CHAPTER 1

INTRODUCTION

1.1 The Concept of Project

A project is defined as ‘something projected or proposed for execution; a plan, scheme, purpose or a proposal’. A project is ‘any undertaking with a defined starting point and defined objectives by which completion is identified’. According to Harrison, a project can be defined as a non-routine, non-repetitive, one-off undertaking, normally with discrete time. Project Management Institute (PMI), USA defines project as ‘a system involving the co-ordination of a number of separate department entities throughout the organization and which must be completed within prescribed schedules and time constraints’. According to the Encyclopedia of Management, project is ‘an organized unit dedicated to the attainment of goal—the successful completion of a development project on time, within budget, in conformance with pre-determined program specifications’. According to Little and Mirrless, a project is any scheme or part of a scheme for investing resources which can be reasonably analyzed and evaluated as an independent unit.

The project is a set of activities that must be completed in a pre-arrangement sequence. A project consumes resources. The resources required for the projects are men, material, money and time. The availability of resources in project is limited. The complex project can be divided into sub-tasks that accomplished in order to achieve to project goals. The goal of the project is to finish on time and budget with limited resources.

1.1.1 Concept of Project Management

Project management is defined as the process used to develop a plan or blueprint to achieve the delivery of a new product or service. It is a process that usually requires the integration of complex steps to achieve the organizational goals. The critical path method (CPM) and Program Evaluation Review Technique (PERT) are the key tools for scheduling in project management.

A schedule ‘network’ represents the project strategy. Activities, where the work is accomplished, are linked by relationships (e.g. finish-start, start-start, finish-to finish) showing how the work is planned. Strings of linked predecessor and successor activities constitute ‘paths’ through the
When two or more paths are to be done simultaneously, they are described as parallel paths.

In project management, generally there is a due date for the project completion. Therefore, in some situations, a project should be completed in a shorter duration than the normal duration. The method of reducing the project duration by shortening an activity time at a cost is called crashing. This important issue in project management is the time and cost trade-off which can be modeled as a mathematical program. By assuming that the direct cost of an activity varies with time, the solution of these mathematical programs determines the optimal duration of a project so that project cost is minimized.

These methods implicitly assume that appropriate resources are available when needed. But in case of practice resources are constrained. Therefore, a variety of mathematical programs have been proposed to tackle so-called resource constrained project scheduling problems. The heuristic methods and meta-heuristic methods are often used to solve large scale problems in practice.

1.1.2 Project Scheduling

Project scheduling has been a major objective of most models and methods proposed to help in planning and managing of projects. Initially, the study of project scheduling has been done considering just the duration and precedence conditions and ignoring the resource requirements.

Scheduling is the allocation of limited resources over time to perform a given set of jobs or activities. Other common uses of the term scheduling include:

- Project scheduling - the determination of activity times and project duration for complex projects composed of multiple activities with precedence relations;
- Workforce scheduling - the determination of the number of workers and their duty cycles to meet certain labor restrictions; and
- Timetabling - the determination of the matching of participants with each other and with resources;
The most important methods to schedule a project assuming deterministic durations are Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). However, most duration have a random nature and therefore, PERT is proposed to determine the distribution of the total duration.

The CPM is a fundamental technique developed for project management. Since the late 1950s, CPM techniques have become widely recognized as valuable tools for the planning and scheduling of large projects. In a traditional CPM analysis, the major objective is to schedule a project assuming deterministic durations. However, project activities must be scheduled under available resources. The activity duration can be looked upon as a function of resource availability. CPM is utilizes a single time estimate for each activity duration. In other words, an accurate estimate of the time required to complete a particular activity can be determined from past job experience.

CPM computes the shortest project completion duration and the completion date from the longest path through the network. The longest path is called the critical path. Any delay on the critical path will delay the project. Conversely, CPM shows that paths that are not critical can be delayed without necessarily delaying the project. It is essential for developing the logic of the project work and for managing the day-to-day project activities. The CPM schedule is only accurate if every activity is started as soon as possible and takes just as long as its duration estimate indicates. Project managers understand that projects do not ever go entirely according to plan, which is one reason for frequent status reviews. Since real projects do not work this way, CPM is just the beginning of project schedule management. Thus the schedule generated by CPM is an early start schedule.

The specific shortcomings of the CPM method are three fold. First, only single time estimates are applied to project activities. This provides no opportunity for the project manager to deal with activity uncertainty and risk. Second, a number of assumptions are made which limit the ability of the CPM analysis: namely, all of the activities are independent; all of the activities must be completed once. Third, all the activities required resources for execution which is available unlimited.
The basic scheduling algorithm (in CPM) is designed to schedule each activity at the earliest feasible time without violating precedence relations. In the schedule generated by CPM, activities are divided into two sets:

- A set of critical activities that are members of the longest sequence of activities connecting the starting point of the project to its end. Critical activities have a zero slack, that is, they cannot be delayed without delaying the end of the project.

