The Performance of Heuristic Rules in Resource Constrained Project Scheduling

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Abstract: - Resource-Constrained project scheduling is a kind of scheduling problem that aims minimizing project duration within limited resource availabilities. There are various types of methods for solving Resource-Constrained project scheduling. Heuristic priority rules are one of efficient methods. In the literature comparison of the heuristic rules within different networks is not sufficient. This study compares 7 heuristic priority rules by the solution of the 4 set of benchmark problems in Project Scheduling Problem Library (PSLIB). And there are four kinds of resource types. Serial scheduling scheme is used for the solution of the problems. The late start rule shows best performance and the second rule is late finish rule.

Key-Words: - Resource Constrained Project Scheduling, Priority-based heuristics, Heuristic Approach, Heuristic Rule Comparison

1 Introduction

Scheduling is a set of decision making processes that modeling a kind of manufacturing system. In the last century various types of scheduling is appeared and their importance was grew. CPM is one of the basic scheduling types. Basically scheduling includes several tasks that planned to execute and includes several resources which is used for execution of these tasks. There are two main kinds of resources, one of them is renewable resources which does not chance due to using by the activities. For example crews in the construction or machines in the workshops can be examples for that. The non-renewable resources can be consumed for the activities in construction works basic construction materials are can be example for that.

Resource constrained project scheduling (RCPS) is a kind of scheduling problem that aims to finish the project within various kinds of resource constraints. In the classical CPM the main constraints are only precedence relationships. However in the projects resource constrains are occurred frequently and affects the project duration. In the modeling of the resource constrained project scheduling the planning is made by taking into consideration resource constraints so the activity delays are determined in the scheduling phase. Objective of the scheduling is the minimum time-span and the minimum net present value are examples of the objectives of the RCPS problems. One of the several usages of RCPS is making decisions about starting and finishing time of the activities. There are several methods for the solution of the problem. The heuristic methods are the most frequently used methods especially in the commercial project management softwares. Despite frequently using of the heuristic rules there is a gap of comparing of these rules. In this study a detailed comparison is introduced. In the literature section a brief literature for RCPS problems is introduced. In the following a description for the RCPS problems and solution methods are explained. In the analysis section the results for PSLIB problems are listed.

2 Formulation

Resource-Constrained project scheduling is a kind of scheduling problem that aims to satisfy several objectives in the case of several lack of resource availabilities. RCPS were described in detail in the articles [1]and [2]. The general assumptions are the project network is not cyclical and not activity-on-arrow. And preemption is disallowed. Activity duration is fixed for each activities in the single mode case. There can be more than one type resources for the schedule. In this study projects include four different of renewable resources are defined. The formulation of the single mode RCPS problem in the equations (1-5).

$$\min T = \sum_{t=EFT_j}^{LFT_j} tX_{jt} \qquad (1)$$

$$\sum_{t=EFT_j}^{LFT_j} tX_{jt} = 1 \qquad j = 1, \dots, J \tag{2}$$

$$\sum_{t=EFT_i}^{LFT_i} tX_{it} \leq \sum_{t=EFT_j}^{LFT_j} (t - d_j)X_{jt} \; j = 2, \dots, J \; i \in P_j \tag{3}$$

$$\sum_{j=1}^{J} r_{jr} \sum_{\tau=t}^{t+d_j-1} X_{j\tau} \leq R_\tau \tag{4}$$

$$X_{jt} = \begin{cases} 1 & if\ LF(j) < t \\ 0, & otherwise \end{cases} \tag{5}$$

X_{jt} is a logical value that it returns 1 if j job ends before t time otherwise it returns 0 value. This notion described in equation (5). In this formulation the objective of the scheduling minimizing time-span of the project. In the equation (1) the main objective is described as minimizing time-span. T is the project duration that is aimed for minimizing. t is an vector that defines time-span of the schedule. The precedence relationships are defined in equation (3). Resource constraint conditions are defined in (4).

