Scheduling Project Management Using Crashing CPM Networks to Get Project Completed on Time & Under Budget

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المستخلص:

معظم الشركات العراقية تعاني من صعوبات وتحديات، نظرا لازدياد تعقد المشاريع، وبسبب اعتمادها على ادوات تقليدية في تخطيط المشاريع ومن ثم متابعتها والسيطرة عليها. لذا فان الحاجة للرقابة المستمرة على وقت وكلفة واداء المشروع وكذلك انهاءه في الوقت المحدد وضمن الموازنة المرصودة والنوعية الجيدة.

يوفر البحث منهج ديناميكي مع اعطاء للمستخدم امكانية تقييم شبكة اعمال المشروع خلال تحديد استراتيجية المبادلة (التعجيل)Crashing في بداية المشروع وخلال فترة حياه المشروع. وباستخدام هذه الطريقة يتم اكمال المشروع وباقل وقت ممكن باستخدام موارد اضافية للانشطة الواقع على المسار الحرج.

استخدم البحث تقنية CPM وطريقة مبادلة الوقت بالكلفة، تساعد الادارة الناجحة للمشاريع للوصول الى الاهداف المطلوبة من خلال انهاء المشروع باقل وقت وكلفة محددة وكذلك يحدد المدة التي يمكن بموجبها تنفيذ المشروع وتحديد كلفة المرتبطة بالمشروع .

Abstract

Most of Iraqi companies suffer from difficulties & challenges due to complexity of project, and because of its dependency on the traditional tool to plan, schedule, and control the project development. The needs for continuous control of time, cost, and performance of projects, also can be completed on time with good quality and within the allocated budget.

This research provident dynamic approach will let the user evaluate the project network to determine a crashing strategy at the beginning of the project and also during the life of the project. To reduce a projects completion time, a technique called "crashing is performed, which involves bringing in additional resources for activities along the critical path of the network.

The research created model to determine the order in which activities should be crashed as well as using CPM technique helps good project management in achieving the objective with minimum of time and least cost and also in predictive the probable project duration and associated cost meeting the desired project.

KEY WORD:- Project management, Activities, WBS (Work Breakdown Structure), CPM (Critical Path Method), Schedule, Slack Time, Crashing.

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1-1 Research Problem

Business and its environment are more complex today than ever before. And decision making has become much more complicated than in the past due to increased decision alternatives, uncertainty, and cost of making errors. As a result, it is very difficult to rely on a trial and error approach in decision making, so managers must become more rational in decision making by using more effective tools and techniques. Nowadays business managers are dealing with different types of projects ranging from implementing a large scale manufacturing plant to a simple sales campaign.

While dealing with projects, to become competitive, sometimes it is required to complete a project within the predetermined deadline to keep cost at lowest possible level. Failure to do so ultimately leads to increase in total cost. This would direct managers to encounter a decision situation: which activities of the project will be crashed to minimize the total cost of crashing project.

1-2 Aim of the Research

This paper objective: mainly provides a framework for reducing total project time at the least total cost by crashing the project network. Then the model is solved with hypothetical data of a hypothetical project by using simulation approach.

1-3 The Methodology of the Research

Study the CPM strategic planning process for planning and development of "Cooling Tower project" in order to get the optimal time at minimum total cost to complete implementation of project, The research which enables the project management to study and analyses the value of project activity during all phases of project, So as to reach the maximum benefit and minimum cost planning.

This was achieved by developing modules that allow assessing activities and resources that may be critical through drawing project network, and may affect the project career and its finish date at normal and crash time.

2-1 Introduction to Project Management

If you were asked to define the term project, what words would come to mind? Time? Resources (or lack of)? One-of-a-kind effort? Deliverables or products? Complex? No authority over other groups? Budget?

A project is a unique effort to introduce or produce a new product or service conforming to certain specifications and applicable standards. This effort is completed within the project parameters including fixed time, cost, human resources, and asset limits. Projects are said to be similar to the mating of two elephants:

They start at a very high level with lots of noise and activity, but it takes forever for anything to materialize! A more serious definition is that a project is a well-organized development of an end product that had a discrete beginning, a discrete end, and a discrete deliverable. Our goal is to help you become more organized as you work toward this objective.

Project management is the discipline that relates all of those words that you thought of that apply to project. This discipline cultivates the expertise to plan, monitor, track, and manage the people, the time, the budget, and the quality of the work on projects. Project management fulfills two purposes:

(1) It provides the technical and business documentation to communicate the plan and, subsequently, the status that facilitates comparison of the plan against actual performance.
(2) it supports the development of the managerial skills to facilitate better management of the people and their project(s). Project management is a proactive style of management.

Negotiation techniques and good communication and analytical skills are integral parts of this approach. Another key ingredient is the evaluation of performance against those objectives. Central to this management style is the application of high standards of quality to the project work.

Project management is a means by which to fit the many complex pieces of the project puzzle together. This is accomplished by dealing with both human and technical elements of the discipline of project management.
Here is our definition of project & project management: (Knudson J. &Bitz T.1991)

All new projects or new releases must be evaluated to make sure they strategically fit the company or division's direction. Phase 1 provides the forum for introducing new project ideas and obtaining approval to continue project definitions.

- **Phase 1 is broken into two steps.**
    - **Step 1: an idea is presented to management**
    - **Step 2: management has the idea vetted for feasibility**

All project ideas should be submitted and reviewed periodically. Ideas for new applications can come from anywhere within an organization. It is best not to stifle the flow of ideas, since this process may be used to spot trends or issues within the organization.

Ideas that come from these experiences should be written down and submitted to the company. The company should develop a method to capture and vet these ideas. For example, the billing department may put in a request that customer statements be made available online, saving the company money on statement printing and mailing costs. (Anita Rosen 2004) It is also defined by the (Panneerselvam, R., 2006) A project consists of interrelated activities which are to be executed in a certain order before the entire task is completed. the activities are interrelated in logical sequence which is know as precedence relationship .the work on project cannot be stared until all its immediate preceding activities that involve planning, procuring the input ….etc .. are completed.

A unique set of coordinated activities, with definite starting and finishing point, under taken by an Individual or organization to meet specific objectives within defined schedule, cost and performance parameters.'

