A HEURISTIC APPROACH TO RESOURCE ALLOCATION

by

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A HEURISTIC APPROACH TO RESOURCE ALLOCATION

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ABSTRACT

The problem considered in this study is that of scheduling the activities of a project network to minimize project duration under limited resource requirements and availabilities. Various heuristic rules and optimization techniques have been applied to this problem and comparisons of their effectiveness with respect to one another have been made in the literature. However, a thorough investigation of the types of network and resource characteristics which play an underlying role in determining heuristic performance and which account for the variability of results has not been performed previously.

The aim of this study is to specify the relationships between individual problem characteristics and heuristic performance, as well as developing a new heuristic rule which will be compared with widely - used rules.

ÖZET

Bu çalışmada üzerinde durulan problem, çeşitli kaynak gereksinimleri ve sınırlamaları kısıtı altında, faaliyetlerin başlangıç ve bitişinin proje süresini asgariye indirerek planlanmasıdır. Literatürde, çeşitli sezgisel ve en iyi çizelgeleme teknikleri ve bunların birbirleriyle kıyaslanması mevcuttur. Buna karşılık, sezgisel kuralların performansını etkileyen faaliyet ağı/kaynak özellikleri ayrıntılı olarak incelenmemiştir. Bu çalışmanın amacı, söz konusu incelemenin gerçekleştirilmesi ve ayrıca diğer sezgisel yöntemlerle karşılaştırılacak yeni bir sezgisel kuralın geliştirilmesidir.

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I. INTRODUCTION

The planning and control of projects is an important problem of modern enterprise that many network planning techniques have tried to handle.

Common network planning techniques, such as Program Evaluation Review Technique (PERT) and Critical Path Method (CPM) concern themselves with the time aspect only. These methods aim to minimize project duration, assuming unlimited resource availability. In practice, however, project completion requires the use of various resources whose limited availability directly influences planning objectives, time estimations, scheduling and progress control.

The various resource problems, that may appear during project scheduling can be divided into three classes: Time / cost trade - off, resource levelling, and resource allocation.

Time / cost trade - off problems may appear when there are no constraints imposed on the availability of resources.

The resource - levelling problem occurs when sufficient resources are available for the completion of the project, but one tries to keep the resource usage at a constant rate as much as possible.

When total resource usage is restricted to a given limit, the objective is to minimize project duration while allocating various resources to activities. It is this type of problem which is dealt with in this study.

This study has two objectives:

(1) Developing a new heuristic which obtains better results with

respect to project duration when compared with widely - used rules. With that purpose in mind a new heuristic has been introduced: The weighted resource utilization and precedence (WRUP).

(2) Investigating the influence of network characteristics on different heuristic rules and thereby classifying problem types best solved by specific heuristic rules. To achieve the above - mentioned goal, a factorial design, covering the most relevant characteristics, has been generated. Furthermore, problems not included in the design have been generated in order to reinforce the claim that WRUP is the best performing rule.

II. PROBLEM DEFINITION

The CPM technique as mentioned previously is based on the assumption that all resources required in the performance of the project are available in unlimited quantities. This assumption is generally unrealistic and consequently, a great deal of research attention has been devoted to the development of scheduling techniques which include resource considerations.

The resource - constrained scheduling problem is expressed as an integer programming model [1] as follows:

$$\text{Minimize} \quad \{ \underset{\text{all ij}}{\text{maximum}} \{ t^f(ij) \} \}$$

subject to

$$t^s(ij) >= \underset{hm \in P(ij)}{\text{maximum}} \{ t^f(hm) \} \quad \text{for all ij.} \quad (1)$$

$$R(K) >= \sum_{ij \in A(t)} r(ijk) \quad \begin{matrix} \text{for all t,} \\ \text{for all k.} \end{matrix} \quad (2)$$

where:

$t^s(ij)$ = scheduled start time for activity ij,

$t^f(ij)$ = scheduled finish time for activity ij,

$P(ij)$ = set of predecessor activities of activity ij,

$R(K)$ = amount of resource type K available per period,

k = index for resource type,

$A(t)$ = set of activities in process at time t,

$r(ijk)$ = requirement of resource type K by activity ij per period.

The objective is to minimize the finish time of the last activity in the project to be completed, i.e., establish a set of feasible start times for all activities such that the entire project is completed in a minimum span of time. The feasibility of the schedule is established by two sets of constraints. Constraint set (1) ensures that all activities, which must technologically precede any activity ij, are completed before activity ij may start. Constraint set (2) ensures resource feasibility ; it states that all resources allocated to those activities in process at any time in the schedule cannot exceed the availability of any of the resources.

The model takes on the following assumptions:

1. A set of activities is to be scheduled.
2. Each activity,
   a. has a known duration,
   b. cannot start until all predecessor activities have finished,
   c. requires a pre - determined level of resources of particular kinds to be expended and these levels cannot exceed the quantity of available resources,
   d. has a constant resource level assignment,
   e. should not be interrupted.
3. Limited quantities of different resources are available.

III. LITERATURE SURVEY

Common network planning techniques, such as PERT and CPM, are solely involved in the time analysis of unlimited resource projects. But for projects which are resource constrained, these techniques are not of much use. The effective management of projects implies meeting deadlines as well as making best use of resources within resource availabilities.

The research done in this more realistic area covers integer programming techniques, the implicit enumeration approach, the bounded enumeration techniques and heuristic programming.

The fact that the mentioned problem is hard to solve by mathematical programming procedures because of its combinatorial nature, has forced the researchers to seek more efficient optimization techniques.

Efforts have been channeled into the decrease of the problem size, i.e., the number of constraints and variables, in order to enable the practical use of the above techniques in project management. One such algorithm is proposed by Talbot and Patterson [2]. The algorithm consists of a systematic enumeration of all possible job finish times for each task in the project, limiting the number of task assignments by the use of network cuts which removes from consideration partial schedules that cannot lead to a reduced project completion time . The algorithm with cuts compares favourably with the classical branch and bound algorithms with respect to their mean solution times.

Hastings [3] and Willis and Hastings [4] try to improve the branch and bound method solving the above problem by the employment of certain dominance rules which enable the pruning of nodes which will not lead to improved solutions.

Stinson, Davis and Khumawala [1] propose an algorithm which incorporates a more powerful lower bound which simultaneously considers both precedence and resource constraints. Furthermore, the development of the branch and bound tree is affected by a node selection heuristic which improves both the dominance (proved by Shrage [5]) and the lower bound pruning of the branch and bound tree. The concept of the critical sequence, pronounced previously by Wiest [6], is also related to the new notion of lower bounds.

The zero - one programming approach proposed by Pritsker, Watters and Wolfe [7] is a more general formulation which accomodates a wide range of real - world situations including multiple resource constraints, due dates, job splitting, resource substitutability and concurrency and non - concurrency of job performance requirements. The three possible objectives discussed are: Minimizing total throughput time for all projects; minimizing makespan; and minimizing total lateness for all projects. Though the formulation is claimed to be more efficient than previously reported models, the number of constraints and variables even for a small sized problem is high.

Patterson and Huber [8] propose algorithms which consist of examining the feasibility of a series of zero - one programming problems rather than solving a single zero - one problem to

optimality, thus increasing the efficiency of the solution claimed by Pritsker, Watters and Wolfe. Computational results demonstrate that through the minimum bound, maximum bound, binary search algorithms, this method is advantageous to apply in comparison with the zero - one programming without bounding and the other exact solution procedures.

Even modest sized projects have an enormous number of possible schedules. Therefore, optimal solutions are usually impossible to find by complete enumeration of possible schedules. Furthermore, the above - mentioned optimization techniques remain computationally impractical for most real - world problems.

The alternative for optimization techniques is the development of heuristics for solving large scheduling problems. Heuristics have the advantage of arriving at a solution (hopefully at a good one) with much less computational effort.

Two broadly different categories of heuristics have been found most effective in minimizing project duration: (1) Heuristics incorporating some measure of time, i.e., job slack, job duration, or start/finish time, and (2) Heuristics incorporating some measure of resource usage.

For single project, multi - resource problems the Resource Scheduling Method (RSM), involving the comparison of job Early Start Times (EST)and Late Start Times (LST); the Minimum Late Finish Time (LFT) and the Minimum Late Start Time (LST) heuristics were proposed.

For multi - project, multi - resource problems, the Greatest Resource Utilization (GRD), the Minimum Job Slack (MINSLK) and the

Shortest Imminent Operation (SIO) heuristics were developed.

A heuristic computer model for scheduling large projects with limited resources has been developed by Wiest [9]. The model is able to handle single or multiple projects, fixed or variable crew sizes and constant or variable shop limits over the scheduling period. The program is based on three heuristics, the first of which allocates resources to jobs listed in order of their early start times. The second one chooses among alternative candidates and gives preference to jobs with the least total slack when allocating resources to several competing jobs. The third heuristic allows for rescheduling of noncritical jobs to free resources for scheduling critical jobs where no slack time is available. The basic program is modified by additional heuristics designed to increase the use of available resources and/or to decrease the length of the schedule.

Thesen [10] introduces a new concept of the heuristic scheduling urgency factor (ranking decision rule). The latter urgency factor does not solely determine the order in which activities are considered for scheduling at a given instant, but determines the "combination" of activities to be scheduled at this instant. His model permits neither variable resource requirements and availabilities nor does it allow job splitting. The difference of Thesen's algorithm from others is the use of multidimensional knapsack algorithm, including the candidate jobs' urgency factors in its objective, to select activities to start at given points in time. The scheduling urgency factor reflects the activity's resource utilization and the impact on schedule duration of

a delay in the activity start time.

A review of the various solutions that have been proposed for the resource - constrained project scheduling problem is given by Herroelen [11]. An attempt is made to give the state of the art to date, as well as to point out potential future courses of development. Emphasis is placed on the basic approach involved in each technique rather than on the computational steps to obtain a solution. With regards to heuristic solutions, Herroelen suggests an exhaustive evaluation and an objective ranking of the available heuristic solutions.

The latter suggestion has come to be realized by various researchers and a comparison of heuristic and optimum solutions is made by Davis and Patterson [12]. Eight heuristics are tested against a "bounded enumeration" procedure obtaining an optimum schedule duration. The experiment demonstrates that the Minimum Slack rule performs best, with second and third - best being the LFT rule and the RSM rule. The performance measures are: (1) the number of times an optimum - duration solution is obtained ; and (2) the average percentage increase in project duration. Davis' and Patterson's conclusion is that no given heuristic steadily produces the best(worst) results in all of the problems. This, in turn, reveals that problem characteristics such as network structure and resource requirements / availabilities account for the variation in heuristic performance.

The most recent review which can be found in the literature is the one prepared by Willis [13]. Willis points to the fact that there is an apparent gap between the published theoretical work and the

requirements of project schedulers and managers. Willis briefly describes the different approaches taken, how they differ and suggests where future efforts may be directed. Related to heuristics it is noted that it has not yet been possible to classify resource - constrained projects such that a suitable heuristic may be selected. In order to solve this problem the approach of "try as many heuristics as you can in the time available" is suggested. An alternative to the approach is to use heuristics iteratively, i.e., to take the resulting schedule from the heuristic as the new ordering and to reschedule in this way.

In her study of network characteristics, E.M.Davies [14] defines OVDUR as the increase in overall project duration over the critical path duration. An equation relating OVDUR with DUM (the percentage of dummy activities), CC (complexity of the network), DENS (density of the network, i.e., a measure of free float under critical path conditions) and PRES (the degree of resource limitation), is reached as the result of the application of analysis of variance, multiple regression and some non - parametric tests to 648 networks. The characteristics of the networks created for this purpose are also given with respect to DUM, CC, DENS and PRES.

A linear model for estimating project resource levels is presented by Yau and Ritchie [15]. An experiment involving 4942 different network / resource configurations establishes a relationship between project completion time and resource availabilities. Network characterisation measures such as Density, Complexity, Aspect Ratio, Critical Path Duration, Obstruction Ratio, and Resource Utilization Factor are

considered. The scheduling heuristic used is total float priority based. The experiment is divided into three phases. Phase I consists of the generation of a set of networks, resource characteristics and corresponding measures. The main analytical work of exploring the relationship between project scheduled time and these measures is conducted in Phase II. Finally, a model of these relationships is established in Phase III. The linear model achieved in the last phase is the result of the inspection of the correlations between the extra scheduled time and resource / network measures.Partial regression models are analyzed within the analysis of variance methods. It is concluded in the paper that general network measures are almost irrelevant to extra scheduled time when compared to resource utilization and obstruction factors. The model enables the prediction of preliminary resource levels in the early stage of planning.

