A Review paper on Resource Management and Scheduling Problems

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***Abstract*— The science of construction scheduling has been important for decades and has been the focus of construction management workers. Scheduling includes listing the milestones, activities, and deliverables of the project, with scheduled start and due dates. This is estimated in relation to resource allocation, budget and duration. Resource limits (manpower, machinery, materials, and money) are practical constraints that exist in most projects and limit the ability of the creator to run and deliver the project as planned. Resource-constrained Single Project Scheduling Problem (RCPSP) and Resource Constrained Multi-Project Scheduling Problem (RCMPSP) have become a well-known standard problem in project scheduling and have attracted numerous researchers in many areas. This article reviews various approaches adopted, such as ant colony optimization (ACO), constraint programming (CP), and backward-forward hybrid genetic algorithms (BFHGA) and focuses on researchers exploring the future scope of this area.**

***Index Terms*—Construction management, Scheduling, Resource constrained scheduling, Ant colony optimization, Constraint programing, Backward-forward hybrid genetic algorithm.**

I. INTRODUCTION

In project management, schedules are lists of milestones, activities, and artifacts of a project that typically have scheduled start and deadlines. These items are often predicted with respect to resource allocations, budgets, and duration linked to dependencies and scheduled events. Successful project management must be able to accurately map the logic and requirements of the project, as well as the manager's ability to manage the stated requirements and available project resources. Typical construction resources include manpower, machinery, materials, money, information and management decisions (Halpin and Woodhead 1998 [10]). A project map is a one-way, fully connected graph of activities that define projects that are fundamentally resource- and costly and can be resolved for the most important activities in the project.

Within the framework of mapping the project's logical network, the science of construction scheduling has become important and a focus for construction management personnel to identify the most important activities to achieve the flow of activities and the specified milestones. Despite its importance, practitioners are naturally dependent on traditional and proven methods because the construction industry is slow to adopt new methodologies. Resource limits are the practical limitations that exist in most projects and limit the ability of the constructor to run and deliver the project as planned.

Resource-constrained single project scheduling issues (RCPSPs) over the last few decades have become a well-known standard problem in project scheduling (Hartmann and Briskorn 2010 [12]) and have attracted many researchers in many fields, including operational research and construction management. RCPSP is nondeterministic polynomial time hard (NP-hard), and the optimal solution can only be achieved by a precise method of small-scale projects with fewer than 60 activities (Alcaraz and Maroto 2001). Therefore, many researchers proposed a heuristic and meta-heuristic method for RCPSP. Empirical research has focused primarily on priority rule-based methods. Meta heuristics, however, included a variety of methods such as genetic algorithm (GA), simulation annealing (SA), particle cluster optimization (PSO), ant colony optimization (ACO) and honeycomb optimization (HMO). And -heuristic. However, in today's business environment, companies manage multiple concurrent projects that share resources. Often, the availability of shared resources is limited and is not sufficient to schedule activities simultaneously. In this situation, optimal allocation of limited shared resources is critical to shortening the project duration and minimizing the cost of achieving project portfolio success.

II. LITERATURE REVIEW

Ant colony optimization is a population-based artificial multi-agent, general search technique proposed by Dorigo et al. al. (1996) [9]; Dorigo and Stutzle (2002) [7] and Dorigo and Blum (2005 [8]) presented solutions to difficult combination problems. Ant colony optimization is affected by the collective action of natural ant colony when optimizing the route from origin (ant nest) to destination (food source). Symeon Christodoulou (2010) [24] proposed a new and improved methodology for planning construction projects with limited resources using algorithms based on ACO using previously acquired knowledge. He applied ACO artificial agents to resource-constrained network topologies and then applied them to resource constrained networks. A case study investigated the impact of resource availability constraints on critical path calculations and project completion times.