The next question that can be asked is 'Why does one need project management? 'What is the difference between project management and management of any other business or enterprise?
Why has project management taken off so dramatically in the last twenty years?

The answer is that project management is essentially management of change, while running.
A functional or ongoing business is managing a continuum or' business-as-usual'.
Project management is not applicable to running a factory making sausage pies, but it will be. The right system when there is a requirement to relocate the factory, build an extension, or produce. A different product requiring new machinery, skills, staff training and even marketing techniques (Lester A., 2006).

Project management techniques are useful when a project consists of several activities, some simultaneous and others sequential. A project is a unique, one time event that is intended to achieve on objective in a given time period. The project is of some length (weeks, months, or even years). And uses resources (human, capital, materials, and equipment) (Reid ,2002,P520).

Project management is a set of principles, methods, tools, and techniques for the effective management of objective-oriented work in the context of a specific and unique organizational environment (Knudson J.&Bitz T. 1991).

Project management: The use of knowledge, skills, tools ,and methodology along the project life cycle in order to achieve its goals (Boaz Ronen,2008).

2-2 A Science and an Art

Project management is both a science and an art. It is perceived as a science because it is supported by charts, graphs, mathematical calculations, and other technical tools. Producing these charts requires the hard skills to manage a project. But project management is also driven by political, interpersonal, and organizational factors—thus the "art" of project management. Communication, negotiation, and conflict resolution are only a few of the soft skills used in the art of project management.

Each topic explored in this book provides you with both the hard and the soft skills you will need to manage your projects efficiently and effectively. This book provides you with the technical tools of project management to address the scientific side of the discipline, as well as the human behavioral techniques (Knudson J.&Bitz T., 1991).

2.3 Initiation and Specification

A project can be initiated from within the organization or by an external customer. In the global and business-oriented view of the project, the goal of the project is always to increase the value of the organization. From this standpoint, the project managers' responsibility is not simply to conform to cost, time, and content. The project manager manages a business that has to contribute to the value of the organization. To avoid over specification that is common among customers and marketing people alike and overdesign that is common among developers, the project team should focus on satisfying goals to increase the organization ' s value.

The initiation and specification stage is critical to the success of the project because at this stage the most critical decisions and commitments are made. Figure (1) depicts the reality of most

projects: in the very short initiation stage, 70 percent of the commitments are taken, whereas the effort put in the project in this stage is only about 1 percent of the total effort. .(Boaz Ronen,2008,346)

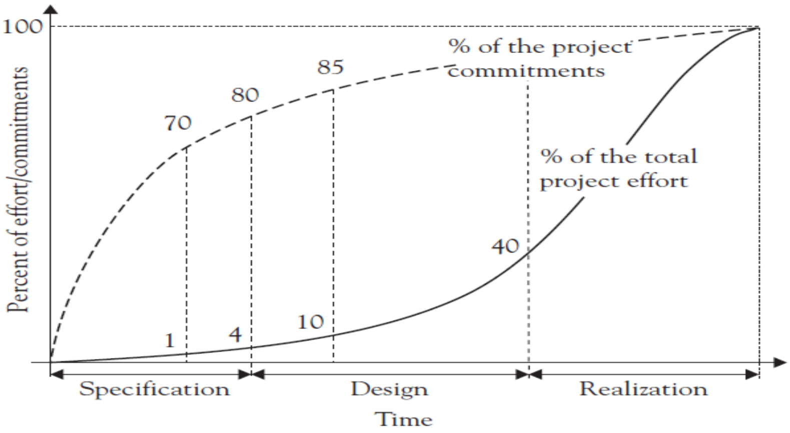


Figure 1 The effort/commitments profile of projects

Boaz ,Ronen & Shimeon Pass " Focused Operations Management " Achieving More with Existing Resources . John Wiley &sons Inc. 2008

2-4 The Objective - Why is the Project Needed?

Regardless of whether the goal is described thoroughly or not, an objective has always been established. The objective is the same as the effect the project is expected to generate .i.e. Why it is Important to carry out the project. Without the knowledge of the objective it will be difficult to motivate the project group and other stakeholders.

When the objective is known, it is possible to assess the goal and analyze the assignment. If the project evaluation finds that the wanted effect is not generated, the project should go back to the sponsor for reevaluation of the problem description and reevaluation of the project and its goal. Sometimes a study should be completed to produce additional facts to add to the foundation. (Tonnquist, B. 2008)

Broadly these objectives, which are usually defined as part of the business case and set out in the project brief, must meet three fundamental criteria:

1 – The project must be completed on time.

2 – The project must be accomplished within the budgeted cost.

3 – The project must meet the prescribed quality requirements.

These criteria can be graphically represented by the well known project triangle (Figure 2).Some organizations like to substitute the word 'quality' with 'performance', but the principle is the same– the operational requirements of the project must be met, and met safely.

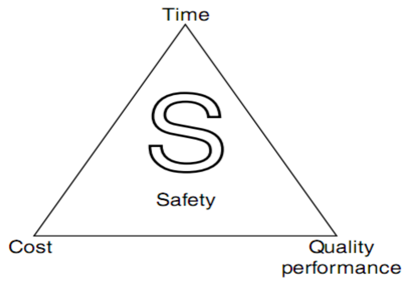


Figure (2) project triangle

Lester Albert, "project management, Planning & control": management engineering, construction and manufacturing project to PMI, APM & BSI Standards, 5ed, Elsevier Science & Technology Books, 2006.

In certain industries like airlines, railways and mining, etc. the fourth criterion, safety, is considered to be equally important, if not more so. In these organizations, the triangle can be replaced by a diamond now showing the four important criteria (Figure 3) (Lester A., 2006).

The order of priority given to any of these criteria is not only dependent on the industry, but also on the individual project. For example, in designing and constructing an aircraft, motor car or railway carriage, safety must be paramount. The end product may cost more than budgeted, may be late in going into service and certain quality requirements in terms of comfort may have to be sacrificed, but under no circumstances can safety be compromised. Aero planes, cars and 1railways must be safe under all operating conditions.

