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# Extension of some project scheduling heuristics and their comparison at low and high levels of resource requirement

Mohammad Nematullah  
*Ryerson University*

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**EXTENSION OF SOME PROJECT SCHEDULING HEURISTICS AND  
THEIR COMPARISON AT LOW AND HIGH LEVELS OF RESOURCE  
REQUIREMENT**

by

Mohammad Nematullah

B.Sc. (Mechanical Engineering)

Dacca, Bangladesh, 1970

A project

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Master of Engineering

in the Program of

Mechanical Engineering

Toronto, Ontario, Canada, 2005

(Mohammad Nematullah) 2005

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# EXTENSION OF SOME PROJECT SCHEDULING HEURISTICS AND THEIR COMPARISON AT LOW AND HIGH LEVELS OF RESOURCE REQUIREMENT

Mohammad Nematullah  
Master of Engineering, Mechanical Engineering, 2005  
Ryerson University

## **Abstract**

Some of the most frequently used scheduling heuristics for resource constrained projects are Activity Time (ACTIM), Activity Resource (ACTRES) and Resource Over Time (ROT), which are based on Brook's Algorithm (BAG). These heuristics assign resources based upon the priority values of the activities that can be scheduled.

In the first part of this study, these heuristics have been modified such that when more than two activities are allowed to be assigned, depending upon the priority rule, that activity is assigned first overriding the priority rule, which, if assigned, will result in minimum resource idle time (MRIT). MRIT is found to improve the performance of these existing heuristics. The second part of the study investigates the performance of these heuristics at high and low levels of resource requirement by each activity. ACTIM was found to perform better than other heuristics at the low level. At the high level, all the heuristics performed equally well.

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## **Nomenclature**

AOA	activity-on-arc
AON	activity-on-node
CPM	critical path method
PERT	program evaluation and review technique
BAG	Brook's algorithm
ACTIM	activity time
ACTRES	activity resource
ROT	resource over time
MRIT	minimum resource idle time
ANOVA	analysis of variance
TES	earliest start time
TEF	earliest finish time
TAS	actual start time
TAF	actual finish time
tNow	the time at which resource assignments are now being considered

# **Chapter 1                      Introduction**

A project is a combination of interrelated activities that must be executed in a particular order to complete an entire task. In project scheduling by network analysis, traditional critical path methods exclude resources restrictions. Resource constrained projects are scheduled by exact procedures or by heuristics. Some of the most frequently used scheduling heuristics are Activity Time (ACTIM), Activity Resource (ACTRES) and Resource over Time (ROT). In the first part of the study, each of these heuristics has been modified using the minimum resource idle time (MRIT) criterion suggested in this study. The effect of MRIT has been investigated for the three heuristics. In the second part of this study, these heuristics were tested for two levels of resource requirements by each activity to determine which heuristic performs better in each situation.

Project management involves planning, staffing, controlling, monitoring and directing a project to its completion. The Gantt chart was the first scientific technique for project planning and scheduling. The basis of most successful project management techniques is the activity network or project network model. Network analysis procedures originated from the Gantt chart. Two most frequently used project network tools are the critical path method (CPM) and the program evaluation and review technique (PERT). Determining the critical activities of a project when resources are unlimited is easily accomplished by CPM or PERT.

## **1.1 Network Analysis**

A project network is the graphical representation of the contents and the objectives of the project. Network analysis is used to describe the various mathematical techniques that have been developed for the planning and control of projects. Network analysis helps answer questions such as

- What is the project completion time?
- What are the critical activities, which if delayed, will delay the project?
- How is the overall project affected if a critical activity is delayed?
- What is the interrelationship between activities?
- What is the complexity of the network

The two most popular techniques for project network analysis are CPM and PERT (Badiru, 1996). The two techniques are very similar, the main difference being their assumptions concerning the accuracy of duration estimates for each activity. PERT emphasizes the uncertainty in estimating activity time while CPM assumes that activity duration can be accurately predicted. CPM and PERT models use a network to portray graphically the project's interrelationship. There are two ways of representing project networks: the Activity-on-Arc (AOA) network and the Activity-on-Node network. The network complexity equals number of activities over number of nodes in AOA network (Badiru, 1996).

### 1.1.1 Activity-on-Arc Networks

In Activity-on-Arc, the arcs represent the project's activities and the nodes are the start and finish of those activities. Start and finish nodes are called 'events'. Any two events (nodes) may be connected by at most one arc. However, if two activities begin with the same event (node) and will lead into the same node, a dummy constraint is used to identify one of the activities. A dummy constraint is an arc on the network that shows a precedence relationship between activities and does not require a time-consuming activity to satisfy (Elsayed, 1985).

Example: Figure 1.1 shows a project network where A, B, C, D and E are activities with the following precedence,  $A \rightarrow C$        $B \rightarrow D, E$        $C \rightarrow D$

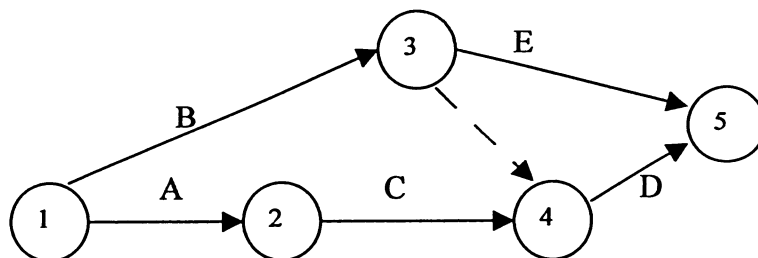


Figure 1.1. Activity-on-Arc (AOA) network

### 1.1.2 Activity-on-Node Networks

Figure 1.2 shows an Activity-on-Node network where nodes represent the activities and the arcs (i.e., the arrows) show the precedence relationships between the activities.



### 1.1.3 Critical Path Method

The primary goal of the critical path method (CPM) analysis of a project is the determination of the ‘critical path.’ The critical path is defined as the path with the least slack in the diagram. All the activities on the critical path are denoted as critical activities. These activities can create bottlenecks in the network if they are delayed. The critical path in CPM analysis can be determined from the forward pass only (Badiru, 1996).

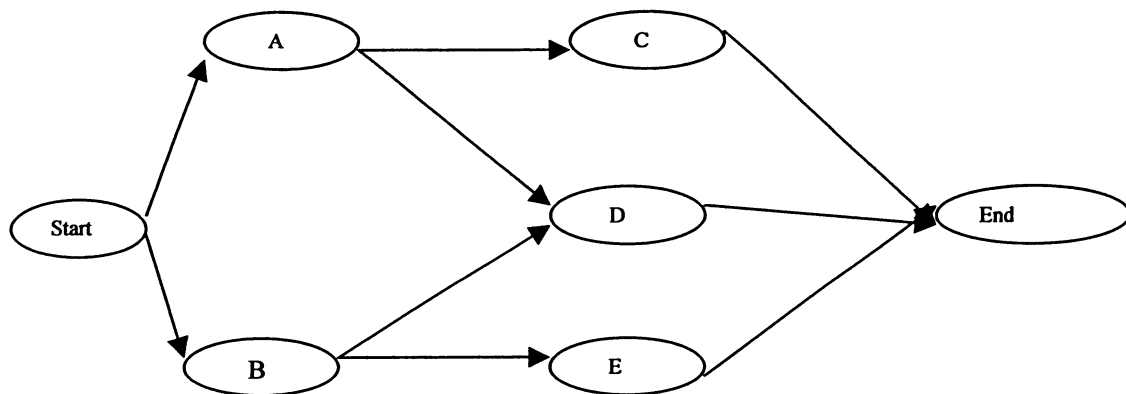


Figure 1.2. Activity-on-Arrow (AOA) network

The forward pass calculation has been shown with the help of an example project network. Table 1.1 gives the data for the sample project network.

Figure 1.3 represents the AOA network for the sample project and shows the forward-pass calculations. Here the nodes represent activities and the letter inside the nodes is the name of activities. Activity duration appears under the activity name in each node. Start and End nodes are dummy activities with zero duration. Thus Earliest Finish Time (TEF) for

Table 1.1. Data of sample project for CPM analysis

Activity	Predecessor	Duration
A	-	2
B	-	6
C	-	4
D	A	3
E	C	5
F	A	4
G	B, D, E	2

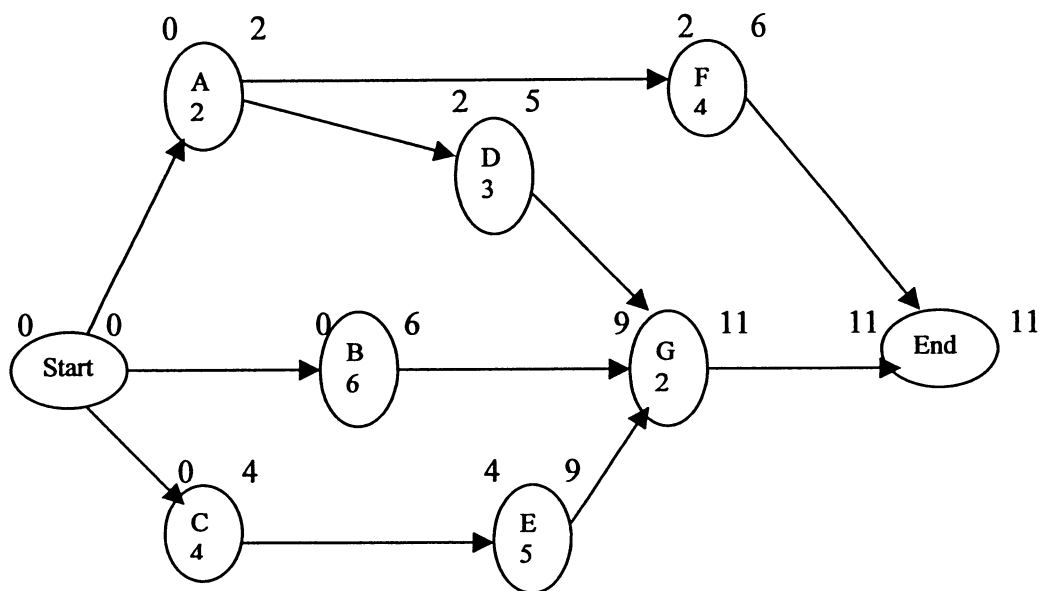


Fig 1.3. Forward pass analysis of sample project

the Start node is equal to its Earliest Start Time (TES). The TES values for the immediate successors of the starting node are set equal to the TEF of the Start node and the resulting TEF values are calculated. Each node is treated as the 'start' node for its successor or successors. If an activity has more than one predecessor, the maximum of the TEFs of the preceding activities is used as the activity's start time. In case of activity G, its start time is

$\text{Max}\{6,5,9\} = 9$ . The TES and TEF of the End activity will be the same because the 'End' node is a dummy one. The earliest project completion time is  $\text{Max}\{6,11\} = 11$ .

Now the critical path can be determined from the forward pass. The last node in the network i.e., the 'End' node is identified as a critical activity. The TES of the node 'End' is 11 and the ECs of its predecessors are 6 and 11. The predecessor having TEC equal to TES of the 'End' node will be marked critical, i.e., activity G is critical. Similarly, TES of the critical activity G is 9. Checking TES of its predecessors, it is found that E is the next critical activity. Next, activity C is the only predecessor and has TES equal to TEF of the critical activity. If there is a single starting node or a single ending node, then that node will always be on the critical path. Hence, the critical path is  $\text{Start} \rightarrow \text{C} \rightarrow \text{E} \rightarrow \text{G} \rightarrow \text{End}$ .

## 1.2 Limited Resource Allocation

In order to see the effect of limited resource allocation on the CPM analysis, the following network of Table 1.2 is considered. The CPM analysis with forward-pass gives a project duration of 16 days if the resources are not limited (Figure 1.4).

Table 1.2. Data for Limited Resource Project

Activity	Predecessor	Duration
A	-	2
B	A	6
C	-	4
D	A, C	3
E	B, D	5
F	A, C	4
G	-	2

A Gantt chart has been drawn as shown in Figure 1.5. There are three critical paths  
 $\text{Start} \rightarrow \text{A} \rightarrow \text{D} \rightarrow \text{E} \rightarrow \text{End}$ ,  $\text{Start} \rightarrow \text{C} \rightarrow \text{D} \rightarrow \text{E} \rightarrow \text{End}$  and  $\text{Start} \rightarrow \text{G} \rightarrow \text{End}$ .

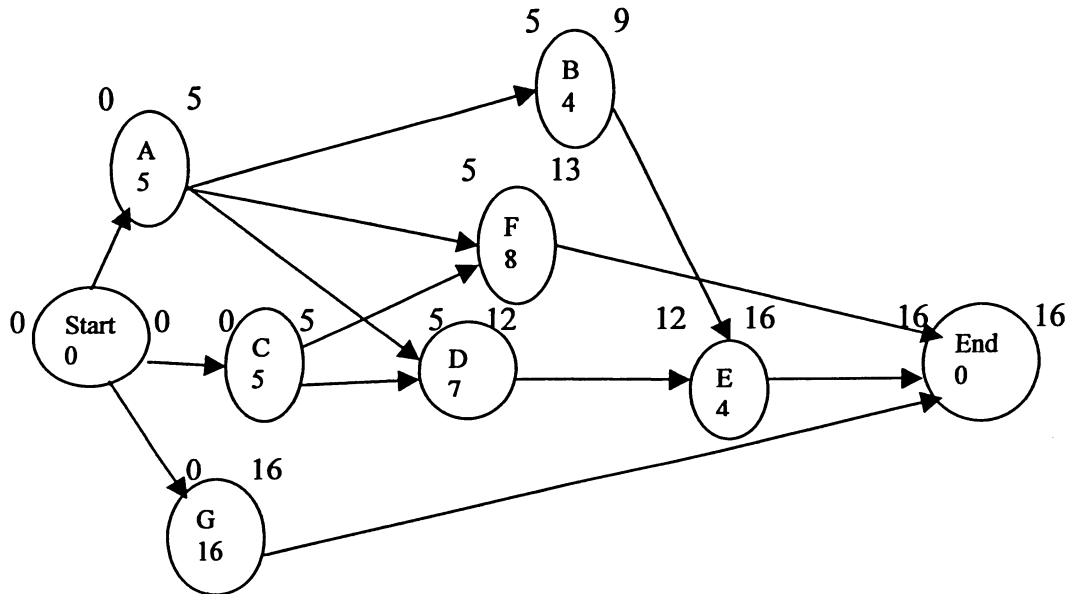


Figure 1.4. Network of resource constrained project

Now, if all the activities need one type of resource, say a fork-lift truck, and three are available, then, for a 16- day schedule, activities G, D, B and F have to be accomplished simultaneously for at least 4 days; it follows that a minimum of 4 trucks would be needed. This assumes that a truck cannot be shared between activities. As activities B and F are not on the critical path, they may be manipulated. The total slack or float of activity B is the difference between the TES of activity E and the TEF of activity B i.e.,  $(12 - 9) = 3$ . Similarly, the total slack of non-critical activity F is  $16 - 13 = 3$ . Delaying activity B by 3 days would not help. The logical way to find the minimum schedule with three trucks would

be to start activity F at time period 9, forcing an elongation of the project to 17 days. By shifting F to time period 9, no critical path now exists in the strict sense.

