z = (x - \mu)/\sigma}$

Where

Z= Random Score

μ=Project mean time or expected date

σ=Project standard mean time

x= Proposed (Specific) time or due date

With the random score (Z) known, the probability can be read from the Normal Distribution Table.

PERT assumes that the expected length of the project is simply the sum of their separate expected lengths. That is, the summation of all the expected times along the critical path gives the length of the project.

Similarly the variance of a sum of independent activity times equal to the sum of their individual variances. In this project the sum of the variances of the critical activities is 669.6 and the standard deviation which is the square root of the total variance is 25.9. Although the expected times are randomly distributed, the average or expected project length approximate follows the Normal Distribution.

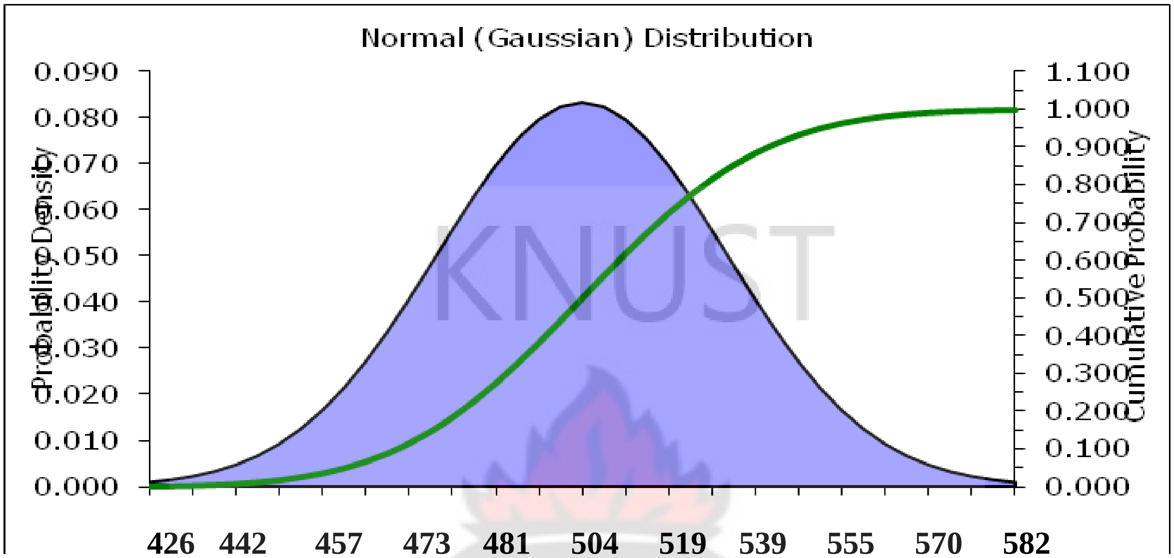
Table 4.5: Showing the Z-values, proposed due dates (within three standard deviations) and percentage of completion times

z- values	Due dates(x)	Percentage of Completion
-3	426	0.1%
-2.85	430	0.2%
-2.7	434	0.3%
-2.55	438	0.5%

-2.4	442	0.8%
-2.25	446	1.2%
-2.1	450	1.8%
-1.95	453	2.6%
-1.8	457	3.6%
-1.65	461	4.9%
-1.5	465	6.7%
-1.35	469	8.9%
-1.2	473	11.5%
-1.05	477	14.7%
-0.9	481	18.4%
-0.75	485	22.7%
-0.6	489	27.4%
-0.45	492	32.6%
-0.3	496	38.2%
-0.15	500	44.0%
0	504	50.0%
0.15	508	56.0%
0.3	512	61.8%
0.45	516	67.4%
0.6	519	72.6%
0.75	523	77.3%
0.9	527	81.6%
1.05	531	85.3%
1.2	535	88.5%
1.35	539	91.1%
1.5	543	93.3%
1.65	547	95.1%
1.8	551	96.4%
1.95	555	97.4%
2.1	558	98.2%
2.25	562	98.8%
2.4	566	99.2%
2.55	570	99.5%
2.7	574	99.7%
2.85	578	99.8%
3	582	99.9%

The above table shows the range of dates the project will be completed when probability, mean and standard deviation is applied and calculated.

Figure 4.6: Graph of the Normal distribution of the Project



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In the scheduling and construction of Kasoa Government Hospital, we require a series of activities, some of which must be performed sequentially and others that can be performed in parallel with other activities.

The steps involved in this project using PERT are

(i) the specific activities and milestones of the project were all identified

(ii) the proper sequence of the various activities were also determined

(iii) the network diagram was then constructed

(iv) the times required for each activity were estimated

(v) the critical path was determined

(vi) the normal distribution curve for the project in order to estimate probabilities of completion times was also determined.

All scheduling computations first involved a forward and then backward pass through the network. Based on a specified project start time, the forward pass computations proceed sequentially from the beginning to the end of the project giving the earliest start and finish times for each activity. The backward pass computations also proceed sequentially from the end to the beginning of the project to produce the latest and finish times. These computations lead to the determination of the critical path and slacks.

The entire project involved eleven (11) activities and shall take 504 working days to complete which is the mean and has about 50% chance of completion. The standard deviation of 25.9 is an indication of how the completion time deviates from the expected date. The project has 99.9% to be completed in 582 working days and 0.1% chance of completion in 426 working days.