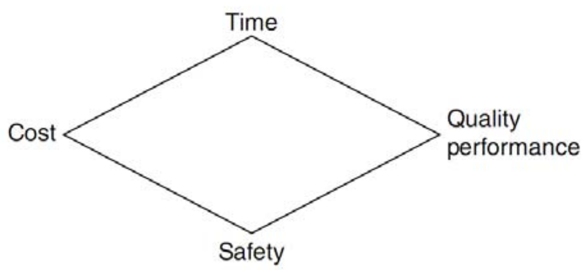


Figure (3) Project Diamond

Lester Albert, "project management, Planning & control": management engineering, construction and manufacturing project to PMI, APM & BSI Standards, 5ed, Elsevier Science & Technology Books, 2006.

2-5 Structure, Processes and Culture

Research within organizational, Theory concentrates around three main topics; namely structure, processes and culture.

The structure of the organization contains visible component e.g. functions, positions, hierarchies, titles and ranking orders, while the processes deals with

actions and events. The organization's culture touch upon work ethics, values ,and norms, beliefs, languages, symbols, leadership and motivation.

It is the processes which constitute the organization's,' vital operations while structure and culture and indicate how the individuals within the organization work, collaborate and obstruct one another, how systems are built up or broken down and how decision levels and authorities are shared (Tonnquist, B. 2008)

The project structure is designed to handle one-time, unique, and nonrecurring endeavors. It is based on a task force assembled for a limited time to achieve a predefined goal. The members of the project team may come from different organizational units and have different educations and backgrounds.

They have a common goal—the project success; and a common leader the project manager. Organizations dealing with projects may adopt a flexible structure in which only a core group has a permanent structure while most of the organization is assigned to project groups (Boaz,2001).

2.6 WBS as a Dictionary for the Project

It is a technique which breaks down the project in sequences into separate components called work activities and at the same time establishes the connection between these components on the lines of family tree to enable the integration of people, hardware and software into project work system (Boaz, 2001).

To carry out a project requires that everything runs smoothly. A well composed WBS will facilitate the work of identifying milestones and planning activities which in turn will make the next steps in the project's preparations more straightforward. The WBS is also a good starting point when it is time to appoint shared responsibilities in the project. The different branches represent different sub-areas which probably demand different competence (Tonnquist, B. 2008).

The division of labor among the parties participating in a project supports specialization. It is also an answer to the need to finish the project work content within a predetermined schedule, which is not determined by the amount of work to be performed. Due to the division of labor, it is possible to perform each part of the work content of the project by the best experts within the required time frame.

These benefits of the division of labor do not come for free—they carry the risks associated with integration. Integration of information, knowledge, and deliverables produced by the different work packages must be based on a common language to ensure a smooth and fault-free process. This common language is based on the WBS.

A well-planned WBS serves as a dictionary of a project. Because each work package is defined in terms of its work content, its deliverables, its required inputs (data, information, resources, etc.), and its relationship to other work packages within the WBS, all the stakeholders have a common reference or a common baseline. Furthermore, careful management of changes to the WBS throughout the project life cycle provides a continuous update to the project dictionary (Boaz,2001).

WBSs can also refer to organizational or management changes aimed at improving performances: the ISO 9000 certification process is a project, as are Just-in-time (JIT) interventions, internal reorganization, the adoption of a new

information system, revising the agents/retailers network, creating partnerships with suppliers, joint ventures, etc. All these projects require careful planning and the definition of the activities to be carried out, which are illustrated by the WBS (Tonchia, S., 2008).

3-Time and Schedule Management

3.1 Project scheduling

The target of project scheduling is to construct a timetable where each individual activity receives a start time and a corresponding finish time within the predefined precedence relations and the various predefined activity constraints.

The scheduling process is based on the traditional critical path based forward (to create an earliest start schedule) and/or backward (to create a latest start schedule) project scheduling calculations aiming to construct a project schedule with a minimal project lead time .

In the remainder of this section, details on the exact use of the precedence relations ,the activity constraints and the forward/backward scheduling options are described in order to create a project baseline schedule (Vanhoucke, M., 2009).

Its necessary to monitor the progress to ensure that everything is going according to schedule. This involves measuring actual progress and comparing it to the schedule. If at any time during the project it is determined that project is behind schedule, corrective action must be taken to get back on schedule. The key to effective project control is to measure actual progress and compare it to planning progress on a timely and regular basis and to take necessary corrective action immediately.

Based on actual progress and on consideration of other changes that may occur, it's possible to calculate an updated project schedule regularly and forecast whether the project will finish ahead of or behind its required completion time (Gido J., 2009).

Project scheduling is often the most visible step in the sequence of steps of project management. The two most common techniques of basic project scheduling are the critical path method (CPM) and program evaluation and review technique (PERT).

The network of activities contained in a project provides the basis for scheduling the project and can be represented graphically to show both the contents and objectives of the project (Badiru, Adedeji B. 2008).

A basic CPM project network analysis is typically implemented in three phases: (Badiru, Adedeji B. 2008)

- **Network-planning phase**
- **Network-scheduling phase**
- **Network-control phase.**

Network Planning: In network-planning process begins by clearly defining the project objective (chudhury , 1988). This step is necessary to find out resources needed. Once the activities have been identified, their sequential relationship needs to be determined, what activities must be completed before other can begin. This step typically I done using flowchart-type diagrams (Stephen 1999).

Precedence requirements may be determined on the basis of the following: (Badiru, Adedeji B. 2008)

- **Technological constraints**
- **Procedural requirements**
- **Imposed limitations.**

Network scheduling: is performed by using forward-pass and backward-pass computations. These computations give the earliest and latest starting and finishing times for each activity. The amount of "slack" or "float" associated with each activity is determined. The activity path that includes the least slack in the network is used to determine the critical activities. This path also determines the duration of the project. Resource allocation and time–cost trade-offs are other functions performed during network scheduling (Badiru, Adedeji B. 2008).

Then the project schedule is compared with the objective and necessary adjustments are made to control the project (Stephen 1999).