Davies and, Yau and Ritchie specify in their study network / resource chracteristics of projects in detail and establish the relationship of the individual problem characteristics with the extra schedule time. The area which has not been explored, however, is the impact of the latter characteristics on specific heuristic rules. Different problem types prevent the generalization of heuristic best(worst) ranking.

IV. THE EXPERIMENT

The experiment consists of establishing the relationships between network/resource characteristics of the resource - constrained project scheduling problem and heuristic procedure performance as well as the comparison of the new rule proposed in this study (WRUP) with other heuristic rules.

Yau and Ritchies' study [15] on the effects of network characteristics on project duration is effective on the selection of the network / resource characteristics to be investigated for their effects on heuristic performance. The detailed specification of the characteristics can be found in Appendix A.

4.1. The Selection of the Heuristic Rules

The heuristic rules whose performances are to be tested against problem characteristics are selected with regards to their success and popularity in previous usage. Three of the time - oriented heuristic rules: MINSLK, LFT, RSM are found most effective by previous research [12]. The SIO rule, though not successful, is chosen because it is one of the most easily applicable of all. GRD, a resource - oriented rule, is claimed to be the best among resource - based rules [12]. The new rule (WRUP) introduced in this study combines the concepts of precedence relationships and resource utilization. Select Jobs Randomly (RAN) gives priority to activities randomly.

The heuristics chosen employ a "parallel" approach in which each activity to be scheduled is determined during scheduling rather than before. In all approaches, ties are broken by lowest activity number. The activity - on arc method is employed and the activities are numbered in an increasing fashion according to precedence relationships, that is, no preceeding activity has a label greater than its successors.

4.2. Description of Heuristic Rules

Minimum Job Slack (MINSLK)

Prioriy is given to activities competing for resources, by computing each acivity's total slack resulting from CPM. The activity having the minimum total slack has the highest priority. Slack is continously updated. This heuristic has been found to be the most successful one in both single - and multi - project scheduling. The MINSLK rule has been proved to be equivalent to the Minimum LST rule by Davis and Patterson [12].

Minimum Late Finish Time (LFT)

This rule assigns priority to activities on the basis of their Late Finish Time resulting from CPM. The Late Finish Time of activities is constantly updated during scheduling. The LFT rule was found to be the second - best heuristic in the mentioned survey [12].

Resource Scheduling Method (RSM)

Activities which have the minimum value of DI(ij, kl) are given the highest priority, where:

DI(ij, kl) = the resulting increase in project duration when activity ij follows activity kl ;

= Max { 0 ; (EFT(kl) - LST(ij) }, where:

EFT(kl) = Early Finish Time of activity kl,

LST(ij) = Late Start Time of activity ij.

The comparison is made on a pairwise basis among all activities in the resource conflict set which is the set of activities competing for the same resource at a certain time.

Greatest Resource Demand (GRD)

This is a resource - oriented heuristic where activity priority is determined by:

$$\text{Priority} = d(ij) \sum_{k} r(ijk) \text{ , where:}$$

d(ij) = duration of activity ij.

Shortest Imminent Operation (SIO)

This rule gives higher priority to activities having shorter durations. The "shortest job first" has been shown to be effective in reducing the average total processing time for a group of activities.

Weighted Resource Utilization Ratio and Precedence (WRUP)

Priority is given to an activity in the conflict set with respect to the weighted combination of its individual resource utilization ratio and the number of its immediate successors. The priority of an activity is therefore:

$$\text{Priority} = w(p)*np + w(r) \sum_{K} r(ijk)/R(k) \text{ , where:}$$

w(p) = precedence weight,

w(r) = 1 - w(p),

= resource utilization weight,

np = number of immediate successors of activity ij.

The difference of this rule from others is that precedence relationships replace the time factor in calculating activity priority. Since the time factor loses much of its significance because of resource limitations, project duration might be minimized by considering precedence relationships. Furthermore, the resource utilization ratio, which considers resource limitations, is included in priority calculations. The corresponding weights are determined experimentally.

Select Jobs Randomly (RAN)

Priority is assigned to competing activities purely randomly. This rule is neutral with respect to network / resource characteristics.

V. HEURISTIC RULE ALGORITHMS

The main algorithm to apply for the above - mentioned heuristic rules, is an altered version of Thesen's [10]. Thesen solves the problem of choosing the activities to be scheduled at a specific time point by solving a multi - dimensional knapsack problem. This portion of Thesen's algorithm is exchanged with a version of activity selection according to priority established by the corresponding rules. Furthermore, many steps related to the identification of the new set of candidate activities have been altered.

The complete algorithm is primarily written for MINSLK rule and instead of repeating the whole of it for every rule, the second portion, which is related to the selection of activities to be scheduled at a specific time, is written accordingly for every rule.

The following are the complete algorithm for MINSLK and the altered versions of the second portion for the rest of the rules:

5.1. The Minimum Job Slack (MINSLK) Algorithm

1. Initialization of variables:
   a. Define and use the following variables to describe individual activity and resource attributes:

      LFT(ij)= late finish time of an activity ij as computed by CPM,

      EST(ij)= early start time of an activity ij as computed by CPM.

   b. Define he following set of activities:

A ={ij: ij is unscheduled },

C ={ij: ij is eligible for scheduling at this time },

IF ={ij: ij is terminated at this time },

F ={ij: ij has been terminated up to this time },

PR ={ij: ij is in progress at this time },

S ={ij: ij is scheduled to start at this time }.

c. Define the following schedule - related variables:

ts(ij) = total slack for activity ij at this time,

RC(K) = amount of resource K currently in use,

t(now) = point in time for which scheduling is currently being performed.

d. Initialize the scheduling process by setting:

t(now) = 0,

A = { set of all activities },

C = { ij: ij has no predecessors },

RC(k) = 0 for all k,

PR = { },

S = { },

IF = { },

F = { }.

2. Choose activities to start at this time:

a. For every ij in C, calculate:

ts(ij) = LFT(ij) - EST(ij) - d(ij).

b. List all activities in C in ascending order of ts(ij), i.e., the activity with minimum ts(ij) is put on top of the list.

c. If C <> { }, continue. Otherwise, go to 2e.

d. Select the activity on top of the list and check resource feasibility:

d1. If r(ijk) <= R(k) - RC(k) for all k, load resources:

RC(K) = RC(K) + r(ijk) for all k ; put ij in S: S ← S + ij;

delete ij from C: C ← C - ij. Go to 2c.

Otherwise, continue.

d2. Remove ij from C: C ← C - ij. Go to 2c.

e. If S <> { }, continue. Otherwise, go to 3.

f. Start the activities in S:

f1. Remove S from the nonscheduled set: A ← A - S.

f2. Include S in the in-progress set: PR ← PR + S.

f3. Save start and finish times:

$t^s(ij)$ = t(now), $ij \in S$,

$t^f(ij)$ = t(now) + d(ij), $ij \in S$.

3. Update clock, release completed activities, determine the time of next action:

a. $t(now) = \underset{ij \in PR}{Min} \{ t^f(ij) \}$.

b. Form the set of activities terminating at this time:

F = { ij: $t^f(ij)$ <= t(now) } and IF = { ij: $t^f(ij)$ = t(now)}.

c. Unload resources:

PR ← PR - IF,

RC(k) = RC(K) - r(ijk) for all k; $ij \in$ IF.

d. Identify the set of new candidate activities:

C ← { ij: A - (sm) if P(sm) F and if P(sm) <> { } }.

4.a. If activities are available for scheduling at this time, i.e., C <> { }, set S = IF = { }. Go to 2.

b. Otherwise, if activities are in progress, i.e., PR <> { }, go to 3.

c. Otherwise, stop, as scheduling is completed.

5.2. The Minimum Late Finish Time (LFT) Algorithm

The MINSLK Algorithm is applied with the following altered version of Steps 2a and 2b:

2. Choose the activities to start at this time:

a. For every ij in C, calculate LFT(ij).

b. List all activities in C in ascending order of LFT(ij).

The remaining portions of the MINSLK Algorithm stay the same for the LFT Algorithm.

5.3. The Resource Scheduling Method (RSM) Algorithm

The MINSLK Algorithm is applied by changing Step 2 as follows:

2. Choose the activities to start at this time:

a. If C contains more than one element, continue. Otherwise, check its resource - feasibility. If feasible, add the activity to scheduled set S and rearrange RC(k), go to 2d.

ai. Create all the possible two - element subsets from the set of activities in C and calculate for each subset:

DI(ij, pq)=Max {0; (EFT(pq) - LST(ij)) } where ij follows pq,

DI(pq, ij)=Max {0; (EFT(ij) - LST(pq)) } where pq follows ij, and add to the list PAIRSUB the minimum duration increase pair (ij, pq) or (pq, ij).

b. List all two - element subsets in PAIRSUB in ascending order of their duration increase factors.

c. Put all activities in PAIRSUB in their proper scheduling order:

c1. Check resource - feasibility of the second activity in the first pair subset of which both elements exist in C.

c2. If r(pqk) <= RC(k) ; load resources: RC(k) = RC(k) + r(pqk), all k; put pq in S: S ← S + pq.

Otherwise, continue.

c3. Eliminate pq from C: C ← C - pq.

c4. If it exists, skip to the next pair subset in PAIRSUB, of which both elements exist in set C. Go to 2c2.

Otherwise, check the resource - feasibility of the remaining last element in C. If feasible, add it to S, rearrange RC(k) and go to 2d. If not feasible, go to 2d.

d. If S <> { }, continue. Otherwise, go to 3.

e. Start the activities in S:

e1. Remove S from nonscheduled set: A ← A - S.

e2. Include S in the in-progress set: PR ← PR + S.

e3. Save start and finish times:

$t^s(ij) = t(now), \quad (ij) \in S,$

$t^f(ij) = t(now) + d(ij), \quad (ij) \in S.$

Furthermore, PAIRSUB is initialized as { } in Step 4a.

5.4. The Greatest Resource Demand (GRD) Algorithm

The MINSLK Algorithm is applied by changing Step 2a and 2b as follows:

2. Choose the activities to start at this time:

a. For all activities in C, calculate the activity priority:

$$\text{Priority} = d(ij) \sum_{k} r(ijk).$$

b. List all activities in C in descending order of priority, i.e., the activity with the greatest resouce demand is on top of the list.

5.5. The Shortest Imminent Operation (SIO) Algorithm

The MINSLK Algorithm is applied with Steps 2a and 2b replaced by the following single step:

2. Choose the activities to start at this time:

a. List all activities in C in ascending order of activity duration, d(ij).

The MINSLK Algorithm continues in the same fashion for the SIO Algorithm.

5.6. The Weighted Resource Utilization Ratio and Precedence (WRUP) Algorithm

The MINSLK Algorithm is applied by changing Steps 2a and 2b as follows:

2. Choose the activities to start at this time:

a. For all activities in C calculate the activity priority:

$$\text{Priority} = w(p) * np + w(r) \sum_{K} r(ijk)/R(k),$$

b. List all activities in C in descending order of priority.