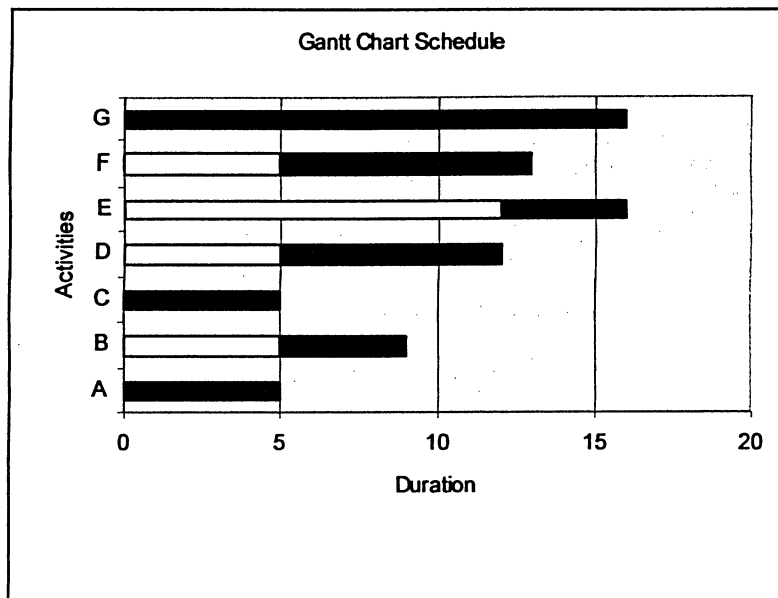


Figure 1.5. The Gantt chart schedule without resource limitation

This solution probably seems to be obvious with such a problem. But if the network is more complex, the answer is difficult. One solution approach is to use a heuristic solution technique. Brooks developed a typical resource allocation heuristic algorithm for a single-resource situation. The above resource constrained problem is solved using the Brooks Algorithm (BAG). The following steps are required to assign the single resource with BAG. Table 1.3 gives the tabular results of the steps.

**Step 1.** From the project network, the Earliest Start Time (TES) for each activity was noted down in the table above.

**Step 2.** For each activity, the maximum time it controls through the network on any one path was determined and called the ACTIM for the activity time. The activities are ranked in the descending ACTIM order G, A, C, D, B, F, E. The activities are entered in ACTIM order, ties are broken in any order.

Table 1.3. Brook's Algorithm solution to limited resources of 3 units

Activity	G	A	C	D	B	F	E
Duration	16	5	5	7	4	8	4
ACTIM	16	16	16	11	8	8	4
Resource Req.	1	1	1	1	1	1	1
TES	0	0	0	5	5	5	12
TAS	0	0	0	5	5	9	12
TAF	16	5	5	12	9	[17]	16
tNow	0			5	9		12
Resource Avail.	(3)	(2)	(1)	0	(2)	(1)	0
Activity Allowed	(G)	(A)	(C)		(D)	(B)	F
Iteration	1			2		3	4

[17] is the project duration, activities within brackets are assigned activities in that iteration, the numbers in the Resource Avail. row in brackets are reduced after each assignment. E.g., in iteration 1, when 1 resource unit was assigned to activity G, total resource units were reduced to 2.

**Step 3.** TAS is the actual start time of the activity. If there is no resource limitation, then TAS would always equal TES. TAF is the actual finish time of each activity and equals the TAS of the activity added to the activity duration. tNow is the time at which resource assignments are being considered. Initially, tNow equals zero but subsequently equals the lowest TAF.

**Step 4.** tNow is set to 0. The activities allowed (Activity Allowed) to be considered for scheduling at tNow of zero are those activities that would have a critical path method starting

time of 0, namely, activities G, A, and C. These are placed in the Activity Allowed row, sequenced in decreasing ACTIM order. In this example, G, A and C all have the same ACTIM and so can be sequenced in any order. In the resource available column, the resources available are placed, namely 3.

**Step 5.** G can be assigned as 3 resources are available and one is required. G is enclosed in brackets to show that G is assigned and 3 resources are enclosed in brackets showing that the available resource after G has been assigned is no more 3 but has been reduced to the next number beside it, namely 2. This procedure is repeated and G, A and C are assigned and 0 resources are available after the first iteration at tNow of zero. TAF for the activities G, A and C are entered in the table by adding the duration in their TAS.

**Step 6.** tNow is raised to the next TAF which happens to be 5, the completion time for A and C. Two resources are now available from A and C which are added to the number remaining after assigning resources at tNow equal to zero (zero in this case). Activity Allowed values are now set to those not assigned at the previous tNow (none in this case), added to those which have a TES equal to or less than tNow and no predecessor limitation fouls the picture (in this case D, B, and F).

**Step 7.** This assignment process is repeated until all activities have been scheduled. The latest TAF gives the duration of the project, which is 17 time units. The steps of allocating resources under ACTRES and ROT are based on BAG and are similar to those under ACTIM except that the ranking of the activities in the table is dependent on the ACTRES

value of the activity under ACTRES and the ROT value of the activity under ROT. ACTRES is calculated by multiplying each activity by its resources and then finding the maximum ACTRES that an activity controls through the network on any one path. Similarly, ROT is calculated as the maximum ROT value that an activity controls through the network on any one path. The proposed methods, which are actually modification of the above-discussed heuristics, are presented in section 3.1.2.

When resources are limited, project activities would lead to an increased project duration than what is obtained using CPM or PERT. Resource constrained projects are solved using two approaches: a. exact procedures (such as integer programming, branch and bound, etc.), and b. heuristics (such as ACTIM, ACTRES, etc.). Exact solutions are quite involved mathematically and are generally not practical. Heuristics are more practical. Some of the most frequently used scheduling rules are ACTIM, ACTRES and ROT. In this study, each of these heuristics has been modified such that when more than one activity are allowed to be assigned, the activity which will give the minimum resource idle time (MRIT) will be assigned first, overriding the controlling scheduling rule (ACTIM, ACTRES or ROT, as the case may be). This study investigates the effect of MRIT on ACTIM, ACTRES and ROT. These heuristics have also been tested for two levels of resource requirements by each activity in a project to determine which scheduling rules perform better in each case.



## Chapter 2                      Literature Review

The critical path method (CPM) and the program evaluation and review technique (PERT) are used to determine critical activities when resources are unlimited. One simply must find the path of technology links through the network with the longest expected duration. The forward-pass method described in Section 1.1.3 gives the critical path. However, when resources are limited, one cannot rely on CPM/PERT to find those activities that are most critical. The resource constrained scheduling problems are either solved by exact methods or by heuristic procedures.

While resource constrained criticality appears to be a practical and useful tool in the analysis of project network analysis, care is needed in its interpretation as any calculation of float is conditional on the particular resource allocation technique (Bowers, 1995). Because the activities must compete for resources, those that originally appear to be critical may actually have slack, and those that originally have slack may prove to be critical. Hence, one must take into consideration the relationship that results from activities sharing resources, as well as the technological relationships, when determining the critical path of a resource constrained project (Bowers, 2000).

New float definitions have been proposed that retain the original meaning of float while accounting for the effect of resource availability on the schedule (Raz and Marshall, 1996).

Apart from the need to track critical activities, there is a need for a scheduling tool that can manage projects with limited resources. Two categories of approaches exist for solving resource-constrained projects: 1) exact procedures, and 2) heuristic or approximate procedures. These two approaches are subdivided into the scheduling of a single project and the scheduling of multiple projects.

A typical resource allocation heuristic algorithm was developed by Brooks for a single-resource situation and is called Brooks Algorithm (BAG). ACTIM (Activity Time) is one of the earliest sequencing rules developed by Brooks and used in his algorithm (Bedworth, 1973). The original algorithm considered only the single project, single resource case, but it can be extended to multi-resource case. The ACTIM scheduling heuristic represents the maximum time that an activity controls through the project network on any one path.

ACTRES (Activity Resource) is a scheduling heuristic, which is a combination of the activity time and resource requirements and obtained by multiplying them. For multiple resources, the computation of ACTRES can be modified to account for various resource types. For this purpose, the resource requirements can be replaced by a scaled sum of resource requirements over different resource types (Bedworth, 1973).

ROT (Resource over time) is a scheduling heuristic proposed by Elsayed in 1982. It is calculated as the resource requirement divided by the activity time. The resource requirement can be replaced by the scaled sum of resource requirements in the case of multiple resource types with different units (Elsayed, 1985). TIMRES (Time Resources) is another priority rule

proposed by (Bedworth, 1973). It is composed of equally weighted portions of ACTIM and ACTRES.

GENERES is a search model. This model also utilizes BAG to generate the project schedule. The criteria used are various weighted combination of ACTIM and ACTRES. GENERES is implemented as a computer search technique. The best project schedule is that which gives the least project duration. The GENERES model was found effective in finding project duration equal to or less than that of ACTIM, ACTRES or TIMRES. The research also found that when the project completion time obtained by the algorithm approaches the critical path duration, resource leveling might be preferred (Whitehouse and Brown, 1979).

Many different heuristics exist today. Some of the other priority rules are CAF (Composite Allocation Factor), RSM (Resource Scheduling Method) and GRD (Greatest Resource Demand). Since no single heuristic scheduler is consistently best, commercial project management packages usually do not create optimal schedules when resources are constrained. Since some rules perform better on certain problems, a combination of heuristics has been attempted to improve the solution of constrained multiple resource networks. A heuristic computer algorithm was developed to find which combination of heuristics minimizes the duration of constrained resource project networks (Morse et al., 1996).

A nontraditional application of BAG to solve constrained multiple-resource single-project networks has been investigated by approaching the networks both in forward and backward

(F&B) directions and reported encouraging improvement to the traditional BAG approach (Whitehouse and DePuy, 2001).

Unlike most of the heuristics previously reviewed, LINRES (Link Resource) does not employ a priority dispatching approach and, thus, it is neither a serial nor a parallel method of schedule construction. The LINRES algorithm uses conventional CPM and Gantt charts to create an unconventional type of ancillary network (containing a number of new rules and concepts) as a tool for solving resource constrained scheduling problems. LINRES showed improvement in some cases (Abeyasinghe, et al., 2001)

Another heuristic using the Look-Ahead technique has been investigated which gave some improvement to some of the heuristics such as MINSLK (minimum job slack) and CAF (Gemmil and Edwards, 1999)

A heuristic genetic algorithm (HGA) has been used for solving resource allocation problems. The proposed algorithm can improve search efficiency and showed superiority over existing search algorithms (Lee, et al., 2003). GA can be used in unconstrained problems and can easily be extended for use in resource constrained problems by making few extra calculations related to the fitness value (Toklu, 2002).

Most optimum solutions use mathematical programming techniques, such as linear programming (Brucker and Knust, 2000), non-linear programming, integer programming, and dynamic programming (Khamooshi, 1999).

A number of research papers have been published on the subject of resource constrained project scheduling, which include research on heuristic procedures and exact methods. Different combinations of heuristics have been tried to come up with better scheduling procedures. Heuristic procedures are practical and easy to implement, but do not guarantee optimal solutions. Though exact methods are mathematically involved, researchers have used them to obtain optimal solutions.

## **Chapter 3                      Problem Description and Methodology**

A resource-constrained scheduling problem arises when the available resources are not enough to satisfy the requirements of activities that can be performed concurrently. Imposing resource restrictions on project activities leads to an increased completion time of the project. Both CPM and PERT approaches assume unlimited resource availability in a project network and cannot be strictly relied on to find those activities that are most critical. Two categories of approaches exist for solving resource-constrained projects: (i) exact procedures such as linear, nonlinear, or integer programming, branch and bound, etc. and (ii) heuristic or approximate procedures. Unfortunately, the optimal techniques are generally not used in practice because of the complexity involved in implementing them. A scheduling heuristic uses logical rules to prioritize and assign resources to competing activities and might lead to an optimum solution but does not guarantee optimality. Several scheduling heuristics have been developed in recent years. Many of these are applied to real projects. Some of the most frequently used scheduling rules are ACTIM (Activity Time), ACTRES (Activity Resource) and ROT (Resource Over Time) (Badiru, 1996). In this study, each of these heuristics has been modified such that when more than one activity are allowed to be assigned to the available resources at the time of assignment, the activity which when assigned will give the minimum resource idle time (MRIT) will be assigned first, overriding the controlling scheduling rule (ACTIM, ACTRES or ROT, as the case may be).

In the first part of this study, the effect of MRIT on ACTIM, ACTRES and ROT has been investigated and, in the second part, the heuristics have been tested for two levels of resource requirement by each activity of the project to determine which heuristic performs better at each level.

### 3.1 Effect of MRIT Criterion on ACTIM, ACTRES and ROT Heuristics

The following example problem is presented to illustrate the steps involved. In this example a project consists of five activities A, B, C, D and E. The predecessors, duration and resource requirement for each activity is given in Table 3.1. The total number of resources available is 4.

Table 3.1. Data of example problem

Activity	Predecessor	Duration	Resource Req.
A	-	7	4
B	-	8	1
C	A	10	2
D	A,B	12	2
E	B	7	2

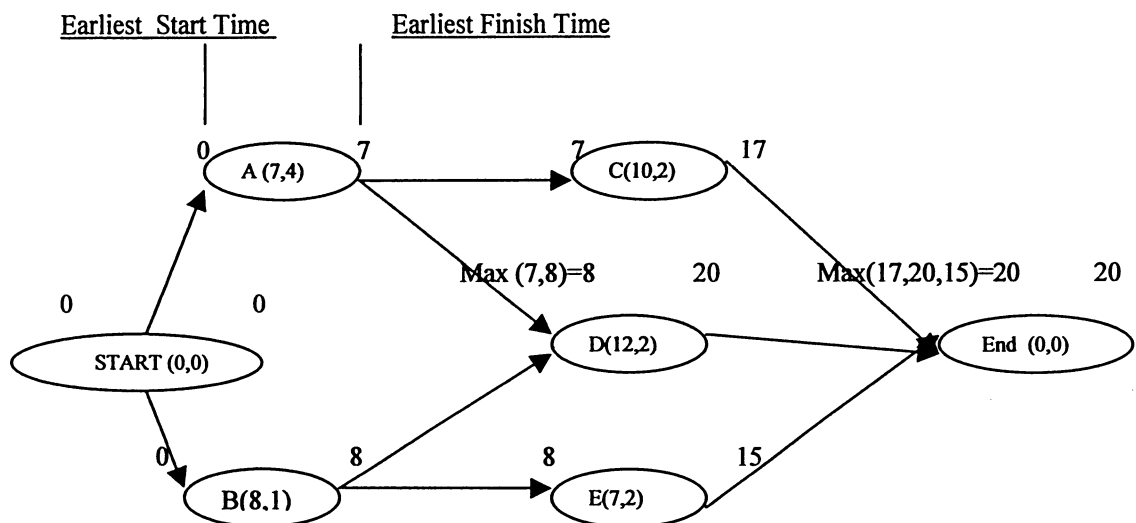
Resource Available = 4

#### 3.1.1 Existing Methods

Over 30 resource constrained scheduling heuristics currently exist, but none of the heuristics always gives the best results. ACTIM, ACTRES and ROT are among the most frequently used resource constrained scheduling heuristics (Badiru, 1996), and have been selected for the present study.

### 3.1.1.1 Resource Allocation by ACTIM Heuristic

**Step 1.** The project network is developed as with the critical path procedure, identifying activities and their required times. Activity-on-arrow (AOA) or activity-on-node (AON) can be used to determine Earliest Start Time (TES) and Earliest Finish Time (TEF). AON has been used in this example as shown in Figure 3.1, where activities are shown on nodes such that node A(7,4) denotes activity A; its duration is 7 and its units of resource required is 4.



A(7,4) denotes activity A, its duration is 7 and resource required is 4 units.

Figure 3.1. Activity-on-Node (AON), Forward Pass Analysis for CPM

**Step 2.** For each activity the maximum time it controls through the network on any one path is determined. This would be like calculating the critical path time through the network assuming that the starting node for each activity being analyzed is the network starting node. This activity control time is designated ACTIM for convenience [Bedworth, 1973]. The first



two columns of Table 3.2 give activities and their corresponding ACTIM values. The third column ranks the activities in the decreasing ACTIM sequence.

