Chapter 1
Introduction

Finishing a project on time, within cost constraints and the required quality standards determine the success of a project. Several techniques, models, research work have been undertaken to achieve these objectives of project management.

Maintaining the time-schedule of project, faces challenge due to two major reasons.

i. Sometimes allowable project duration is shorter than estimated normal duration. This may be due to over optimistic time estimate or time constraints enforced by market forces. Execution of project in a shorter time frame, calls for crashing or expediting of activities to meet the tight time schedule.

ii. Projects are dynamic and are carried out in changing environments under uncertainty. Among the factors liable to change the existing plan are: the revision of activities' duration estimates, delivery failures, changes in technical specifications, technical difficulties, unexpected weather conditions, and labour unrest. Due to environmental changes, it is very difficult to exactly maintain the project schedules.

So it is necessary to have a monitoring system that generates feedback enabling corrective action. Monitoring time-schedule is collecting information concerning the progress of the project. Control involves using the data obtained through monitoring to bring actual performance into congruence with the plan (Meredith and Mantel, 1989). A contractor's failure to complete a project on time may be a breach of contractual obligation that gives rise to a potential liability for delay damages (Finke, 1997). So if the project lags behind due to slippages or environmental factors, corrective action requires some activities to be expedited to ensure timely completion of project.

1.1 Literature Survey

Literature on monitoring and expediting of projects may be grouped into three main categories.
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- Prioritization of projects
- Time cost trade-off for crashing of project duration
- Development of systems for monitoring the progress of work to identify slack areas and taking corrective action

Expeditious control of project plans is a major challenge faced by project managers during project execution. Normally, projects are expedited by informal and intuitive method. But a rational approach would be to develop a system which can help in taking expediting decision on scientific basis based on project progress data.

Decision for expediting is generally based on assessment of delays. Shi et al. (2001) have presented a method for computing activity delays and assessing their contributions to project delay. The method consists of a set of equations, which can be coded into a computer program that allows speedy access to project delay information and activity contributions.

Normally, monitoring activities are held at regular intervals; however, other possibilities exist. Variable review periods provide several alternatives: less intensive monitoring in the early stages of the project and more reviews as the project moves toward completion; more frequent monitoring at the beginning and less afterward; review of the project upon the completion of each activity or major activities; or "progress plotting" (Schmidt, 1988). Some common factors affecting the amount of monitoring in a project are the cost of monitoring, total duration of the project, average time span of the tasks involved, the degree of completion of the project's groundwork, the urgency of the project, and exposure to delays due to unforeseen circumstances (Krupp, 1984).

Planners usually need to adjust the selection of resources in order to shorten or lengthen the project duration. Liu et al. (1995) have shown that a CPM network with only eight activities, each with two options, will have 256 \((2^8)\) alternatives. Exhaustive enumeration is not economically feasible even with very fast computers. They have presented an algorithm using linear and integer programming for making optimal resource selections that optimize time and cost of a construction project.

Lee and Yi (1999) have adopted a numerical approach to the integration of the time and cost data sets. In their research study, mathematical matrices of time and cost data sets of projects are defined. The interrelationships among the matrices are investigated and time and cost related matrix equations are presented. Based on
these they have developed a project planning and control algorithm that estimates the expected project cost and duration.

Padberg Frank [2004] has presented a dynamic software process model as a discrete-time Markov decision process. The software process stochastically moves between states over time. In each state, a scheduling action is chosen. Once an action has been chosen, the transition to the next state is governed by transition probabilities. Each transition bears some cost. An optimal scheduling strategy minimizes the expected project cost. The model focuses on capturing how the feedback between development activities affects the cost and schedule of a software project. Padberg has also used this model to compute optimal strategies for several sample projects and analyze the resulting optimal strategies.

A number of parameters such as, activity relationships, time lags, calendars, resources constraints, time elapsed, activity progress etc have effect on the project completion date. Que (2002) has presented an approach that considers all these factors in optimization of project management system by using Genetic Algorithm (GA).

During the execution phase, the project managers need to effectively plan the work with respect to work schedule, resources available and various other factors. Faniran et al. (1998) have provided a framework for the development of strategies for improving planning practices for construction projects. They have observed that while much emphasis is given to development of tactical and operational plans for project implementation; hardly any emphasis is given to development of schedules for monitoring and controlling project progress.