Network control involves tracking the progress of a project on the basis of the network schedule and taking corrective actions when needed. An evaluation of actual performance versus expected performance determines deficiencies in the project progress. The advantages of project network analysis are as follows:

Advantages for communication

- **Clarifies project objectives**
- **Establishes the specifications for project performance**
- **Provides a starting point for more detailed task analysis**
- **Presents a documentation of the project plan**
- **Serves as a visual communication tool.**

Advantages for control

- **Presents a measure for evaluating project performance**
- **Helps determine what corrective actions are needed**
- **Gives a clear message of what is expected**
- **Encourages team interaction. (Badiru, Adedeji B. 2008)**

3.2 Network Techniques: CPM, MPM, PERT, GERT, VERT

Network techniques are used for managing time; they are called so because they are based on the network diagrams, in this case not intended to illustrate data but to elaborate them, so as to do the following:

– *Schedule activities*, namely define the start and end date of each activity and, consequently, the duration of the entire project.

– *Analyse allowable floats* (*or slacks*) – for non-critical activities – that do not increase the duration of the project, which means identifying those activities that, if delayed, would prolong the duration of the project, and are therefore known as *critical* There are three types of starting data:

1. The activities (task name or identification code)

2. Their duration

3. The links of precedence between the activities (Tonchia S., 2008).

Network is a system, which manager projects both large and small by analyzing the project activities. Project is broken down into individual tasks or activities, which are arranged in logical sequence (Chudhury, S.1988)

3.2.1 There are therefore various network techniques:

● *CPM*, used when the duration of all the activities is considered fixed, and likewise the links of precedence, which are of the Finish-to-Start type (namely, the beginning of a certain activity is linked to the end of a previous one)
● *MPM* (*Metra Potential Method*): it is similar to CPM, but also includes three other types of relationship between the activities (namely, Start-to-Finish, Start to-Start, Finish-to-Finish: e.g. it can sometimes be useful to have two activities finishing at the same time, and in this case a Finish-to-Finish link is established between them)
● *PERT*, namely a CPM having all durations expressed in a probabilistic manner
● *GERT* (*Graphical Evaluation and Review Technique*), namely a PERT that also has the precedence links expressed in a probabilistic manner (logical gates are therefore used to trace the paths, ensuring feedback among the activities and various types of conclusion)
● *VERT* (*Venture Evaluation and Review Technique*), which takes into account the time, cost, resources and risk variables contemporaneously, and is particularly suited in *what-if* scenario analyses and when evaluating and reviewing new businesses or strategic initiatives (as the name suggests)
CPM and MPM can thus be considered deterministic techniques, whereas PERT, GERT and VERT are probabilistic ones. (Tonchia S., 2008)

3.2.1.1 PERT

Program Evaluation and Review Technique "PERT" was originally developed in 1958 and 1959 to meet the needs of the “age of massive engineering” where the techniques of Taylor and Gantt were inapplicable. The Special Projects Office of the U.S. Navy, concerned with performance trends on large military development programs, introduced PERT on its Polaris Weapon System in 1958, after the technique had been developed with the aid of the management consulting firm of Booz, Allen, and Hamilton. Since that time, PERT has spread rapidly throughout almost all industries. At about the same time, the DuPont Company initiated a similar technique known as the critical path method (CPM), which also has spread widely, and is particularly concentrated in the construction and process industries.(Kerzner H., 2006)

To describes the basic concepts and calculations for project scheduling with PERT/CPM. These include the construction of network diagrams, the calculation of feasible project schedules, determining the effect of uncertainty on project schedules, and adjusting schedules to conform to time and resource constraints. The tools are important for planning a project and for keeping it on track once it has begun. (Robert A. Shumsky, 2003)

3.2.1.2 (CPM)

The critical path method is a fundamental quantitative technique developed for project management. Assuming deterministic activity completion times, CPM determines the minimum time needed to complete the project. In the management of a project, it is often possible to compress the duration of some of the activities at an additional expense in order to reduce the total project’s

duration, and generally there is a due date (or in some cases called soft deadline) for project completion, so a decision problem considered in the project management literature is to determine the activities for crashing and the extent of crashing. By assuming that the direct cost of an activity varies with time (limited by normal and crash times), mathematical programming models were developed to minimize the project direct cost (Iranmanesh, H. 2008) .

3.3 Estimating Activity Time

Determining the elapsed time between events requires that responsible functional managers evaluate the situation and submit their best estimates.

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

The best project managers continually try to assess what can go wrong and perform perturbation analysis on the schedule. (This should be obvious because the constraints and objectives of the project can change during execution.) Primary objectives on a schedule are: (Kerzner H., 2006)

- **Best time**
- **Least cost**
- **Least risk**

Secondary objectives include:

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

Obviously, these objectives are limited by such constraints as:

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

3.4 PERT& CPM Critical path Procedure

Develop a list of the activities that make up the project.

1- **Determine the immediate predecessors for each activity in the project.**
2- **Estimate the completion time for each activity.**
3- **Draw a project network depicting the activities and immediate predecessors listed in steps 1 and 2.**
4- **Use the project network and the activity time estimates to determine the earliest start and the earliest finish time for each activity by making a forward pass through the network. The earliest finish time for the last activity in the project identifies the total time required to complete the project.**

5- Use the project completion time identified in step 5 as the latest finish time for the last activity and make a backward pass though the network to identify the latest start and latest finish time for each activity. (Sweeney Dennis J. & Anderson David R., 2009)

3.5 Effects of Activity Dependencies

A dependency is simply a relationship that exists between pairs of activities. To say that activity (A) depends on activity (B) means that activity (B) produces a deliverable that is needed in order to do the work associated with activity (A) There are four types of activity dependencies. (Wysocki et al., 2000)

