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A HEURISTIC PROJECT SCHEDULING APPROACH

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ABSTRACT

This work documents a conventional heuristic project scheduling approach for solving multiple resource-constrained project scheduling problems.

Thus, the intent of this paper, is to demonstrate the design aspects of a suggested heuristic approach for resource leveling to projects scheduling under limited resource availabilities.

The typical characteristics of the suggested heuristic procedure are:

a- Resource leveling program utilizes the parallel approach.

b- Multi-resource constrained with variable resource availabilities.

c- Make use of different priority rules

d- Possibility of activity splitting

Test problem results are represented

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Introduction

The absence of practical mathematical solutions for solving the resource-constrained project scheduling problems, led to developing and proposing many heuristic algorithms.

However, there is considerable conflicting evidence regarding the relative merit of such heuristic algorithms, owing to their nature, which is usually "tailor made" to fit a particular set of conditions.

Obviously, heuristic procedures for resolution of project scheduling problems, are mainly problem-oriented. Several among them are proprietory programs on which no detailed information concerning internal logical structure is available.

Hence, a suggested conventional heuristic model, for solving multi-resource constrained project scheduling problems, will be presented.

This suggested heuristic model incorporates a modification through additional capabilities and generalization of mainly two heuristic models, viz.; SPAR-1 Model [1, 2, 3] and PROJACS Model [5].

The following discussion demostrates the main ideas and features of the suggested heuristic model.

The main feature of the suggested heuristic program is allocation of resources on a period-by-period basis to some subset of the available activities for scheduling - those activities whose early start dates have been reached and their predecessor activities have been completed.

The project is treated as series of discrete-time intervals for each of which, resource availabilities are specified and the availability set of activities ready for scheduling process is defined. Hence, the scheduling process proceeds in a manner such that, schedule as many of the available activities as are possible and deferring remainder for consideration in a subsequent time-interval.

The essential heuristics (priority rules) are predefined. These heuristic are those that determine which activities shall be scheduled and which shall be postponed in any period. Furthermore, heuristics or priorities are evaluated dynamically, within each time-interval, from properties of the considered activities and without detailed regard for the rest of the project.

The heuristic incorporated in the suggested model may be listed as follows :

Select the activity which

§ has the earliest start time

§ has the minimum late strart time

§ has the minimum early finish time

§ has the minimum late finish time

§ has the least total float

§ has the shortest duration

Other heuristic can be easily involved into such model.

Moreover, the suggested heuristic approach offers many computation capabilities. These capabilities can be stated as follows :

a- Scheduling Policy. There are two general policies for scheduling, namely, a fixed-time scheduling and a fixed-resource scheduling.

In fixed-time scheduling approach, priority is given to meeting target dates, even if this entails providing additional amount of resources. With fixed-resource scheduling approach, priority is given to staying within estimated levels of available resources, even if this entails delaying certain activities.

b- Multi-Resource Constrained. The resource scheduling process is laid out to manipulate Multi-Resource Constrained considerations. More than three different types of resources can be defined as resources to be allocated. The word resources is not sufficiently descriptive, therefore, labels, parameters and attributes are needed.

As mentioned before, many kinds of resources can be used in the scheduling process. Each resource type can be treated as one of the following two resource categories :

§ the carried-forward (reusable) resource type on which the resource used by an activity is available for another activity as soon as the first one has finished using it.

§ the used-by-job resource type on which the resource used by an activity is no longer available for any other activity.

To carry out resource analysis, the availability of resources must be defined in straight forward way. The level of resource availability is variable. This is expressed as a resource availability vector which represents changes in level of resource along the considered planning horizon. Thus, the availabilities of any resource kind may vary throughout the time. These changes are based on date, i.e., at a given date, the availability takes on a new value which remains until the following change.