Table 3.2. ACTIM calculation and ranking of activities

Activity	Activity Control Time (ACTIM)	Ranking
A	Max([Duration of A is 7 + Duration of C is 10], [Duration of A is 7 + Duration of D is 12]) = 19	2
B	Max([8+7], [8+12]) = 20	1
C	Duration of C = 10	4
D	Duration of D = 12	3
E	Duration of E = 7	5

**Step 3.** The activities are ranked in decreasing ACTIM sequence in Table 3.3, which gives the tabular result of the steps. Ties are ranked in any order. The duration and resources required for each activity are entered in Table 3.3. The rows titled TES, TAF and tNow are explained below.

- TES is the earliest time that is possible, due to precedence and time limitation, to schedule each activity. The actual time will be equal to or later than TES. TES equals the *latest* actual finish time (TAF) for *all immediate predecessor* activities.
- TAS is the *actual* start time of the activity. If there are no resource limitations then TAS would always equal TES.
- TAF is the *actual* finish time of the activity. This equals the TAS of the activity added to the activity duration time.
- tNow is the time at which resource assignments are now being considered. *Initially* tNow equals zero but subsequently equals the lowest TAF.

**Step 4.** tNow is set at 0. The allowable activities (Act. Allowed) to be considered for scheduling at tNow of zero are those activities that would have a critical path method starting time of 0, namely activities A and B. These are placed in Act. Allowed row, sequenced in decreasing ACTIM order, namely B, A. In the resource available (Res. Available) row the resources initially available are placed, namely 4.

**Step 5.** It is determined if the first activity in 'Act. Allowed', B, can be assigned. It can, as 4 resources are available and B requires only one. Also no predecessor limitations foul the picture. Activity B is enclosed in a pair of parenthesis to indicate that the required resources have been assigned to it and the number of resources available is reduced by one to a value 3, since B requires one resource. TAS for activity B is set at the current tNow and the TAF is set at TAS plus activity B's duration time. Now it is necessary to determine if activity B being completed will allow any other activity to be feasible at some future time. This same process is repeated for the remainder of Act. Allowed activities until the resources available are depleted. In this case, activity A cannot be assigned as 3 resources are available and A requires 4 resources. This is the first iteration, called Iteration 1 in Table 3.3.

**Step 6.** tNow is raised to the next TAF which happens to be 8, the completion time of activity B. The resources available at tNow of 8 is set to the number remaining after assigning resources at tNow equal to zero (3 in this case) added to the number of resources freed due to activity completion at the new tNow (1 in this case), making the total available resources as 4. In iteration 2, 'Act. Allowed' is now set at those not assigned at the previous tNow (A in this case), added to those which have a TES equal to or less than tNow provided

their predecessor activities have been completed (E in this case). Repeat this assignment process until all activities have been scheduled. The latest TAF gives the duration of the project, which is 32 time units. TAS and TAF rows give the actual start and actual finish time of each activity under ACTIM heuristic.

**Step 7.** Efficiency of the heuristic is calculated using the expression:

Efficiency =  $[(\text{Project duration} * \text{Total number of available resources}) - \sum (\text{Number of Idle resources} * \text{Duration the resources were idle between consecutive tNow values})] / (\text{Project duration} * \text{Total number of available resource})$ .

The efficiency of the heuristic for the project network is calculated as:

Efficiency =  $[(32 * 4) - \{(3 * (8 - 0)) + (0 * (15 - 8)) + (0 * (25 - 15)) + (0 * (27 - 25)) + (2 * (32 - 27))\}] / (32 * 4) = (128 - 34) / 128 = 0.734$

Table 3.3. Resource Allocation by ACTIM

Activity	B	A	D	C	E
Duration	8	7	12	10	7
ACTIM	20	19	12	10	7
Resource Req.	1	4	2	2	2
TES	0	0	8	7	8
TAS	0	8	15	15	25
TAF	8	15	27	25	[32]
tNow	0	8	15	25	27
Act. Allowed	(B), A	(A), E	(D),(C),E	(E)	
Res. Available	(4) 3	(4) 0	(4) (2) 0	(2) 0	2
Iteration	1	2	3	4	

[32] is the project duration. Activities within brackets are assigned activities in that iteration, the numbers in the Resource Avail. row in brackets are reduced after each assignment e.g., in iteration 1 when 1 resource unit was assigned to activity B, total resource units were reduced to 3.

Total Resources Available=4

### **3.1.1.2 Resource Allocation by ACTRES Heuristic**

The steps in allocating resources to activities based on the ACTRES heuristic are similar to those of ACTIM with the exception that the ranking of the activities is based on their ACTRES values [Bedworth, 1973]. ACTRES is calculated by multiplying each activity's time by its resources and then finding the maximum ACTRES that an activity controls through the network on any one path. Now the ACTRES heuristic is used to determine the project duration of the example problem. As shown in Table 3.4, the project completion time under the ACTRES heuristic is 27. TAS and TAF rows give the actual start and actual finish time of each activity under the ACTRES heuristic. And similarly the efficiency is calculated as 0.8703 for ACTRES.

### **3.1.1.3 Resource Allocation by ROT Heuristic**

The steps in allocating resources to activities based on the ROT heuristic are similar to those of ACTIM, with the exception that the ranking of the activities is based on their ROT values (Elsayed, 1985). ROT is calculated by dividing each activity's resource by its duration and then finding the maximum ROT that an activity controls through the network on any one path. Now the ROT heuristic is used to determine the project duration of the example problem. As shown in Table 3.5, the project completion time under the ROT heuristic is 29. TAS and TES rows give the actual start and actual finish time of each activity under the ROT heuristic. Similarly, the efficiency is calculated as 0.8103.

Table 3.4. Resource allocation by ACTRES

Activity	A	B	D	C	E
Duration	7	8	12	10	7
ACTRES	52	32	24	20	14
Resource Req.	4	1	2	2	2
TES	0	0	8	7	8
TAS	0	7	15	7	17
TAF	7	15	[27]	17	24
tNow	0	7	15	17	24
Act. Allowed	(A), B	(B ), (C)	(D),E	(E)	-
Res. Available	(4) 0	(4) (3) 1	(2) 0	(2) 0	2
Iteration	1	2	3	4	5

[27] is the project duration. Activities within brackets are assigned activities in that iteration, the numbers in the Resource Avail. row in brackets are reduced after each assignment e.g., in iteration 1 when 4 resource unit was assigned to activity A, total resource units were reduced to 0.

Total Resources Available=4

Table 3.5. Resource allocation by ROT

Activity	A	B	E	C	D
Duration	7	8	7	10	12
ROT	0.77	0.4107	0.2857	0.20	0.166
Resource Req.	4	1	2	2	2
TES	0	0	8	7	8
TAS	0	7	15	7	17
TAF	7	15	22	17	[29]
tNow	0	7	15	17	22
Act. Allowed	(A), B	(B ), (C)	(E),D	(D)	-
Res. Available	(4) 0	(4) (3) 1	(2) 0	(2) 0	2
Iteration	1	2	3	4	5

[29] is the project duration. Activities within brackets are assigned activities in that iteration, the numbers in the Resource Avail. row in brackets are reduced after each assignment e.g., in iteration 1 when 4 resource unit was assigned to activity A, total resource units were reduced to 0.

Total Resources Available=4

### 3.1.2 Proposed Methods

The minimum resource idle time criterion is applied to each of the three selected heuristics, ACTIM, ACTRES and ROT, giving rise to three proposed methods: ACTIM with MRIT, ACTRES with MRIT and ROT with MRIT. In the following sections these proposed methods are described.

### 3.1.2.1 Resource Allocation by ACTIM Heuristic with MRIT Criterion

Steps 1 through 3 are same as in Section 3.1.1 above and Table 3.6 gives tabular results of the steps.

**Step 4.** tNow is set at 0. The allowable activities (Act. Allowed) to be considered for scheduling at tNow of zero are those activities that would have a critical path method starting time of 0, namely, activities A and B. Their ACTIM sequence in decreasing ACTIM order is B,A. Before placing these activities in Act. Allowed row, resource idle time for each activity is calculated. If resource B is assigned, (resource available, namely 4 – resource assigned to activity B, namely 1) \* (duration of resource B, namely 8) = 24 resource time units would be idle. Similarly, if resource A is assigned,  $(4 - 4) * 7 = 0$ , i.e., zero resource time unit would be idle. The minimum of 24 and 0 is zero, and hence activity A should be assigned first, the new order by MRIT would be A, B, overriding the ACTIM sequence of B, A in the ‘Res. Available’ row in Table 3.6. A tie in MRIT is broken by ACTIM values.

**Step 5.** It is determined if the first activity in Act. Allowed, A, can be assigned. It can, as 4 resources are available and A requires 4. Also, no predecessor limitations foul the picture. A is enclosed in a pair of parenthesis to indicate assignment, and the number of resources available is reduced by 4 to a value 0. TAS for activity A is set at the current tNow and the TAF is set at TAS plus activity A’s duration time. Now it is necessary to determine if activity A being completed will allow any other activity to be feasible at some future time. This same process is repeated for the remainder of Act. Allowed activities until the resources available

are depleted. In this case, activity B cannot be assigned as 0 resources are available and B requires 1 resource. This is the first iteration, called Iteration 1 in Table 3.6.

**Step 6.** tNow is raised to the next TAF which happens to be 7, the completion time of activity A. The resources available at tNow of 7 is set to the number remaining after assigning resources at tNow equal to zero (0 in this case) added to the number of resources freed due to activity completion at the new tNow (4 in this case), making the total available resources 4. In iteration 2, Act. Allowed is now set at those not assigned at the previous tNow (B in this case), added to those which have a TES equal to or less than tNow, provided their predecessor activities have been completed (C in this case). Their ACTIM sequence in decreasing ACTIM order is B, C. Before placing these activities in Act. Allowed row, the resource idle time for each activity is calculated. If resource B is assigned, (resource available, namely 4 – resource assigned to activity B, namely 1) \* (duration of resource B, namely 8) = 24 resource time units would be idle. Similarly, if resource C is assigned, (4-2) \* 10 = 20 resource time units would be idle. The minimum of 24 and 20 is 20, and hence the new sequence by MRIT would be C, B overriding ACTIM sequence of B, C in the ‘Res. Available’ row in Table 3.6. A tie in MRIT is broken by ACTIM. This assignment process is repeated until all activities have been scheduled. The latest TAF gives the duration of the project, which is 27 time units. TAS and TAF rows give the actual start and actual finish time of each activity under ACTIM with the MRIT criterion. ACTIM with MRIT gives a project completion time of 27 compared to that of 32 obtained by ACTIM heuristic alone.

**Step 7.** Efficiency of the heuristic is calculated using the expression:

Efficiency =  $[(\text{Project duration} * \text{Total number of available resources}) - \Sigma (\text{Number of Idle resources} * \text{Duration the resources were idle between consecutive tNow values})] / (\text{Project duration} * \text{Total number of available resource})$ .

The efficiency of the heuristic for the project network is calculated as:

$$\text{Efficiency} = [(27 * 4) - \{(0 * (7 - 0)) + (1 * (15 - 7)) + (0 * (17 - 15)) + (0 * (24 - 17)) + (2 * (27 - 24))\}] / (32 * 4) = (108 - 14) / 108 = 0.87037$$

Table 3.6. Resource Allocation by ACTIM with MRIT

Activity	B	A	D	C	E
Duration	8	7	12	10	7
ACTIM	20	19	12	10	7
Resource Req.	1	4	2	2	2
TES	0	0	8	7	8
TAS	7	0	15	7	17
TAF	15	7	[27]	17	24
tNow	0	7	15	17	24
Act. Allowed	(A), B	(C ), (B)	(D),E	(E)	-
Res. Available	(4) 0	(4) (2) 1	(2) 0	(2) 0	2
Iteration	1	2	3	4	5

[27] is the project duration. Activities within brackets are assigned activities in that iteration, the numbers in the Res. Available row in brackets are reduced after each assignment e.g., in iteration 1 when 4 resource unit was assigned to activity A, total resource units were reduced to 0.

Total Resources Available=4

### 3.1.2.2 Resource Allocation by ACTRES Heuristic with MRIT Criterion

The steps in allocating resources to activities based on ACTRES with MRIT criterion are similar to those of ACTIM with MRIT with the exception that the ranking of the activities is based on their ACTRES values. Now ACTRES with the MRIT criterion is used to determine the project duration of the example problem. As shown in Table 3.7, the project completion time under ACTRES with the MRIT criterion is 27. TAS and TAF rows give the actual start and actual finish time of each activity under the ACTRES heuristic. Similarly, the efficiency



of the heuristic is calculated as 0.87037. Here the MRIT criterion has no effect on the ACTRES heuristic.

### 3.1.2.3 Resource Allocation by ROT Heuristic with MRIT Criterion

The steps in allocating resources to activities based on ROT with the MRIT criterion are similar to those of ACTIM with MRIT with the exception that the ranking of the activities is based on their ROT values. Now, ROT with the MRIT criterion is used to determine the project duration of the example problem. As shown in Table 3.8, the project completion time under ROT with the MRIT criterion is 29. TAS and TAF rows give the actual start and actual finish time of each activity under ROT with the MRIT criterion. Similarly, the efficiency of the heuristic is calculated as 0.81034. Here, the MRIT criterion has no effect on the ROT heuristic.

Table 3.7. Resource Allocation by ACTRES with MRIT

Activity	A	B	D	C	E
Duration	7	8	12	10	7
ACTRES	52	32	24	20	14
Resource Req.	4	1	2	2	2
TES	0	0	8	7	8
TAS	0	7	15	7	17
TAF	7	15	[27]	17	24
tNow	0	7	15	17	24
Act. Allowed	(A), B	(B ), (C)	(D),E	(E)	-
Res. Available	(4) 0	(4) (3) 1	(2) 0	(2) 0	2
Iteration	1	2	3	4	5

[27] is the project duration. Activities within brackets are assigned activities in that iteration, the numbers in the Res. Available row in brackets are reduced after each assignment e.g., in iteration 1 when 4 resource unit was assigned to activity A, total resource units were reduced to 0.

Total Resources Available=4

Table 3.8. Resource Allocation by ROT with MRIT

Activity	A	B	E	C	D
Duration	7	8	7	10	12
ROT	0.77	0.4107	0.2857	0.20	0.166
Resource Req.	4	1	2	2	2
TES	0	0	8	7	8
TAS	0	7	15	7	17
TAF	7	15	22	17	[29]
tNow	0	7	15	17	22
Act. Allowed	(A), B	(B ), (C)	(E),D	(D)	-
Res. Available	(4) 0	(4) (3) 1	(2) 0	(2) 0	2
Iteration	1	2	3	4	5

[29] is the project duration. Activities within brackets are assigned activities in that iteration, the numbers in the Res. Available row in brackets are reduced after each assignment e.g., in iteration 1 when 4 resource unit was assigned to activity A, total resource units were reduced to 0.

Total Resources Available=4

If another project network is taken and MRIT is applied to ACTIM, ACTRES and ROT heuristics, different results are expected. In this report a number of project networks have been analyzed to determine the effect of MRIT on the three heuristics.

### 3.2 Performance of Heuristics at High and Low Levels of Resource Requirements

The other problem undertaken for study is to determine which heuristic performs better when the resource requirements by activities in the project are at a low level and also at a high level compared to the total resource available for the project. The methodology is to fix the number of total resources available for the project network and then calculate project duration and efficiency at two fixed levels of resource requirement for the network using each heuristic. The procedure is repeated for a number of project networks keeping the number of total resources available exactly the same and similarly, keeping the range of each level of resource requirement exactly the same.