5.7. Select Jobs Randomly (RAN) Algorithm

The MINSLK Algorithm is applied by incorporating Steps 2a and 2b into a single step as follows:

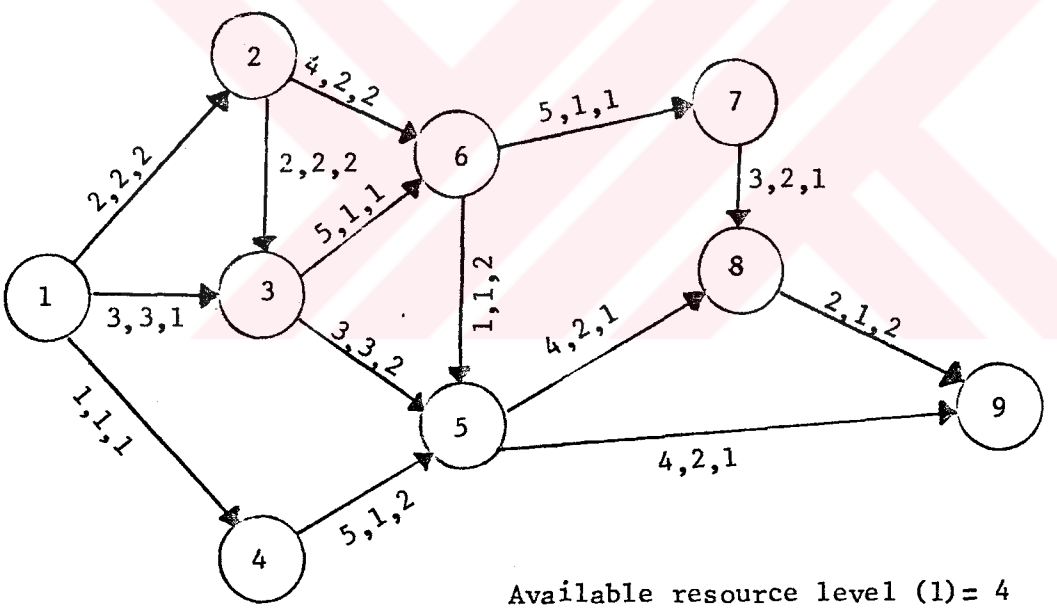
2. Choose the activities to start at this time:

a. List all activities in C randomly with the use of a random function.

VI. THE EXAMPLE PROBLEM

An example problem of two resource types, fourteen activities and nine events, is generated and solved by each of the aforementioned rules in order to demonstrate how each rule works.

The example problem is represented by a still popular method, i.e., the activity - on - arc method. The problem representation is given in Figure 1.



Available resource level (1)= 4

Available resource level (2)= 3

(d(ij), r(ij1), r(ij2)) =(duration, resource requirement (1), resource requirement (2))

Figure 6.1. The example problem.

6.1. The Solution of the Example Problem by Heuristics

The first step in the solution of the example problem is to utilize CPM assuming unlimited resources. The Early Start Time, Late Start Time and Total Slack of all activities and the minimum possible project duration obtained by CPM are listed in Table 6.1.1.

The problem is then solved by each of the above mentioned algorithms. Tables 6.1.2. - 6.1.8. consist of scheduled start times, $t^s(ij)$, and scheduled finish times, $t^f(ij)$, of all activities, and the amounts of resource types currently in usage, RC(1), RC(2), up to specific points in time which correspond to activity completion times.

Though this is a very early phase of the study to draw any conclusions, an idea of how the mentioned rules perform on such a problem is given in Table 6.1.9., which consists of the resulting project durations. A point which should be noted is the successful performance of WRUP, the new heuristic rule introduced in this study.

TABLE 6.1.1. The solution of the example problem of Fig. 1 by CPM

Activity(ij)	EST(ij)	LST(ij)	TS(ij)
1, 2	0	0	0
1, 3	0	1	1
1, 4	0	2	2
2, 3	2	2	0
2, 6	2	5	3
3, 5	4	5	1
3, 6	4	4	0
4, 5	1	3	2
5, 6	7	8	1
5, 8	7	13	6
5, 9	7	15	8
6, 7	9	9	0
7, 8	14	14	0
8, 9	17	17	0

TABLE 6.1.2. The solution of the example problem of Fig. 1 by MINSLK rule.

Activity(ij)	$t^s(ij)$	$t^f(ij)$	time	RC(1)	RC(2)
1, 2	0	2	<1	3	3
1, 3	2	5	<2	2	2
1, 4	0	1	<5	4	3
2, 3	7	9	<7	1	2
2, 6	9	13	<9	2	2
3, 5	13	16	<13	3	3
3, 6	9	14	<14	4	3
4, 5	2	7	<16	3	2
5, 6	16	17	<17	3	3
5, 8	16	20	<20	3	2
5, 9	20	24	<22	3	2
6, 7	17	22	<24	4	2
7, 8	22	25	<25	2	1
8, 9	25	27	<27	1	2

TABLE 6.1.3. The solution of the example problem of Fig.1 by LFT rule.

Activity(ij)	$t^s(ij)$	$t^f(ij)$	time	RC(1)	RC(2)
1, 2	0	2	<1	3	3
1, 3	2	5	<2	2	2
1, 4	0	1	<5	4	3
2, 3	7	9	<7	1	2
2, 6	12	16	<9	2	2
3, 5	9	12	<12	4	3
3, 6	9	14	<14	3	3
4, 5	2	7	<16	4	3
5, 6	16	17	<17	3	3
5, 8	14	18	<18	3	3
5, 9	18	22	<22	3	2
6, 7	17	22	<25	2	1
7, 8	22	25	<27	1	2
8, 9	25	27			

TABLE 6.1.4. The solution of the example problem of Fig.1 by RSM rule

Activity(ij)	$t^s(ij)$	$t^f(ij)$	time	RC(1)	RC(2)
1, 2	0	2	<1	3	3
1, 3	2	5	<2	2	2
1, 4	0	1	<5	4	3
2, 3	7	9	<7	1	2
2, 6	9	13	<9	2	2
3, 5	13	16	<13	3	3
3, 6	9	14	<14	4	3
4, 5	2	7	<16	3	2
5, 6	16	17	<17	3	3
5, 8	16	20	<20	4	2
5, 9	17	21	<21	3	2
6, 7	20	25	<25	1	1
7, 8	25	28	<28	2	1
8, 9	28	30	<30	1	2

TABLE 6.1.5. The solution of the example problem of Fig.1 by GRD rule

Activity(ij)	$t^S(ij)$	$t^f(ij)$	time	RC(1)	RC(2)
1, 2	6	8	<1	1	1
1, 3	0	3	<3	4	3
1, 4	0	1	<6	1	2
2, 3	12	14	<8	2	2
2, 6	8	12	<12	2	2
3, 5	14	17	<14	2	2
3, 6	14	19	<17	4	3
4, 5	1	6	<19	3	2
5, 6	21	22	<21	4	2
5, 8	17	21	<22	3	3
5, 9	19	23	<23	3	2
6, 7	22	27	<27	1	1
7, 8	27	30	<30	2	1
8, 9	30	32	<32	1	2

TABLE 6.1.6. The solution of the example problem of Fig.1 by SIO rule

Activity(ij)	$t^s(ij)$	$t^f(ij)$	time	RC(1)	RC(2)
1, 2	0	2	<1	3	3
1, 3	4	7	<2	2	2
1, 4	0	1	<4	2	2
2, 3	2	4	<7	4	3
2, 6	13	17	<9	2	3
3, 5	9	12	<12	4	3
3, 6	7	12	<13	3	3
4, 5	4	9	<16	4	3
5, 6	12	13	<17	4	3
5, 8	12	16	<20	3	2
5, 9	16	20	<22	1	1
6, 7	17	22	<25	2	1
7, 8	22	25	<27	1	2
8, 9	25	27			

TABLE 6.1.7. The solution of the problem of Fig.1 by WRUP rule
(Pre. wt: 0.7
Res. wt: 0.3)

Activity(ij)	$t^S(ij)$	$t^S(ij)$	time	RC(1)	RC(2)
1, 2	0	2	<1	3	3
1, 3	2	5	<2	2	2
1, 4	0	1	<5	4	3
2, 3	7	9	<7	1	2
2, 6	12	16	<9	2	2
3, 5	9	12	<12	4	3
3, 6	9	14	<14	3	3
4, 5	2	7	<16	4	3
5, 6	16	17	<17	3	3
5, 8	14	18	<18	3	2
5, 9	18	22	<22	3	2
6, 7	17	22	<25	2	1
7, 8	22	25	<27	1	2
8, 9	25	27			

TABLE 6.1.8. The solution of the example problem of Fig.1 by RAN rule

Activity(ij)	$t^s(ij)$	$t^f(ij)$	time	RC(1)	RC(2)
1, 2	6	8	<1	4	2
1, 3	0	3	<3	4	3
1, 4	0	1	<6	1	2
2, 3	8	10	<8	2	2
2, 6	13	17	<10	2	2
3, 5	10	13	<13	4	3
3, 6	10	15	<15	3	3
4, 5	1	6	<17	4	3
5, 6	17	18	<18	3	3
5, 8	15	19	<19	4	2
5, 9	18	22	<22	3	3
6, 7	19	24	<24	1	1
7, 8	24	27	<27	2	1
8, 9	27	29	<29	1	2

TABLE 6.1.9. A summary of the solutions obtained by all the rules to the problem in Fig.1

Rule	MINSLK	LFT	RSM	SIO	GRD	WRUP	RAN
Project Duration	27	27	30	27	32	27	29

VII. NETWORK / RESOURCE CHARACTERISTICS

The network / resource characteristics which have been found effective on project duration in a previous study by Yau and Ritchie [15] are considered in this study as worthy of investigation. They have specified eight different network characterisation measures which were thought to affect the project duration of a problem when solved by a time - based heuristic. Additionally, a correlation matrix of extra schedule time percentage and general network characterisation measures has been calculated.

In this study, four of the above measures which have been found to be relevant to extra schedule time are selected for further investigation.

These four measures can be partitioned into two groups as follows:

(i). Network characteristics,

(ii). Resource characteristics.

The network characteristics consist of Aspect Ratio (ASP) and Complexity(CPX). Resource Utilization Factor (UF) and Dominant Obstruction Value (DOV) are resource characteristics. Furthermore, the above four network / resource characteristics, the definitions of which are found in Appendix A, are the best ones to give a thorough understanding of the project, regarded as a whole.This fact constitutes another reason for the selection of the measures besides their correlation coefficients as reported in [15]. The correlation coefficients related to extra schedule time are found in Table 7.1. as well as the definition of the extra schedule time ratio which is

TABLE 7.1.Correlations of network/resource characteristics with respect to extra schedule time ratio [15].

Characteristic	Extra shedule time ratio (PC)
Utilization Factor (UF)	0.970
Dominant Obstruction Value (DOV)	0.890
Complexity (CPX)	-0.439
Aspect Ratio (ASP)	0.408

$$\text{Extra schedule time ratio} = \frac{\text{Project scheduled duration} - \text{CPL}}{\text{CPL}}$$

considered as the performance criterion for the following reason: Since project sizes of test problems are different, the critical path durations for all networks ranged from 20 to 162 time units. In order to analyse all the different projects on the same basis, standardisation of project schedule times was made through a ratio of extra scheduled time to original critical path durations. The extra schedule time is defined as the difference between the scheduled time and the critical path duration [15].

The extra schedule time ratio has been found to have extremely high correlations to the Utilization Factor (UF) and the Dominant Obstruction Value (DOV). Complexity (CPX) and Aspect Ratio (ASP) have moderate correlations with respect to extra schedule time ratio, the former being negatively correlated to it.

VIII. THE DESIGN OF THE EXPERIMENT

The experimental design used in this study is a factorial design where the joint effects of the four resource / network measures or factors on extra schedule time ratio are sought after. The factors are considered each at only two levels , thus constituting a 2^4 full factorial design mentioned by D.C.Montgomery [16].

The 64 test problems belonging to the design constitute a complete replicate of it, each treatment combination having four replicates. While only 48 different networks are used, some are assigned different combinations of resource availabilities, giving a total of 64 different problems. The test problems of the design consist on the average of 20 activities, the largest having 33 activities and up to 3 resource types per project. All resource types are subject to fixed resource availabilities which are constant over the project duration. The size of the problems is consistent with those of previous research [12].

The novelty in the application of this design to the problem which is the subject of this study, lies in the fact that once the test problem is stated, the observation, that is, the project scheduled duration is deterministically obtained by each heuristic rule. The randomness of the experiment arises from the random generation of the problem's network configuration, activity durations, and resource requirements.

The levels of the four factors, Resource Utilization Factor (Factor A), Dominant Obstruction Value (Factor DOV), Complexity Factor

(Factor C), and Aspect Ratio (Factor D) are specified in Table 8.1. It should be noticed that the high and low levels of Complexity Factor are as specified because of the fact that Factor C and extra schedule time ratio (PC) are negatively correlated. The levels given in Table 8.1. have been developed both by considering the information found in previous research [12] and [15] and through insight of the levels gained by rearranging levels and observing the corresponding project schedule durations.

Each replicate of a specific treatment combination is solved by all of the seven dispatch methods and the observations, that is, project schedule durations are transformed to the actual performance criterion, which is the extra schedule time ratio.