We compared the proposed ACO-based Resource Constraint Scheduling Problem (RCSP) algorithm with traditional CPM algorithms and artificial intelligence techniques such as genetic algorithm (GA) and particle swarm optimization (PSO) algorithms. The ACO-based resource constraint scheduling problem algorithm has been found to be a better alternative considering various aspects such as arbitrary node computation, activity start time flexibility and absence of computation time.

The ACO Meta-heuristic provides users with an alternative way to configure the longest path solution in a promising network topology and to solve resource unconstrained and resource limited problems. Through the proposed algorithm, the solution obtained from the case study shows 100% accuracy for resource unconstrained problems and 97% for resource limited problems. The convergence to the obtained solution was made with very few iterations and the observed deviations in the resource constraints were within the allowable margin range. The limitation of this approach, however, is the assumption that resources can be transferred between projects without time and expense.

Constraint Programming (CP) has been used to combine operational research with logic programming techniques and successfully solve complex combination problems in various areas (Chan and Hu 2002 [4], Heipcke 1999 [13]). To make it easier to use CP algorithms to schedule problems, IBM developed a powerful software library called IBM ILOG CPLEX Optimization Studio (Beck et al. 2011 [2]). CPLEXCP incorporates the CP modeling tool (CPLEXCP), which includes special syntax for modeling scheduling problems and other combinatorial problems that can not be easily linearized or solved using traditional math programming methods. Unlike many met heuristic approaches, the CP model provides an almost optimal solution for project scheduling problems (MRCPSP) with limited multimodal resources for projects that are fast and have hundreds of activities in minutes. Wail Menesi and Tarek Hegazy (2014) [25] studied the multimode resource-constrained project scheduling problem (MRCPSP) to minimize the total project time and cost for large projects. In addition to a single objective multimodal model, another dual purpose multimodal model has been developed to minimize fluctuations in resource usage (resource leveling). Two case studies were considered to compare the results.

In the first case study, a single goal CP optimization was considered for small and medium-sized projects with activities of 10, 100, 500, 1000, 1500 and 2000. The results show that there are three met heuristic methods: ant colony optimization (ACO), particle group optimization (PSO) and genetic algorithm (GA). The results show superior performance of the CP model in terms of solution quality and throughput. The ACO algorithm was the best after PSO and GA. In the second case study, an interactive goal model was tested for the same activity. We found that the results are much better than the results of a single-purpose solution to a resource profile and do not require additional processing time. Thus, unlike many meta-heuristic approaches, the CP model with bidirectional goals provides a near-optimal solution for project scheduling problems (MRCPSP) with limited multimodal resource constraints for projects that are fast and have hundreds of activities in minutes.

Genetic algorithm (GA) is a population-based search algorithm based on evolutionary computational principles inspired by the Darwinian principle of natural selection (Holland, 1975). In recent years, interest in adoption of GAs has been increasing to optimize construction management issues. The problem of resource equalization, construction resource utilization plan, time-cost compromise problem and time-cost-quality compromise problem is one of the problems other than the resource constrained project scheduling problem (RCPSP) proposed by GA. On the other hand, simulated annealing (SA) is a probabilistic meta-heuristic algorithm inspired by the physical process of annealing. Simulation annealing is a popular local search meta-heuristic used to solve individual optimization problems such as Resource Constrained Multi Project Scheduling Problem (RCMPSP). Unlike GA, SA is not a population-based algorithm, but it uses energy functions to try to improve an individual's condition. Simulated annealing in construction management has been adopted for several optimization problems, such as cash flow optimization and resource leveling for linear schedules.

In recent years, many skilled combinations of simulated annealing and genetic algorithms have been proposed to achieve efficient search algorithms by incorporating the complementary strengths of both methods. The results of genetic algorithms using simulated annealing are promising because hybrid algorithms can escape local optimizations, have fine tuning capabilities, and can implement searches in parallel architectures (Wang and Zheng 2001 [26], Chen et al. Han et al. (2006), Chen and Shahandashti (2009), Sonmez and Bettemir 2012 (23).