With reusable resources (human, m/cs ......etc.), under utilization cannot be carried forward to the next time period, as in the case of used by job resources (financial or material resources). Such resource feature brings into consideration, the periodic updating of resource availability vectors, which determines the changes in resource levels as a result of resources which can be passed from one time period to the next.

c- Possibility of Activity Splitting. The basic issue, of the suggested heuristic scheduling algorithm, involves pre-emptive capability for non-critical activities. In this way, splitting of an activity can be done for one time or more and this is allowed in the case where resource limits are extremely tight.

d- Critique Resorts. There are four parameters that are introduced in the suggested heuristic algorithm, namely the secondary resource availability levels, the allowed delay, the dynamic float and the critical slack.
Each activity can be scheduled on the basis either of primary resource availability levels (as mentioned before) or on a set of secondary availability levels correspond to the alternate use of resources than those primarily assigned.

The allowed delay is defined as the difference project target completion date and the completion date obtained from CPM-conventional time duration.

As the criticism of an activity must be considered as a dynamic value, the dynamic float represents the expected delay (in the mathematical sense) in the completion of an activity without violating the constraint of project completion target date.
Critical slack is a predefined parameter which determines a significant value of the dynamic float of activities.

In Fig. (1) and Fig. (2) the above mentioned definitions are clarified and demostrated.

The Heuristic Model Description

The workings of the proposed heuristic model will be explained by tracing through the main flow chart representation shown in Fig. (3).

Nevertheless, the model can be described in terms of the following major modules :

Network and Resource Description Modules

The first phase of the system execution, is the preparatory phase. During this phase, the network layout is described in terms of a set of input data parameters. Also, both resource requirements and availabilities, are described in a similar way. Hence, the calculation of the conventional critical path configurations is processed and directed through the considered modules.

Activities Ranking Module

The subsequent phase in the considered heuristic program is an activity ranking phase. Evidently, the set of activities scheduled to start execution at any time instant are ordered according to a predefined priority rule. Thus, every activity is assigned a rank according to its priority and should be handled according to its associated preference.

Resource Assignment Module

Having ordered the set of activities to be handled, each activity is dealt with in turn.
An activity cannot start execution if any of its resource requirements is not satisfied.

Normally, when an activity asks for resources, the system attempts to fulfill its demand from the primary level of resource availability. If the primary level is not sufficient, an attempt to fulfill the remaining shortage from the secondary level of resource availabilities is done.

If the remaining shortage problem persists, the system will delay the activity so that it would start execution after one time slice. However, an exception to this occurs if the activity is critical, i.e., it has no more dynamic float. In this case , the system

will look among the more prior activities handled at this time instant, in search for one or more non-critical activities which would possibly be delayed. This subset of activities are reranked in view of a specified weighting rule, where they are dealt with from the least prior activity to the most prior activity.
The number of activities, whose resource requirements would compansate the shortage quantity, is delayed one time slice, i.e., pre-emption would occur, and hence all the resources assigned to them are disengaged and allocated to hanging critical activity.

A worst case may occur if, the last resort, of delaying non-critical activities having higher priority leads to a failure. In this situation, the hanging critical activity is delayed one time slice and consequently postponing the start time of execution of all the subsequent activities.

Thus, the project completion time will be delayed one time slice.

A Case Example

6 To investigate the applicability of the suggested heuristic model. Consider the project of eight activities shown in Fig. (4). There are three different type of resources of variable availabilities along the planning horizon of 20 time periods. Moreover, these variable availabilities of resources are categorized as primary resource availabilities and secondary resource availabilities.

The conventional CPM analysis yields to a schedule which has a total duration of 14 time periods.

Experimentation with the suggested heuristic model and considering the earliest start time as a priority rule, yields to the schedule shown in Fig. (5).
This schedule has a completion time = 16 time periods.
A summary of the input data with the output results is exhibited in Table (1).

On the other hand, a similar and equivalent results, has been obtained in case of using the shortest duration as an alternative priority rule. The results are typical with the exception of both periods 3 and 4. In period 3 the scheduled activities were (2-3), (2-4) and (1-3). While, in period 4, the scheduled activities were (2-4) and (1-3).

By considering the CPM activity float as a priority rule the schedule shown in Fig. (6) was obtained for the same project example. Table (2) exhibits the input data and results obtained from implementing the suggested heuristic model in the considered situation.