TABLE 8.1. Levels of factors in the 2^4 factorial design.

FACTOR	LEVEL	
	HIGH	LOW
Utilization Factor (A)	1.25 - 1.55	0.58 - 0.78
Dominant Obstruction Value (B)	0.90 - 1.20	0.00 - 0.35
Complexity (C)	1.00 - 1.40	2.00 - 2.75
Aspect Ratio (D)	2.00 - 3.00	0.30 - 1.00

IX. THE INTERPRETATION OF RESULTS OBTAINED BY THE EXPERIMENT

The extra schedule time ratios of the design's 64 problems are conveyed in a compact form in Table 9.1. where each cell is the summation of PC's of the four test problems belonging to the corresponding treatment combination.

The analysis of variance tables for 2^4 design are demonstrated in Tables 9.2.-9.8. Table 9.9. gives an overview of the design's treatment combinations' significance with respect to all dispatch rules, at both 5 per cent and 1 per cent levels of significance.

It should be noted that all dispatch rules have in common the Resource Utilization Factor (UF) and the Dominant Obstruction Value (DOV) as significant factors. Furthermore, the interaction of the Utilization Factor and Complexity is also significant in almost all cases, whereas the interaction of the Dominant Obstruction Value and Complexity is not that widely significant. The Aspect Ratio is significant in the performance of some of the rules, but through the inspection of the Fo values, it does not seem as significant as the Utilization Factor or the Dominant Obstruction Value.The interaction of the Dominant Obstruction Value and the Aspect Ratio is only significant on LFT rule. Three - way interactions are not generally significant, whereas the four - way interaction is. The importance of the latter is thought to be arising from the fact that with all the factors interacting together at their high levels, there exist the worst possible conditions to apply a scheduling method and therefore, the project durations increase, causing the treatment combination to be effective.

TABLE 9.1. Extra schedule time ratio table for each treatment combination of 2^4 design consisting of 4 test problems in each cell.

Treatment Combination	MINSLK	LFT	RSM	GRD	SIO	RAN	WRUP
1	0.15	0.14	0.17	0.18	0.17	0.42	0.07
A (UF)	1.82	1.86	1.78	1.84	2.03	1.97	1.61
B (DOV)	0.82	0.56	1.00	1.53	0.94	2.01	0.95
AB	4.22	4.04	4.65	4.96	4.53	5.06	4.18
C(CPX)	0.33	0.14	0.27	0.44	0.37	0.37	0.10
AC	2.02	2.04	2.20	2.08	2.11	2.01	1.94
BC	1.82	1.66	1.91	2.01	2.21	2.20	1.69
ABC	2.88	2.89	3.14	3.41	3.34	3.38	2.76
D (ASP)	0.13	0.15	0.15	0.25	0.13	0.17	0.15
AD	2.32	2.37	2.33	2.36	2.53	2.57	2.34
BD	2.26	2.23	2.28	2.52	2.50	2.31	1.99
ABD	4.80	4.64	4.69	4.84	4.86	4.98	4.19
CD	0.57	0.57	0.57	0.57	0.60	0.57	0.57
ACD	1.95	1.92	1.97	2.05	2.00	2.10	2.03
BCD	1.79	1.69	2.09	2.19	2.02	1.94	1.76
ABCD	3.71	3.54	3.75	3.61	3.75	3.69	3.58
TOTAL PC	31.59	30.44	32.95	34.84	34.09	35.75	29.91
% INCREASE OVER WRUP	5.62	1.77	10.16	16.48	13.98	19.53	00.00

TABLE 9.2. Analysis of variance table for 2^4 design problems solved by MINSLK rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo	
A (UF)	3.925	1	3.925	186.90	(a, b)
B (DOV)	2.645	1	2.645	125.95	(a, b)
C (CPX)	0.033	1	0.033	1.57	
D (ASP)	0.188	1	0.188	8.95	(a, b)
AB	0.062	1	0.062	2.95	(b)
AC	0.219	1	0.219	10.43	(a, b)
BC	0.086	1	0.086	4.09	(a, b)
AD	$6.89*10^{-5}$	1	$6.89*10^{-5}$	<1	
BD	0.074	1	0.074	3.52	(b)
CD	0.036	1	0.036	1.71	
ABC	0.074	1	0.074	3.52	(b)
ABD	$6.89*10^{-5}$	1	$6.89*10^{-5}$	<1	
ACD	0.012	1	0.012	<1	
BCD	0.013	1	0.013	<1	
ABCD	0.102	1	0.102	4.86	(a, b)
ERROR	0.995	48	0.021		
TOTAL	8.465	63			

For Tables 9.2.-9.9. : (a) = significant at 5% level.
(b) = significant at 1% level.

Fo (0.05, 1, 48) = 4.048

Fo (0.01, 1, 48) = 2.820

TABLE 9.3. Analysis of variance table for 2^4 design problems solved by LFT rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo	
A (UF)	4.080	1	4.080	240.00	(a, b)
B (DOV)	2.272	1	2.272	133.65	(a, b)
C (CPX)	0.037	1	0.037	2.18	
D (ASP)	0.223	1	0.223	13.12	(a, b)
AB	0.049	1	0.049	2.88	(b)
AC	0.191	1	0.191	11.24	(a, b)
BC	0.053	1	0.053	3.12	(b)
AD	0.004	1	0.004	<1	
BD	0.070	1	0.070	4.12	(a, b)
CD	0.051	1	0.051	3.00	(b)
ABC	0.070	1	0.070	4.12	(a, b)
ABD	0.003	1	0.003	<1	
ACD	0.006	1	0.006	<1	
BCD	0.029	1	0.029	1.71	
ABCD	0.117	1	0.117	6.88	(a, b)
ERROR	0.818	48	0.017		
TOTAL	8.073	63			

TABLE 9.4. Analysis of variance table for 2^4 design problems solved by RSM rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Fo
A (UF)	4.035	1	4.035	21.58 (a, b)
B (DOV)	3.093	1	3.093	16.54 (a, b)
C (CPX)	0.021	1	0.021	<1
D (ASP)	0.115	1	0.115	<1
AB	0.052	1	0.052	<1
AC	0.206	1	0.206	1.1
BC	0.083	1	0.083	<1
AD	0.009	1	0.009	<1
BD	0.036	1	0.036	<1
CD	0.015	1	0.015	<1
ABC	0.115	1	0.115	<1
ABD	0.011	1	0.011	<1
ACD	0.005	1	0.005	<1
BCD	$7.66*10^{-5}$	1	$7.66*10^{-5}$	<1
ABCD	0.119	1	0.119	<1
ERROR	0.187	48	0.004	
TOTAL	8.983	63		

TABLE 9.5. Analysis of variance table for 2^4 design problems solved by GRD rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Fo	
A (UF)	3.734	1	3.734	155.58	(a, b)
B (DOV)	3.658	1	3.658	152.42	(a, b)
C (CPX)	0.070	1	0.070	2.92	(b)
D (ASP)	0.059	1	0.059	2.46	
AB	0.044	1	0.044	1.83	
AC	0.200	1	0.200	8.33	(a, b)
BC	0.154	1	0.154	6.42	(a, b)
AD	0.010	1	0.010	<1	
BD	0.005	1	0.005	<1	
CD	0.015	1	0.015	<1	
ABC	0.081	1	0.081	3.38	(b)
ABD	0.029	1	0.029	1.21	
ACD	0.004	1	0.004	<1	
BCD	0.000	1	0.000	0.00	
ABCD	0.047	1	0.047	1.96	
ERROR	1.168	48	0.024		
TOTAL	9.278	63			

TABLE 9.6. Analysis of Variance table for 2^4 design problems solved by SIO rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Fo	
A (UF)	4.106	1	4.106	186.64	(a, b)
B (DOV)	3.155	1	3.155	143.41	(a, b)
C (CPX)	0.026	1	0.026	1.18	
D (ASP)	0.113	1	0.113	5.14	(a, b)
AB	0.031	1	0.031	1.41	
AC	0.277	1	0.277	12.59	(a, b)
BC	0.047	1	0.047	2.14	
AD	$3.91*10^{-5}$	1	$3.91*10^{-5}$	<1	
BD	0.037	1	0.037	1.68	
CD	0.063	1	0.063	2.86	(b)
ABC	0.061	1	0.061	2.77	
ABD	0.011	1	0.011	<1	
ACD	0.014	1	0.014	<1	
BCD	0.028	1	0.028	1.27	
ABCD	0.115	1	0.115	5.23	(a, b)
ERROR	1.047	48	0.022		
TOTAL	9.131	63			

TABLE 9.7. Analysis of variance table for 2^4 design problems solved by WRUP rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Fo	
A (UF)	3.681	1	3.681	184.05	(a, b)
B (DOV)	2.364	1	2.364	118.20	(a, b)
C (CPX)	0.017	1	0.017	<1	
D (ASP)	0.171	1	0.171	8.55	(a, b)
AB	0.026	1	0.026	1.3	
AC	0.138	1	0.138	6.9	(a, b)
BC	0.061	1	0.061	3.05	(b)
AD	$1.56*10^{-6}$	1	$1.56*10^{-6}$	<1	
BD	0.005	1	0.005	<1	
CD	0.003	1	0.003	<1	
ABC	0.069	1	0.069	3.45	(b)
ABD	0.005	1	0.005	<1	
ACD	0.009	1	0.009	<1	
BCD	$1.26*10^{-4}$	1	$1.26*10^{-4}$	<1	
ABCD	0.123	1	0.123	6.15	(a, b)
ERROR	0.964	48	0.020		
TOTAL	7.636	63			

TABLE 9.8. Analysis of variance table for 2^4 design problems solved by RAN rule.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Fo	
A (UF)	3.886	1	3.886	228.59	(a, b)
B (DOV)	3.701	1	3.701	217.71	(a, b)
C (CPX)	0.163	1	0.163	9.59	(a, b)
D (ASP)	0.013	1	0.013	<1	
AB	0.037	1	0.037	2.18	
AC	0.199	1	0.199	11.71	(a, b)
BC	0.147	1	0.147	8.65	(a, b)
AD	0.014	1	0.014	<1	
BD	0.002	1	0.002	<1	
CD	$8.27*10^{-4}$	1	$8.27*10^{-4}$	<1	
ABC	0.063	1	0.063	3.71	(b)
ABD	0.005	1	0.005	<1	
ACD	$1.56*10^{-6}$	1	$1.56*10^{-4}$	<1	
BCD	$1.89*10^{-4}$	1	$1.89*10^{-4}$	<1	
ABCD	0.057	1	0.057	3.35	(b)
ERROR	0.817	48	0.017		
TOTAL	9.1054	63			

TABLE 9.9. Significance of treatment combinations with respect to dispatch rules.

Treatment Combination	MINSLK	LFT	RSM	GRD	SIO	WRUP	RAN
A (UF)	a, b	a, b	a, b	a, b	a, b	a, b	a, b
B (DOV)	a, b	a, b	a, b	a, b	a, b	a, b	a, b
AB	b	b					
C (CPX)				b			a, b
AC	a, b	a, b		a, b	a, b	a, b	a, b
BC	a, b	b		a, b		b	a, b
ABC	b	a, b		b		b	b
D (ASP)	a, b	a, b			a, b	a, b	
AD							
BD	b	a, b					
ABD							
CD		b			b		
ACD							
BCD							
ABCD	a, b	a, b			a, b	a, b	b

As it is observed in Table 9.9., the treatment combinations which are significant differ from one rule to another. For example, RSM is insensitive to any combination except for the two main effects, UF and DOV. This is possibly accounted for by the pairwise comparison RSM uses in activity selection. RSM is not affected by the presence or absence of Complexity interacting with UF or DOV in project networks, whereas GRD does, since it only considers resource requirements without the perspective of the network configuration. WRUP, on the other hand, taking precedence relationships into account, is affected by combination AC, since the precedence relationships do not differ much from activity to activity in a non - complex network. The interactions of Aspect Ratio and UF or DOV are not generally significant on the rules, the reason being that either resource - oriented or time - oriented, the rules somehow deal with UF or DOV unaffected by the level of Aspect Ratio.

To summarize, project networks can thus be classified into groups according to their characteristics, such that certain types will be solved by specific heuristic rule in order to minimize the project schedule duration.

