CHAPTER 2
LITERATURE REVIEW

2.1 CPM and PERT
The CPM and PERT is a fundamental technique developed for project management assuming under the unlimited resource availability. In real life project activities must be schedule under the limited resource; such as limited crew sizes, limited equipment amounts and limited materials. The practical problem of allocating resources over the time to perform collective tasks arises in a variety of situation and frequency the scheduler must take account of the trade-off between availability of resources and activity duration. To solve these problems people use mathematical models but the primary disadvantage is that they could not solve bigger or complex problems. The scheduling of tasks and the allocation of resources in medium to large schedule projects is an extremely hard problems and challenges of project management due to its complexity. The resource constrained project scheduling problem (RCPSP) is one of the most classical scheduling problems.

2.2 Exact Solution Approaches

RCPSP is a NP-hard problem (Blazewicz, Lenstra, and Rinooy, 1883). NP-hard problems are very difficult to solve realistic size problem and it necessary to use of heuristic methods. In RCPSP, the complex problem with an exact solution is very time consuming. The application and difficulties of the RCPSP are continuously attracts the attention of researcher and project managers. A vast amount of research and literature is addressed RCPSP solution using
optimization or heuristic approaches (Demeulemeester and Herroelen 1992, Kolisch and Hartmann, 1999). The RCPSP are inheritably multi-objective, but most often solving deterministically for minimizing the project makespan while other objectives such as minimizing project cost maximizing net present value.

Herroelen and Leus (2004b, 2005) made a survey of the various approaches of scheduling under uncertainty. There is several solution procedures have been proposed in the literature. A very small sized problem with 30 activities can be solved exactly in satisfactory manner. Lova et al. (2000) developed a multi-criteria heuristic that improves lexicographically two criteria: one time type (mean project delay in relation to the unconstrained critical path duration or multi-project duration increase) and no time type (project splitting, in-process inventory, resource leveling or idle resources) that can be chosen by the user.

Patterson and Huber (1974) proposed bounding technique with 0-1 programming to produce minimum duration scheduling for the RCPSP by examining the feasibility of the series of zero-one programming problems rather than solving zero-one problem optimally. Doersch and Patterson (1977) developed a 0-1 integer programming model to handle the maximization of net present value subject to capital rationing constraints. Pritsker et al. (1969) and Patterson and Roth (1976) developed a 0-1 linear programming for the RCPSP with multiple resource constraints. Kolisch (1996b) explained the efficient priority rule for RCPSP. Kolisch and Sprecher (1996) considered a standard set of RCPSP and benchmarked by many researchers in the study of RCPSP. They were reported three important variables on the computational time for the RCPSP: computer memory, search strategy, and lower bound.

For solving RCPSP exactly, the most powerful exact procedure competitive algorithms has developed and seen in Brucker et al. (1999), Demeulemeester and Herroelen (1992), Klein (2000), Patterson et al., (1989), Sprecher (2000). Demeulemeester and Herroelen (1992) developed an effective branch-and-bound algorithm performed better than all other exact methods in RCPSP. However, the exact methods required exponentially more time as the number of constraints increases. These methods fail to get an optimal solution with a reasonable amount of time (Kolisch et al. 1995). The other disadvantage of these exact methods were that
they become computational incapable for the problem because the project size too large or solution algorithm is too lengthy or both. Thus the development of heuristics provides an important role for the solution techniques for large projects.

2.3 Heuristic Approaches
Solving in heuristic methods based on the serial and parallel scheduling generation schemes procedures make feasible solution to handle practical resource constrain project scheduling problem. Many heuristic approaches have been proposed in RCPSP. Ulusoy and Ozdamar (1995) made a comparable analysis on projects through parallel methods using different priority rules with non-renewable resources. In parallel method algorithms it takes multiple project decision criteria (resource constraints, activity duration, slack, latest finish, etc). Thomos and Lova (2003) developed an effective multi-pass heuristic for project scheduling with resource constraints problem.

Tormos and Lova (2001) described a hybrid multi-pass competitive heuristic solution technique for resource constrained project scheduling problem. They combined random sampling procedure with a forward and backward scheduling technique. They compared against the best availably heuristic using PSPLIB (Kolisch 1995, Kolisch and Sprecher 1996), the algorithm gives the best heuristic solution as compare with other algorithm for the RCPSP. Cooper (1976) proposed experimental investigation of heuristic method using randomizing techniques for scheduling resource constrained problem. He compered the parallel method with the sampling method produced better result with the parallel method.