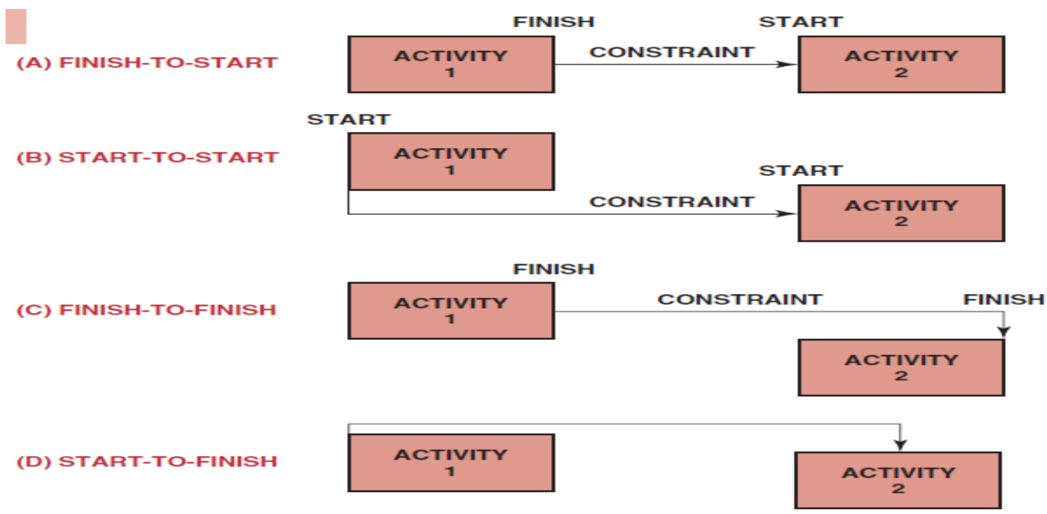
A - Finish to start: The finish to start (FTS) dependency says that activity (A) must be complete before activity (B) can begin. The finish to start dependency is displayed with an arrow emanating from the right edge of the predecessor activity and leading to the left edge of the successor activity.

B- Start to start : The start to start (SS) dependency says that activity (B) may begin once activity (A) has begun. The start to start dependency is displayed with an arrow emanating from the left edge of the predecessor (A) and leading to the left edge of the successor(B).

C- Start to finish: The start to finish (SF) dependency is a little more complex than the (FS) and (SS) dependencies. Here activity (B) can not be finished sooner than activity (A) has started. The start to finish dependency is displayed with an arrow emanating from the left edge of activity (A) to the right edge of activity (B).

D- Finish to finish: The finish to finish (FF) dependency states that activity (B) can not finish sooner than activity (A). The finish to finish dependency is displayed with an arrow emanating from the right edge of activity (A) to the right edge of activity (B). (Wysocki et al, 2000) shown in Figure (4) in each of these figures, work is accomplished during the activity.

This is sometimes referred to as the activity-on-node method. The arrow represents the relationship or constraint between activities. (Kerzner,H,2006)



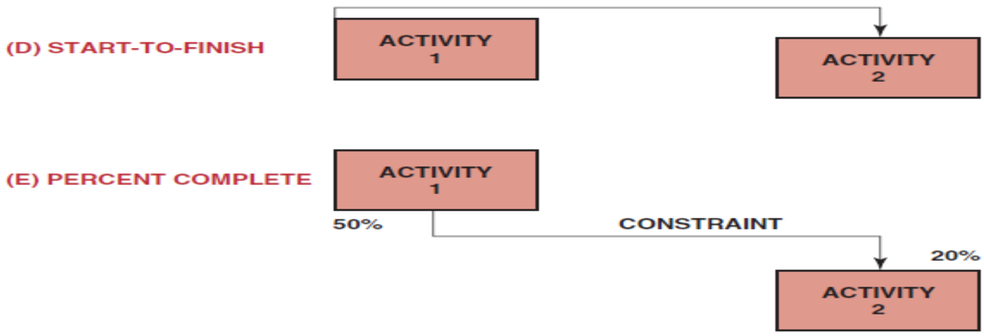


Figure (4) Typical Precedence Relationships

Kerzner Harold, "Project Management " A Systems Approach to Planning, Scheduling, and Controlling, 9ed, Published by John Wiley & Sons, Inc., Hoboken, New Jersey 2006.

E- SLACK Extra time an activity is allowed before it delays the project (assuming that it begins at ES). Under this definition, "slack" is sometimes also called "total slack" or "total float." In a network, earliest start and finish times are found by repeatedly calculating from the beginning of the project node (A) until the end (END). Use the following equations:
Earliest Start time = ES = max [EF of immediate predecessors]……1
Earliest Finish time = EF = ES + activity duration……..2
Latest start and finish times for each activity are found by working backwards, from the end of the project to the beginning:
Latest Finish time = LF = min [LS of immediate successors]…….3
Latest Start time = LS = LF - activity duration……4
(*Robert A. Shumsky*, 2003)

3.6 Slack time

AS the name implies, is the time when one can relax, delay a task but still the project is finished on time. A more formal definition from the Project Management Body of knowledge (PMBOK) is "The amount of time that a schedule activity can be delayed without delaying the early start of any immediately following schedule activities." Slack time is such an adverse-sounding term that managers tend to remove them in the schedule and present one that does not contain it to impress their bosses or clients. While this may look good on the surface, there are consequences when reducing slack times is not done properly.

For starters, accept the fact that slack times are a normal phenomenon in project schedules. The role of a manager is to identify and minimize them. By identifying the slack time, a manager becomes aware in keeping estimates and dependencies accurate. Once there is acceptance, start thinking of ways to reduce slack times and improve productivity. Determining the best strategy separates experienced managers from the novice, but some of the common ways are: (Project SMART, 2008) *http://www.executivebrief.com/*

- **Give additional tasks to the resource assigned during the slack time.**
- **Ask the resource to help out in other critical tasks.**

- **Share the resource with another project.**

The activity slack for each node may be easily calculated:
Activity Slack = SLACK = LS - ES = LF – EF …….5

In any network, there will be activities with zero slack. Any delay to these activities will produce a delay in the completion of the project as a whole. We call these tasks *critical activities*, and a path through the network made up of critical activities is called a *critical path*. There will always be at least one critical path, and there may be more than one.

All critical paths have the same length. Not surprisingly, critical paths are the longest paths through the network and the length of a critical path is equal to the duration of the Project (*Robert A. Shumsky,*2003).

3.7 Crashing

Crashing is the process of fine-tuning your project schedule to shorten delivery time. It is a possible solution when stakeholders ask for a faster delivery while not willing to reduce the scope of work. So, how does crashing work? Simple. Reduce the time to complete the tasks in the critical path. Note that crashing works only on tasks in the critical path because reducing time on non-critical tasks will not affect the project delivery time. Do not waste your time crashing non-critical path tasks; instead, crash on tasks in the critical path to get immediate results.