X. THE PERFORMANCE OF THE WEIGHTED RESOURCE UTILIZATION AND PRECEDENCE (WRUP) RULE

WRUP, which is introduced in this study, is distinguished from the rest of the rules by the fact that it is neither resource - nor time - oriented. Although it does not consider the time factor, WRUP's performance is better than the rest of the rules as it takes the number of immediate successors of activities into account. WRUP, has a better understanding of the network than LFT or MINSLK, which are the two rules selected as performing best in previous studies, [11], [12], and [13].

Taking the minimization of extra schedule time ratio as the performance criterion for heuristic rules, WRUP has proved to be 1.77 per cent better than LFT and 5.62 per cent better than MINSLK. This is demonstrated in Table 9.1. where total PC is equivalent to the summation of the extra schedule time ratios of 64 test problems. With WRUP rating as the best, LFT, MINSLK, and RSM rules are claimed to be second - , third - , and fourth - best. GRD, SIO and Random Selection are the worse performing rules as expected.

Furthermore, since WRUP is a list priority rule, it is more efficient and fast compared to LFT, MINSLK and RSM. This point gains significance in the case of large networks.

47 more project networks have been created randomly, free of any design, in order to reinforce the claim that WRUP is the best rule among the rest. The free problems range from 16 to 101 activities and up to 6 resources in size. WRUP is consistent in its success in large

networks and a considerable reduction is observed in problem - solving durations. Complexity, in these free problems, ranges from 1.25 to 2.64, the Utilization Factor ranges from 0.55 to 1.78, the Dominant Obstruction Value ranges from 0.08 to 1.10, and the Aspect Ratio , from 0.21 to 3.25. All of the 111 test problems can be found in Appendix B.

Based on the results obtained from the test problems, WRUP obtains results 2.04 per cent better than LFT and 6.45 per cent better than MINSLK as observed in Table 10.1.Furthermore, in 83 of the 111 problems, that is, 74.77 per cent of the time, WRUP obtains results as well as or better than LFT rule. As mentioned before, WRUP, by scheduling the activity which precedes more activities than others, is generally successful in eliminating the obstruction created by precedence obligations.

Through inspection of the last column in Table 10.1.which indicates the resource and utilisation weights used to obtain the best result WRUP can achieve, it is observed that parametric analysis is helpful in about 60 per cent of the case. Parametric analysis is an advantage for WRUP over the others, since it enables the rule to show flexibility according to the network configuration and resource requirements of the project. For problems having high resource requirements it is necessary to use high resource weights in comparison to precedence weights. An experienced user can assign the appropriate weights by simple inspection of the network. As observed in Table 10.1. the precedence and resource weights assigned to the test problems included in the design justify the claim that high resource weights are needed to

TABLE 10.1. Extra schedule time ratio table for 64 problems of 2^4 design and 47 free problems.

Problem Type	Problem Number	MINSLK	LFT	RSM	RULES GRD	SIO	RAN	WRUP	Weight Pre.	Weight Res.
1	1.1	.00	.00	.00	.00	.00	.00	.00	all	
	1.2	.00	.07	.07	.00	.07	.14	.00	.4 .6	.6, .4
	1.3	.00	.00	.03	.03	.03	.13	.00	all	
	1.4	.15	.07	.07	.15	.07	.15	.07	all	
A	a.1	.53	.53	.53	.53	.47	.50	.47	.3 .5 .7	.7, .5, .3
	a.2	.42	.49	.47	.47	.51	.56	.22	.5	.5
	a.3	.41	.35	.35	.38	.46	.41	.49	all	
	a.4	.46	.49	.43	.46	.59	.50	.43	.2	.8
B	b.1	.03	.03	.07	.22	.17	.28	.03	.2	.8
	b.2	.01	.01	.01	.23	.03	.60	.09	.4	.6
	b.3	.47	.47	.53	.60	.47	.64	.47	<=.4	.6
	b.4	.31	.05	.39	.48	.29	.49	.36	.25 .3	.75, .7
AB	ab.1	1.06	1.06	1.23	1.19	1.19	1.39	1.13	.5 .7	.5, .3
	ab.2	1.03	1.00	1.14	1.34	1.10	1.17	1.07	.5 .7	.5, .3

	ab.3	1.15	1.05	1.28	1.28	1.28	1.28	1.05	<=.5 .5
	ab.4	.98	.93	1.00	1.15	.96	1.22	.93	>=.5 .5
C	c.1	.21	.02	.02	.32	.02	.02	.02	all
	c.2	.00	.00	.00	.00	.00	.00	.00	all
	c.3	.12	.12	.12	.12	.12	.12	.08	all
	c.4	.00	.00	.13	.00	.23	.23	.00	all
AC	ac.1	.55	.55	.53	.58	.55	.50	.42	.5 .5 - .7 .3
	ac.2	.46	.46	.57	.46	.46	.46	.46	all
	ac.3	.42	.44	.46	.40	.46	.46	.42	all
	ac.4	.59	.59	.64	.64	.64	.59	.64	all
BC	bc.1	.42	.42	.46	.42	.60	.60	.46	.4 .6, .9 .1
	bc.2	.48	.41	.48	.55	.55	.43	.40	.4 .6
	bc.3	.43	.43	.48	.55	.62	.64	.43	all
	bc.4	.49	.40	.49	.49	.44	.53	.40	<=.5 .5
ABC	abc.1	.64	.65	.82	1.00	.90	.85	.79	.4 .6, .6 .4
	abc.2	.70	.70	.70	.79	.70	.79	.43	.5 .5
	abc.3	.84	.84	.84	.84	.84	.84	.84	all
	abc.4	.70	.70	.78	.78	.90	.90	.70	all

D	d.1	.00	.00	.00	.00	.00	.00	.00	all
	d.2	.04	.04	.04	.08	.04	.08	.04	.5 .5
	d.3	.09	.11	.11	.17	.09	.09	.11	all
	d.4	.00	.00	.00	.00	.00	.00	.00	all
AD	ad.1	.65	.60	.65	.65	.60	.65	.60	>=.4 .6
	ad.2	.57	.57	.57	.61	.64	.71	.57	.4 .6 - .7 .3
	ad.3	.48	.51	.42	.45	.48	.48	.48	all
	ad.4	.62	.69	.69	.65	.81	.73	.69	all
BD	bd.1	.57	.57	.54	.51	.43	.60	.43	.5 .5
	bd.2	.42	.42	.45	.61	.52	.70	.48	.2 .8
	bd.3	.59	.56	.78	.72	.81	.57	.56	>=.4 .6
	bd.4	.68	.68	.51	.68	.74	.44	.52	.2 .8
ABD	abd.1	1.29	1.24	1.24	1.12	1.29	1.18	1.06	.5 .5
	abd.2	1.06	1.10	1.03	1.13	1.19	1.26	1.03	.4 .6
	abd.3	1.33	1.18	1.30	1.61	1.30	1.33	1.12	all
	abd.4	1.12	1.12	1.12	.98	1.08	1.21	.98	<=.5 .5
CD	cd.1	.03	.03	.03	.03	.03	.03	.03	all
	cd.2	.00	.00	.00	.00	.03	.00	.00	all
	cd.3	.54	.54	.54	.54	.54	.54	.54	all
	cd.4	.00	.00	.00	.00	.00	.00	.00	all

ACD	acd.1	.53	.53	.58	.56	.61	.61	.58	.4 .6
	acd.2	.43	.43	.43	.50	.43	.50	.43	all
	acd.3	.53	.50	.50	.53	.50	.53	.53	all
	acd.4	.46	.46	.46	.46	.46	.46	.49	all
BCD	bcd.1	.44	.44	.47	.44	.47	.57	.44	.5 .5, .6 .4
	bcd.2	.60	.50	.60	.73	.60	.52	.57	.5 .5 - .7 .3
	bcd.3	.42	.42	.42	.42	.52	.42	.42	all
	bcd.4	.33	.33	.60	.60	.43	.43	.33	<=.6 .4
ABCD	abcd.1	.98	.95	.98	.98	.98	.98	.95	.4 .6, .5 .5
	abcd.2	1.12	1.12	1.12	1.12	1.12	1.12	1.12	all
	abcd.3	.45	.45	.45	.45	.45	.45	.45	all
	abcd.4	1.16	1.02	1.20	1.06	1.20	1.14	1.06	.3 .7, >=.5 .5
Total PC for 64 Problems		31.59	30.44	32.95	34.84	34.09	35.75	29.91	
% Increase over WRUP		5.62	1.77	10.16	16.48	13.98	19.53	00.00	

PROBLEMS FREE OF DESIGN

Problem Number	MINSLK	LFT	RSM	RULE GRD	SIO	RAN	WRUP	Weight Pre.	Weight Res.
F1	.85	.92	.85	.85	.92	.85	.85	<.9	.1
F2	.89	.89	.89	.94	.94	.94	.89	.1	.9
F3	.61	.55	.61	.74	.77	.81	.68	<=.4	.6
F4	.81	.81	.88	.84	.77	.79	.93	<=.2	.8
F5	.39	.39	.59	.33	.43	.67	.33	<=.3	.7
F6	.90	.79	1.19	.90	1.08	.92	.79	>=.2	.8
F7	1.49	1.50	1.49	1.54	1.62	1.49	1.25	.0	1.0
F8	1.59	1.41	1.31	1.74	1.47	1.55	1.53	.3	.7
F9	.63	.56	.63	.74	.52	.59	.52	>=.2	.8
F10	1.70	1.59	1.46	2.00	1.85	2.06	1.48	.3	.7
F11	.45	.43	.45	.48	.59	.59	.48	>=.2	.8
F12	1.72	1.66	1.97	1.79	1.87	1.93	1.58	.3	.7
F13	.07	.07	.07	.07	.07	.07	.07	all	
F14	.58	.44	.40	.44	.44	.44	.40	<=.5	.5
F15	.93	.93	.86	1.23	1.10	1.21	1.01	.1	.9
F16	1.45	1.33	1.39	1.60	1.56	1.76	1.22	.4	.6
F17	.50	.50	.50	.50	.53	.50	.50	all	
F18	.77	.77	.93	.77	.77	.93	.77	>=.3	.7
F19	.71	.71	.71	.89	.71	.89	.71	>=.5	.5

F20	1.00	.87	.87	.90	.90	1.03	.90	all
F21	.39	.39	.39	.39	.42	.39	.39	all
F22	.58	.58	.58	.58	.61	.50	.50	.9 .1
F23	.83	.80	.85	.85	.85	.80	.80	all
F24	.59	.49	.41	.81	.59	.81	.43	>=.2 .8
F25	.13	.08	.08	.13	.08	.13	.08	all
F26	.93	1.00	.85	1.00	1.16	1.09	.87	.1 .9, .2 .8
F27	.16	.20	.20	.23	.23	.08	.05	.1 .9, .2 .8
F28	.31	.38	.38	.31	.38	.43	.33	>=.2 .8
F29	1.25	1.25	1.25	1.25	1.31	1.25	1.25	.1 .9, .2 .8
F30	.29	.29	.22	.29	.22	.29	.22	<=.2 .8
F31	.59	.48	.63	.48	.48	.50	.48	all
F32	.66	.68	.66	.61	.77	.68	.61	all
F33	.73	.56	.68	.90	.80	.78	.58	.4 .6
F34	.06	.06	.17	.17	.11	.11	.17	all
F35	1.12	1.03	1.12	1.24	1.27	1.03	1.03	all
F36	1.37	1.28	1.43	1.53	1.69	1.58	1.44	.4 .6
F37	1.28	1.31	1.37	1.42	1.31	1.51	1.37	.1 .9
F38	.92	.97	1.06	1.06	.98	.94	.82	.2 .8, .3 .7
F39	.75	.65	.74	.74	.92	.72	.57	.3 .7
F40	1.16	1.25	1.23	1.23	1.20	1.37	1.11	.0 1.0
F41	1.26	1.29	1.32	1.59	1.61	1.43	1.22	.2 .8
F42	.69	.71	.67	.69	.82	.64	.47	>=.4 .6

F43	.93	.90	1.19	1.15	1.32	1.10	1.04	.0	1.0
F44	1.40	1.13	1.31	1.43	1.29	1.43	1.33	.0	1.0
F45	1.29	1.19	1.29	1.48	1.48	1.19	1.16	all	
F46	.85	.74	.81	1.03	.91	1.07	.71	.4	.6
F47	.79	.75	.83	1.15	.93	.86	.81	.4	.6
Total PC for 47 Free Problems	39.35	37.56	39.77	43.03	42.65	42.73	36.73		
Total PC for 111 Problems	70.94	68.00	72.72	77.87	76.74	78.48	66.64		
% Increase over WRUP	6.45	2.04	9.12	16.85	15.16	17.77	00.00		

obtain reduced project durations for high resource requirement problems. For moderate resource utilization ratio networks , good results can be achieved by the employment of 1 : 1 ratio between precedence and resource utilization weights.