Tsai and Chiu (1996) proposed two effective heuristic priority rules for resource constrained multi project scheduling. Valls et al. (2003) developed a two-phase local search methods based on the topological order representation and the serial SGS. In the first move, they used forward and backward direction and second move applied random sampling within a time window derived from the current solution. Wiest (1967) described a heuristc model for scheduling large project with limited resources. Russell (1986) addressed a comparison of heuristic for scheduling projects with cash flows and resource restriction.
Patterson (1976) described project scheduling and the effect of problem structure on heuristics performance. Ellen and John (1993) examined resource policies in a dynamic multi project environment. Abbasi and Arabiat (2001) analyzed project cash flow was classified according to a priority rule that can be described as a combination of the latest start time (LST) and shortest processing time (SPT) methods. Klevin (2000) used parallel methods and different priority rules and figured out that LFT priority gives better performance. Davis and Patterson (1975) looked at the effectiveness of various priority rules. In their study, the MINSLK priority rule gives the best result in comparison to other priority rules.

Kolisch and Hartmanna (1999) have given an over view of heuristics on X-pass methods with single pass, multi-pass methods, sampling procedure and meta-heuristic i.e. simulated annealing, genetic algorithms, and tabu search. The result shows that the best meta-heuristic outperform the best sampling approach. Schirmer (1999) schedule his projects with 30 activities and used heuristic rules, out of which LFT priority showed the highest level of performance. Hong et al. (2001) presented a resource allocation point that took into account the dynamic and stochastic characteristics of simulation system for the proposed of processing a decision making ability.

Talbot (1982) formulated the non-preemptive case with on resource constraints project scheduling problem for discrete duration resource tradeoff. He developed a solution technique that can be used for real life large scale problem. Drexl and Grunewald (1993) developed a stochastic model for solving RCPCP and it out forms the other existing heuristic rules. Lawrence and Morton (1993) addressed some work relating the single-mode, resource constrained multi-project scheduling problem.

Herroelen and Leus (2004) have dropped the hypothesis of unrestricted resource availability by using a resource flow network for robust resource allocation to a feasibility baseline scheduling. A branch-and-bound algorithm was proposed by the authors for this purpose. Kelley (1963) used the parallel generation scheduling scheme (PGSS) and serial generation scheduling scheme (SGSS) to find the optimum or near-optimum solution within a reasonable amount of time. Holland (1975) utilized genetic algorithms (GAs), which imitate natural evolution based on survival of the fittest, to search for an ideal solution.

Valls et al. (2003) developed a hybrid genetic algorithm with forward – backward improvement of activity list based genetic algorithm. Fleszar and Hindi (2004) applied Variable Neighborhood Search (VNS) in RCPSP. The shift of activities allowed moving together with their predecessors and successors. Boctor (1990) analyzed a combination of heuristic rules and the probability of getting best solution and the number of heuristic rules used. The combination of four or five heuristic rules will produce better result but cannot be suitable to solve a problem of large size.

Thomos and Lova (2001) developed an iterative forward-backward heuristic. Their approach used by serial or parallel schedule generation scheme (SGS) by means of regret-biased sampling method with the latest finish time priority rule. Kolisch (1996) developed three new priority rules for the parallel scheduling scheme and tests them in a single-pass mode. Kolisch (1996) compared some good priority rules within both the serial and the parallel scheduling scheme with sampling procedures.

Kolisch and Drexl (1996) introduced adaptive search procedure which applies a scheduling scheme. Alvarez-Valdes and Tamarit (1987) used Lagrangian relaxation in order to compute lower bounds on the minimal project make span. Palpant et al. (2004) developed a embedding forward and backward scheduling with the serial SGS and constraint-based optimization of partial scheduling with local search procedure. The overall procedure consists of activities, the optimal partial schedules, and forward and backward scheduling criterion. Kolisch and Hartmann (1999) presented heuristic algorithm for RCPSP.
2.4 Meta-heuristic Approaches

There are meta-heuristic approaches like genetic algorithms, tabu search, simulated annealing and ant colony systems are describe for the solution of RCPSP. Genetic algorithms are stochastic search based upon the mechanism of natural selection and population genetics. Holland (1975) was developed genetic algorithms (GA) based on mechanism of natural selection in biological system. It uses random direct search by the process of genetic evolution and principle of “survival of fittest”. Feng et al. (1997), Li et al. (1999) applied successfully genetic algorithm for construction scheduling for time-cost trade-off problems. There are several studies has been done in GA (Hartmann 1998, Alcaraz and Maroto 2001, Hartmann 2001, Hinid et al. 2002, Toklu 2002, Valls et al 2003, Chan et al 1996, Leu and Yang 1999, Hegazy 1999) used successfully to solve construction management problem with resource scheduling.