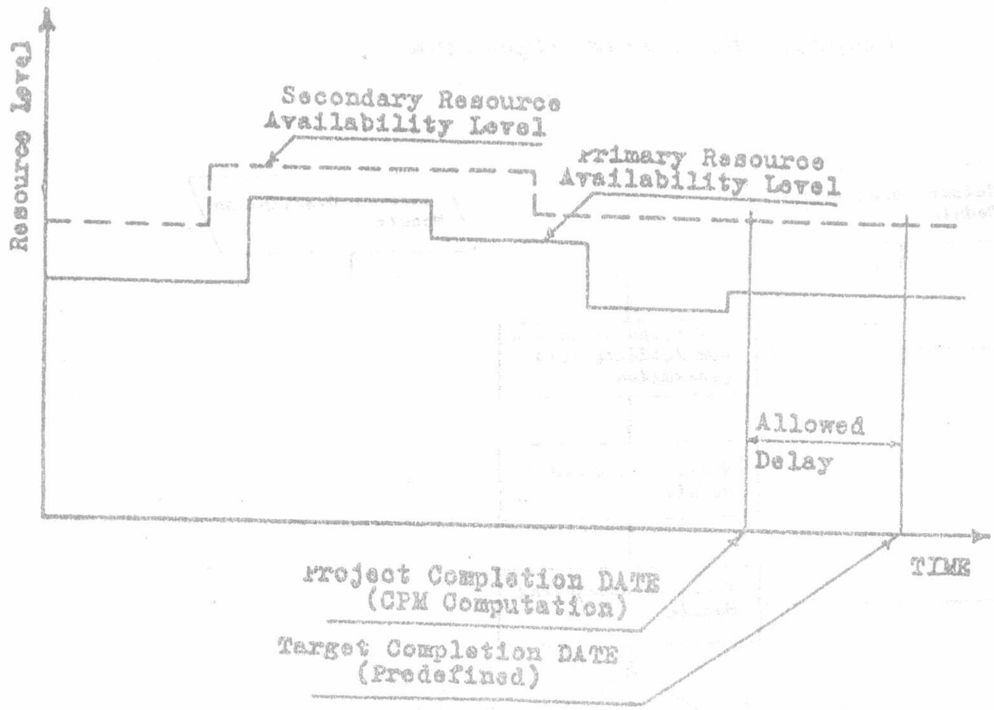


Fig. (1) Resource Availability Levels And Allowed Delay