A point to be made is the unbalance of the scales among the weighted precedence and resource utilization. Obviously, the number of successors of an activity is an integer number whereas resource utilization ratio is a fraction, thus making weighted precedence considerably larger than weighted resource utilization as the corresponding weights add up to one. An effort was made to improve the unbalance of the scale between the two by dividing the number of successors of an activity by the maximum number of successors in the network.The results obtained with the latter scale were highly inferior to the ones obtained with the unbalanced one. In consequence, WRUP's initial definition stayed intact.

As a conclusion, the general performance of WRUP is found to be quite satisfactory in the sense that its priority distribution to activities enable it to cope with almost all types of problems more successfully than the rest of widely - used heuristics.

APPENDIX A

DEFINITIONS OF NETWORK / RESOURCE CHARACTERISTICS

$$1.\ \text{ASPECT RATIO} = \frac{\text{Number of activities on critical path}}{\text{Number of noncritical activities}}$$

$$2.\ \text{COMPLEXITY} = \frac{\text{Number of activities}}{\text{Number of network events}}$$

3. DOMINANT OBSTRUCTION VALUE = 1.5 MO if 0.5 MO > MO2 ;
= MO + MO2 if 0.5 MO <= MO2.

where : MO2 is the second largest obstruction ratio ;

MO = Max { O(k) } ;

$$O(k) = \frac{\sum_{t=1}^{CPL} \text{Max} \{ 0; R^{est}(kt) - R(k) \}}{W(k)} ;$$

R(k) = Units available per period of resource type k ;

$R^{est}(kt)$ = Required units of resource type k based on EST scheduling in time period t ;

CPL = Critical path length ;

W(k) = Required total work content of resource k ;

$$= \sum_{\text{All } ij} d(ij) * r(ijk) ;$$

d(ij) = Duration of activity ij ;

r(ijk) = Required units per period of resource type k by activity ij.

4. RESOURCE UTILIZATION FACTOR (UF) = Max { f(k) } ;

where : $f(k) = \frac{W(k)}{CPL * R(k)}$.

APPENDIX B

TEST PROBLEMS

Problem Name : 1.1

No of Activities: 22

No of Resources : 3

Resource Limit (1) : 5

Resource Limit (2) : 6

Resource Limit (3) : 7

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	3	1	1	1
1, 3	2	2	1	2
1, 4	1	1	1	1
1, 10	5	1	2	1
2, 3	1	1	1	1
2, 5	2	1	2	1
2, 8	6	1	1	1
3, 4	4	0	1	0
3, 5	1	0	0	1
3, 6	1	0	0	1
4, 7	8	0	1	1
4, 10	9	1	1	1
5, 6	3	1	2	1
5, 8	4	2	1	2
6, 7	5	1	2	1
6, 8	2	1	2	1
7, 8	3	1	1	1
7, 9	4	1	2	1
7, 10	6	2	1	2
8, 9	3	1	2	2
8, 10	3	2	2	1
9, 10	7	1	2	1

Problem Name : 1.2

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 5

Activity Label	Duration	Resource Req. (1)
1, 2	5	2
1, 3	7	1
1, 4	3	1
2, 4	2	2
2, 5	5	2
3, 5	4	1
3, 6	1	0
4, 8	3	2
4, 9	4	1
5, 6	7	1
5, 7	3	2
5, 8	8	0
6, 7	2	2
6, 10	5	2
7, 8	1	1
7, 9	1	1
7, 10	4	2
8, 9	2	1
8, 10	7	1
9, 10	1	1

Problem Name : 1.3

No of Activities: 22

No of Resources : 1

Resource Limit (1) : 7

Activity Label	Duration	Resource Req. (1)
1, 2	1	0
1, 3	2	1
1, 4	6	1
1, 10	6	1
2, 3	1	3
2, 5	1	2
2, 8	4	2
3, 4	4	3
3, 5	1	1
3, 6	5	2
4, 7	9	0
4, 10	3	1
5, 6	1	0
5, 8	7	1
6, 7	3	2
6, 8	5	1
7, 8	7	1
7, 9	3	3
7, 10	6	1
8, 9	2	2
8, 10	9	3
9, 10	3	2

Problem Name : 1.4

No of Activities: 21

No of Resources : 2

Resource Limit (1) : 8

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	6	1
1, 3	2	0	2
1, 4	15	3	1
2, 3	6	3	1
2, 4	5	2	0
2, 5	8	0	2
3, 5	8	2	1
3, 6	12	2	0
3, 7	5	1	1
4, 5	10	1	1
4, 8	11	0	1
5, 6	5	2	1
5, 8	20	2	0
6, 7	5	1	1
6, 9	10	1	1
7, 8	3	1	0
7, 9	6	2	3
7, 10	7	3	1
8, 9	12	2	3
8, 10	8	1	0
9, 10	10	1	0

Problem Name : A.1

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	1	2
1, 3	2	2
1, 4	2	1
1, 5	6	0
1, 7	5	1
2, 4	3	2
2, 6	1	3
2, 7	2	1
2, 8	3	2
3, 4	2	1
3, 5	5	1
3, 6	3	2
4, 6	4	1
5, 6	6	2
5, 8	4	1
5, 9	5	1
6, 7	2	0
6, 8	5	3
7, 8	8	3
8, 9	7	3

Problem Name : A.2

No of Activities: 21

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	1	3
1, 3	3	1
1, 4	3	1
1, 5	4	2
2, 3	3	2
2, 4	3	1
2, 6	3	1
2, 9	5	1
3, 4	9	3
3, 7	2	1
4, 5	9	3
5, 6	8	1
5, 7	3	2
5, 8	4	3
5, 9	4	1
6, 7	1	1
6, 8	7	1
6, 9	4	2
7, 8	1	1
7, 9	9	2
8, 9	8	3

Problem Name : A.3

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 2

Activity Label	Duration	Resource Req. (1)
1, 2	5	1
1, 3	1	1
1, 4	3	1
1, 5	3	1
1, 7	2	1
2, 4	2	1
2, 6	2	0
2, 7	1	1
2, 8	2	2
3, 4	1	1
3, 5	9	1
3, 6	2	0
4, 6	9	1
5, 6	5	2
5, 8	4	2
5, 9	1	0
6, 7	7	0
6, 8	7	2
7, 8	9	2
8, 9	5	2

Problem Name : A.4

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	20	4
1, 3	5	0
2, 3	3	3
2, 4	12	2
2, 5	2	4
2, 6	3	2
3, 6	4	1
3, 8	5	3
3, 9	6	4
4, 5	7	4
4, 6	5	1
4, 7	12	2
4, 8	5	2
5, 7	4	3
5, 10	4	2
6, 8	3	1
7, 8	20	4
8, 9	2	1
8, 10	10	4
9, 10	3	2

Problem Name : B.1

No of Activities: 33

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	9	2	1
1, 3	6	6	6
1, 4	8	1	2
1, 5	6	2	4
1, 8	6	2	3
1, 9	8	1	1
2, 3	9	0	0
2, 5	1	0	0
3, 4	8	0	0
3, 5	8	0	0
3, 6	3	1	1
3, 7	1	1	1
4, 6	1	2	2
4, 7	4	2	1
4, 8	3	1	1
5, 6	4	1	1
5, 9	3	2	1
5, 11	9	2	2
5, 12	7	5	2
6, 7	2	2	2
6, 9	2	1	2
6, 10	8	2	2
7, 8	8	1	2
7, 10	5	2	2
7, 11	5	1	1
8, 10	1	2	1
8, 11	9	0	0
8, 12	2	1	1
9, 10	6	1	1
9, 12	9	1	1
10, 11	1	1	1
10, 12	2	1	1
11, 12	9	0	0

Problem Name : B.2

No of Activities: 22

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	9	2	3
1, 3	7	3	3
1, 4	6	3	3
1, 5	8	2	3
1, 9	6	4	2
2, 3	8	1	0
2, 6	6	1	0
2, 7	3	2	1
3, 4	7	0	0
3, 7	1	1	1
3, 8	2	0	1
4, 5	9	0	0
5, 6	6	2	1
5, 7	5	3	4
5, 8	5	3	4
5, 9	5	3	3
6, 7	9	1	0
6, 8	4	0	1
6, 9	3	0	1
7, 8	8	0	0
7, 9	4	1	0
8, 9	9	0	1

Problem Name : B.3

No of Activities: 33

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	4	3
1, 3	5	4	3
1, 4	9	1	0
1, 5	5	1	0
1, 8	7	1	2
1, 9	5	2	2
2, 3	1	2	0
2, 5	4	0	3
3, 4	1	2	2
3, 5	2	1	0
3, 6	2	1	0
3, 7	3	1	0
4, 6	3	4	3
4, 7	2	2	3
4, 8	8	1	0
5, 6	5	1	1
5, 9	6	1	0
5, 11	4	1	1
5, 12	4	2	3
6, 7	4	1	0
6, 9	6	0	0
6, 10	5	0	0
7, 8	3	1	0
7, 10	9	0	0
7, 11	3	0	1
8, 10	2	0	0
8, 11	9	0	0
8, 12	3	1	1
9, 10	3	1	0
9, 12	2	2	0
10, 11	3	0	1
10, 12	20	0	0
11, 12	17	0	0

Problem Name : B.4

No of Activities: 24

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	10	3	2
1, 3	13	2	2
1, 4	14	3	3
1, 7	25	4	3
1, 10	30	2	2
2, 3	10	2	1
2, 5	8	3	3
2, 6	10	3	3
2, 7	14	2	3
2, 8	12	2	2
3, 4	6	2	2
3, 5	5	3	3
4, 5	6	1	2
4, 9	2	1	1
4, 10	5	1	0
5, 6	3	1	1
5, 8	6	0	1
5, 9	3	0	0
6, 8	20	0	0
7, 8	4	3	3
7, 10	5	3	3
8, 9	15	0	1
8, 10	3	2	0
9, 10	25	0	0

Problem Name : AB.1

No of Activities: 23

No of Resources : 2

Resource Limit (1) : 7

Resource Limit (2) : 9

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	3	3
1, 3	9	7	7
1, 8	9	2	7
1, 9	8	2	3
2, 3	3	1	2
2, 4	4	3	1
2, 5	6	3	3
2, 6	7	2	2
3, 5	5	2	2
3, 7	6	3	5
3, 9	8	2	6
4, 5	3	3	3
4, 6	6	2	1
4, 8	8	2	1
5, 6	5	2	3
5, 7	9	3	2
5, 9	7	2	3
6, 7	6	3	2
6, 8	9	2	1
6, 9	7	3	3
7, 8	1	0	0
7, 9	6	0	0
8, 9	3	0	1

Problem Name : AB.2

No of Activities: 20

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	1	1	1
1, 3	2	2	1
1, 5	5	3	3
1, 8	4	0	3
2, 3	3	1	1
2, 4	1	1	1
2, 6	3	2	1
2, 8	4	2	2
3, 4	2	1	2
3, 5	6	1	1
3, 7	3	2	1
3, 8	5	1	1
4, 5	8	2	1
4, 6	7	3	3
5, 6	1	2	2
5, 7	4	3	3
5, 8	6	1	2
6, 7	5	1	2
6, 8	6	2	3
7, 8	9	0	0

Problem Name : AB.3

No of Activities: 20

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 2

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	3	5	2
1, 3	5	3	1
1, 5	5	3	0
1, 8	5	3	0
2, 3	1	3	1
2, 4	6	5	2
2, 6	6	5	2
2, 8	5	3	1
3, 4	4	5	2
3, 5	9	3	0
3, 7	7	5	2
3, 8	8	2	2
4, 5	3	4	0
4, 6	3	3	0
5, 6	5	3	2
5, 7	11	1	0
5, 8	5	3	2
6, 7	4	0	1
6, 8	3	1	1
7, 8	15	0	1