The procedure is illustrated with the help of the following example network. Here the resource available is fixed at 4, and the range of low resource level is defined as 1 to 2 resources for the activities A, B, C, D and E. Five random numbers between 1 and 2 are generated and assigned to the resource required for the 5 activities in Table 3.9. In this low-level resource requirement case, the activities have a resource requirement of 25 % or 50 % of the total resource available. For the network of Table 3.9, project duration and efficiency are calculated for each heuristic. The calculation for project duration and efficiency is repeated for several other networks, keeping the resource available as 4 and the range of low resource level between 1 and 2 resources randomly generated for each activity as before. The result is analyzed to determine which heuristic performs better at the low level resource requirement of component activities of a project.

Table 3.9. Data of example network for low level resource requirement

Activity	Predecessor	Duration	Resource Req.
A	-	7	1
B	-	8	2
C	A	10	2
D	A,B	12	1
E	B	7	2

Resource Available = 4

Similarly, the procedure for a high level resource requirement is illustrated with the help of the example network given in Table 3.10. Here, the resource available is fixed at 4, and the range of high resource level is between 3 and 4 resources for the activities A, B, C, D and E. Five random numbers between 3 and 4 are generated and assigned to the resource required

for the 5 activities in Table 3.10. In this high level resource requirement case, the activities have resource requirement of 75 % or 100 % of total resource available. For the network of Table 3.10, project duration and efficiency are calculated for each heuristic. The calculation for project duration and efficiency is repeated for several other networks, keeping the resource available as 4 and the range of high resource level between 3 and 4 resources randomly generated for each activity as before. The result is analyzed to determine which heuristic performs better at the high level resource requirement of component activities of a project.

Table 3.10. Data of example network for high level resource requirement

Activity	Predecessor	Duration	Resource Req.
A	-	7	4
B	-	8	3
C	A	10	3
D	A,B	12	4
E	B	7	3
Resource Available = 4			

## Chapter 4 Experiment

In order to investigate the effect of MRIT on ACTIM, ACTRES and ROT heuristics, thirty different size networks consisting of 5 to 14 activities have been taken from available literature. As manual calculation is not only cumbersome but also prone to mistakes, a computer program has been developed in Java. The program is interactive where total number of resources available, name of each activity with its predecessors, its duration and number of resource units required are entered as input for a network. The program calculates ACTIM values for each activity, uses the ACTIM values to sort the activities in the descending order, calculates earliest start time (TES), uses TES ranking order, precedence restraint and availability of resources, and assigns the resources to the allowed activity after checking the MRIT criterion. It also keeps track of remaining resources after assigning at each tNow. After all the resources are assigned and the last activity is finished, the program gives the efficiency and duration of the project as obtained by the modified heuristic of ACTIM with MRIT.

Then the program executes similar routines for ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT. After that, the program produces an output file that consists of eighteen tables, three tables for each heuristic. The first table gives the name of the activity, its ACTIM, ACTRES or ROT values and the ranking of the activity. The second table gives the activity name, duration, resource required, predecessors, earliest start time (TES), earliest

finish time (TEF), actual start time (TAS) and actual finish time (TAF). The third table gives tNow and the remaining resources after each tNow step including the tNow at project completion. This is required to calculate the efficiency and project completion time, which are printed after the third table for each heuristic. The program was run for thirty project networks and from the output file of each run, project duration and efficiency for each network have been collected. The result is summarized in the Results and Discussion section in Table 5.1.

In the second part of the experiment, ten networks collected from the available literature have been used. Using the method discussed in section 3.2, the program is run for low level and high level resource requirements for each network to produce computer output giving project duration and efficiency obtained by each heuristic. The result is summarized in the Results and Discussion section in Table 5.8.

## Chapter 5                      Results and Discussions

### 5.1      Effects of MRIT on ACTIM, ACTRES and ROT Heuristics

Table 5.1 is the summary of the project duration and efficiency obtained from each heuristic. In order to analyze the result, efficiency value is used instead of project duration. Before analyzing the effect of MRIT on the existing heuristics (TIM, ACTRES and ROT), a single factor analysis of variance (ANOVA) with  $\alpha = 0.05$  has been carried out on the results obtained by ACTIM, ACTRES and ROT without MRIT criterion. The results of ‘ANOVA’ show no significant difference among the three existing methods.

Similarly, analysis of variance was carried out on the efficiency obtained by all six heuristics, ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT as shown in Table 5.3. The results of ‘ANOVA’ shows no significant difference among the six methods.

Efficiency obtained by these heuristics is significantly not different from each other because one heuristic may give a better result for one network but it may give a poor result for another network. Hence, the average efficiency for 30 networks obtained by one heuristic may not be significantly different from the average efficiency for 30 networks obtained by other heuristics. Looking closely, the average efficiency of one heuristic is different from the

**Table 5.1 (Spreadsheet Table)**



average efficiency obtained from other heuristics. In order to reach a conclusion regarding which heuristic performs better or to conclude if MRIT criterion has any effect on the existing heuristics, a comparison analysis by the ranking method has been used. The method has been described in Section 5.1.1.

Table 5.2 Analysis of variance for the existing methods without MRIT

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
ACTIM	30	21.9653	0.732177	0.011315
ACTRES	30	22.0803	0.73601	0.013322
ROT	30	22.0806	0.73602	0.014424

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.000295	2	0.000147	0.011315	0.98875	3.101292
Within Groups	1.132784	87	0.013021			
Total	1.133079	89				

Table 5.3 Analysis of variance for existing and proposed methods

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
ACTIM + MRIT	30	22.5925	0.753083333	0.017102992
ACTIM	30	21.9653	0.732176667	0.011315194
ACTRES +MRIT	30	22.5925	0.753083333	0.017102992
ACTRES	30	22.0803	0.73601	0.01332193
ROT +MRIT	30	22.5149	0.750496667	0.016323749
ROT	30	22.0806	0.73602	0.014424389

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.014187	5	0.002837397	0.190022816	0.966062	2.266063
Within Groups	2.598146	174	0.014931874			
Total	2.612333	179				

### 5.1.1 Comparison Analysis Using Ranks

If A, B, C, D, E, and F are the objective values (e.g., efficiency) obtained using ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT, and ROT heuristics respectively, then the objective values can be compared using ranks from 1 to 6 where 1 is the best and 6 is the worst. If a solution  $A > B > C > D > E > F$  has been obtained for a network from the six heuristics, the rank of the heuristics would be (1,2,3,4,5,6) for that network. If two objective values A and B are equal such as  $A = B > C > D > E > F$ , the rank would be (2,2,3,4,5,6) (Zolfaghari and Liang, 2002). The rank for the solution  $A = B > C > D > E > F$  can also be taken as (1,1,2,3,4,5), which is an optimistic ranking method compared to the previous ranking method, which may be called a pessimistic ranking method. First, the pessimistic ranking method is used for comparison of efficiency. The solutions and their pessimistic rankings are shown in Table 5.4 below:

Table 5.4 Pessimistic ranking schedule

Comparison of Solutions	Rank	Comparison of Solutions	Rank
$A > B > C > D > E > F$	(1,2,3,4,5,6)	$A < B < C < D < E < F$	(6,5,4,3,2,1)
$A = B > C > D > E > F$	(2,2,3,4,5,6)	$A = B < C < D < E < F$	(6,6,4,3,2,1)
$A > B = C > D > E > F$	(1,3,3,4,5,6)	$A < B = C < D < E < F$	(6,5,5,3,2,1)
$A > B > C = D > E > F$	(1,2,4,4,5,6)	$A < B < C = D < E < F$	(6,5,4,4,2,1)
$A > B > C > D = E > F$	(1,2,3,5,5,6)	$A < B < C < D = E < F$	(6,5,4,3,3,1)
$A > B > C > D > E = F$	(1,2,3,4,6,6)	$A < B < C < D < E = F$	(6,5,4,3,2,2)

A, B, C, D, E, and F are the objective values (efficiency) obtained using ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT, and ROT heuristics respectively.

In Table 5.5, efficiency obtained by each heuristic is ranked using the above ranking schedule for 30 networks. The average rankings are 5.233, 5.567, 5.233, 5.533, 5.233 and

5.533 for the heuristics ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT respectively

From the average ranking values, it is concluded that on the average, MRIT improved performance of all the three heuristics, viz., ACTIM, ACTRES and ROT. Since the ranking values for MRIT with ACTIM, ACTRES and ROT are the same, on the average, MRIT can be used to give same better performance with any of the heuristics, ACTIM, ACTRES or ROT. The results also suggest that on the average, the MRIT criterion improves the performance of ACTIM the most.

Next, the optimistic ranking method is used. Table 5.6 gives the optimistic ranking schedule.

Table 5.6 Optimistic ranking schedule

Comparison of Solutions	Rank	Comparison of Solutions	Rank
A>B>C>D>E>F	(1,2,3,4,5,6)	A<B<C<D<E<F	(6,5,4,3,2,1)
A=B>C>D>E>F	(1,1,2,3,4,5)	A=B<C<D<E<F	(5,5,4,3,2,1)
A>B=C>D>E>F	(1,2,2,3,4,5)	A<B=C<D<E<F	(5,4,4,3,2,1)
A>B>C=D>E>F	(1,2,3,3,4,5)	A<B<C=D<E<F	(5,4,3,3,2,1)
A>B>C>D=E>F	(1,2,3,4,4,5)	A<B<C<D=E<F	(5,4,3,2,2,1)
A>B>C>D>E=F	(1,2,3,4,5,5)	A<B<C<D<E=F	(5,4,3,2,1,1)

A, B, C, D, E, and F are the objective values (efficiency) obtained using ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT, and ROT heuristics respectively.

In Table 5.7, efficiency obtained by each heuristic is ranked using the optimistic ranking method for 30 networks. The average ranking are 1.100, 1.533, 1.266, 1.433, 1.333 and 1.500 for the heuristics ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT respectively.

From the average ranking values, it is concluded that, on the average, MRIT improved the performance of all the three heuristics, viz., ACTIM, ACTRES and ROT. Since the average

ranking value for MRIT with ACTIM is minimum, it is the best performing heuristic.

Comparing the results of both pessimistic and optimistic ranking methods of comparison, it can be concluded that, on the average, MRIT improves the performance of ACTIM, ACTRES and ROT. The MRIT criterion improves ACTIM heuristic the most and ACTIM with MRIT performs the best compared to the other five heuristics.

## **5.2 Performance of Heuristics at High and Low Levels of Resource Requirement**

The result of the second part of the experiment is summarized in Table 5.8. The upper part of table gives the efficiency and project duration when the resource requirement is restricted to a low level at 25 % or 50 % of the total available resources. The lower part of the table gives efficiency and project duration when the resource requirement is restricted to a high level at 75 % or 100 % of the same total available resources as before. It is interesting to note from the table that at the high-level resource requirement, the efficiency and project duration obtained by all the six heuristics are exactly the same for each network. Table 5.13 and Table 5.14 give pessimistic and optimistic ranking comparisons of all the six heuristics. In the pessimistic ranking method, the average ranking is 6 for all six heuristics, which means that all the heuristics are equally bad. For the optimistic ranking, the average ranking is 1. This means that when the activities have a high level of resource requirement, ACTIM, ACTRES and ROT perform equally well and MRIT has no effect at a high-level resource requirement.

The upper part of the table, which has values at the low level resource requirement needs further analysis. Before analyzing the effect of MRIT at the low level resource requirement

on the existing heuristics, ACTIM, ACTRES and ROT, a single factor ANOVA with  $\alpha = 0.05$  was carried out on the results obtained by ACTIM, ACTRES and ROT without MRIT. The results of 'ANOVA' show no significant difference among the three existing methods (Table 5.9).

Similarly, ANOVA was carried out on the efficiency obtained by all six heuristics, ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT as shown in Table 5.10. The result of 'ANOVA' shows no significant difference among the six methods.

Efficiency obtained by these heuristics is significantly not different from each other because one heuristic may give better result for one network but it may give poor result for another network. Hence, the average efficiency for 10 networks obtained by one heuristic may not be significantly different from the average efficiency for 10 networks obtained by other heuristic.

Now the ranking method described in section 5.1.1 has been used to determine which heuristic performs better when the resource requirement level is low compared with the total resource available. Table 5.11 and Table 5.12 give the pessimistic ranking and optimistic ranking of the scheduling heuristics based on efficiency. Table 5.11 gives average ranking of 6, 3.9, 6, 4.7, 6 and 5.6 for ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT heuristics, respectively. Table 5.12 gives average ranking of 1.6,

1.1, 1.6, 1.2, 1.6 and 1.5 for ACTIM with MRIT, ACTIM, ACTRES with MRIT, ACTRES, ROT with MRIT and ROT heuristics, respectively.

Comparing the results of both pessimistic and optimistic ranking methods of comparison, it can be concluded that, on the average, the performance of ACTIM is the best at the low level resource requirement and the MRIT criterion actually degrades the performance of the existing heuristics at the low level resource requirement.

On the average, the MRIT criterion improves the performance of the existing heuristics if there is no restriction in the resource level of component activities of a project. When the resource requirement level is restricted to a high level, the existing heuristics perform equally well and MRIT does not affect their performance. At the low-level resource requirement restriction, the ACTIM scheduling heuristic performs the best and the MRIT criterion rather degrades the performance of the existing scheduling heuristics.

Table 5.5. Comparison of efficiency by pessimistic ranking method.

Network No.	ACTIM + MRI	ACTIM	ACTRES + MRI	ACTRES	ROT + MRIT	ROT	ACTIM + MRI	ACTIM	ACTRES + MRI	ACTRES	ROT + MRIT	ROT
	Eff	Eff	Eff	Eff	Eff	Eff	Rank	Rank	Rank	Rank	Rank	Rank
1	0.8704	0.7344	0.8704	0.8704	0.8103	0.8103	3	6	3	3	5	5
2	0.4600	0.5750	0.4600	0.4600	0.4600	0.4600	6	1	6	6	6	6
3	0.6032	0.6032	0.6032	0.6032	0.6032	0.6032	6	6	6	6	6	6
4	0.6923	0.6429	0.6923	0.6923	0.6923	0.6923	5	6	5	5	5	5
5	0.9071	0.7471	0.9071	0.7471	0.9071	0.7056	3	5	3	5	3	6
6	0.9545	0.8077	0.9545	0.8077	0.9545	0.9545	4	6	4	6	4	4
7	0.7538	0.7538	0.7538	0.7538	0.7538	0.7538	6	6	6	6	6	6
8	0.4545	0.4545	0.4545	0.4545	0.4545	0.4545	6	6	6	6	6	6
9	0.6613	0.6613	0.6613	0.6613	0.6613	0.6613	6	6	6	6	6	6
10	0.8333	0.8333	0.8333	0.8333	0.8333	0.8333	6	6	6	6	6	6
11	0.6154	0.6154	0.6154	0.6154	0.6154	0.6154	6	6	6	6	6	6
12	0.7031	0.7031	0.7031	0.7031	0.7759	0.7759	6	6	6	6	2	2
13	0.9743	0.8888	0.9743	0.8587	0.9743	0.8888	3	5	3	6	3	5
14	0.8642	0.8642	0.8642	0.8642	0.9722	0.9722	6	6	6	6	2	2
15	0.7365	0.7365	0.7365	0.7365	0.7365	0.7365	6	6	6	6	6	6
16	0.8718	0.8718	0.8718	0.8718	0.8095	0.8095	4	4	4	4	6	6
17	0.6928	0.6928	0.6928	0.6928	0.6928	0.6609	5	5	5	5	5	6
18	0.6780	0.6780	0.6780	0.6780	0.6780	0.6780	6	6	6	6	6	6
19	0.6667	0.6667	0.6667	0.6667	0.6667	0.6667	6	6	6	6	6	6
20	0.8517	0.8517	0.8517	0.8517	0.8517	0.8517	6	6	6	6	6	6
21	0.6872	0.6872	0.6872	0.6872	0.6872	0.6872	6	6	6	6	6	6
22	0.9682	0.9682	0.9682	0.9682	0.8714	0.8714	4	4	4	4	6	6
23	0.8046	0.8046	0.8046	0.8046	0.8046	0.8046	6	6	6	6	6	6
24	0.7833	0.7833	0.7833	0.7833	0.7833	0.7833	6	6	6	6	6	6
25	0.7319	0.7319	0.7319	0.7319	0.7319	0.7319	6	6	6	6	6	6
26	0.6923	0.6923	0.6923	0.6923	0.6923	0.6923	6	6	6	6	6	6
27	0.8083	0.7186	0.8083	0.7185	0.8083	0.6929	3	5	3	5	3	6
28	0.8034	0.7286	0.8034	0.8034	0.7642	0.7642	3	6	3	3	5	5
29	0.6515	0.6515	0.6515	0.6515	0.6515	0.6515	6	6	6	6	6	6
30	0.8169	0.8169	0.8169	0.8169	0.8169	0.8169	6	6	6	6	6	6
	Sum						157	167	157	166	157	166
	Average						5.23	5.57	5.23	5.53	5.23	5.53

Table 5.7. Comparison of efficiency by optimistic ranking method.