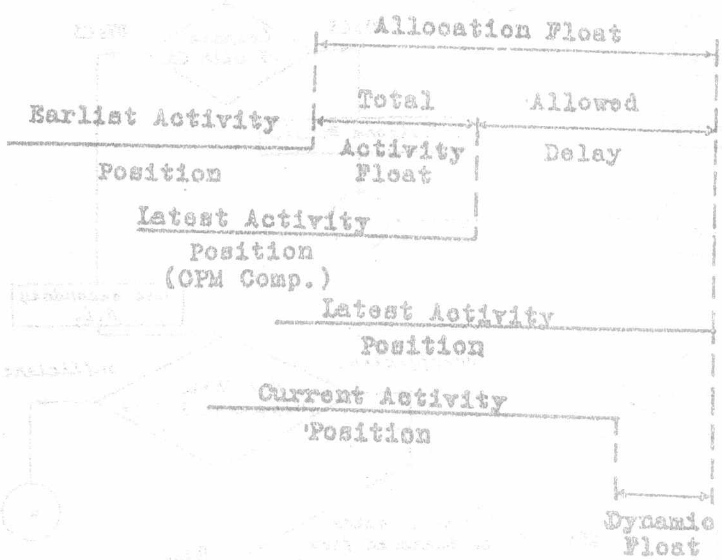
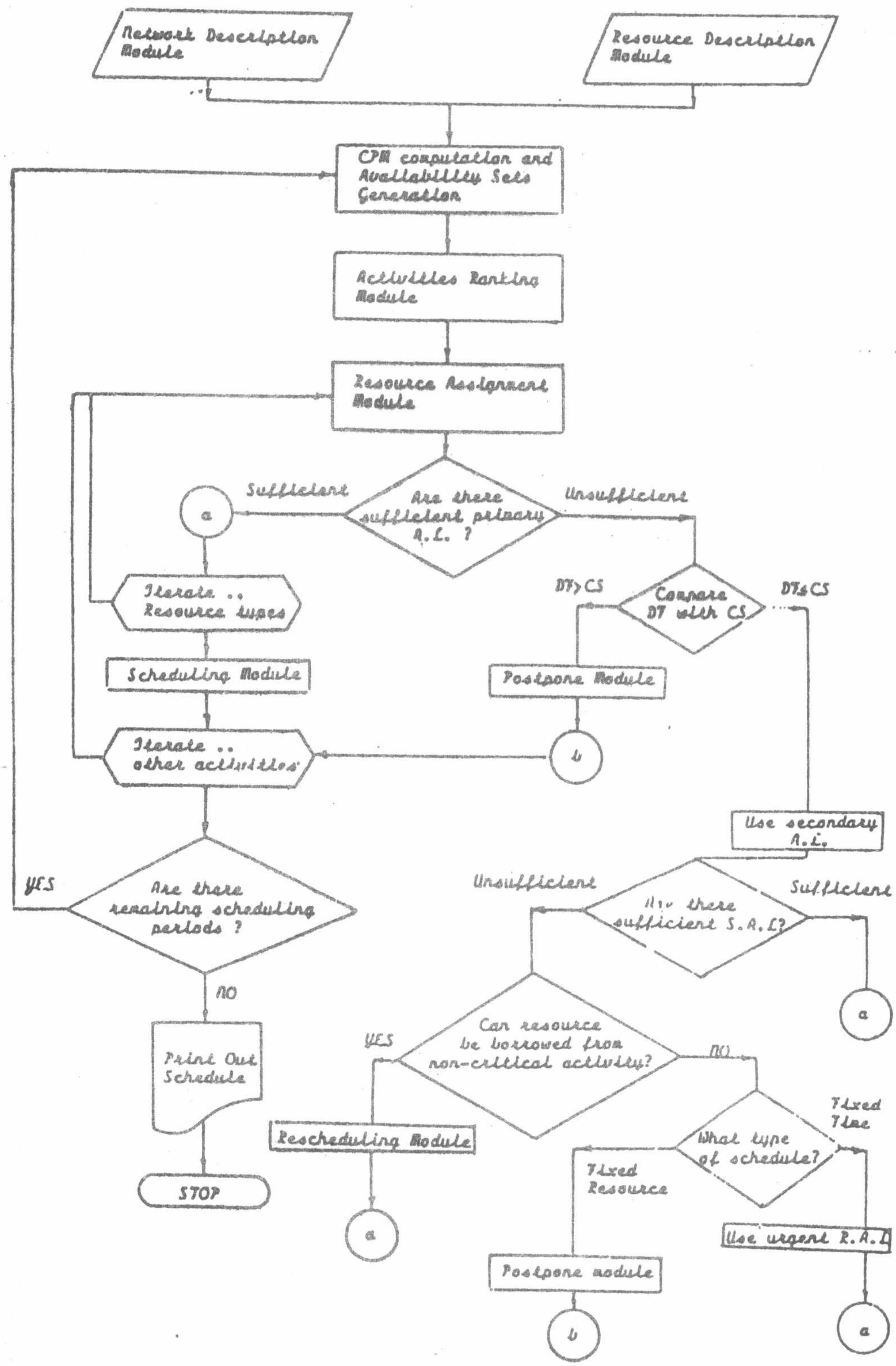


Fig. (2) Different Floats Of An Activity

Fig.(3)