Problem Name : AB.4

No of Activities: 23

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	0	1
1, 3	12	3	4
1, 4	15	2	0
1, 5	11	0	3
1, 6	10	1	0
2, 3	9	5	3
2, 4	10	4	4
2, 5	15	2	0
2, 8	15	0	1
2, 9	20	0	1
3, 4	8	2	3
3, 7	10	2	0
3, 8	8	3	1
4, 5	4	3	3
4, 7	12	2	2
5, 6	1	0	3
5, 7	3	4	4
6, 7	2	2	2
6, 8	5	5	1
6, 9	6	5	2
7, 8	1	0	2
7, 9	3	0	1
8, 9	20	0	1

Problem Name : C.1

No of Activities: 20

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	1	3	3
1, 3	2	4	1
2, 5	5	0	1
3, 4	3	3	2
4, 5	7	1	3
4, 6	4	2	0
5, 9	9	1	0
6, 7	9	1	1
6, 8	6	2	1
7, 10	7	1	1
8, 10	5	2	2
9, 11	8	1	2
10, 12	5	1	2
11, 13	6	2	2
11, 16	7	1	1
12, 15	1	1	1
13, 14	5	2	2
14, 17	3	1	2
15, 16	2	1	1
16, 17	4	2	1

Problem Name : C.2

No of Activities: 19

No of Resources : 2

Resource Limit (1) : 9

Resource Limit (2) : 10

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	2	2	2
1, 3	1	1	1
1, 4	9	3	2
2, 3	1	1	1
3, 5	3	2	1
4, 6	1	2	2
4, 12	8	2	3
5, 7	1	2	1
5, 9	5	1	3
6, 8	2	2	3
6, 11	8	2	3
7, 8	2	1	1
8, 10	1	1	1
8, 13	3	2	3
9, 11	2	2	0
10, 11	3	2	1
11, 13	4	3	2
12, 13	6	3	3
13, 14	4	4	2

Problem Name : C.3

No of Activities: 19

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	2	1
1, 3	12	3	0
1, 4	8	1	1
2, 3	2	1	1
3, 5	15	1	1
4, 6	4	3	3
4, 12	10	2	0
5, 7	20	1	1
5, 9	10	3	4
6, 8	7	1	1
6, 11	5	1	2
7, 8	8	0	0
8, 10	2	1	2
8, 13	20	1	2
9, 11	5	1	3
10, 11	3	1	0
11, 13	3	0	1
12, 13	12	2	2
13, 14	10	0	1

Problem Name : C.4

No of Activities: 15

No of Resources : 1

Resource Limit (1) : 5

Activity Label	Duration	Resource Req. (1)
1, 2	10	3
1, 3	15	4
2, 6	8	3
3, 4	12	0
3, 5	10	1
3, 8	20	1
4, 6	10	1
5, 7	10	0
6, 7	5	2
7, 9	5	1
7, 10	10	1
8, 9	20	2
9, 11	15	1
10, 12	5	2
11, 12	10	1

Problem Name : AC.1

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	1	2
1, 3	3	3
2, 4	6	1
2, 5	2	1
3, 6	5	2
3, 5	2	1
4, 7	8	2
5, 8	1	1
5, 9	2	1
6, 7	1	1
6, 12	3	2
7, 10	3	3
8, 11	2	2
9, 11	5	2
10, 12	4	3
11, 12	3	1
11, 13	3	3
12, 13	2	3
13, 14	8	3
14, 15	6	3

Problem Name : AC.2

No of Activities: 17

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	8	0	3
1, 3	3	1	0
2, 6	2	0	2
2, 7	9	1	0
3, 4	2	0	1
4, 5	3	0	2
5, 7	2	0	3
6, 8	1	1	2
6, 10	5	1	2
7, 11	6	3	3
8, 9	2	1	3
9, 12	1	3	2
10, 12	3	2	3
11, 13	3	3	3
12, 13	3	0	2
13, 14	1	3	3
14, 15	1	3	3

Problem Name : AC.3

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 5

Activity Label	Duration	Resource Req. (1)
1, 2	2	1
1, 3	8	5
2, 4	3	2
2, 5	5	2
3, 5	4	4
3, 6	12	5
4, 7	1	1
5, 8	2	2
5, 9	1	5
6, 7	1	0
6, 12	20	5
7, 10	2	5
8, 11	3	5
9, 11	1	2
10, 12	1	3
11, 12	2	1
11, 13	5	4
12, 13	3	5
13, 14	5	4
14, 15	4	5

Problem Name : AC.4

No of Activities: 13

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	2	1
1, 3	12	3
1, 4	5	3
2, 5	8	2
3, 4	7	2
4, 7	10	3
5, 6	5	2
6, 8	3	2
7, 9	5	3
8, 9	2	1
8, 10	3	0
9, 11	5	3
10, 11	2	1

Problem Name : BC.1

No of Activities: 17

No of Resources : 3

Resource Limit (1) : 4

Resource Limit (2) : 4

Resource Limit (3) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	6	0	0	0
2, 3	9	0	0	0
3, 4	3	4	4	2
3, 5	1	3	3	0
4, 8	8	3	4	2
5, 6	2	3	3	0
5, 7	3	4	4	2
6, 7	4	2	4	1
7, 9	5	3	3	1
7, 10	6	4	2	1
8, 10	7	3	3	3
9, 11	2	3	3	3
10, 12	7	0	0	0
11, 12	3	3	3	2
11, 13	2	3	3	0
12, 14	8	0	0	1
13, 14	1	3	0	3

Problem Name : BC.2

No of Activities: 19

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	8	6	2
1, 3	3	6	0
1, 5	4	6	1
2, 6	9	3	2
2, 9	6	3	3
3, 4	4	1	6
4, 6	9	2	2
4, 8	8	1	4
5, 7	6	6	6
6, 9	6	0	0
7, 10	6	6	6
8, 14	5	0	0
9, 10	2	2	6
9, 11	9	2	3
10, 12	3	3	3
11, 12	8	0	0
12, 13	9	0	0
13, 15	9	0	0
14, 15	9	0	3

Problem Name : BC.3

No of Activities: 17

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	15	1	0
2, 3	20	0	0
3, 4	8	3	4
3, 5	10	3	4
4, 8	22	2	4
5, 6	5	2	4
5, 7	15	1	4
6, 7	6	3	1
7, 9	22	2	2
7, 10	25	3	3
8, 10	15	1	2
9, 11	5	2	0
10, 12	15	0	0
11, 12	3	0	0
11, 13	8	1	0
12, 14	30	0	1
13, 14	4	1	0

Problem Name : BC.4

No of Activities: 15

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	4	3
1, 3	7	3	3
1, 4	14	3	0
2, 3	3	4	3
3, 4	5	0	0
4, 5	2	4	3
4, 6	8	3	3
5, 7	5	4	3
6, 7	4	0	4
6, 11	2	0	3
7, 8	4	0	1
7, 11	30	0	0
8, 9	2	4	3
8, 11	4	4	3
9, 11	2	4	3

Problem Name : ABC.1

No of Activities: 20

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	3	4	4
1, 3	3	4	4
1, 4	4	4	4
2, 5	6	4	4
3, 7	5	4	4
4, 7	5	4	4
5, 6	1	0	0
5, 10	6	0	1
6, 9	8	3	3
7, 8	7	0	0
8, 11	6	2	3
8, 14	8	4	3
9, 11	3	0	1
10, 11	6	4	4
10, 12	7	3	0
11, 12	8	0	0
11, 13	2	1	0
12, 15	9	0	0
13, 15	7	0	1
14, 15	3	1	1

Problem Name : ABC.2

No of Activities: 21

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	3	3	4
1, 3	2	3	4
1, 4	3	3	4
2, 5	6	3	4
3, 7	7	3	4
4, 5	5	3	4
4, 6	5	3	4
5, 8	9	3	4
6, 9	5	3	4
7, 8	6	3	4
7, 9	4	3	4
9, 10	6	0	0
8, 10	8	2	3
10, 11	9	1	0
11, 12	3	3	4
11, 13	6	3	4
12, 15	4	3	4
13, 14	3	1	1
14, 15	8	2	3
15, 16	6	3	4
16, 17	5	2	3

Problem Name : ABC.3

No of Activities: 21

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	15	6	4
1, 3	8	4	3
1, 4	10	6	4
2, 5	5	4	4
3, 7	11	6	4
4, 5	7	6	4
4, 6	10	4	3
5, 8	15	4	4
6, 9	15	4	3
7, 8	11	6	4
7, 9	10	6	4
8, 10	20	4	4
9, 10	10	4	3
10, 11	22	1	2
11, 12	10	2	1
11, 13	8	4	1
12, 15	18	3	4
13, 14	5	1	0
14, 15	6	6	4
15, 16	7	6	1
16, 17	4	3	2

Problem Name : ABC.4

No of Activities: 14

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	10	1	1
2, 3	15	4	3
2, 4	12	4	3
3, 5	15	4	3
3, 6	20	4	3
4, 8	20	4	3
5, 7	10	2	2
5, 11	20	1	1
6, 7	12	2	1
7, 8	15	0	1
8, 9	2	4	3
8, 11	10	2	3
9, 10	3	4	3
10, 11	2	4	2

Problem Name : D.1

No of Activities: 20

No of Resources : 2

Resource Limit (1) : 13

Resource Limit (2) : 13

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	4	0	1
1, 3	8	0	1
1, 8	9	3	2
1, 9	4	3	3
2, 3	4	2	2
2, 6	2	3	2
3, 4	2	1	1
3, 5	3	2	1
3, 6	8	1	1
3, 7	9	1	1
4, 5	1	1	1
4, 6	6	3	2
4, 10	3	2	2
5, 6	5	2	1
5, 7	6	1	1
6, 7	1	1	1
6, 10	6	3	2
7, 10	5	2	1
8, 9	8	1	1
9, 10	4	3	2

Problem Name : D.2

No of Activities: 21

No of Resources : 3

Resource Limit (1) : 10

Resource Limit (2) : 10

Resource Limit (3) : 12

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	2	2	2	3
1, 3	3	2	1	3
1, 4	5	1	3	2
2, 3	1	2	1	3
2, 4	4	1	1	1
3, 5	6	2	1	2
3, 6	8	3	2	1
4, 5	3	2	1	2
4, 7	8	1	1	1
4, 8	6	2	1	2
5, 6	2	1	1	1
5, 9	9	1	2	1
6, 7	3	1	1	2
6, 8	5	1	2	1
6, 9	7	2	1	2
6, 10	6	1	3	1
7, 8	2	2	2	2
7, 10	9	1	1	1
8, 9	1	3	2	1
8, 10	9	1	3	1
9, 10	7	2	1	3

Problem Name : D.3

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 9

Activity Label	Duration	Resource Req. (1)
1, 2	9	2
1, 3	5	2
1, 8	20	0
1, 9	5	3
2, 3	3	4
2, 6	9	1
3, 4	1	3
3, 5	3	4
3, 6	6	3
3, 7	14	2
4, 5	1	0
4, 6	1	1
4, 10	2	1
5, 6	3	3
5, 7	11	2
6, 7	8	0
6, 10	17	1
7, 10	9	1
8, 9	10	1
9, 10	5	1

Problem Name : D.4

No of Activities: 21

No of Resources : 1

Resource Limit (1) : 7

Activity Label	Duration	Resource Req. (1)
1, 2	5	2
1, 3	3	2
1, 4	15	1
2, 3	2	3
2, 4	10	0
3, 4	2	1
3, 5	3	1
4, 5	3	0
4, 6	6	3
4, 8	31	2
4, 10	20	1
5, 6	3	1
5, 7	8	0
5, 8	28	0
6, 7	5	2
6, 8	25	1
7, 8	20	2
7, 9	30	1
8, 9	10	2
8, 10	25	2
9, 10	15	1