	ACTIM + MRI	ACTIM	ACTRES +MRI	ACTRES	ROT +MRIT	ROT	ACTIM + MRI	ACTIM	ACTRES +MRI	ACTRES	ROT +MRIT	ROT
Network No.	Eff	Eff	Eff	Eff	Eff	Eff	Rank	Rank	Rank	Rank	Rank	Rank
1	0.8704	0.7344	0.8704	0.8704	0.8103	0.8103	1	3	1	1	2	2
2	0.4600	0.5750	0.4600	0.4600	0.4600	0.4600	2	1	2	2	2	2
3	0.6032	0.6032	0.6032	0.6032	0.6032	0.6032	1	1	1	1	1	1
4	0.6923	0.6429	0.6923	0.6923	0.6923	0.6923	1	2	1	1	1	1
5	0.9071	0.7471	0.9071	0.7471	0.9071	0.7056	1	2	1	2	1	3
6	0.9545	0.8077	0.9545	0.8077	0.9545	0.9545	1	2	1	2	1	1
7	0.7538	0.7538	0.7538	0.7538	0.7538	0.7538	1	1	1	1	1	1
8	0.4545	0.4545	0.4545	0.4545	0.4545	0.4545	1	1	1	1	1	1
9	0.6613	0.6613	0.6613	0.6613	0.6613	0.6613	1	1	1	1	1	1
10	0.8333	0.8333	0.8333	0.8333	0.8333	0.8333	1	6	6	6	6	6
11	0.6154	0.6154	0.6154	0.6154	0.6154	0.6154	1	1	1	1	1	1
12	0.7031	0.7031	0.7031	0.7031	0.7759	0.7759	2	2	2	2	1	1
13	0.9743	0.8888	0.9743	0.8587	0.9743	0.8888	1	2	1	3	1	2
14	0.8642	0.8642	0.8642	0.8642	0.9722	0.9722	2	2	2	2	1	1
15	0.7365	0.7365	0.7365	0.7365	0.7365	0.7365	1	1	1	1	1	1
16	0.8718	0.8718	0.8718	0.8718	0.8095	0.8095	1	1	1	1	2	2
17	0.6928	0.6928	0.6928	0.6928	0.6928	0.6609	1	1	1	1	1	1
18	0.6780	0.6780	0.6780	0.6780	0.6780	0.6780	1	1	1	1	1	1
19	0.6667	0.6667	0.6667	0.6667	0.6667	0.6667	1	1	1	1	1	1
20	0.8517	0.8517	0.8517	0.8517	0.8517	0.8517	1	1	1	1	1	1
21	0.6872	0.6872	0.6872	0.6872	0.6872	0.6872	1	1	1	1	1	1
22	0.9682	0.9682	0.9682	0.9682	0.8714	0.8714	1	1	1	1	2	2
23	0.8046	0.8046	0.8046	0.8046	0.8046	0.8046	1	1	1	1	1	1
24	0.7833	0.7833	0.7833	0.7833	0.7833	0.7833	1	1	1	1	1	1
25	0.7319	0.7319	0.7319	0.7319	0.7319	0.7319	1	1	1	1	1	1
26	0.6923	0.6923	0.6923	0.6923	0.6923	0.6923	1	1	1	1	1	1
27	0.8083	0.7186	0.8083	0.7185	0.8083	0.6929	1	2	1	2	1	3
28	0.8034	0.7286	0.8034	0.8034	0.7642	0.7642	1	3	1	1	2	2
29	0.6515	0.6515	0.6515	0.6515	0.6515	0.6515	1	1	1	1	1	1
30	0.8169	0.8169	0.8169	0.8169	0.8169	0.8169	1	1	1	1	1	1
Sum							33	46	38	43	40	45
Average							1.100	1.53	1.27	1.43	1.33	1.5
Eff means Efficiency												



Table 5.8. Efficiency and duration at low and high levels of resource requirement

No. Of Activities	Network No.	Total Resource Available	Resource Req.	ACTIM+MRIT		ACTIM		ACTRES+MRIT		ACTRES		ROT+MRIT		ROT	
				Eff	Dur	Eff	Dur	Eff	Dur	Eff	Dur	Eff	Dur	Eff	Dur
5	1	4	1-2	0.639	27	0.718	24	0.639	27	0.639	27	0.639	27	0.639	27
8	2	4	1-2	0.813	24	0.848	23	0.813	24	0.886	22	0.813	24	0.813	24
7	3	4	1-2	0.607	21	0.638	20	0.607	21	0.638	20	0.607	21	0.607	21
5	4	4	1-2	0.650	10	0.650	10	0.650	10	0.650	10	0.650	10	0.650	10
7	5	4	1-2	0.760	24	0.830	22	0.760	24	0.830	22	0.760	24	0.760	24
6	6	4	1-2	0.607	7	0.607	7	0.607	7	0.607	7	0.607	7	0.607	7
7	7	4	1-2	0.804	14	0.865	13	0.804	14	0.804	14	0.804	14	0.865	13
7	8	4	1-2	0.636	11	0.636	11	0.636	11	0.636	11	0.636	11	0.636	11
8	9	4	1-2	0.737	19	0.737	19	0.737	19	0.737	19	0.737	19	0.737	19
6	10	4	1-2	0.633	15	0.633	15	0.633	15	0.633	15	0.633	15	0.633	15
5	1	4	3-4	0.858	44	0.858	44	0.858	44	0.858	44	0.858	44	0.858	44
8	2	4	3-4	0.819	51	0.819	51	0.819	51	0.819	51	0.819	51	0.819	51
7	3	4	3-4	0.890	34	0.890	34	0.890	34	0.890	34	0.890	34	0.890	34
5	4	4	3-4	0.854	24	0.854	24	0.854	24	0.854	24	0.854	24	0.854	24
7	5	4	3-4	0.878	49	0.878	49	0.878	49	0.878	49	0.878	49	0.878	49
6	6	4	3-4	0.875	14	0.875	14	0.875	14	0.875	14	0.875	14	0.875	14
7	7	4	3-4	0.865	26	0.865	26	0.865	26	0.865	26	0.865	26	0.865	26
7	8	4	3-4	0.837	26	0.837	26	0.837	26	0.837	26	0.837	26	0.837	26
8	9	4	3-4	0.924	36	0.924	36	0.924	36	0.924	36	0.924	36	0.924	36
6	10	4	3-4	0.810	25	0.810	25	0.810	25	0.810	25	0.810	25	0.810	25

Dur means duration, Eff means Efficiency

Table 5.9 Analysis of variance for existing methods at low level resource requirement

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
ACTIM	10	7.162	0.7162	0.009853
ACTRES	10	7.06	0.706	0.010069
ROT	10	6.947	0.6947	0.008532

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.00231	2	0.001157	0.12195	0.885678	3.354131
Within Groups	0.25608	27	0.009485			
Total	0.25839	29				

Table 5.10 Analysis of variance for existing and proposed methods at low level resource requirement

Anova:  
Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
ACTIM+M	10	6.886	0.6886	0.006595
ACTIM	10	7.162	0.7162	0.009853
ACTRES+M	10	6.886	0.6886	0.006595
ACTRES	10	7.06	0.706	0.010069
ROT+M	10	6.886	0.6886	0.006595
ROT	10	6.947	0.6947	0.008532

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.00667	5	0.001333	0.165804	0.974054	2.386066
Within Groups	0.43416	54	0.00804			
Total	0.44082	59				

Table 5.11. Comparison of efficiency at low level resource requirement by pessimistic ranking method

No. Of Activities	NW No.	Total Resource Available	Resource Req'd.	ACTIM+MRIT		ACTIM		ACTRES+MRIT		ACTRES		ROT+MRIT		ROT	
				Eff.	Ranking	Eff.	Ranking	Eff.	Ranking	Eff.	Ranking	Eff.	Ranking	Eff.	Ranking
5	1	4	1-2	0.639	6	0.718	1	0.639	6	0.639	6	0.639	6	6	6
8	2	4	1-2	0.813	6	0.848	2	0.813	6	0.886	1	0.813	6	6	6
7	3	4	1-2	0.607	6	0.638	2	0.607	6	0.638	2	0.607	6	6	6
5	4	4	1-2	0.650	6	0.650	6	0.650	6	0.650	6	0.650	6	6	6
7	5	4	1-2	0.760	6	0.830	2	0.760	6	0.830	2	0.760	6	6	6
6	6	4	1-2	0.607	6	0.607	6	0.607	6	0.607	6	0.607	6	6	6
7	7	4	1-2	0.804	6	0.865	2	0.804	6	0.804	6	0.865	6	6	2
7	8	4	1-2	0.636	6	0.636	6	0.636	6	0.636	6	0.636	6	6	6
8	9	4	1-2	0.737	6	0.737	6	0.737	6	0.737	6	0.737	6	6	6
6	10	4	1-2	0.633	6	0.633	6	0.633	6	0.633	6	0.633	6	6	6
				Sum		39		60		47		60		56	
				Average		3.9		6		4.7		6		5.6	
Eff means Efficiency															

Table 5.12. Comparison of efficiency at low level resource requirement by optimistic ranking method

No. Of Activities	NW No.	Total Resource Available	Resource Req'd	ACTIM+MRIT		ACTIM		ACTRES+MRIT		ACTRES		ROT+MRIT		ROT	
				Eff	Ranking	Eff	Ranking	Eff	Ranking	Eff	Ranking	Eff	Ranking	Eff	Ranking
5	1	4	1-2	0.639	2	0.718	1	0.639	2	0.639	2	0.639	2	0.639	2
8	2	4	1-2	0.813	3	0.848	2	0.813	3	0.886	1	0.813	3	0.813	3
7	3	4	1-2	0.607	2	0.638	1	0.607	2	0.638	1	0.607	2	0.607	2
5	4	4	1-2	0.650	1	0.650	1	0.650	1	0.650	1	0.650	1	0.650	1
7	5	4	1-2	0.760	2	0.830	1	0.760	2	0.830	1	0.760	2	0.760	2
6	6	4	1-2	0.607	1	0.607	1	0.607	1	0.607	1	0.607	1	0.607	1
7	7	4	1-2	0.804	2	0.865	1	0.804	2	0.804	2	0.865	2	0.865	1
7	8	4	1-2	0.636	1	0.636	1	0.636	1	0.636	1	0.636	1	0.636	1
8	9	4	1-2	0.737	1	0.737	1	0.737	1	0.737	1	0.737	1	0.737	1
6	10	4	1-2	0.633	1	0.633	1	0.633	1	0.633	1	0.633	1	0.633	1
				Sum		11		16		12		16		15	
				Average		1.1		1.6		1.2		1.6		1.5	
Eff means Efficiency															

Table 5.13. Comparison of efficiency at high level resource requirement by pessimistic ranking method

No. Of Activities	Network No.	Total Resource Availabl	Resource Req.	ACTIM+MRIT		ACTIM		ACTRES+MRIT		ACTRES		ROT+MRIT		ROT	
				Eff	Ranking	Eff	Ranking	Eff	Ranking	Eff	Ranking	Eff	Ranking	Eff	Ranking
5	1	4	3-4	0.858	6	0.858	6	0.858	6	0.858	6	0.858	6	0.858	6
8	2	4	3-4	0.819	6	0.819	6	0.819	6	0.819	6	0.819	6	0.819	6
7	3	4	3-4	0.890	6	0.890	6	0.890	6	0.890	6	0.890	6	0.890	6
5	4	4	3-4	0.854	6	0.854	6	0.854	6	0.854	6	0.854	6	0.854	6
7	5	4	3-4	0.878	6	0.878	6	0.878	6	0.878	6	0.878	6	0.878	6
6	6	4	3-4	0.875	6	0.875	6	0.875	6	0.875	6	0.875	6	0.875	6
7	7	4	3-4	0.865	6	0.865	6	0.865	6	0.865	6	0.865	6	0.865	6
7	8	4	3-4	0.837	6	0.837	6	0.837	6	0.837	6	0.837	6	0.837	6
8	9	4	3-4	0.924	6	0.924	6	0.924	6	0.924	6	0.924	6	0.924	6
6	10	4	3-4	0.810	6	0.810	6	0.810	6	0.810	6	0.810	6	0.810	6
				Sum		60		60		60		60		60	
				Average		6		6		6		6		6	
Eff means Efficiency															

Table 5.14. Comparison of efficiency at high level resource requirement by optimistic ranking metho

No. Of Activities	NW No.	Z	Resource Req'd	ACTIM+MRIT	ACTIM	ACTRES+MRIT	ACTRES	ROT+MRIT	ROT	ACTIM+M	ACTIM	ACTRES+M	ACTRES	ROT+M	ROT
5	1	4	3-4	0.858	0.858	0.858	0.858	0.858	0.858	1	1	1	1	1	1
8	2	4	3-4	0.819	0.819	0.819	0.819	0.819	0.819	1	1	1	1	1	1
7	3	4	3-4	0.890	0.890	0.890	0.890	0.890	0.890	1	1	1	1	1	1
5	4	4	3-4	0.854	0.854	0.854	0.854	0.854	0.854	1	1	1	1	1	1
7	5	4	3-4	0.878	0.878	0.878	0.878	0.878	0.878	1	1	1	1	1	1
6	6	4	3-4	0.875	0.875	0.875	0.875	0.875	0.875	1	1	1	1	1	1
7	7	4	3-4	0.865	0.865	0.865	0.865	0.865	0.865	1	1	1	1	1	1
7	8	4	3-4	0.837	0.837	0.837	0.837	0.837	0.837	1	1	1	1	1	1
8	9	4	3-4	0.924	0.924	0.924	0.924	0.924	0.924	1	1	1	1	1	1
6	10	4	3-4	0.810	0.810	0.810	0.810	0.810	0.810	1	1	1	1	1	1
				Sum											
				Average											
				1											
				1											

Eff means Efficiency

## **Chapter 6**

## **Conclusion and Future Research**

### **Direction**

There are over 30 existing resource constrained project scheduling heuristics. Some of the most frequently used scheduling heuristics are Activity Time (ACTIM), Activity Resource (ACTRES) and Resource over Time (ROT). For a project, ACTIM scheduling heuristic may give a smaller project duration compared with the project duration obtained by the ACTRES or ROT heuristic, while for some other project ACTRES or ROT may give a smaller project duration. From the average ranking values obtained in the previous section, it is concluded that, on the average, the MRIT criterion improved performance of all the three heuristics considered viz., ACTIM, ACTRES and ROT. Since the ranking values for MRIT with ACTIM, ACTRES and ROT are the same, on the average, MRIT can be used to give the same better performance with any of the heuristics, ACTIM, ACTRES or ROT. The results also suggest that, on the average, the MRIT criterion improves the performance of ACTIM the most. In this part of the study, the component activities of a project are not restricted to any resource requirement level. In other words, activities may require any resource value from zero to the total resources available.