Proposed Heuristic Algorithm



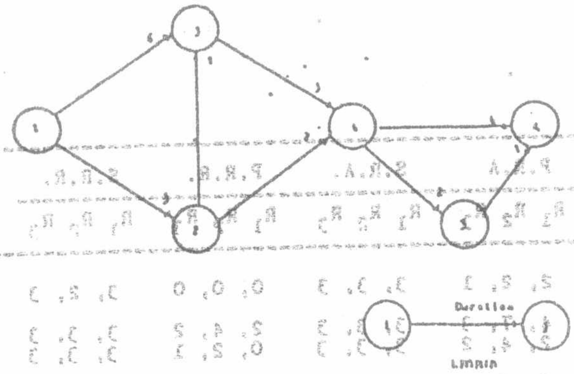


Fig.(4) Example Project Network

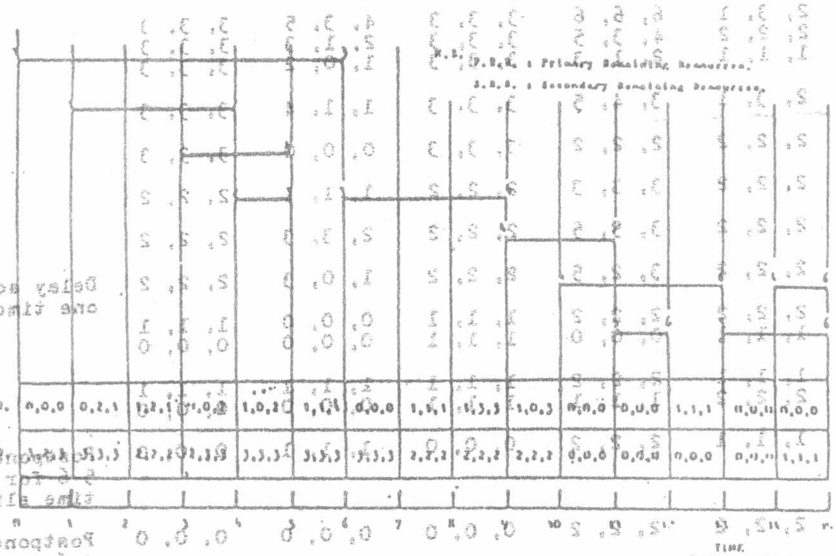


Fig.(5) Resulted Project Schedule -Priority Rule: Earliest Start-

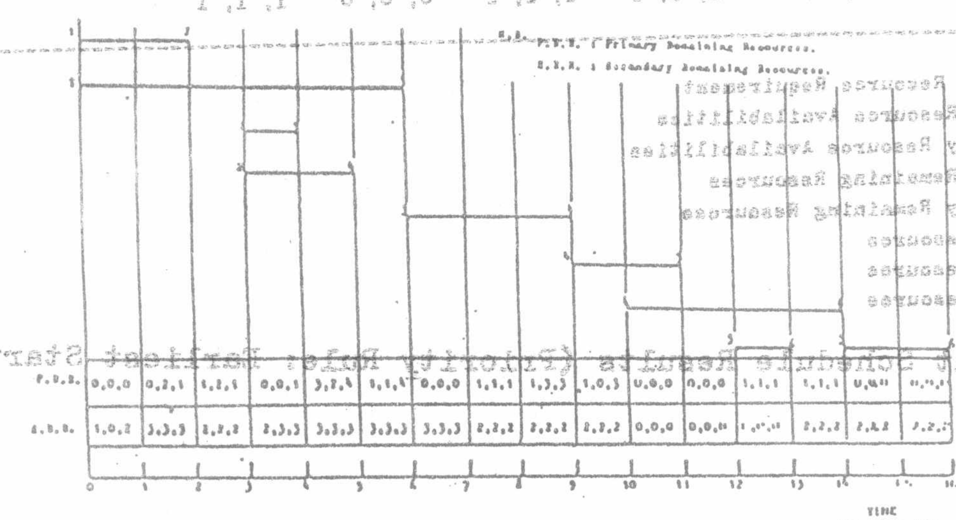


Fig.(6) Resulted Project Schedule -Priority Rule: CPM Float-

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Start Time	Activity	Duration	R.Req. (R_1 R_2 R_3)	P.R.A (R_1 R_2 R_3)	S.R.A. (R_1 R_2 R_3)	P.R.R. (R_1 R_2 R_3)	S.R.R. (R_1 R_2 R_3)	Remarks
0	1-3	6	2, 3, 1	2, 2, 1	3, 3, 3	0, 0, 0	3, 2, 3	
1	1-3	6	2, 3, 1	4, 7, 3	3, 3, 3	2, 4, 2	3, 3, 3	
	1-2	3	2, 2, 1	2, 4, 2	3, 3, 3	0, 2, 1	3, 3, 3	
2	1-3	6	2, 3, 1	5, 7, 3	2, 2, 2	3, 4, 2	2, 2, 2	
	1-2	3	2, 2, 1	3, 4, 2	2, 2, 2	1, 2, 1	2, 2, 2	
3	1-3	6	2, 3, 1	5, 6, 5	2, 3, 3	3, 3, 4	2, 3, 3	
	1-2	3	2, 2, 1	3, 3, 4	2, 3, 3	1, 1, 3	2, 3, 3	
4	1-3	6	2, 3, 1	6, 6, 6	3, 3, 3	4, 3, 5	3, 3, 3	
	2-3	1	2, 2, 2	4, 3, 5	3, 3, 3	2, 1, 3	3, 3, 3	
	2-4	2	1, 1, 1	2, 1, 3	3, 3, 3	1, 0, 2	3, 3, 3	
5	1-3	6	2, 3, 1	3, 4, 5	3, 3, 3	1, 1, 4	3, 3, 3	