- A set of non-critical activities. These activities can be delayed as long as the delay is no longer than the activity’s slack and the project can still finish on time.

A project consists of a set of interrelated activities that have to carry out in order to find the project completion. Project scheduling is a mechanism which translates the performance of a project plan into a sequence of activities to be executed in order to find the optimized project completion duration. The optimal project schedule must respect the precedence, duration, capacity and constraints. One most desirable objective of the scheduling is to minimize of the project duration (makespan). Other desirable objective are minimize the variation of resource usage over time, reduce extraordinary demands resources, and cost minimization. During project execution, project activities are often consider uncertainty, it may take more or less time than originally estimated, resources may be become unavailability, materials may be arrive behind the schedule, workers may be absents, may be costly in certain contexts. Project scheduling and managing the resources are among the top challenges in project management.

The development of PERT and CPM has been widely used by practitioner for planning, coordinating and solving scheduling problems. The planning and scheduling of project activities has vital importance because of amount of time, resource and materials requirements will be known before the commencement of the project. The PERT and CPM is useful to generate information for the project manager to plan and control the project more effectively. CPM is useful only when the project deadline is fixed and the resources are not constrained by either availability or time. However, both methods assume availability of unlimited resources. A traditional CPM schedule is not realistic since it assumes unlimited resources, some of which are highly limited in practice. Therefore, resource scheduling arises as a result of project scheduling problem with availability of limited resources becomes the most important factor affecting the
project scheduling performance. The scheduler must focus on making the best use of scarce resources through the project scheduling problem.

In project management, managing resources is a difficult process. The main task of the project scheduling process and the algorithms is to schedule the exact allocation of resources (e.g. people, machines, raw materials, etc.) to activities over time. A manager does not want to have too few resources because work will not get done in time and have too much of the resources, because the cost of ideal time will cut the profit. So the scheduler must take into account the trade-off between the reduction of certain activity duration by allocating more resources and increase in cost required as more resources are consumed. The common objective on a scheduling is the minimization of the project duration (makespan).

1.2 Research Background

1.2.1 Resource Constrained Project Scheduling Problems

Resource Constrained Project Scheduling Problem (RCPSP) is modeled as a static and deterministic problem and one of the most classical problems in project scheduling problem with the objective of makespan minimization. It consists of set of activities with processing times and scarce resources per time. In RCPSP the objective to allocate the resources to a set of interrelated activities, with associated processing times and resources limited per time and precedence relations between activities. The aim is to find the minimal scheduling that respects the precedence relations and resource limits (Brucker et al. 1999). The scheduling objective is to extend the project duration as small as possible to the original critical path duration in such a way that the source constraints are met.

The activities are interrelated by two kinds of constraints, first, precedence constraints force each activity not to be started before its entire immediate predecessor activities comprised in the set have been finished. Second, performing the activities requires renewable resources. In all the cases resources may be of three categories: (1) renewable which means that resources are limited in quantity but renewable from period to period (2) Non-renewable means that both the total amount is limited over the project life (3) double constrained means that the both the total and pre-period resource amounts are limited. When the resources are renewable, activity duration are
resource driven. The activity durations are independent continuous random variables, preemptive is not allowed. The problem is to determine when the activity will begin and which resource duration mode should be used in order to minimize the project duration. The objective of the problem is the feasible sequence for project activities such that makespan of project minimized.

The RCPSP is one of the most general and most difficult project scheduling problems and as generalization of the well know job shop problem. It belongs to the class of the NP (non-polynomial) hard problems (Blazemicz et al. 1983). Scheduling of multi projects under resource constrained is extremely difficult computation. Kelley (1963) solved the resource constrained project scheduling problem (RCPSP) for optimal solution or heuristic solution.

RCPSP can be divided into two categories: single project scheduling problem and the multi-project scheduling problem. There are two approaches have been used to solve the RCPSP. These techniques can be grouped into two categories: optimal based and heuristic base techniques. Optimization based techniques aim is to producing the best solution i.e. shortest project duration. Solving RCPSP with optimal solution is time consuming, and it increases exponentially as the problem scale increases. There are two approaches that can produce optimal solutions. The first approach maximizes and minimizes the objective function with set of constraints. The second approach involves enumeration techniques, generating possible solution that lead to the minimum project duration.