Sycamore and Collofello [1999] have described the use of system dynamics modelling for improving the planning and tracking abilities of project. They have used system dynamics modelling to develop a prototype tool to manage software projects. It uses four primary status indicators for monitoring progress of project, namely, (i) Schedule (ii) Budget (iii) Percent Complete and (iv) Quality. The status information collected on a project suggests problems requiring corrective actions. For this the tool abstracts the controllable elements into four basic parameters, namely (i) Resources, (ii) Work Sequence, (iii) Project Scope and (iv) Productivity.

Choo et al. (1999) have developed a database program called WorkPlan that has been created to systematically develop weekly work plans. It is shown that such
work plans can be used by crew foremen in scheduling work packages and allocating available labour and equipment resources. WorkPlan guides the user through the process of spelling out work packages, identifying constraints, checking constraint satisfaction, releasing work packages, and allocating resources; then at the end of the week, collecting field progress data and reasons for plan failure.

The above literature survey was done to determine broad objectives for doctoral research work. After finalization the board research objectives, further literature survey was done to gain greater insight of research area.

1.2 Research Objectives

The doctoral research work was done for following broad objectives.

i. To develop understanding of various issues relating to timely execution of projects

ii. To develop a dynamic model for monitoring and expediting of projects under uncertainty

iii. To develop model/ algorithm for time-cost-quality trade-off to crash the duration of a project

iv. To develop model to crash the duration of a project, monitoring and control of project in practical situation

1.3 Methodologies of Research

The following methodologies have been adopted in undertaking research work.

i. Do detailed literature survey relating to all major aspects of project management, particularly project planning and control.

ii. Study various models, algorithm, computer software related to project planning and control, activity crashing in project management, multi-project systems, and project management information system.

iii. Study various mathematical tools such as optimisation techniques, system dynamics, fuzzy logic, neural network, theory of constraints etc with a view to analyse how these can be applied in developing model for expediting of...
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iv. Collect data from some typical project for development and analysis of model for expediting of projects.
v. Develop and run computer simulation for testing of model.

1.4 View Point on Project Expediting

There can be different view points on project expediting depending on type of organization, organizational function and managerial activities. Many project-based organizations manage a number of simultaneous projects that share resources from a limited pool. The individual projects vary in terms of cost, requirement of resources, time, complexities, risks, demand of clients, deadline, etc. In order to satisfy the demands of every client, work is often pushed through the system. The client and the manager handling the project demand that their work be expedited on priority. So proper allocation of resources among projects to minimize the cost and meet the deadline of various clients is an important issue for managing multiple projects. Expediting can be done in multi-project environment by assigning priority to different project for preferential allocation of resources.

For managing a project, the total work content is often successively broken down into smaller and manageable work elements called activities. The work components are arranged in a tree-like hierarchical structure called 'Work Breakdown Structure' (WBS) of project. After the creation of work breakdown structure, the next step is to find the dependency among activities. For example the activity testing of program code cannot be undertaken unless coding activity is completed. Similarly coding activity cannot be done before design. Dependency among the different activities determines the order in which the different activities would be carried out. The sequential relationship among various activities can be effectively represented by activity network diagram. Project schedule is the time table of activities. It specifies the start date and end date of each activity. The schedule is decided based on:

- Activity dependency that specifies the requirement of precedence activities for executing an activity.
- Criticality of activity. The activities that are critical are scheduled on priority.
- Resources required for activities and availability of these resources at the
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given time. The resources are machinery, equipments, space and people are some important resources for any project.

A good plan determines successful execution. The success of a project much depends on its project plan. Sometimes the project is required to be done in less than its normal duration. This is called activity crashing. Activity crashing is done by reducing the duration of some activities by incurring extra cost. Here the key issue is to select and expedite the activities in such a way that it results in reduction in project duration at optimum cost. So planning is done to expedite some select activities. The selected activities are expedited accordingly by incurring extra cost to reduce the duration of the (time-cost trade-off). These problems are also popularly known as Time-Cost Trade-off problem in project management.

A work component may be considered as a project as well as an activity at the same time. Consider construction of new road highway between two cities. Construction of road may involve building of several big and small bridges. Construction of each bridge may be considered as activity of highway project. But for a contractor construction of a particular bridge may be project. Making the structural design of a bridge is an activity. But the consulting firm who is making the design may consider this as a project.