In the second part of the study, the performance of ACTIM, ACTRES and ROT are compared when the resource requirement of the component activities of a project is restricted. First the component activities of a project are restricted to have only a low level

resource requirement (25 % or 50 % of the total available resources) and then, they are restricted to have only a high level resource requirement (75% or 100 % of the total available resources). Project duration and efficiency are obtained for each level using ACTIM, ACTRES and ROT, with and without the MRIT criterion. At the low level resource requirement, ACTIM performed best and the MRIT criterion has degrading effects on all the three heuristics. At the high level resource requirement, the efficiency (and project duration) obtained by all the six heuristics are exactly the same for each network. This means that when the activities have a high level of resource requirement, ACTIM, ACTRES and ROT perform equally well and MRIT has no effect for a high-level resource requirement.

There are several areas for further research based on this study:

- The effects of MRIT on the size and complexity of a project network may be studied.
- The effect of MRIT may also be studied on a combination of heuristics such as TIMRES, GENRES and other existing combinations of heuristics.
- Some other criterion similar to MRIT may be studied.
- Investigation of different heuristic performances and individual problem characteristics could be considered in future



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# **APPENDIX**

**Sample Computer Outputs for the First 10 Project Networks**

Network 1

Total Resources: 4

[Sorted List]

\*\*\*\*\*

* Activity	ACTIMS	Ranking *
B	20.0	1
A	19.0	2
D	12.0	3
C	10.0	4
E	07.0	5

-----

[Table usig ACTIM with MRIT ]

\*\*\*\*\*

* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
B	0008	1	-,	0000	0008	00007	00015
A	0007	4	-,	0000	0007	00000	00007
D	0012	2	A,B,	0000	0012	00015	00027
C	0010	2	A,	0000	0010	00007	00017
E	0007	2	B,	0008	0015	00017	00024

-----

[Duration Sorted List]

\*\*\*\*\*

* tNow	Resources	*
27	0004	
24	0002	
17	0000	
15	0000	
7	0001	
0	0000	

-----

Efficiency: 0.8703704 Project Duration: 27

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B              20.0              1
  A              19.0              2
  D              12.0              3
  C              10.0              4
  E              07.0              5
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B      0008      1      -,      0000      0008      00000      00008
  A      0007      4      -,      0000      0007      00008      00015
  D      0012      2      A,B,      0000      0012      00015      00027
  C      0010      2      A,      0000      0010      00015      00025
  E      0007      2      B,      0008      0015      00025      00032
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  32              0004
  27              0002
  25              0000
  15              0000
   8              0000
   0              0003
-----
```

Efficiency: 0.734375 Project Duration: 32

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  A                      52.0                   1
  B                      32.0                   2
  D                      24.0                   3
  C                      20.0                   4
  E                      14.0                   5
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A          0007       4           -,      0000       0007       00000       00007
  B          0008       1           -,      0000       0008       00007       00015
  D          0012       2           A,B,      0000       0012       00015       00027
  C          0010       2           A,       0000       0010       00007       00017
  E          0007       2           B,       0008       0015       00017       00024
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  27                  0004
  24                  0002
  17                  0000
  15                  0000
   7                  0001
   0                  0000
-----
```

Efficiency: 0.8703704 Project Duration: 27

[Sorted List]

*****		
* Activity	ACTRES	Ranking *
*****		
A	52.0	1
B	32.0	2
D	24.0	3
C	20.0	4
E	14.0	5

[Table using ACTRES]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
A	0007	4	-,	0000	0007	00000	00007
B	0008	1	-,	0000	0008	00007	00015
D	0012	2	A,B,	0000	0012	00015	00027
C	0010	2	A,	0000	0010	00007	00017
E	0007	2	B,	0008	0015	00017	00024

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
27	0004
24	0002
17	0000
15	0000
7	0001
0	0000

Efficiency: 0.8703704 Project Duration: 27

[Sorted List]

*****		
* Activity	ROT	Ranking *
*****		
A	00.7	1
B	00.4	2
E	00.2	3
C	00.2	4
D	00.1	5

[Table using ROT with MRIT]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
A	0007	4	-,	0000	0007	00000	00007
B	0008	1	-,	0000	0008	00007	00015
E	0007	2	B,	0008	0015	00015	00022
C	0010	2	A,	0000	0010	00007	00017
D	0012	2	A,B,	0000	0012	00017	00029

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
29	0004
22	0002
17	0000
15	0000
7	0001
0	0000

Efficiency: 0.8103448 Project Duration: 29



[Sorted List]

*****		
* Activity	ROT	Ranking *
*****		
A	00.7	1
B	00.4	2
E	00.2	3
C	00.2	4
D	00.1	5

[Table using ROT ]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
A	0007	4	-,	0000	0007	00000	00007
B	0008	1	-,	0000	0008	00007	00015
E	0007	2	B,	0008	0015	00015	00022
C	0010	2	A,	0000	0010	00007	00017
D	0012	2	A,B,	0000	0012	00017	00029

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
29	0004
22	0002
17	0000
15	0000
7	0001
0	0000

Efficiency: 0.8103448 Project Duration: 29

## Network 2

Total Resources: 5

### [Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  C                08.0             1
  F                07.0             2
  A                06.0             3
  B                03.0             4
  D                03.0             5
  E                02.0             6
-----
```

### [Table usig ACTIM with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  C      0001      1      -,      0000      0001      00000      00001
  F      0007      1      C,      0001      0008      00003      00010
  A      0003      1      -,      0000      0003      00000      00003
  B      0001      1      -,      0000      0001      00000      00001
  D      0003      2      A,      0003      0006      00003      00006
  E      0002      4      B,      0001      0003      00001      00003
-----
```

### [Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  10          0005
   6          0004
   3          0002
   1          0000
   0          0005
-----
```

Efficiency: 0.46 Project Duration: 10

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  C                08.0             1
  F                07.0             2
  A                06.0             3
  B                03.0             4
  D                03.0             5
  E                02.0             6
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  C      0001      1          -,      0000      0001      00000      00001
  F      0007      1          C,      0001      0008      00001      00008
  A      0003      1          -,      0000      0003      00000      00003
  B      0001      1          -,      0000      0001      00000      00001
  D      0003      2          A,      0003      0006      00003      00006
  E      0002      4          B,      0001      0003      00006      00008
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  8              0005
  6              0000
  3              0002
  1              0003
  0              0005
-----
```

Efficiency: 0.575 Project Duration: 8

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      09.0                   1
  A                      09.0                   2
  C                      08.0                   3
  E                      08.0                   4
  F                      07.0                   5
  D                      06.0                   6
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B      0001      1      -,      0000      0001      00000      00001
  A      0003      1      -,      0000      0003      00000      00003
  C      0001      1      -,      0000      0001      00000      00001
  E      0002      4      B,      0001      0003      00001      00003
  F      0007      1      C,      0001      0008      00003      00010
  D      0003      2      A,      0003      0006      00003      00006
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  10                      0005
   6                      0004
   3                      0002
   1                      0000
   0                      0005
-----
```

Efficiency: 0.46 Project Duration: 10

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      09.0                   1
  A                      09.0                   2
  C                      08.0                   3
  E                      08.0                   4
  F                      07.0                   5
  D                      06.0                   6
-----
```

[Table using ACTRES]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0001       1           -,          0000       0001       00000       00001
  A          0003       1           -,          0000       0003       00000       00003
  C          0001       1           -,          0000       0001       00000       00001
  E          0002       4           B,          0001       0003       00001       00003
  F          0007       1           C,          0001       0008       00003       00010
  D          0003       2           A,          0003       0006       00003       00006
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  10                      0005
   6                      0004
   3                      0002
   1                      0000
   0                      0005
-----
```

Efficiency: 0.46 Project Duration: 10

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B              03.0             1
  E              02.0             2
  C              01.1             3
  A              01.0             4
  D              00.6             5
  F              00.1             6
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B      0001      1              -,      0000      0001      00000      00001
  E      0002      4              B,      0001      0003      00001      00003
  C      0001      1              -,      0000      0001      00000      00001
  A      0003      1              -,      0000      0003      00000      00003
  D      0003      2              A,      0003      0006      00003      00006
  F      0007      1              C,      0001      0008      00003      00010
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  10              0005
  6              0004
  3              0002
  1              0000
  0              0005
-----
```

Efficiency: 0.46 Project Duration: 10

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B                03.0          1
  E                02.0          2
  C                01.1          3
  A                01.0          4
  D                00.6          5
  F                00.1          6
-----
```

[Table using ROT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0001       1          -,          0000       0001       00000       00001
  E          0002       4          B,          0001       0003       00001       00003
  C          0001       1          -,          0000       0001       00000       00001
  A          0003       1          -,          0000       0003       00000       00003
  D          0003       2          A,          0003       0006       00003       00006
  F          0007       1          C,          0001       0008       00003       00010
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  10              0005
   6              0004
   3              0002
   1              0000
   0              0005
-----
```

Efficiency: 0.46 Project Duration: 10

Network 3

Total Resources: 3

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B              20.0              1
  E              18.0              2
  C              13.0              3
  G              10.0              4
  A              09.0              5
  D              03.0              6
  F              01.0              7
-----
```

[Table usig ACTIM with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B      0002      2          -,      0000      0002      00000      00002
  E      0008      1          B,      0002      0010      00002      00010
  C      0003      1          -,      0000      0003      00000      00003
  G      0010      1          E,C,      0010      0020      00010      00020
  A      0008      1          -,      0000      0008      00003      00011
  D      0002      1          B,      0002      0004      00002      00004
  F      0001      3      A,D,E,C,      0010      0011      00020      00021
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  21              0003
  20              0000
  11              0002
  10              0001
   4              0001
   3              0000
   2              0000
   0              0000
-----
```

Efficiency: 0.6031746 Project Duration: 21



[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B                20.0             1
  E                18.0             2
  C                13.0             3
  G                10.0             4
  A                09.0             5
  D                03.0             6
  F                01.0             7
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B      0002      2      -,      0000      0002      00000      00002
  E      0008      1      B,      0002      0010      00002      00010
  C      0003      1      -,      0000      0003      00000      00003
  G      0010      1      E,C,    0010      0020      00010      00020
  A      0008      1      -,      0000      0008      00002      00010
  D      0002      1      B,      0002      0004      00003      00005
  F      0001      3      A,D,E,C, 0010      0011      00020      00021
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  21              0003
  20              0000
  10              0002
   5              0001
   3              0000
   2              0000
   0              0000
-----
```

Efficiency: 0.6031746 Project Duration: 21

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      22.0                   1
  E                      18.0                   2
  C                      13.0                   3
  A                      11.0                   4
  G                      10.0                   5
  D                      05.0                   6
  F                      03.0                   7
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0002      2          -,          0000      0002      00000      00002
  E          0008      1          B,          0002      0010      00002      00010
  C          0003      1          -,          0000      0003      00000      00003
  A          0008      1          -,          0000      0008      00003      00011
  G          0010      1          E,C,        0010      0020      00010      00020
  D          0002      1          B,          0002      0004      00002      00004
  F          0001      3          A,D,E,C,    0010      0011      00020      00021
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  21                  0003
  20                  0000
  11                  0002
  10                  0001
  4                   0001
  3                   0000
  2                   0000
  0                   0000
-----
```

Efficiency: 0.6031746 Project Duration: 21

[Sorted List]

```
*****
* Activity          ACTRES          Ranking *
*****
  B                22.0             1
  E                18.0             2
  C                13.0             3
  A                11.0             4
  G                10.0             5
  D                05.0             6
  F                03.0             7
-----
```

[Table using ACTRES]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B        0002     2        -,      0000     0002     00000     00002
  E        0008     1        B,      0002     0010     00002     00010
  C        0003     1        -,      0000     0003     00000     00003
  A        0008     1        -,      0000     0008     00002     00010
  G        0010     1        E,C,     0010     0020     00010     00020
  D        0002     1        B,      0002     0004     00003     00005
  F        0001     3        A,D,E,C, 0010     0011     00020     00021
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  21              0003
  20              0000
  10              0002
   5              0001
   3              0000
   2              0000
   0              0000
-----
```

Efficiency: 0.6031746 Project Duration: 21

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B                04.5          1
  D                03.5          2
  C                03.3          3
  E                03.1          4
  A                03.1          5
  F                03.0          6
  G                00.1          7
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0002       2          -,          0000       0002       00000       00002
  D          0002       1          B,          0002       0004       00002       00004
  C          0003       1          -,          0000       0003       00000       00003
  E          0008       1          B,          0002       0010       00002       00010
  A          0008       1          -,          0000       0008       00003       00011
  F          0001       3      A,D,E,C,       0010       0011       00020       00021
  G          0010       1          E,C,       0010       0020       00010       00020
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  21              0003
  20              0000
  11              0002
  10              0001
  4               0001
  3               0000
  2               0000
  0               0000
-----
```

Efficiency: 0.6031746 Project Duration: 21

[Sorted List]

*****		
* Activity	ROT	Ranking *
*****		
B	04.5	1
D	03.5	2
C	03.3	3
E	03.1	4
A	03.1	5
F	03.0	6
G	00.1	7

[Table using ROT ]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
B	0002	2	-,	0000	0002	00000	00002
D	0002	1	B,	0002	0004	00002	00004
C	0003	1	-,	0000	0003	00000	00003
E	0008	1	B,	0002	0010	00002	00010
A	0008	1	-,	0000	0008	00003	00011
F	0001	3	A,D,E,C,	0010	0011	00020	00021
G	0010	1	E,C,	0010	0020	00010	00020

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
21	0003
20	0000
11	0002
10	0001
4	0001
3	0000
2	0000
0	0000

Efficiency: 0.6031746 Project Duration: 21

Network 4

Total Resources: 5

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  A              10.0              1
  B              09.0              2
  D              08.0              3
  E              06.0              4
  C              05.0              5
-----
```

[Table using ACTIM with MRIT ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  A      0002      1          -,      0000      0002      00000      00002
  B      0003      1          -,      0000      0003      00002      00005
  D      0008      1          A,      0000      0008      00005      00013
  E      0006      2          A,B,     0000      0006      00005      00011
  C      0005      4          -,      0000      0005      00000      00005
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  13              0005
  11              0004
   5              0002
   2              0000
   0              0000
-----
```

Efficiency: 0.6923077 Project Duration: 13

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  A                10.0             1
  B                 09.0             2
  D                 08.0             3
  E                 06.0             4
  C                 05.0             5
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A         0002       1          -,      0000      0002      00000      00002
  B         0003       1          -,      0000      0003      00000      00003
  D         0008       1          A,      0000      0008      00002      00010
  E         0006       2          A,B,     0000      0006      00003      00009
  C         0005       4          -,      0000      0005      00009      00014
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  14                0005
  10                0001
   9                0000
   3                0002
   2                0003
   0                0003
-----
```

Efficiency: 0.64285713 Project Duration: 14

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  C                      20.0                   1
  B                      15.0                   2
  A                      14.0                   3
  E                      12.0                   4
  D                      08.0                   5
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  C          0005       4           -,      0000       0005       00000       00005
  B          0003       1           -,      0000       0003       00000       00003
  A          0002       1           -,      0000       0002       00003       00005
  E          0006       2          A,B,      0000       0006       00005       00011
  D          0008       1           A,      0000       0008       00005       00013
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  13                      0005
  11                      0004
   5                      0002
   3                      0000
   0                      0000
-----
```