An optimization technique involves mathematical programming approach, including integer programming, dynamic programming, branch and bound methods have been considered for an optimal solution. Davis (1975) applied linear programming (LP) and dynamic programming to search an optimal solution. In order to obtain good scheduling for problems of practical size, in efficient time, heuristic approaches have been developed based on methods like priority rules, branch-bound algorithms and local search techniques. In particular, a branch-and-bound algorithm implemented by Demeulemeester and Herroelen (1992) has produced a good result.
1.2.2 Heuristic Approaches to Resource Constrained Project Scheduling

Resource constrained project scheduling problem (RCPSP) models can be classified into two categories: deterministic scheduling and non-deterministic scheduling. RCPSP focus mostly on deterministic situations. The most popular deterministic resource constrained models are heuristic and meta-heuristic. The classical RCPSP schedule the project to minimize its total duration subject to precedence relationship and availability of renewable resources.

If resources are not sufficient available for the commencement of an activity, the activity is delayed for non-adequate of resources. The aim is to minimize the project duration caused by the resource shortage. It is required to assigned priorities to the activities which demand for the same resources and best combination of activity priorities is searched by analytic or heuristic algorithms. The heuristic can be defined as the method that facilitates the process of finding the solution group by means of a simple rule. The limited resource project scheduling problem falls into a category of combinatorial problems.

The heuristic procedures classify into two categories: constructive heuristic and improvement heuristic. In constructive heuristic consists of two major components: scheduling scheme and the priority rule. The scheduling scheme determines the feasible schedule by assigning starting times to the different activities. Heuristic based on priority rules have been one of the most important solution method for RCPSP. The priority rule determines the activities that selected during the heuristic processes with a specific algorithm. Priority rules based heuristic give some rule of thumb to determine priority among activities for available of resources. They combine one or two priority rules and scheduling scheme (serial or parallel) to generate one or more makespan and objective is to starting the activity with the minimum or the maximum value is selected.

1.2.3 Meta-heuristic Approaches to Resource Constrained Project Scheduling

The classical optimization techniques such as mathematical and heuristic approach cannot give optimal solution for large scale project scheduling problems. The meta-heuristic such as genetic algorithm (GA), simulated annealing (SA), tabu search (TS), and ant colonies (AC) have been applied to RCPSP to find optimal or near optimal solution. Genetic algorithm(GA) approach has become popular in dealing with large combinatorial scheduling problem i.e. constrained or
unconstrained optimization, scheduling and sequencing, transportation, reliability optimization, artificial intelligence and many others (Goldberg, 1989). Although genetic algorithm based search does not always give an optimal solutions but it can give feasible and near optimal solutions may provide sufficient information for decision making. Resource constrained project scheduling problem belongs to one type of sequencing problem. Genetic algorithm allocates the individual activities in a possible sequence manner to solve a resource constrained allocation problem for minimum makespan.

The meta-heuristic approaches for searching optimal solution from possible solution has more costly, take more time for compute and complex then heuristic methods. The advantages of heuristic methods are very simple to understand, less cost and computational time, easy to apply and making it manageable for practical size of problems (Hegazy, 1999).

In resource constrained project scheduling problem time-cost trade-off analysis is one of the most important for project planning and control. The objective of time-cost trade-off is to allocate available resources to project activities so that the tasks of the project can be completed with required duration and at a minimum time. IN RCPSP, mathematical or heuristic model are more efficient algorithms to obtain good and near optimal solution for practical projects.

1.3 Motivation of Research

Predicting a project success of failure is mostly depending upon project scheduling factors. Most of the professional of project management organizations have given a little important to the resource constrained project scheduling procedures that constitute the main part of the project scheduling research. However, the most of the project planning software do not include sufficient details of the capability of dealing with resource constrained project scheduling problems. Wit De and Herroelen (1990) report shows that the procedures for resource leveling and resource constrained scheduling used by the commercial project software packages are not explained the details. This motivates to conduct a research to develop an effective and efficient scheduling procedure and solution approach that are applicable in practical project settings.
1.4 Objectives of Research

Decision making is the most important function of the management. It is the quality of the management decisions which ultimately decides on the profitability and long growth of any business. Today's business has to live with a large number of constraints like shortages of raw materials, delay in deliveries from vendor, insufficient funds etc.

The objectives of the research is to analyzing the heuristic models and their scheduling generation scheme, priority rules, meta-heuristics, genetic algorithm (GA) models for project scheduling problems under resource constrained environment. These techniques address some important practical problems (1) scheduling in the phase of uncertain estimates on activity durations with resource constrained condition (2) integrated planning of scheduling and resources allocation (3) scheduling in unstructured or poor formulation circumstances (4) Trade-off between the project completion times with project budgets.

The main objective of this research is to compare the heuristic and meta-heuristic algorithm and their performance for the medium and large project networks with resource constrained project scheduling problems. The process of resource allocation finds an optimal allocation of a limited resource for optimizing the objective function subject to the resource constrained.