You can think of several ways to crash a task. You can put two resources to work in parallel and have the task completed in half the time. Or you can assign a more productive resource who can finish the work earlier. In any case, make sure you assess the risks. There are tasks that cannot be performed by two persons, like installing a software or hammering a nail. Also, make sure you are not over-assigning critical tasks to your best resource, because he can only be 100% productive and anything above it will be counter-productive. It is mindless to assume that your best resource can work 16 hours a day for the next three weeks.(Meyer Brad C.2002) (Project SMART, 2008) *http://www.executivebrief.com/*

For many projects there is a trade-off between project cost and project duration. When a project lags behind its schedule, extra people may be assigned to the job to speed it up.

Even for an on-time project there may be opportunities to 'crash' the project by hiring personnel or purchasing additional equipment. A manager must assess the costs and benefits of speeding up the project. *(Robert A. Shumsky* 2003)

3.8 Method for Crashing a Project

Step 1: Assess the cost-effectiveness of crashing activities on the critical paths (it may be necessary to crash more than one activity to have an effect). If no set of crashes leads to a net gain, stop;
Step 2: Implement the most cost-effective crash until it is no longer cost effective or the paths involved are no longer critical;
Step 3: A crash in step (2) may create new critical paths. Revise the network and identify the new critical paths. Return to step (1). *(Robert A. Shumsky* 2003)

3.9 The benefits of network planning techniques (Reid ,2002,P520)

- Graphical display of the project, including the relationships and sequence of activities.
- Estimate of the expected project length.
- Method for determining which activities is critical to the timely completion of the project and is therefore included in the critical path.
- Method for determining the amount of slack associated with individual projects activities.

4-Scheduling of the Cooling Tower Process for Crashing Time

4-1 Introduction

Investigate the scheduling for the Cooling Tower process in order to suggest improvements that could reduce the time by crashing the time. The schedule analysis project activities consist of (17) different activates including different works. As shown in table (1). The process is simulated to reveal its critical path, which identifies the activities that determine the overall completion time required by the process. The analysis of the project which have been developed according to a timeline that stretches into the days, are used to formulate an estimation of the time to recovery and assess the efficiency of the schedule of repair activities. An evaluation of the tradeoffs between the time to recovery and resource investments is used to investigate how costly project delays can be avoided.

4-2 Requirements for Projects

1. Well defined activities

Dismantle Steel Structure ------- 46 days
Transfer Steel Remaining ------- 15 days

2. Some Activities may be started & finished independently
3. Some activities may require completion of other activities
4. If an activity is started, it must be completed without interruption

Table (1)

NO	Activity	Activity Description	Predecessors	Tim activity (days)
1	A	Dismantle Steel Structure	-	46
2	B	Transfer Steel Remaining	A	15
3	C	Bracing Concert Beams	A	30
4	D	Concreting Tie Beams	C	16
5	E	Prepare Pre-cast Pieces	B	90
6	F	Assemble Wall Pre-cast	D	80
7	G	Concreting Columns	D	90
8	H	Concreting Roof Beams	F,G	46
9	I	Building Electric room	E	15
10	J	Concert for Roof	H,I	15
11	K	Assemble Roof Pre-cast	J	31
12	L	Fabricate Round Outlet	-	45
13	M	Fabricate Steel Ladder	-	60
14	N	Fabricate Hand Rail	-	31
15	O	Install the steel Leader	M	14
16	P	Concrete Round Outlet	L	15
17	Q	Install Steel Hand Rail	O,N	15

4-3 Network Representation of a Project

Project and activities represented by a network.

Network is a graph showing each activity to be performed, its predecessor & successor

- Activity: Represented by an arrow - generally needs some resource for its performance

Use letters

Nodes: Activities end or start at points called nodes Represented by circles/ Use numbers

Event: A point in time

Dummy Activity: Uses no resources & is used for showing precedence requirements only, figure (5) show network of a project

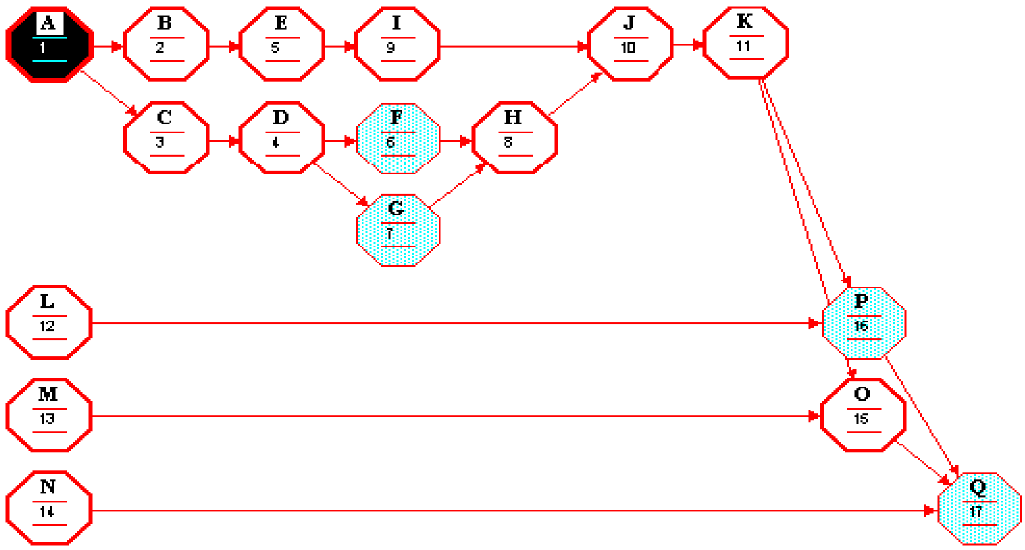


Figure (5) Shown Network of Activities

4-4 Establishment of Critical Path

Critical Path: Minimum time needed for completion of project. And paths of project:

- A-B-E-I-J-K-P-G = 46+15+ 90+ 45 + 15+ 31+ 15+ 15 =272
- A-B-E-I-J-K-O-Q = 46+ 15+ 90+ 45+ 15+ 31 + 15+ 15=272
- A-C-D-F-H-J-K-P-Q = 46+ 30+ 16+ 80+ 46 + 15 + 31+ 15 +15 = 294
- A-C-D-F-H-J-K-O-Q = 46+ 30 + 16+ 80+ 46 + 15+ 31 + 15 + 15 =294
- A-C-D-G-H-J-K-P-Q = 46 + 30 + 16 + 90+ 46+ 15+ 31 + 15 +15 = 304
- A-C-D-G-H-J-K-O-Q = 46 + 30 + 16 + 90 + 46 +15 + 31 + 14 +15 =304
- L-P-Q = 45+ 15 + 15 =75
- M-O-Q = 60+ 15 +15 =90
- N-Q = 31 + 15 = 46

Method: Sequence of activities with no slack time - Add times of all these activities

Slack: Is determined by finding earliest/latest start and finish times.

Earliest Starting Time: Earliest time an activity can be started when all preceding activities are completed as quickly as possible.

Earliest Finish Time: EF = ES + t , (t = time for an activity)

Latest Starting Time: Latest time when an activity can be started (for finishing project
in appropriate time)

Latest Finish Time: LF = LS + t OR LS = LF - t

We first develop a network diagram. Then we find ES,EF moving forward in the network
and LS, LF by moving backward in the network.

Then Slack = LS – ES OR Slack = LF - EF

Table (2)

NO	Activity	ES	EF	LS	LF
1	A	0	46	0	46
2	B	46	61	78	93
3	C	46	76	46	76
4	D	76	92	76	92
5	E	61	151	93	183
6	F	92	172	102	182
7	G	92	182	92	182
8	H	182	228	182	228
9	I	151	196	183	228
10	J	228	243	228	243
11	K	243	274	243	274
12	L	0	45	229	274
13	M	0	60	214	274
14	N	0	31	258	289
15	O	274	288	275	289
16	P	274	289	274	289
17	Q	289	304	289	304

4.5 'Crashing' a Project to Shorten Duration

This is the project of doing one or more activities in a shorter than normal time.

Questions to be answered:-

1- **How much does it cost activities?**
2- **Do the benefits of completing the project in a shorter than normal times outweigh the extra cost of crashing activities?**

Sometime crashing is necessary because an activity gets behind and the project is in danger of being late

4-5-1 TIME – COST TRADEOFF

It may be possible to reduce time needed to complete an activity by utilizing more resources (workers, machinery etc.) ---- This will result in extra costs (labor, overtime,…etc).

These are increases in direct costs.

Indirect costs such as supervisory, management, other overhead may be reduced because of reduced time for completing the project. In addition, there may be savings due to avoidance of penalty costs. MINIMUM COST schedule is obtained by balancing the two costs, figure (6) show this.

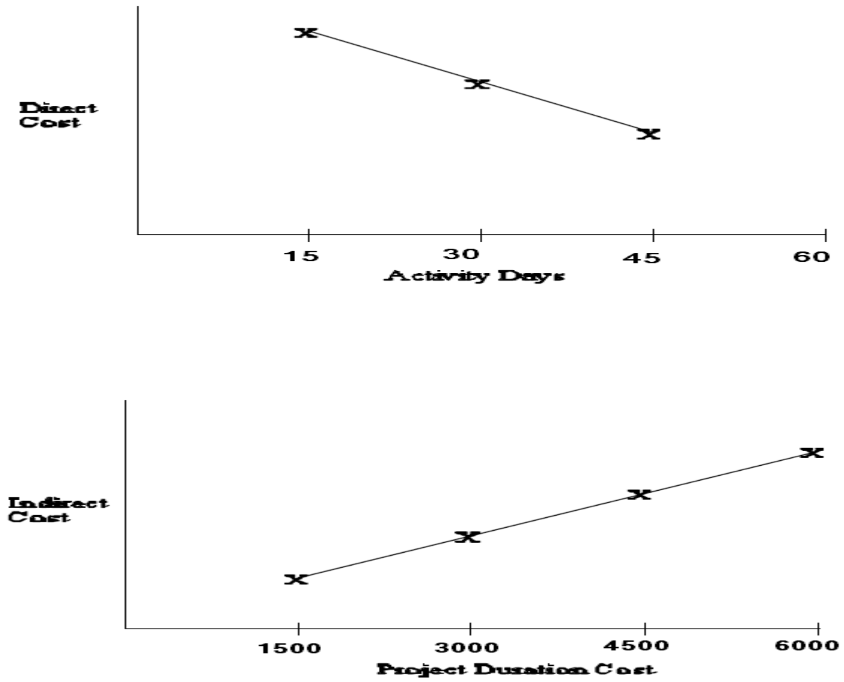


Figure (6)Activity day & Duration cost

4-5-2 Cost Monitoring Path

The information related to cost monitoring of activities as show on table (3) showed that all activates expected to be finished with material cost and labor cost

Table (3)

NO	Activity	Activity Description	Material cost /(000)D	Labor cost /(000)D	Normal cost /(000)D
1	A	Dismantle Steel Structure	650	7000	7650
2	B	Transfer Steel Remaining	-	2300	2300
3	C	Bracing Concert Beams	-	3000	3000
4	D	Concreting Tie Beams	2500	1000	3500
5	E	Prepare Pre-cast Pieces	30000	15000	45000
6	F	Assemble Wall Pre-cast	-	20500	20500
7	G	Concreting Columns	21000	9000	30000
8	H	Concreting Roof Beams	8000	3500	11500
9	I	Building Electric room	-	2000	2000
10	J	Concert for Roof	4000	2000	6000
11	K	Assemble Roof Pre-cast	2200	1000	3200
12	L	Fabricate Round Outlet	4800	1200	6000
13	M	Fabricate Steel Ladder	4000	1300	5300
14	N	Fabricate Hand Rail	800	200	1000
15	O	Install the steel Leader	250	1950	2200
16	P	Concrete Round Outlet	2500	1500	4000
17	Q	Install Steel Hand Rail	40	400	440