Efficiency: 0.6923077 Project Duration: 13



[Sorted List]

*****		
* Activity	ACTRES	Ranking *
*****		
C	20.0	1
B	15.0	2
A	14.0	3
E	12.0	4
D	08.0	5

[Table using ACTRES]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
C	0005	4	-,	0000	0005	00000	00005
B	0003	1	-,	0000	0003	00000	00003
A	0002	1	-,	0000	0002	00003	00005
E	0006	2	A,B,	0000	0006	00005	00011
D	0008	1	A,	0000	0008	00005	00013

[Duration Sorted List]

*****		
* tNow	Resources	*
*****		
13	0005	
11	0004	
5	0002	
3	0000	
0	0000	

Efficiency: 0.6923077 Project Duration: 13

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  A              00.8            1
  C              00.8            2
  B              00.6            3
  E              00.3            4
  D              0.125           5
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  A      0002      1      -,      0000      0002      00000      00002
  C      0005      4      -,      0000      0005      00000      00005
  B      0003      1      -,      0000      0003      00002      00005
  E      0006      2      A,B,      0000      0006      00005      00011
  D      0008      1      A,      0000      0008      00005      00013
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources      *
*****
  13              0005
  11              0004
   5              0002
   2              0000
   0              0000
-----
```

Efficiency: 0.6923077 Project Duration: 13

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  A                00.8          1
  C                00.8          2
  B                00.6          3
  E                00.3          4
  D                0.125         5
-----
```

[Table using ROT ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  A        0002     1        -,      0000    0002    00000    00002
  C        0005     4        -,      0000    0005    00000    00005
  B        0003     1        -,      0000    0003    00002    00005
  E        0006     2        A,B,     0000    0006    00005    00011
  D        0008     1        A,      0000    0008    00005    00013
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  13                0005
  11                0004
   5                0002
   2                0000
   0                0000
-----
```

Efficiency: 0.6923077 Project Duration: 13

Network 5

Total Resources: 5

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B                19.0             1
  A                18.0             2
  E                16.0             3
  D                14.0             4
  C                12.0             5
  G                08.0             6
  F                02.0             7
-----
```

[Table using ACTIM with MRIT ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B      0003      1      -,      0000      0003      00000      00003
  A      0004      4      -,      0000      0004      00000      00004
  E      0016      3      B,      0000      0016      00010      00026
  D      0006      4      A,      0000      0006      00004      00010
  C      0010      2      A,      0000      0010      00010      00020
  G      0008      1      D,      0000      0008      00020      00028
  F      0002      4      C,      0010      0012      00026      00028
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  28              0005
  26              0000
  20              0001
  10              0000
   4              0001
   3              0001
   0              0000
-----
```

Efficiency: 0.9071429 Project Duration: 28

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B                19.0             1
  A                18.0             2
  E                16.0             3
  D                14.0             4
  C                12.0             5
  G                08.0             6
  F                02.0             7
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B      0003      1      -,      0000      0003      00000      00003
  A      0004      4      -,      0000      0004      00000      00004
  E      0016      3      B,      0000      0016      00004      00020
  D      0006      4      A,      0000      0006      00020      00026
  C      0010      2      A,,     0000      0010      00004      00014
  G      0008      1      D,      0000      0008      00026      00034
  F      0002      4      C,      0010      0012      00026      00028
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  34              0005
  28              0004
  26              0000
  20              0001
  14              0002
   4              0000
   3              0001
   0              0000
-----
```

Efficiency: 0.7470588 Project Duration: 34

[Sorted List]

```
*****
* Activity          ACTRES          Ranking *
*****
  B                51.0             1
  E                48.0             2
  A                48.0             3
  D                32.0             4
  C                28.0             5
  F                08.0             6
  G                08.0             7
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0003       1           -,          0000       0003       00000       00003
  E          0016       3           B,          0000       0016       00010       00026
  A          0004       4           -,          0000       0004       00000       00004
  D          0006       4           A,          0000       0006       00004       00010
  C          0010       2           A,          0000       0010       00010       00020
  F          0002       4           C,          0010       0012       00026       00028
  G          0008       1           D,          0000       0008       00020       00028
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  28                0005
  26                0000
  20                0001
  10                0000
   4                0001
   3                0001
   0                0000
-----
```

Efficiency: 0.9071429 Project Duration: 28

[Sorted List]

*****		
* Activity	ACTRES	Ranking *
*****		
B	51.0	1
E	48.0	2
A	48.0	3
D	32.0	4
C	28.0	5
F	08.0	6
G	08.0	7

[Table using ACTRES]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
B	0003	1	-,	0000	0003	00000	00003
E	0016	3	B,	0000	0016	00004	00020
A	0004	4	-,	0000	0004	00000	00004
D	0006	4	A,	0000	0006	00020	00026
C	0010	2	A,	0000	0010	00004	00014
F	0002	4	C,	0010	0012	00026	00028
G	0008	1	D,	0000	0008	00026	00034

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
34	0005
28	0004
26	0000
20	0001
14	0002
4	0000
3	0001
0	0000

Efficiency: 0.7470588 Project Duration: 34

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  A              03.2             1
  C              02.2             2
  F              02.0             3
  D              00.7             4
  B              00.5             5
  E              0.1875           6
  G              0.125            7
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A      0004      4      -,      0000      0004      00000      00004
  C      0010      2      A,      0000      0010      00010      00020
  F      0002      4      C,      0010      0012      00026      00028
  D      0006      4      A,      0000      0006      00004      00010
  B      0003      1      -,      0000      0003      00000      00003
  E      0016      3      B,      0000      0016      00010      00026
  G      0008      1      D,      0000      0008      00020      00028
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  28              0005
  26              0000
  20              0001
  10              0000
   4              0001
   3              0001
   0              0000
-----
```

Efficiency: 0.9071429 Project Duration: 28



[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  A                03.2          1
  C                02.2          2
  F                02.0          3
  D                00.7          4
  B                00.5          5
  E                0.1875        6
  G                0.125         7
-----
```

[Table using ROT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A          0004       4          -,          0000       0004       00000       00004
  C          0010       2          A,          0000       0010       00004       00014
  F          0002       4          C,          0010       0012       00020       00022
  D          0006       4          A,          0000       0006       00022       00028
  B          0003       1          -,          0000       0003       00000       00003
  E          0016       3          B,          0000       0016       00004       00020
  G          0008       1          D,          0000       0008       00028       00036
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  36              0005
  28              0004
  22              0001
  20              0001
  14              0002
   4              0000
   3              0001
   0              0000
-----
```

Efficiency: 0.70555556 Project Duration: 36

Network 6

Total Resources: 2

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  A                06.0             1
  B                04.0             2
  C                04.0             3
  D                03.0             4
  E                03.0             5
  F                03.0             6
-----
```

[Table usig ACTIM with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A          0003       1          -,      0000      0003      00001      00004
  B          0001       2          -,      0000      0001      00000      00001
  C          0001       1          -,      0000      0001      00001      00002
  D          0003       2          A,      0003      0006      00005      00008
  E          0003       1          B,      0001      0004      00002      00005
  F          0003       2          C,      0001      0004      00008      00011
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11              0002
   8              0000
   5              0000
   4              0001
   2              0000
   1              0000
   0              0000
-----
```

Efficiency: 0.95454544 Project Duration: 11

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  A                06.0             1
  B                04.0             2
  C                04.0             3
  D                03.0             4
  E                03.0             5
  F                03.0             6
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  A        0003     1        -,    0000    0003    00000    00003
  B        0001     2        -,    0000    0001    00003    00004
  C        0001     1        -,    0000    0001    00000    00001
  D        0003     2        A,    0003    0006    00004    00007
  E        0003     1        B,    0001    0004    00007    00010
  F        0003     2        C,    0001    0004    00010    00013
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  13                0002
  10                0000
   7                0001
   4                0000
   3                0000
   1                0001
   0                0000
-----
```

Efficiency: 0.8076923 Project Duration: 13

[Sorted List]

```
*****
* Activity          ACTRES          Ranking *
*****
  A                09.0             1
  C                07.0             2
  D                06.0             3
  F                06.0             4
  B                05.0             5
  E                03.0             6
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A          0003       1          -,          0000       0003       00001       00004
  C          0001       1          -,          0000       0001       00001       00002
  D          0003       2          A,          0003       0006       00005       00008
  F          0003       2          C,          0001       0004       00008       00011
  B          0001       2          -,          0000       0001       00000       00001
  E          0003       1          B,          0001       0004       00002       00005
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11              0002
   8              0000
   5              0000
   4              0001
   2              0000
   1              0000
   0              0000
-----
```

Efficiency: 0.95454544 Project Duration: 11

[Sorted List]

```
*****
* Activity          ACTRES          Ranking *
*****
  A                09.0             1
  C                07.0             2
  D                06.0             3
  F                06.0             4
  B                05.0             5
  E                03.0             6
-----
```

[Table using ACTRES]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  A        0003     1        -,    0000     0003     00000     00003
  C        0001     1        -,    0000     0001     00000     00001
  D        0003     2        A,    0003     0006     00003     00006
  F        0003     2        C,    0001     0004     00006     00009
  B        0001     2        -,    0000     0001     00009     00010
  E        0003     1        B,    0001     0004     00010     00013
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  13                0002
  10                0001
   9                0000
   6                0000
   3                0000
   1                0001
   0                0000
-----
```

Efficiency: 0.8076923 Project Duration: 13

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B              02.3             1
  C              01.6             2
  A              01.0             3
  D              00.6             4
  F              00.6             5
  E              00.3             6
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B      0001      2      -,      0000      0001      00000      00001
  C      0001      1      -,      0000      0001      00001      00002
  A      0003      1      -,      0000      0003      00001      00004
  D      0003      2      A,      0003      0006      00005      00008
  F      0003      2      C,      0001      0004      00008      00011
  E      0003      1      B,      0001      0004      00002      00005
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11              0002
   8              0000
   5              0000
   4              0001
   2              0000
   1              0000
   0              0000
-----
```

Efficiency: 0.95454544 Project Duration: 11

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B                02.3          1
  C                01.6          2
  A                01.0          3
  D                00.6          4
  F                00.6          5
  E                00.3          6
-----
```

[Table using ROT ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B        0001    2        -,    0000    0001    00000    00001
  C        0001    1        -,    0000    0001    00001    00002
  A        0003    1        -,    0000    0003    00001    00004
  D        0003    2        A,    0003    0006    00005    00008
  F        0003    2        C,    0001    0004    00008    00011
  E        0003    1        B,    0001    0004    00002    00005
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11                0002
   8                0000
   5                0000
   4                0001
   2                0000
   1                0000
   0                0000
-----
```

Efficiency: 0.95454544 Project Duration: 11

Network 7

Total Resources: 10

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  C                11.0             1
  B                08.0             2
  E                07.0             3
  A                07.0             4
  D                05.0             5
  F                04.0             6
  G                02.0             7
-----
```

[Table usig ACTIM with MRIT ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  C      0004     4      -,      0000     0004     00000     00004
  B      0006     5      -,      0000     0006     00002     00008
  E      0005     4      C,      0004     0009     00004     00009
  A      0002     3      -,      0000     0002     00000     00002
  D      0003     2      A,      0002     0005     00008     00011
  F      0004     2      A,      0002     0006     00008     00012
  G      0002     6      B,D,E,    0009     0011     00011     00013
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  13              0010
  12              0004
  11              0002
   9              0006
   8              0002
   4              0001
   2              0001
   0              0003
-----
```

Efficiency: 0.75384617 Project Duration: 13



[Sorted List]

*****		
* Activity	ACTIMS	Ranking *
C	11.0	1
B	08.0	2
E	07.0	3
A	07.0	4
D	05.0	5
F	04.0	6
G	02.0	7

[Complete Table using ACTIM ]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
C	0004	4	-,	0000	0004	00000	00004
B	0006	5	-,	0000	0006	00000	00006
E	0005	4	C,	0004	0009	00004	00009
A	0002	3	-,	0000	0002	00006	00008
D	0003	2	A,	0002	0005	00008	00011
F	0004	2	A,	0002	0006	00008	00012
G	0002	6	B,D,E,	0009	0011	00011	00013

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
13	0010
12	0004
11	0002
9	0006
8	0002
6	0003
4	0001
0	0001

Efficiency: 0.75384617 Project Duration: 13

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  C                      48.0                   1
  B                      42.0                   2
  E                      32.0                   3
  A                      24.0                   4
  D                      18.0                   5
  G                      12.0                   6
  F                      08.0                   7
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  C          0004       4           -,          0000       0004       00000       00004
  B          0006       5           -,          0000       0006       00002       00008
  E          0005       4           C,          0004       0009       00004       00009
  A          0002       3           -,          0000       0002       00000       00002
  D          0003       2           A,          0002       0005       00008       00011
  G          0002       6           B,D,E,       0009       0011       00011       00013
  F          0004       2           A,          0002       0006       00008       00012
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  13                  0010
  12                  0004
  11                  0002
   9                  0006
   8                  0002
   4                  0001
   2                  0001
   0                  0003
-----
```

Efficiency: 0.75384617 Project Duration: 13

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  C                      48.0                   1
  B                      42.0                   2
  E                      32.0                   3
  A                      24.0                   4
  D                      18.0                   5
  G                      12.0                   6
  F                      08.0                   7
-----
```

[Table using ACTRES]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  C      0004      4          -,    0000    0004    0000    0004
  B      0006      5          -,    0000    0006    0000    0006
  E      0005      4          C,    0004    0009    0004    0009
  A      0002      3          -,    0000    0002    0006    0008
  D      0003      2          A,    0002    0005    0008    0011
  G      0002      6      B,D,E,    0009    0011    0011    0013
  F      0004      2          A,    0002    0006    0008    0012
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  13                      0010
  12                      0004
  11                      0002
   9                      0006
   8                      0002
   6                      0003
   4                      0001
   0                      0001
-----
```

Efficiency: 0.75384617 Project Duration: 13

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  A                05.1          1
  C                04.8          2
  B                03.8          3
  E                03.8          4
  D                03.6          5
  G                03.0          6
  F                00.5          7
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  A          0002       3          -,      0000       0002       00000      00002
  C          0004       4          -,      0000       0004       00000      00004
  B          0006       5          -,      0000       0006       00002      00008
  E          0005       4          C,      0004       0009       00004      00009
  D          0003       2          A,      0002       0005       00008      00011
  G          0002       6          B,D,E,    0009       0011       00011      00013
  F          0004       2          A,      0002       0006       00008      00012
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  13              0010
  12              0004
  11              0002
   9              0006
   8              0002
   4              0001
   2              0001
   0              0003
-----
```

Efficiency: 0.75384617 Project Duration: 13

[Sorted List]

*****		
* Activity	ROT	Ranking *
*****		
A	05.1	1
C	04.8	2
B	03.8	3
E	03.8	4
D	03.6	5
G	03.0	6
F	00.5	7

[Table using ROT ]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
A	0002	3	-,	0000	0002	00000	00002
C	0004	4	-,	0000	0004	00000	00004
B	0006	5	-,	0000	0006	00002	00008
E	0005	4	C,	0004	0009	00004	00009
D	0003	2	A,	0002	0005	00008	00011
G	0002	6	B,D,E,	0009	0011	00011	00013
F	0004	2	A,	0002	0006	00008	00012