Decisions relating to expediting are taken in a dynamic environment based on actual progress data, obtained through monitoring (Meredith and Mantel, 1989). Once the project commences, progress reports monitor the advance of each activity and control actions are taken if required. Monitoring is collecting information concerning the time-schedule performance of the project. Criticality of projects as well as their activities changes with time due to various uncertainties inherent in project management. So expediting also involves quick response and decision-making relating to various issues that arise during project execution.

1.5 Overview of Thesis

The research work on monitoring and expediting of projects was done in three parts/ folds. The overview of this three fold thesis work is given below.

Expediting of projects is very important for minimizing project delays. Due to uncertainty factors the progress of work of a project may lag behind its schedule. So expediting some select projects is an important control action. The projects are
expedited with different intensity by using different expediting strategies. For this, individual projects requiring expediting must be identified. Normally, this is done by informal and intuitive method.

But when projects are expedited based only on intuitive judgment, it sometimes results in incurring expenditure on expediting projects that are not warranted. So it is desirable to follow a rational basis for taking these decisions. Determination of objective measures such as effectiveness index of expediting is useful in selecting priority level without any subjective bias. When numbers of projects are being executed simultaneously, each project is competing with the other for utilizing maximum share of organization resources. Determination of priority level of projects provides a basis for distribution of resources among projects. It also makes it easier for the project manager to incur extra expenditure for expediting a project. So a simple mathematical model has been developed and presented as the first fold of thesis work. Application of model has been illustrated by applying the same on some typical projects.

Minimizing time and cost are both preferred by the project manager. So the project expediting process can be transferred to the typical time-cost trade-off analysis. Time-cost trade-off means that we can shorten (i.e. crash) the duration of an activity by using additional resources/cost. The second fold of this thesis work is on time cost trade off for reducing the duration of project.

Traditionally, the time-cost problem is addressed by analytical approaches. The analytical method involves lot of computation work. The CPM-based analytical approaches, assume unlimited resources and the existence of a continuous time-cost function. However, given the discrete nature of many resources, the activities can often be crashed only stepwise. Activity crashing for discrete time-cost function is also known as the activity modes selection problem in project management. This problem is known to be NP-hard. Several sophisticated optimization and soft-computing techniques such as Dynamic Programming, Integer Programming, Genetic Algorithm, etc. that have been used for finding efficient solution to activity modes selection problem. These techniques are quite complex, and are difficult to apply to real life projects that consist of large number of activities. A simple method that can provide efficient solution to activity modes selection problem for project crashing is presented in the second part.

The method is based on simulation and is implemented on an electronic Dynamic Model for Monitoring and Expediting of Projects under Uncertainty 7
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The use of spreadsheets for solving the Management Science and Operations Research problems make the techniques more accessible to practitioners. Spreadsheets provide a natural interface for model building, are easy to use in terms of inputs, solutions and report generation, and allow users to perform what-if analysis. The method is illustrated with the help of examples. It is shown that an approach based on simple heuristic and deterministic simulation can give good result comparable to sophisticated optimization techniques.

The existing models and methods of project scheduling implicitly assume uniform quality while evaluating time/cost tradeoffs, but do not model quality explicitly. It was recently suggested that the quality of a project should also be taken into considerations in this decision-making. Currently many industries have started including clauses in project contracts that provide incentives for quality. These emerging contracts place an increasing pressure on decision makers to search for an optimal resource utilization plan that minimizes cost and time while maximizing its quality. Considering the inter twined effects of time, cost and quality in project management, it seems reasonable to develop a mathematical model, which considers project's time, cost and quality simultaneously. This problem may be hereafter referred to as Discrete Time Cost Quality Trade-off Problem (DTCQTP).

In DTCQTP, project's activities are performed in one of several alternatives. For each activity a set of time, cost and quality triplet, referred to as mode, are given. The proposed method to solve discrete Time Cost Trade-off problem was extended to include quality consideration. The method was tested on number of problems consisting of activities having discrete time, cost and quality relationship. Because of simplicity of this approach, it can easily be extended to solve other types of time-cost trade-off problems, when more constraints are added or more factors are considered.