4-5-3 Procedure to minimum cost schedule

Let NT = normal time = completion time of an activity with normal allocation of resources
NC = normal cost = cost associated with NT
CT = crash time = shortest possible completion time of an activity with extra resources.
CC = crash cost = cost/day associated with CT (assumed linear)
M = The cost slope and calculated as :

$$M = \frac{\text{Crash cost} - \text{normal cost}}{\text{Normal time} - \text{crash time}} \quad \ldots\ldots\ldots\ldots 6$$

1. Prepare network diagram
2. Find ES, LS, EF, LF, slack, critical path and normal time (normal cost)schedule
3. Determine direct cost of decreasing activity time by one unit for all the activities on the critical path -- choose activity with minimum direct cost.
4. Weigh it against the decrease in indirect cost by one unit.
5. If Indirect cost reduction > direct cost; reduce the activity by time one unit.
CAUTION: Make sure that critical path does not change.
6. Go step # 3 and repeat till minimum cost schedule is obtained

Table (4)

NO	Activity	Time		cost		Cost slop
		NT	CT	NC (000)	CC (000)	M
1	A	46	30	7650	9500	116
2	B	15	7	2300	3500	150
3	C	30	15	3000	4000	67
4	D	16	7	3500	4500	111
5	E	90	60	45000	50000	167
6	F	80	50	20500	25000	150
7	G	90	60	30000	37000	233
8	H	46	30	11500	15000	219
9	I	15	7	2000	7500	688
10	J	15	10	6000	8000	400
11	K	31	7	3200	5500	96
12	L	45	30	6000	7000	67
13	M	60	30	5300	7500	73
14	N	31	7	1000	2000	42
15	O	14	7	2200	3000	114
16	P	15	7	4000	5000	125
17	Q	15	7	440	800	45
	total	684	391	153590	194800	

5- Results

Because crashing a non-critical activity does not affect the overall project time to completion, only critical activities that can be crashed are considered. The activities to be crashed are chosen in order of increasing expense. Therefore, the activity with the smallest crash cost in Table (3) (Activity Q) is chosen to be crashed first. Thus, the time required for Activity Q decreases from 15 to 7 days , and the project cost increases by (360 D). The next activity to be crashed is Activity C, because it has the next highest crash cost. This progression continues until all critical activities have been crashed.

The analysis shows that, because nearly some of the activities lie on the critical path, the current schedule of repair activities is sensitive and highly dependent on a majority of the activities being completed on time.

Critical Path is A-C-D-G-H-J-K-P-Q
Normal Time for critical path = 46+ 30 + 16+ 90 + 46 +15+ 31 +15+ 15 = 304 days

1- Minimum direct cost activity on the critical path is Q(440)
Savings the cost =800
We use extra resources and reduce activity time of Q by 8 day (15 to 7 days)
Critical path time = 298 days
The total cost = 154310
Note: Critical path is still the same

2- Minimum direct cost activity is C is 3000
Saying the cost = 4000
reduce activity time of C by 15 day (30 to 15 days)
Critical path time = 283 days
The total cost = 155310
Note: Critical path is still the same

3- Minimum direct cost activity is K is 3200
Saying the cost = 5500
reduce activity time of K by 16 day (31 to 15 days)
Critical path time = 267 days
The total cost = 157610
Note: Critical path is still the same

4- Minimum direct cost activity is D is 3500
Saying the cost = 4500
reduce activity time of D by 9 day (16 to 7 days)
Critical path time = 258 days
The total cost = 158610
Note: Critical path is still the same

5- Minimum direct cost activity is P is 4000
Saying the cost = 5000
reduce activity time of K by 8 day (15 to 7 days)
Critical path time = 250 days

The total cost = 159610
Note: Critical path is still the same

6- **Minimum direct cost activity is J is 6000**
Saying the cost = 8000
reduce activity time of J by 5 day (15 to 10 days)
Critical path time = 245 days
The total cost = 161610
Note: Critical path is still the same

7- **Minimum direct cost activity is A is 7650**
Saying the cost = 9500
reduce activity time of A by 16 day (46 to 30 days)
Critical path time = 229 days
The total cost = 163460
Note: Critical path is still the same

8- **Minimum direct cost activity is H is 11500**
Saying the cost = 15000
reduce activity time of H by 16 day (46 to 30 days)
Critical path time = 213 days
The total cost = 166960
Note: Critical path is still the same

9- **Minimum direct cost activity is G is 30000**
Saying the cost = 37000
reduce activity time of G by 30 day (90 to 60 days)
Critical path time = 183 days
The total cost = 173960
more than savings of 153590 D/day

Optimal (Minimum cost) critical path time is 183 days with total cost of project 153,590 (000 D)

Though the project costs remain stable across continual reductions in project time, a significant cost change occurs when reducing the project time to 183 days, which results from the crashing of activities, the installation process.

6- Conclusion & Recommendations

1- In the project management literature, quantitative models were developed for project crashing to determine the appropriate activities for crashing at minimal cost. In this paper, we suggest that the project quality may be affected by project crashing and develop models to study the tradeoffs among time, cost, and quality.

2- many traditional cost –time trades off models are computational expensive to use due to the complexity of algorithms especially large scale problems .in this

paper shown the overall repair process completion time can be reduced if the individual activities lying on the critical path of the repair process are completed in less time. The length of time required by an activity depends on the resources available. For example, if more personnel are assigned to the assessment of damage (Activity A), then A could become a non-critical activity.

3- The project (The cooling Tower) investments should be further investigated in terms of the impact additional resources have on the time to completion of the installation process. Tradeoff analysis reveals that the
length of time required to complete the activities lying on the critical path of the repair process can be reduced, or crashed, without a significant increase in cost.

4-Reducing the length of completion time for the project activities, which places greater pressure on the resources employed (for example, equipment and more employments), may be prudent under extreme situations because of the minimal impact on cost.

5- In the project you must use the data to investigate the possibility of dividing up the equipment installation tasks into parallel operations. Examine the impacts of assigning more resources such as personnel and equipment to the installation task.

6- Value engineering technique for project activities must be compulsory for managers and contractors .

7- Daily project monitoring is a successful factor for successful projects .

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