6	3-4	3	2, 2, 2	2, 2, 2	3, 3, 3	0, 0, 0	3, 3, 3	
7	3-4	3	2, 2, 2	3, 3, 3	2, 2, 2	1, 1, 1	2, 2, 2	
8	3-4	3	2, 2, 2	3, 5, 5	2, 2, 2	2, 3, 3	2, 2, 2	
9	4-5	2	2, 2, 2	3, 2, 5	2, 2, 2	1, 0, 3	2, 2, 2	Delay activity 4-6 one time slice.
10	4-5	2	2, 2, 2	2, 2, 2	1, 1, 1	0, 0, 0	1, 1, 1	
	4-6	4	1, 1, 1	0, 0, 0	1, 1, 1	0, 0, 0	0, 0, 0	
11	4-6	4	1, 1, 1	2, 2, 2	1, 1, 1	1, 1, 1	1, 1, 1	
	5-6	3	2, 2, 2	1, 1, 1	1, 1, 1	0, 0, 0	0, 0, 0	
12	4-6	4	1, 1, 1	2, 2, 2	0, 0, 0	1, 1, 1	0, 0, 0	Postpone activity 5-6 for the first time slice.
13	5-6	3	2, 2, 2	2, 2, 2	0, 0, 0	0, 0, 0	0, 0, 0	Postpone activity 4-6 for the second time slice.
14	4-6	4	1, 1, 1	2, 2, 2	2, 2, 2	1, 1, 1	2, 2, 2	
	5-6	3	2, 2, 2	1, 1, 1	2, 2, 2	0, 0, 0	1, 1, 1	

N.B. R.Req. : Activity Resource Requirement
P.R.A. : Primary Resource Availabilities
S.R.A. : Secondary Resource Availabilities
P.R.R. : Primary Remaining Resources
S.R.R. : Secondary Remaining Resources
R_1 : Type 1 Resource
R_2 : Type 2 Resource
R_3 : Type 3 Resource

Table (1) Output Schedule Results (Priority Rule: Earliest Start Time)