Hartmann (1998) developed a permutation based genetic algorithm making use of activity representation. The genetic algorithm of Hartmann (1998) performed best among the 16 heuristic tested in the computational study of Hartmann and Kolisch (2000). They used the serial SGS and add a gene that decides whether the activity list is scheduled in forward and backward direction. Leu and Yang (1999) proposed a multi-criteria computational model optimal scheduling model that integrated a time-cost trade off model, resource-limited model and a resource leveling model. The method produced more on suboptimal solutions for finding cost minimization. Hindi et al. (2002) developed a genetic algorithm employed the activity representation with serial SGS. The different form Hartmann (1998) algorithms are that the initial population is generated by a pure random process; while Hartmann (1998) generated an initial population based on the finish time based sampling. Toklu (2002) formed a genetic algorithm that applied on schedules using a vector of start times.

Xu et al. (2008) developed an augmenting priority heuristic rules to solve RCPSP. Alcaraz and Maroto (2001) developed a genetic algorithms based on activity priority value encoding with scheduling mode. The results showed that the variant using an encoding with scheduling mode generates better solutions than the variant where the encoding does not include the scheduling mode. Hartmann (2002) developed a self-adapting genetic algorithm for project scheduling under resources constraints conditions.
Hartmann (2001) presented a genetic algorithm for scheduling projects of multiple models of activity execution. The genetic encoding is based on a precedence feasible list of activities and a mode assignment. Valls et al. (2003) introduce a new a heuristic algorithm for RCPSP. The algorithm is implementation of fundamentals concepts of tabu search without explicitly using memory structures embedded in a population-based framework. Lee and Kim (1996) compared a genetic algorithm (GA), a simulated annealing heuristic, and a tabu search method. Al Fawzan and Haouari (2005) developed a multi-objective tabu search heuristic for solving a bi-objective RCPSP. They consider the objectiveness of quality-robustness maximization along with makespan minimization and used several variants of the algorithms in order to find an approximate set of effective solution.

Tabu search starts with looking to local minima. The search records moves in one or more tube lists in order to avoid retracing the steps used. Thomas and Salhi 1998, Klein 2000, Nonobe and Ibaraki (2002) applied tabu search in resource constrained project scheduling problem. Thomas and Salhi (1998) introduced a tabu search directly on scheduling by defining three different moves. Glover and Kochenberger (2003) employed the tabu search (TS) method to overcome regional optimized solution by multiple regional searches and the method depended on the ability of the flexible memory frame to sequentially record moving decisions from different cycles.

Boctor (1996) applied a simulated annealing to solve non-preemptive RCPSP problems, in which resources are limited but renewable from period to period. Lee and Kim (1996) developed a simulated annealing procedure to compare three meta-heuristic methods, such as genetic algorithm, a simulated annealing heuristic and a tabu search method (Cho and Kim 1997). The solution of simulated annealing and tabu search gives best solution then the genetic algorithm. Bouleimen and Lecocq (1996) developed a simulated annealing algorithm for multi-mode resource constraints project scheduling problem.

Dorigo et al. (1996) employed ant colony optimization (ACO) imitates an ant movement to find an optimal solution. The main objective of ant system include positive feedback for discovery of good solutions computation avoid premature convergence, use of constructive heuristic and help acceptable solution in early stage of the search process. Based on the simulation result, the ant colony optimization (ACO) is robust and can be used in RCPSP for optimization solution. Hindi (2004) presented a solution scheme based on variable neighborhood search for solving RCPSP. Zhang et al. (2006) developed partial swarm optimization based schemes for RCPSP. The solution to RCPSP in view of minimizing project duration is presented by the multidimensional particle. Merkel et al. (2002) developed first application of ant colony optimization (ACO) approach to the resource constrained project scheduling problem (RCPSP). They combine ant colony algorithm with other heuristics used by Hartmann and Kolisch (2000).