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
13	0010
12	0004
11	0002
9	0006
8	0002
4	0001
2	0001
0	0003

Efficiency: 0.75384617 Project Duration: 13

# Network 8

Total Resources: 15

## [Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  C                11.0             1
  B                08.0             2
  E                07.0             3
  A                07.0             4
  D                05.0             5
  F                04.0             6
  G                02.0             7
-----
```

## [Table usig ACTIM with MRIT ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  C      0004      1      -,      0000      0004      00000      00004
  B      0006      4      -,      0000      0006      00000      00006
  E      0005      3      C,      0004      0009      00004      00009
  A      0002      0      -,      0000      0002      00000      00002
  D      0003      0      A,      0002      0005      00002      00005
  F      0004      7      A,      0002      0006      00002      00006
  G      0002      2      B,D,E,    0009      0011      00009      00011
-----
```

## [Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11            0015
  9             0013
  6             0012
  5             0001
  4             0001
  2             0003
  0             0010
-----
```

Efficiency: 0.45454547 Project Duration: 11

[Sorted List]

*****		
* Activity	ACTIMS	Ranking *
C	11.0	1
B	08.0	2
E	07.0	3
A	07.0	4
D	05.0	5
F	04.0	6
G	02.0	7

[Complete Table using ACTIM ]

*****							
* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
*****							
C	0004	1	-,	0000	0004	00000	00004
B	0006	4	-,	0000	0006	00000	00006
E	0005	3	C,	0004	0009	00004	00009
A	0002	0	-,	0000	0002	00000	00002
D	0003	0	A,	0002	0005	00002	00005
F	0004	7	A,	0002	0006	00002	00006
G	0002	2	B,D,E,	0009	0011	00009	00011

[Duration Sorted List]

*****	
* tNow	Resources *
*****	
11	0015
9	0013
6	0012
5	0001
4	0001
2	0003
0	0010

Efficiency: 0.45454547 Project Duration: 11

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      28.0                    1
  F                      28.0                    2
  A                      28.0                    3
  C                      23.0                    4
  E                      19.0                    5
  D                      04.0                    6
  G                      04.0                    7
*****
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0006       4           -,          0000       0006       00000       00006
  F          0004       7           A,          0002       0006       00002       00006
  A          0002       0           -,          0000       0002       00000       00002
  C          0004       1           -,          0000       0004       00000       00004
  E          0005       3           C,          0004       0009       00004       00009
  D          0003       0           A,          0002       0005       00002       00005
  G          0002       2           B,D,E,       0009       0011       00009       00011
*****
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  11                  0015
   9                  0013
   6                  0012
   5                  0001
   4                  0001
   2                  0003
   0                  0010
*****
```

Efficiency: 0.45454547 Project Duration: 11



[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      28.0                   1
  F                      28.0                   2
  A                      28.0                   3
  C                      23.0                   4
  E                      19.0                   5
  D                      04.0                   6
  G                      04.0                   7
-----
```

[Table using ACTRES]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B        0006     4         -,    0000    0006    00000    00006
  F        0004     7         A,    0002    0006    00002    00006
  A        0002     0         -,    0000    0002    00000    00002
  C        0004     1         -,    0000    0004    00000    00004
  E        0005     3         C,    0004    0009    00004    00009
  D        0003     0         A,    0002    0005    00002    00005
  G        0002     2        B,D,E,  0009    0011    00009    00011
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  11                  0015
   9                  0013
   6                  0012
   5                  0001
   4                  0001
   2                  0003
   0                  0010
-----
```

Efficiency: 0.45454547 Project Duration: 11

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  C                1.85          1
  F                1.75          2
  A                1.75          3
  B                01.6          4
  E                01.6          5
  D                01.0          6
  G                01.0          7
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  C          0004       1          -,          0000       0004       00000       00004
  F          0004       7          A,          0002       0006       00002       00006
  A          0002       0          -,          0000       0002       00000       00002
  B          0006       4          -,          0000       0006       00000       00006
  E          0005       3          C,          0004       0009       00004       00009
  D          0003       0          A,          0002       0005       00002       00005
  G          0002       2          B,D,E,       0009       0011       00009       00011
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11              0015
   9              0013
   6              0012
   5              0001
   4              0001
   2              0003
   0              0010
-----
```

Efficiency: 0.45454547 Project Duration: 11

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  C                1.85          1
  F                1.75          2
  A                1.75          3
  B                01.6          4
  E                01.6          5
  D                01.0          6
  G                01.0          7
-----
```

[Table using ROT ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  C        0004    1        -,    0000    0004    00000    00004
  F        0004    7        A,    0002    0006    00002    00006
  A        0002    0        -,    0000    0002    00000    00002
  B        0006    4        -,    0000    0006    00000    00006
  E        0005    3        C,    0004    0009    00004    00009
  D        0003    0        A,    0002    0005    00002    00005
  G        0002    2        B,D,E, 0009    0011    00009    00011
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  11            0015
  9             0013
  6             0012
  5             0001
  4             0001
  2             0003
  0             0010
-----
```

Efficiency: 0.45454547 Project Duration: 11

Network 9

Total Resources: 4

[Sorted List]

```
*****
* Activity                ACTIMS                Ranking *
  B                      17.0                    1
  A                      17.0                    2
  E                      12.0                    3
  D                      11.0                    4
  C                      09.0                    5
  F                      07.0                    6
  H                      07.0                    7
  G                      01.0                    8
-----
```

[Table usig ACTIM with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B      0005      1      -,      0000      0005      00000      00005
  A      0006      2      -,      0000      0006      00014      00020
  E      0005      3      B,      0005      0010      00009      00014
  D      0004      2      A,B,      0006      0010      00020      00024
  C      0002      3      -,      0000      0002      00000      00002
  F      0006      3      C,      0002      0008      00002      00008
  H      0007      2      D,E,      0010      0017      00024      00031
  G      0001      4      B,F,      0008      0009      00008      00009
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  31                0004
  24                0002
  20                0002
  14                0002
   9                0001
   8                0000
   5                0001
   2                0000
   0                0000
-----
```

Efficiency: 0.66129035 Project Duration: 31

[Sorted List]

\*\*\*\*\*

* Activity	ACTIMS	Ranking *
B	17.0	1
A	17.0	2
E	12.0	3
D	11.0	4
C	09.0	5
F	07.0	6
H	07.0	7
G	01.0	8

[Complete Table using ACTIM ]

\*\*\*\*\*

* Name,	Dur,	Resrc,	Pred,	TES,	TEF,	TAS,	TAF *
B	0005	1	-,	0000	0005	00000	00005
A	0006	2	-,	0000	0006	00000	00006
E	0005	3	B,	0005	0010	00006	00011
D	0004	2	A,B,	0006	0010	00011	00015
C	0002	3	-,	0000	0002	00015	00017
F	0006	3	C,	0002	0008	00017	00023
H	0007	2	D,E,	0010	0017	00023	00030
G	0001	4	B,F,	0008	0009	00030	00031

-----

[Duration Sorted List]

\*\*\*\*\*

* tNow	Resources *
31	0004
30	0000
23	0002
17	0001
15	0001
11	0002
6	0001
5	0002
0	0001

-----

Efficiency: 0.66129035 Project Duration: 31

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      34.0                   1
  A                      34.0                   2
  E                      29.0                   3
  C                      28.0                   4
  D                      22.0                   5
  F                      22.0                   6
  H                      14.0                   7
  G                      04.0                   8
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B      0005      1      -,      0000      0005      00000      00005
  A      0006      2      -,      0000      0006      00014      00020
  E      0005      3      B,      0005      0010      00009      00014
  C      0002      3      -,      0000      0002      00000      00002
  D      0004      2      A,B,      0006      0010      00020      00024
  F      0006      3      C,      0002      0008      00002      00008
  H      0007      2      D,E,      0010      0017      00024      00031
  G      0001      4      B,F,      0008      0009      00008      00009
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  31                      0004
  24                      0002
  20                      0002
  14                      0002
   9                      0001
   8                      0000
   5                      0001
   2                      0000
   0                      0000
-----
```

Efficiency: 0.66129035 Project Duration: 31

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      34.0                   1
  A                      34.0                   2
  E                      29.0                   3
  C                      28.0                   4
  D                      22.0                   5
  F                      22.0                   6
  H                      14.0                   7
  G                      04.0                   8
-----
```

[Table using ACTRES]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B        0005    1        -,      0000    0005    00000    00005
  A        0006    2        -,      0000    0006    00000    00006
  E        0005    3        B,      0005    0010    00006    00011
  C        0002    3        -,      0000    0002    00011    00013
  D        0004    2        A,B,    0006    0010    00013    00017
  F        0006    3        C,      0002    0008    00017    00023
  H        0007    2        D,E,    0010    0017    00023    00030
  G        0001    4        B,F,    0008    0009    00030    00031
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  31                      0004
  30                      0000
  23                      0002
  17                      0001
  13                      0002
  11                      0001
   6                      0001
   5                      0002
   0                      0001
-----
```

Efficiency: 0.66129035 Project Duration: 31

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  C              06.0             1
  F              04.5             2
  B              04.2             3
  G              04.0             4
  A              01.1             5
  E              00.8             6
  D              00.7             7
  H              00.2             8
-----
```

[Table using ROT with MRIT]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  C      0002      3          -,    0000      0002      00000      00002
  F      0006      3          C,    0002      0008      00002      00008
  B      0005      1          -,    0000      0005      00000      00005
  G      0001      4          B,F,    0008      0009      00008      00009
  A      0006      2          -,    0000      0006      00014      00020
  E      0005      3          B,    0005      0010      00009      00014
  D      0004      2          A,B,    0006      0010      00020      00024
  H      0007      2          D,E,    0010      0017      00024      00031
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  31              0004
  24              0002
  20              0002
  14              0002
   9              0001
   8              0000
   5              0001
   2              0000
   0              0000
-----
```

Efficiency: 0.66129035 Project Duration: 31



[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
```

C	06.0	1
F	04.5	2
B	04.2	3
G	04.0	4
A	01.1	5
E	00.8	6
D	00.7	7
H	00.2	8

-----

[Table using ROT ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
```

C	0002	3	-,	0000	0002	00000	00002
F	0006	3	C,	0002	0008	00002	00008
B	0005	1	-,	0000	0005	00000	00005
G	0001	4	B,F,	0008	0009	00008	00009
A	0006	2	-,	0000	0006	00009	00015
E	0005	3	B,	0005	0010	00015	00020
D	0004	2	A,B,	0006	0010	00020	00024
H	0007	2	D,E,	0010	0017	00024	00031

-----

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
```

31	0004
24	0002
20	0002
15	0001
9	0002
8	0000
5	0001
2	0000
0	0000

-----

Efficiency: 0.66129035 Project Duration: 31

Network 10

Total Resources: 3

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B                15.0             1
  C                13.0             2
  A                13.0             3
  E                10.0             4
  D                09.0             5
  F                04.0             6
-----
```

[Table usig ACTIM with MRIT ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B      0002      2          -,      0000      0002      00000      00002
  C      0004      1          B,      0002      0006      00002      00006
  A      0004      2          -,      0000      0004      00002      00006
  E      0006      1          B,      0002      0008      00006      00012
  D      0005      2          A,C,      0006      0011      00006      00011
  F      0004      2          D,E,      0011      0015      00012      00016
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  16              0003
  12              0001
  11              0002
   6              0000
   2              0000
   0              0001
-----
```

Efficiency: 0.8333333 Project Duration: 16

[Sorted List]

```
*****
* Activity          ACTIMS          Ranking *
  B                15.0             1
  C                13.0             2
  A                13.0             3
  E                10.0             4
  D                09.0             5
  F                04.0             6
-----
```

[Complete Table using ACTIM ]

```
*****
* Name,      Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B      0002      2      -,      0000      0002      00000      00002
  C      0004      1      B,      0002      0006      00002      00006
  A      0004      2      -,      0000      0004      00002      00006
  E      0006      1      B,      0002      0008      00006      00012
  D      0005      2      A,C,     0006      0011      00006      00011
  F      0004      2      D,E,     0011      0015      00012      00016
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  16                      0003
  12                      0001
  11                      0002
   6                      0000
   2                      0000
   0                      0001
-----
```

Efficiency: 0.8333333 Project Duration: 16

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      26.0                   1
  A                      26.0                   2
  C                      22.0                   3
  D                      18.0                   4
  E                      14.0                   5
  F                      08.0                   6
-----
```

[Table using ACTRES with MRIT ]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B        0002     2        -,      0000     0002     00000     00002
  A        0004     2        -,      0000     0004     00002     00006
  C        0004     1        B,      0002     0006     00002     00006
  D        0005     2        A,C,     0006     0011     00006     00011
  E        0006     1        B,      0002     0008     00006     00012
  F        0004     2        D,E,     0011     0015     00012     00016
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  16                      0003
  12                      0001
  11                      0002
   6                      0000
   2                      0000
   0                      0001
-----
```

Efficiency: 0.8333333 Project Duration: 16

[Sorted List]

```
*****
* Activity                ACTRES                Ranking *
*****
  B                      26.0                   1
  A                      26.0                   2
  C                      22.0                   3
  D                      18.0                   4
  E                      14.0                   5
  F                      08.0                   6
-----
```

[Table using ACTRES]

```
*****
* Name,    Dur,    Resrc,    Pred,    TES,    TEF,    TAS,    TAF *
*****
  B        0002     2        -,    0000    0002    00000    00002
  A        0004     2        -,    0000    0004    00002    00006
  C        0004     1        B,    0002    0006    00002    00006
  D        0005     2        A,C,    0006    0011    00006    00011
  E        0006     1        B,    0002    0008    00006    00012
  F        0004     2        D,E,    0011    0015    00012    00016
-----
```

[Duration Sorted List]

```
*****
* tNow                Resources                *
*****
  16                      0003
  12                      0001
  11                      0002
   6                      0000
   2                      0000
   0                      0001
-----
```

Efficiency: 0.8333333 Project Duration: 16

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B                2.15          1
  A                01.4          2
  C                1.15          3
  D                00.9          4
  E                00.6          5
  F                00.5          6
-----
```

[Table using ROT with MRIT]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0002       2          -,          0000       0002       00000       00002
  A          0004       2          -,          0000       0004       00002       00006
  C          0004       1          B,          0002       0006       00002       00006
  D          0005       2          A,C,         0006       0011       00006       00011
  E          0006       1          B,          0002       0008       00006       00012
  F          0004       2          D,E,         0011       0015       00012       00016
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  16              0003
  12              0001
  11              0002
   6              0000
   2              0000
   0              0001
-----
```

Efficiency: 0.8333333 Project Duration: 16

[Sorted List]

```
*****
* Activity          ROT          Ranking *
*****
  B              2.15             1
  A              01.4             2
  C              1.15             3
  D              00.9             4
  E              00.6             5
  F              00.5             6
-----
```

[Table using ROT ]

```
*****
* Name,      Dur,      Resrc,      Pred,      TES,      TEF,      TAS,      TAF *
*****
  B          0002       2          -,      0000      0002      00000      00002
  A          0004       2          -,      0000      0004      00002      00006
  C          0004       1          B,      0002      0006      00002      00006
  D          0005       2          A,C,     0006      0011      00006      00011
  E          0006       1          B,      0002      0008      00006      00012
  F          0004       2          D,E,     0011      0015      00012      00016
-----
```

[Duration Sorted List]

```
*****
* tNow          Resources          *
*****
  16              0003
  12              0001
  11              0002
   6              0000
   2              0000
   0              0001
-----
```

Efficiency: 0.8333333 Project Duration: 16