Start Time	Activity	Duration	R.Req. R_1 R_2 R_3	P.R.A. R_1 R_2 R_3	S.R.A. R_1 R_2 R_3	P.R.R. R_1 R_2 R_3	S.R.R. R_1 R_2 R_3	Remarks
0	1-2	3	2, 2, 1	2, 2, 1	3, 3, 3	0, 0, 0	3, 3, 3	
	1-3	6	2, 3, 1	0, 0, 0	3, 3, 3	0, 0, 0	1, 0, 2	
1	1-2	3	2, 2, 1	4, 4, 3	3, 3, 3	2, 5, 2	3, 3, 3	
	1-3	6	2, 3, 1	2, 5, 2	3, 3, 3	0, 2, 1	3, 3, 3	
2	1-2	3	2, 2, 1	5, 7, 3	2, 2, 2	3, 5, 2	2, 2, 2	
	1-3	6	2, 3, 1	3, 5, 2	2, 2, 2	1, 2, 1	2, 2, 2	
3	1-3	6	2, 3, 1	5, 6, 5	2, 3, 3	3, 3, 4	2, 3, 3	
	2-3	1	2, 2, 2	3, 3, 4	2, 3, 3	1, 1, 2	2, 3, 3	
	2-4	2	1, 1, 1	1, 1, 2	2, 3, 3	0, 0, 1	2, 3, 3	
4	1-3	6	2, 3, 1	6, 6, 6	3, 3, 3	4, 3, 5	3, 3, 3	
	2-4	2	1, 1, 1	4, 3, 5	3, 3, 3	3, 2, 4	3, 3, 3	
5	1-3	6	2, 3, 1	3, 4, 5	3, 3, 3	1, 1, 4	3, 3, 3	
6	3-4	3	2, 2, 2	2, 2, 2	3, 3, 3	0, 0, 0	3, 3, 3	
7	3-4	3	2, 2, 2	3, 3, 3	2, 2, 2	1, 1, 1	2, 2, 2	
8	3-4	3	2, 2, 2	3, 5, 5	2, 2, 2	1, 3, 3	2, 2, 2	
9	4-5	2	2, 2, 2	3, 2, 5	2, 2, 1	1, 0, 3	2, 2, 2	Delay activity 4-5 one time slice.
10	4-5	2	2, 2, 2	2, 2, 2	1, 1, 1	0, 0, 0	1, 1, 1	
	4-6	4	1, 1, 1	0, 0, 0	1, 1, 1	0, 0, 0	0, 0, 0	
11	4-6	4	1, 1, 1	2, 2, 2	1, 1, 1	1, 1, 1	1, 1, 1	
	5-6	3	2, 2, 2	1, 1, 1	1, 1, 1	0, 0, 0	0, 0, 0	
12	4-6	4	1, 1, 1	2, 2, 2	0, 0, 0	1, 1, 1	0, 0, 0	Postpone activity 5-6 for the first time slice.
13	4-6	4	1, 1, 1	2, 2, 2	0, 0, 0	1, 1, 1	0, 0, 0	Postpone activity 5-6 for the second time slice
14	5-6	3	2, 2, 2	2, 2, 2	2, 2, 2	0, 0, 0	2, 2, 2	
15	5-6	3	2, 2, 2	2, 2, 2	2, 2, 2	0, 0, 0	2, 2, 2	

N.B. R.Req. : Activity Resource Requirement
P.R.A. : Primary Resource Availabilities
S.R.A. : Secondary Resource Availabilities
P.R.R. : Primary Remaining Resources
S.R.R. : Secondary Remaining Resources
R_1 : Type 1 Resource
R_2 : Type 2 Resource
R_3 : Type 3 Resource

Table (2) Output Schedule Results (Priority Rule: CPM Float)

REFERENCES

1- Batterby, A. : "Network Analysis for Planning and Scheduling".
McMillan, London, 1970.

2- Cooper, D.F. : "Heuristics for Scheduling Resource - Constrained Projects: An Experimental Investigation".
Management Science, Vol. 22, No.11
July, 1976.

3- Elmaghraby, S.E. : "The Design Of Production Systems".
Reinhold, New York, 1966.

4- Elmaghraby, S.E. : "Activity Networks: Project Planning and Control by Network Models".
John Wiley & Sons Inc, New York, 1977.

5- IBM Application Program : Project Analysis and Control System (PROJACS) - General Information.
Manual, Program No. 5746-XP1(DO5/VS)
GH 19-1055-3,
1978.

6- Kurtulus, I. and E.W.Davis : "Multi-Project Scheduling: Categorization of Heuristic Rules Performance".
Management Science, Vol.28, No. 2,
Feb., 1982.

7- Weist, J.D. : "Some Properties of Schedules for Large Projects with Limited Resources".
Oper. Res., Vol. 12, No. 3,
1964.