The reverse forward (BF) scheduling method (Li and Willis 1992 [20]) combines the forward and reverse scheduling methods in a special way. BF scheduling starts with reverse scheduling scheduled as late as possible in the reverse time according to the priority list. When reverse scheduling is completed, forward scheduling is performed in order of the start time obtained from the reverse scheduling. Rifat Sonmez and Furkan Uysal (2014) [21] developed a method to implement efficient algorithms by integrating the complementary strengths of genetic algorithm (GA), simulation annealing (SA) optimization technique and reverse forward (BF) scheduling technique. Resources limited the Multiple Project Scheduling Problem (RCMPSP). Two case studies with a single project scheduling problem with resource constraints and a case study with multiple resource scheduling problems with limited resources were considered and compared to the heuristic methods.

The first case study was about a single project scheduling problem with limited resources and four projects were considered. The project had activities from 17 to 25 with resources between 1 and 6. We compared the results to RESCON. The optimal solution for a project network with relatively small resources, including finishing starting a priority relationship, is from RESCON. The Backward-Forward Hybrid Genetic Algorithm (BFHGA) was able to achieve a successful optimal solution within 0.5 CPU seconds. The results of the BFHGA were also compared to those of the ACO and were found to be excellent. The second case study was a resource-constrained multi-project scheduling problem and two multi-project cases presented by Chen and Shahandashti (2009). Five empirical methods, single genetic algorithm, single-simulation annealing algorithm, , A mathematically improved modified simulation annealing algorithm, and an algebraically improved modified simulation annealing algorithm. The first part consisted of three test projects, which included 74 activities and two resources, and the second part consisted of three actual projects, which included 130 activities and 11 resources. The result indicates that the Backward-Forward Hybrid Genetic Algorithm (BFHGA) is superior to both meta-heuristics for both test and real-life projects in minimizing duration. Among the five meted heuristics, the modified simulated annealing-2 method showed the best performance in the test project and the actual project, and the hybrid genetic algorithm using the simulated annealing method found the best solution.

Thus, Backward-Forward Hybrid Genetic Algorithm (BFHGA) proves to be very effective for the approach of resource constrained multi project scheduling problem (RCMPSP).

III. CONCLUSION AND FUTURE SCOPE

Scheduling is an important part of the project planning and it is affected by resource availability, budget and the duration. Limited resources are one of the common constraints observed in all the projects and it affects a constructor's ability to execute and deliver a project as originally planned. There is a need to develop the most optimum method to schedule a project keeping the resources as constraint. The approaches mentioned in this paper were resource constrained project scheduling problems (RCPSP), and the objective was to obtain optimum solution. All the approaches were non-deterministic polynomial-time hard (NP-hard) problems. The ant colony optimization (ACO) and Constraint programming (CP) are single project scheduling problems whereas Backward-Forward Hybrid Genetic Algorithm (BFHGA) is a multi-project scheduling problem. The ant colony optimization (ACO) and Backward-Forward Hybrid Genetic Algorithm (BFHGA) aims at single objective of optimum scheduling whereas Constraint programming (CP) model aims at resource levelling along with the optimal schedule. Many researches have been made in this field in past few years to optimize the solution and have obtained good results. But still there are many future works which the researchers should look for. Developing a bi-objective Constraint programming (CP) model for much more complex problems, model for linear project scheduling problems which would help the projects having repetitive activities such as road works and railway projects and for resource constrained multi-project scheduling problems may be taken as a future scope. Modification of ant colony optimization (ACO) approach mentioned in this paper by considering resource transfer times and costs, applying ant colony optimization (ACO) model for much more complex problems, developing a model for linear scheduling problem, bi-objective scheduling and combining ant colony optimization (ACO) with other met heuristics to get more optimal solutions for resource constrained project scheduling problem would be a promising area for future work. Further, the approaches mentioned in this paper viz. ant colony optimization, constraint programming and backward forward hybrid genetic algorithm may be tested in different type of civil constructions including minor and major irrigation projects. A comparative study of these approaches for small, medium and large construction projects may also be taken up as future work.

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