1.5 Scope of Research

In order to achieve the objective of research, the scope of the study includes of randomly selection of projects from project library and test priority rules with scheduling schemes. The results compare with the priority rules using statistical tools. The problems are consider with resources are renewable, preemption is not allowed. Most of the resource constrained projects scheduling problems have been made under deterministic resource constrained project scheduling such as level of resource of each type and level of resource availability of each resource type remain constant throughout the scheduling process.

Effective and efficient scheduling methods like meta-heuristics: genetic algorithms, simulated annealing, tabu search, stochastic project scheduling and ant colonies have been applied to RCPSP to find optimal or near optimal solution. We have focused to develop genetic algorithms,
stochastic project scheduling algorithm for RCPSP for finding better solution. The genetic
algorithm is coded in a computer program in visual C++ and enable user to solve the various
project problems with given input. The verification and validation of the algorithm is using
experimental model examples of different projects.

1.6 Gaps in Existing Research

The survey conducted among project management practitioners revel that there is a wide gap
between project management practice and the development of project scheduling theory. Study
reveal that managers often use information systems for project planning mainly for
communication and representation, rather than for optimization. There is a lack in finding an
effective procedure for RCPSP that is computationally optimal or near optimal for large and
complex projects which occur in practice. The commercial software package for project
planning does not focused on resource constrained project scheduling in details. Most research
efforts have concentrated on single project scheduling, while surveys indicate that multi-project
settings often occur in practice. The current practice of validating exact and heuristic scheduling
procedures generated by commonly used problem reveals that the need for additional research.

1.7 Problem Statement

The main objective of research on Resource Constrained Project Scheduling Problem (RCPSP) is
to obtaining optimal or near optimal solution for resource allocation and project completion. This
research aim is to develop effective algorithms for RCPSP that search feasible optimal and/or
near optimal solution for the RCPSP with complex network and limited renewable resources.
The study of heuristic algorithms, Davis E. W. (1975), Patterson and Huber (1974), Davis and
Heidorn (1971) have shown that one heuristic which gives a good result for a project might not
give that much successful result for another project. This is a greatest disadvantage of the
heuristic rules perform well on one problem cannot give grante to perform well in the other
problem. Even most sophisticated heuristic algorithms cannot give guarantee in which particular
heuristic or combination of heuristic will produced best results for a given problem. Even if not
guarantee finding global optima and/or near optima, heuristic algorithms are used widely for the
solution of RCPSP.
Meta-heuristic methods like genetic algorithm (GA) have been recognized as a powerful techniques based on the biological concept of survival of the fitness. This GA has been proven a most effective at obtaining near optimal solutions than the analytical techniques.

This thesis consists of solution of different type of RCPSP. Firstly, it is aim to compare the heuristic algorithms and performance for medium and large sized project networks with resource constrained project scheduling problems. The project with multi-mode activity execution aim is to minimize the project duration by choosing the activity priority and their execution mode. Secondly, the aim is to developing a genetic algorithm for finding an efficient optimal or near optimal algorithms to the RCPSP and need for a global search approach to the problem. Thirdly, the aim is to develop an algorithm for cost-time trade-off and resource availability in stochastic PERT network by crashing the project activities for minimization of duration with limited resources.

1.8 Usefulness of Research

Scheduling and sequencing is concerned with the optimal allocation of scarce resources to activities over time. The project scheduling problem involves the scheduling of project activities subject to precedence and/or resource constraints. The practical application helps practitioners to plan and execute projects with multi project resource constrained environment within time and limited budget. Heuristic based scheduling procedure will compare of alternative sequencing rules, relative to one another, compare optimum and heuristic based solutions over a group of projects.

The powerful meta-heuristics method i.e. genetic algorithm (GA) would provide practitioners to uplift the performance of the commercially available project planning software and satisfying the various customer specifications. The crashing stochastic PERT network with resource constrained would help the practitioner to trade-off between resource availability and project duration for completion of project with the budget.
1.9 Thesis Outlines
This thesis consists of seven chapters. Chapter 1 presents concept of project management, research background, objectives and scope of the research, gaps in existing research, problem statement, usefulness of research and summarized the chapter outlines of the thesis. Chapter 2 presents literature review. The review starts with existing methods include various exact methods, heuristic and meta-heuristic approached and others. Chapter 3 presents research methodology. The overall research procedure is described. Chapter 4 contains description of heuristic method of resource constrained project scheduling problem. It described priority rules and their performance in various medium and large project scheduling problems.

Chapter 5 described proposed genetic algorithm (GA) and scheduling representation. The GA is tested with numerous problem instances for finding best fitness value. Chapter 6 presents stochastic crashing PERT network with resource constrained environment. The algorithm is developed and tested with two experimental models and summarized the performance of the algorithm. Chapter 7 summarized this thesis with conclusions, contributions and recommendation of possible future research and applications to industry.