3 Heuristic Approach

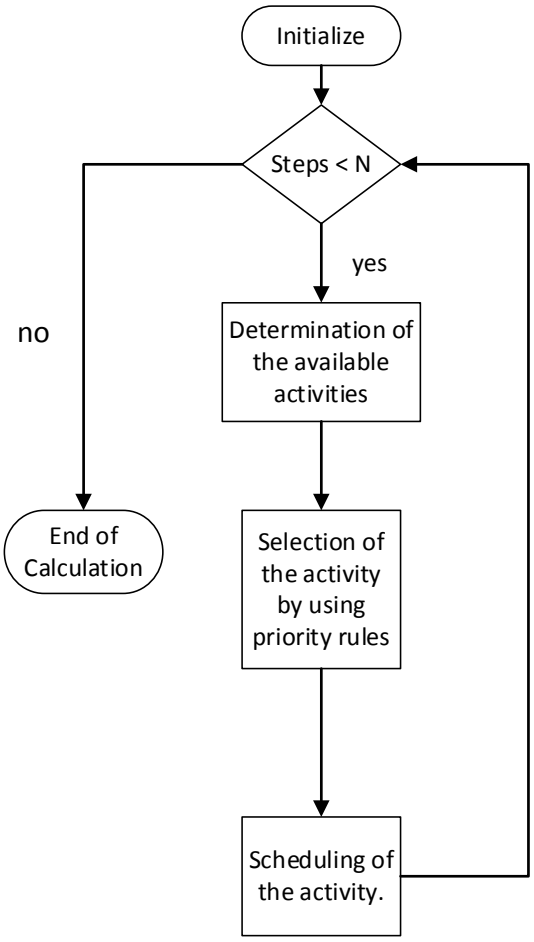
Heuristic methods are widely used for solving RCPS problems. In this section a brief introduction for heuristic rules is made and one of scheduling schemes is described.

4.1 Serial Scheduling Scheme

Serial scheduling scheme is the widely used scheme for heuristic/meta heuristic RCPS solving methods. It was proposed by Kelley[3]. There are two main definitions are included in the Scheme. First definition is Partial Schedule and another definition is the available activities. In the partial schedule, activities from beginning activity is scheduled. The meaning of "Scheduling" is assigning the start and finish times for the activity in order to do not violate the resource constraints and precedence relationships. The available activities which have not been scheduled. And immediate predecessors of the available activities are scheduled activities. One of the available activities are selected by using the heuristic priority rule in order to the activity gets involved in the scheduled activities.

The serial scheduling scheme was introduced by Kelley [3]. There are N numbers of solution steps that equals to activity number of the project. There are two separated sets in the schedule. One of them is called as scheduled set S_n. This set includes activities that have been scheduled in the previous steps. Another one is called decision set D_n includes immediate successors of scheduled activities. Immediate predecessors of the activities in the decision set is in the activities of the scheduled set. In the Klein's book [2] the decision set is called as available activities.

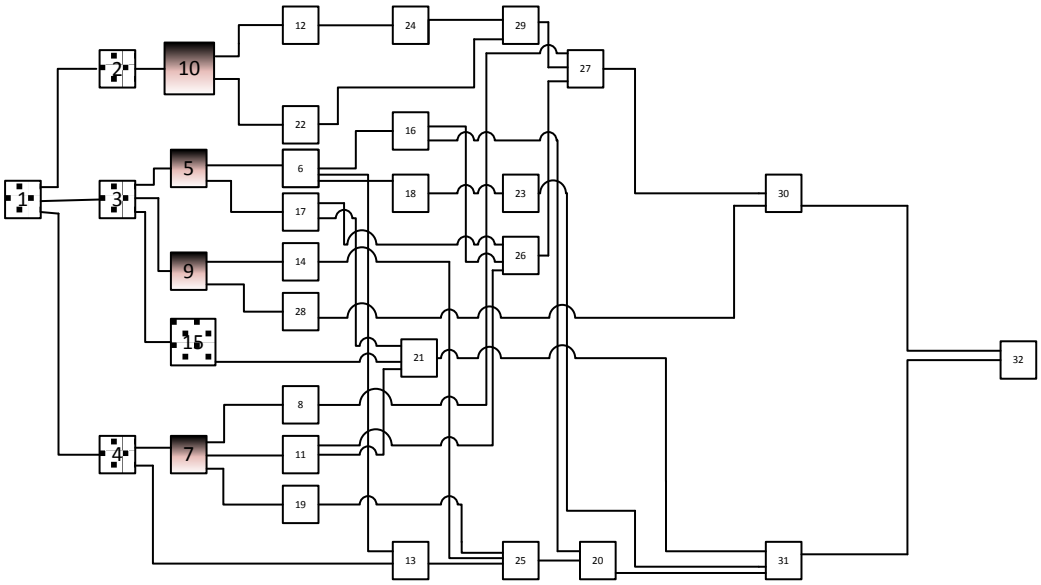
Figure 1 A step of the serial scheduling



In the figure 1 the flowchart of the serial scheduling scheme is shown. In the first step, scheduling begins with dummy start activity. After the start activity is scheduled, the available (decision set) activities are determined. By the using of priority rule one of the activities are scheduled without violating resource and network conditions. After the scheduling of the selected activity, the activity is included in

scheduled set. After scheduling of the activity successors of the scheduled activity is determined for next step calculations. After all activities are scheduling of the resource constrained project is ended.