In project management scenario, there is much uncertainty and also significant error in project estimate. So the exact solution obtained by analytical and quantitative techniques is also prone to error. Due to high complexity, quantitative and analytical methods are sometimes difficult to apply for activity crashing in the real project scenario. The qualitative assessment can be useful technique in these situations. A methodology based on qualitative assessment and group decision-making for activity crashing is presented in this study to reduce the duration of a project. The methodology is illustrated through a case study done on "Shutdown Dynamic Model for Monitoring and Expediting of Projects under Uncertainty"
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Maintenance Work" in a medium sized thermal power plant situated in Orissa, India. Shutdown maintenance work in any process plant consists of numerous inter-related activities and involves significant amount of resource and cost. Shutdown maintenance work is managed as a project. Since the plant remains idle during the shutdown period, it is very important to complete the shutdown maintenance work in minimum time. Activity crashing sometimes becomes necessary to reduce the duration of a project. The case study presented in this thesis illustrates how the complex problem of activity crashing can be solved by qualitative assessment through participation and involvement of people.

The third fold of my thesis work consists of developing a model and structured approach for monitoring and control of project activities at operational level. For purpose of planning and execution, a project is generally broken down into smaller manageable work packages called activities. The activities may be further broken down into individual tasks or work-elements for detailed planning and execution. In addition to planning, proper monitoring is also necessary for successful execution a project. Periodic progress reporting and use of earned value concept are useful project monitoring tools for senior managers. However it is also necessary to monitor different work-elements at operational level. Practically it is difficult to thoroughly monitor each and every work-element. Some tools, techniques and planning may be required for this purpose. The design and use of checklist for selective monitoring of work-elements at operational level is illustrated in this thesis.

Any real project is very complex. Many of the issues of project management are too difficult to be solved by mathematical programming. So the project tasks are very often undertaken on the basis of extremely informal planning. Project activities are also much non-routine in nature as compared to production. This poses problems to devise a structured method and to work in a structured way.

This thesis presents a structured approach for execution, monitoring and control of project activities at operational level. Here we have proposed subjective evaluation as a means to determine index for activity criticality for selective monitoring and control, index for readiness level for starting execution of an activity, and a structured way to sort out issues for execution of activities. The scope of this work was kept limited to operational aspects of task execution and did not include purchase of materials, recruitment of human resources, and finance.
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1.6 Structure of Thesis

The chapter 1 is this chapter. It gives the introduction and overview of the thesis. The chapter 2 describes the background theory related to the research work and the literature survey. It contains the gist of various literatures that was studied for carrying out this research work. Chapter 3 covers the first fold of my thesis work and describes the mathematical model for expediting the execution of projects under uncertainty. The second fold of my thesis work relates to activity crashing to reduce the duration of project. These are covered in chapter 4, 5 and 6. The third fold of my thesis work covered in chapter 7 and 8, relates to use of checklist and structured approach for monitoring and control of project activities. The result of research work is discussed in chapter 9. The chapter 10 gives the conclusion of my research work.

1.7 Usefulness of Research

Delays in completion of projects cause considerable loss due to following reasons.

- Loss of interest due to huge amount of locked-up capital in incomplete project
- Escalation of project cost result in further delay and losses
- Loss of reputation with customers, investors and bankers
- Loss due to liquidated damage clause that are invariably imposed in most project contracts

Expediting of activities is very important to minimise project delays. Expediting of activities is important also because jobs of project management are much less structured as compared to operation management. Large projects are very complex. Specialised software have been developed for managing such projects. Most project management software have excellent graphical tools, database systems, query and report generators. However there is need for developing more decision support (DSS) capabilities into these software. The research outcome will in some way help in developing intelligent project management software.

The idea of expediting can also be extended to other areas such as:
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- Inventory Management: for expediting supplies from vendors
- Marketing Management: for expediting shipment of goods and realisation of payments
- Production planning: for expediting jobs at different work stations

Expediting is an integral part of control. It has wide applicability. So the proposed research work will be quite useful.

1.8 Publication of Research Output

The output of this research work has resulted into six papers as given below.


5. Activity Modes Selection for Project Crashing through Deterministic Simulation, Accepted by ‘Journal of Industrial Engineering and Management’ on 11-10-2011 ref. JIEM#224 for publication in their forthcoming issue.


Out of above six papers, three papers have already been published, two papers have been accepted for publication and one paper is under review.