The PERT approach to project scheduling cannot be over emphasized due to its enormous advantages such as

(i). it gives an estimated completion date

By using the PERT formula combined with bottom-up estimating in project management, a savvy project manager can then determine the estimated completion date for a project. The way this date is calculated is by adding up the cumulative task durations that have been estimated utilizing the PERT formula.

(ii) in the case where a client wants a specific completion date

The PERT formula can help determine what chance the project has of being completed by that date. If the date lies within the standard deviation of the formula, there is a better chance of completion by that date the closer the date is to the pessimistic estimated date and a smaller probability for completion if the requested date is closer to the optimistic estimate for completion.

(iii) the project manager can determine flexibility

Items with a large range between the optimistic estimate and the pessimistic estimate for completion are flexible. Because of this, if a project manager needs to crash the project schedule or fast track the project schedule, the PERT formula can help them determine which action items contain this flexibility. In this case, the PERT formula has a distinct advantage for project managers. By estimating the time it will take to complete tasks using the PERT Formula and the Standard Deviation formula, project managers can schedule start and finish times for tasks in a more accurate manner. This is a great benefit, especially in construction of the government hospital where start and finish dates might not be clear. Using the task estimation method, the project manager would schedule all tasks due to their estimated completion time, and then use the start time of the first scheduled task and the end time of the final scheduled task as the start and finish dates of the hospital construction

5.2 Recommendation

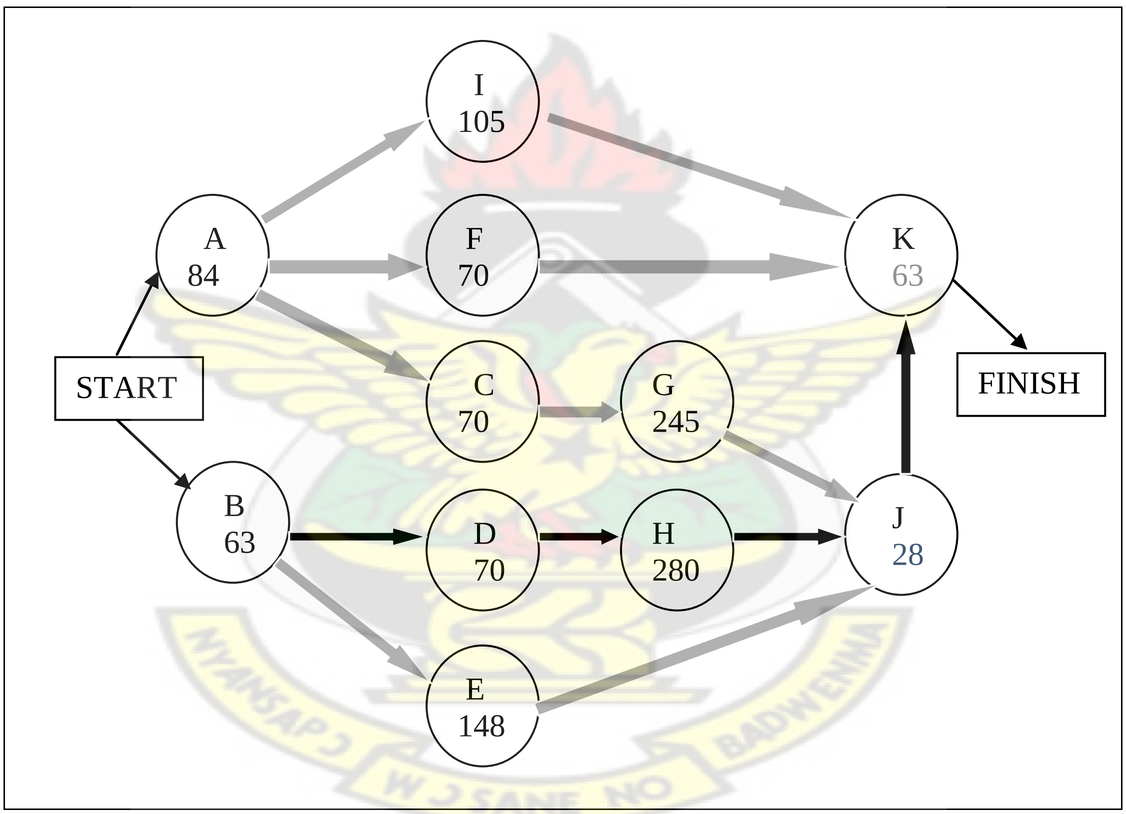
Keeping the project within schedule and as well keeping the customer satisfied are the key qualities of a successful project.

Successful project management involves the use of a good project management tool. The correct project management tool can help a project manager spot the early warning trends that could spell the downfall of a project. It also allows the project manager to monitor a project, keeping abreast with trends and possible problems whether it is deviating from the schedule and planned completion time in order to keep it on track.

It is however highly recommended for the adoption of an appropriate project management tool by any organization to save cost and time. Otherwise the project may be too expensive and be delayed unnecessarily because the more time spent on a project the higher the cost incurred.

APPENDIX 1

The associated network is:



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