Fig 2 A Sample Network Diagram With Decision and Scheduled Set



In the figure 2 a sample network from PSLIB is shown. There are 30 activities are intended scheduled within resource limits. 1, 2, 3, 4, 15th activities are already scheduled and these activities are included in scheduled set (S_n). The activities is selected and scheduled. For instance activity 10 is selected from priority criteria and inserted to scheduled activities. In the next step activity 12 and 22 are become new members of the decision set for next step calculations.

4.2 Heuristic Priority Rules

Heuristic methods are widely used in RCPS problems one of their main advantages is their simplicity and their fastness. Heuristic priority rules are used in most commercial planning softwares for resource leveling. Studies about comparison between heuristic priority rules have been made for decades. In the study, Browning et al compared 20 heuristic priority rules on 12320 test problems and they classified the usage of priority rules[4]. A detailed statistical analysis for determining a proper priority rule is needed. There are several attempts for classifying with project types. In the article[5] the optimum heuristic rules are found for specific project with using Artificial Neural Network. In this article 30,60,90 and 120 activity problems in the PSLIB are solved by 7 heuristic priority rules. Each rules are compared with each other. The heuristic priority rules are compiled from [2] and described in the table 1 below.

Table 1 List of Heuristic rules and Descriptions

Heuristic Rule	Min/Max	Description
SPT	Min	d_j : Shortest processing time
MIS	Max	F_j : Most immediate total successors
MTS	Max	F_j^* Most total successors
RPW	Max	$d_j + \sum_{i \in F_j} d_i$ Greatest rank positional weight
ESTD	Min	Dynamical early start time
LST	Min	LS_j Late start time of activity j
LFT	Min	LF_j Late finish time of activity j

5 Problem Description

The PSLIB is a set of RCPS benchmark problems includes four sets of different size problems. A random problem generator called ProGen is used for generating the problems.[6]. The PSLIB library introduced in 1996 and described detailed in[7]. In the web page the problems were announced, the researchers submit their results for the problems. And the best of results for each problem is demonstrated on the web page.

In this study the single mode benchmark problems from PSLIB are solved and the heuristic rules are compared. There are four type of problem sets. Each problem sets have 480, 480, 480, 600 problems and each problems in different sets have 30, 60, 90, 120, activities respectively. All of 2040 problems were solved with 7 heuristic rules.

6 Test Result and Discussions

The success project numbers of priority rules are given in Table 2. According to the table, there is

more than one successful rule in some RCS problems. Table 2 show us the number of successful rules that a rule is successful when there are a number of minimum project durations.

Table 2 Success Project Number of heuristic priority rules

	Activities				
Heuristic Rules	30	60	90	120	Total
SPT	141	134	135	11	421
MIS	182	168	178	31	559
MTS	239	262	277	101	879
RPW	278	302	323	193	1096
ESTD	180	158	143	5	486
LST	305	351	371	283	1310
LFT	285	308	328	210	1131

In the table 2, LST priority rule gives shortest project duration in 1310 problems. LFT is the shortest in 1131 problems, RPW is the shortest in 1096 problems. By the investigation of the effects of the activity numbers to, the first three successful priority rules are not changed due to changing of the activity number.

In the table 2 the number of coming firsts is more than the problem sets. For example in the J30 set there are only 480 examples of the problems are included however there are 3295 first places appeared. In the J120 set there are 1013 first places appeared however there are only 600 number of problems in the J120 set.

The main advantage of heuristic rules is fastness of the solution and simpleness of the rules. For efficient scheduling, finding appropriate heuristic rule gives an advantageous situation.

In the literature there are lack of studies encountered that aims comparing heuristic rules. In this study a detailed comparison was made in order to find the optimal heuristic rules. Despite its simplicity, the minimum late start rule shows better performance than the other rules. After the late start rule the late finish rule shows an efficient performance. Both of these rules look quite simple than the other rules. This study shows that simple heuristic rules show better performance that complicated rules.

The main advantage of heuristic rules is fastness of the solution and simpleness of the rules. Finding the suitable rule provides an advantageous situation in order to solving a problem in efficient way. In the literature there are lack of studies encountered that aims comparing heuristic rules. It is not easy to estimate which priority rule exhibits the best performance at RCPS problem. There are many kinds of research which investigate performance of the priority rules on RCPS.

In order to investigating of the studies about comparing heuristic rules in the literature, there are a lot of factors such that Project type, the scope of the project, number of the resources and restrictions affects to performance of the heuristic priority rules.

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