Problem Name : AD.1

No of Activities: 22

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 2

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	1	0	1
1, 3	3	1	1
1, 7	2	0	0
2, 3	2	2	2
2, 6	1	0	2
3, 4	4	0	1
3, 5	6	3	1
4, 5	2	0	1
5, 6	2	1	1
5, 7	2	0	2
5, 9	4	2	0
6, 9	2	0	1
6, 10	6	1	0
7, 8	1	0	2
7, 9	2	0	0
7, 11	4	0	0
8, 9	1	1	1
8, 10	2	0	2
8, 11	3	1	0
9, 10	4	1	0
9, 11	8	0	1
10, 11	3	3	2

Problem Name : AD.2

No of Activities: 26

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	2	2
1, 3	3	1
1, 4	5	0
2, 3	1	2
2, 4	3	0
2, 5	8	1
3, 4	2	0
3, 5	7	1
3, 6	3	2
4, 6	4	2
4, 7	2	1
4, 10	3	1
5, 6	6	2
5, 8	9	1
5, 9	3	0
6, 7	1	3
7, 8	2	1
7, 10	7	1
8, 9	2	0
8, 10	5	3
9, 10	3	0
9, 11	5	0
9, 12	7	1
10, 11	2	1
10, 12	4	2
11, 12	2	0

Problem Name : AD.3

No of Activities: 22

No of Resources : 1

Resource Limit (1) : 2

Activity Label	Duration	Resource Req. (1)
1, 2	5	1
1, 3	9	0
1, 7	5	1
2, 3	4	1
2, 6	16	1
3, 4	2	1
3, 5	9	0
4, 5	7	1
5, 6	3	1
5, 7	1	1
5, 9	6	2
6, 9	3	1
6, 10	8	1
7, 8	1	1
7, 9	1	1
7, 11	12	0
8, 9	1	0
8, 10	1	2
8, 11	2	1
9, 10	5	1
9, 11	7	1
10, 11	2	1

Problem Name : AD.4

No of Activities: 21

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	2	1	
1, 3	3	0	
1, 4	3	1	
1, 7	6	1	
2, 5	2	2	
2, 7	4	1	
3, 5	1	1	
4, 5	1	2	
4, 6	2	0	
4, 8	4	1	
5, 6	1	2	
5, 7	2	2	
6, 7	1	1	
6, 8	3	0	
6, 10	8	1	
7, 8	10	2	
7, 9	2	0	
7, 10	5	1	
8, 9	3	1	
8, 10	20	2	
9, 10	7	0	

Problem Name : BD.1

No of Activities: 25

No of Resources : 2

Resource Limit (1) : 8

Resource Limit (2) : 7

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	2	5	3
1, 3	1	5	1
1, 4	3	8	3
1, 5	8	1	2
2, 3	2	3	1
2, 6	2	3	3
2, 7	4	4	1
2, 8	6	3	2
2, 9	6	2	2
3, 4	3	3	3
3, 7	4	3	1
4, 5	1	4	3
4, 7	1	2	2
5, 8	3	5	3
5, 10	2	1	1
6, 7	4	3	2
6, 9	2	3	2
6, 10	3	4	3
7, 8	3	3	3
7, 9	4	3	3
7, 10	3	2	3
8, 10	6	0	0
9, 10	5	0	1
10, 11	9	0	0
11, 12	9	0	0

Problem Name : BD.2

No of Activities: 23

No of Resources : 2

Resource Limit (1) : 11

Resource Limit (2) : 9

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	7	0	0
2, 3	9	0	0
2, 5	2	1	1
3, 4	1	3	4
3, 5	3	4	4
3, 6	7	3	3
3, 7	8	2	4
3, 8	7	4	2
4, 6	6	8	3
4, 8	8	5	4
5, 6	4	4	3
5, 7	5	3	4
5, 10	6	2	3
6, 8	2	3	4
6, 9	4	3	2
7, 8	1	1	1
7, 9	3	3	0
7, 11	2	3	1
8, 9	5	1	0
8, 10	5	1	0
8, 11	8	1	1
9, 11	3	1	1
10, 11	3	1	0

Problem Name : BD.3

No of Activities: 24

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	8	1	0
1, 3	6	4	3
1, 4	6	3	3
1, 5	12	2	2
2, 3	2	1	4
2, 6	6	3	3
2, 7	9	1	0
2, 8	14	3	3
2, 9	2	3	3
3, 4	1	1	0
3, 7	1	1	0
4, 5	1	3	0
4, 7	6	2	0
5, 8	10	2	3
5, 10	10	1	3
6, 7	3	3	3
6, 9	9	0	0
6, 10	3	3	3
7, 8	5	3	0
7, 9	8	0	0
7, 10	5	3	1
8, 10	12	0	0
9, 10	9	1	0
10, 11	20	0	0

Problem Name : BD.4

No of Activities: 22

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	5	5
1, 3	5	4	5
1, 4	8	5	3
1, 6	10	5	5
2, 3	5	3	5
2, 4	8	2	5
2, 5	11	2	2
3, 4	3	1	2
3, 5	6	1	2
4, 5	3	0	1
4, 6	7	2	1
5, 6	4	3	2
5, 8	14	2	2
5, 9	29	0	1
5, 10	20	1	0
6, 7	5	1	2
6, 8	10	2	2
7, 8	5	2	3
7, 9	20	0	0
7, 10	10	1	0
8, 9	15	0	1
9, 10	45	1	0

Problem Name : CD.1

No of Activities: 23

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	5	0
2, 3	2	3
3, 4	4	1
4, 5	6	2
4, 7	2	0
5, 6	8	1
6, 7	1	1
6, 8	3	0
7, 9	3	0
8, 9	2	1
8, 10	6	2
9, 12	9	2
9, 14	8	0
10, 11	3	0
11, 12	1	1
12, 13	9	3
13, 14	1	1
14, 15	4	1
14, 17	6	3
15, 16	1	2
16, 17	1	1
17, 18	2	2
18, 19	6	3

Problem Name : CD.2

No of Activities: 18

No of Resources : 3

Resource Limit (1) : 6

Resource Limit (2) : 7

Resource Limit (3) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	5	0	3	2
1, 5	7	3	4	3
2, 3	3	0	2	1
3, 4	6	0	0	2
4, 6	2	0	0	4
5, 7	4	0	3	0
5, 9	9	2	0	2
6, 7	1	0	1	3
7, 8	3	1	1	1
7, 10	5	0	1	0
8, 9	5	1	2	2
9, 11	3	0	1	2
10, 11	6	3	4	3
10, 12	1	3	1	0
10, 14	6	0	0	0
11, 13	6	2	3	2
12, 14	7	2	1	0
13, 14	2	1	2	0

Problem Name : CD.3

No of Activities: 18

No of Resources : 3

Resource Limit (1) : 4

Resource Limit (2) : 3

Resource Limit (3) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	5	0	1	3
1, 5	22	2	1	0
2, 3	2	0	1	3
3, 4	6	1	0	0
4, 6	1	0	1	0
5, 7	11	0	1	1
5, 9	20	0	1	1
6, 7	2	0	2	0
7, 8	6	1	1	0
7, 10	7	2	0	0
8, 9	3	0	3	1
9, 11	15	0	0	1
10, 11	17	1	0	1
10, 12	15	1	0	2
10, 14	45	1	1	0
11, 13	8	3	0	3
12, 14	30	1	0	1
13, 14	20	1	2	2

Problem Name : CD.4

No of Activities: 15

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	3	2
1, 3	6	1
2, 5	12	0
3, 4	3	2
3, 6	8	1
4, 6	3	2
5, 7	4	2
6, 9	10	1
7, 8	2	2
8, 10	2	2
8, 12	11	1
9, 10	1	0
9, 11	1	1
10, 11	3	1
11, 12	4	2

Problem Name : ABD.1

No of Activities: 24

No of Resources : 2

Resource Limit (1) : 7

Resource Limit (2) : 7

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	8	2	3
1, 3	8	7	7
1, 4	3	3	1
1, 6	7	6	6
1, 10	9	3	3
2, 5	8	0	3
2, 6	7	3	3
2, 9	5	3	3
3, 4	3	3	2
3, 5	8	3	3
4, 5	5	2	3
4, 6	9	3	1
5, 6	4	3	0
5, 7	7	2	1
5, 9	9	2	0
6, 7	3	1	1
6, 8	5	3	3
6, 10	6	3	3
7, 8	2	1	1
7, 9	4	3	3
7, 10	7	3	2
8, 9	9	0	0
8, 10	9	0	0
9, 10	7	0	1

Problem Name : ABD.2

No of Activities: 27

No of Resources : 3

Resource Limit (1) : 6

Resource Limit (2) : 8

Resource Limit (3) : 12

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	2	2	3	3
1, 3	3	2	1	3
1, 4	2	2	3	3
1, 5	6	6	8	3
2, 3	2	2	2	2
2, 4	1	1	1	1
2, 5	4	3	2	3
3, 5	3	5	4	2
3, 6	4	5	4	2
4, 5	4	3	3	3
4, 7	5	3	2	3
4, 9	9	6	8	1
5, 6	2	2	4	1
5, 7	1	3	4	1
5, 8	3	6	8	1
6, 8	1	2	2	1
7, 8	2	2	3	1
7, 9	4	2	4	1
8, 9	2	2	3	1
8, 10	7	3	4	2
9, 10	5	2	1	2
9, 11	6	1	3	2
9, 12	3	3	4	2
9, 13	8	2	2	2
10, 12	5	1	1	1
11, 13	8	0	0	1
12, 13	9	0	1	0

Problem Name : ABD.3

No of Activities: 24

No of Resources : 2

Resource Limit (1) : 7

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	7	3
1, 3	5	1	1
1, 4	10	2	3
1, 6	19	1	0
1, 10	12	5	5
2, 5	6	1	3
2, 6	6	3	3
2, 9	6	2	3
3, 4	5	2	2
3, 5	7	2	1
4, 5	2	3	3
4, 6	9	2	1
5, 6	7	2	1
5, 7	10	1	2
5, 9	5	2	3
6, 7	3	3	1
6, 8	8	1	0
6, 10	3	7	0
7, 8	5	3	1
7, 9	7	2	0
7, 10	11	2	0
8, 9	2	0	0
8, 10	6	0	0
9, 10	4	1	1

Problem Name : ABD.4

No of Activities: 22

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	10	3	3
1, 3	22	2	0
1, 5	29	1	1
2, 3	12	3	3
3, 4	5	0	0
3, 11	15	1	0
4, 5	2	3	1
4, 7	11	1	2
4, 8	13	3	3
4, 11	20	0	1
5, 6	4	1	0
5, 7	9	2	2
6, 7	5	3	1
6, 8	7	0	0
7, 8	2	3	3
7, 10	5	1	0
8, 9	6	0	0
8, 10	2	1	1
8, 11	12	0	0
9, 10	3	0	1
9, 11	6	0	1
10, 11	2	0	0

Problem Name : ACD.1

No of Activities: 20

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	2	3
1, 3	2	4
2, 4	3	1
3, 4	3	4
4, 5	1	3
4, 6	2	1
4, 8	5	1
5, 7	3	3
6, 7	2	3
7, 8	8	4
7, 9	5	4
8, 9	9	4
9, 10	2	3
9, 11	3	2
10, 12	2	3
11, 13	3	4
12, 14	1	3
13, 14	2	4
13, 15	4	1
14, 15	2	4

Problem Name : ACD.2

No of Activities: 21

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	1	2
1, 3	2	2
2, 3	2	1
3, 4	1	3
4, 5	1	3
5, 6	1	3
6, 7	1	3
7, 8	2	3
8, 9	2	3
8, 11	3	3
9, 10	5	3
10, 11	3	3
11, 12	1	3
12, 13	1	3
12, 16	3	2
13, 14	3	2
13, 15	2	2
14, 17	4	3
15, 16	2	3
16, 17	4	3
17, 18	1	3

Problem Name : ACD.3

No of Activities: 21

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	1	0
1, 3	4	3
2, 3	1	1
3, 4	2	3
4, 5	5	3
5, 6	2	3
6, 7	10	3
7, 8	1	2
8, 9	3	1
8, 11	8	3
9, 10	2	0
10, 11	1	2
11, 12	2	3
12, 13	4	0
12, 16	15	2
13, 14	6	1
13, 15	1	3
14, 17	15	3
15, 16	10	2
16, 17	10	2
17, 18	3	3

Problem Name : BCD.4

No of Activities: 16

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	7	5	3
1, 3	10	5	5
1, 5	6	5	3
2, 3	3	5	5
2, 6	17	0	1
3, 4	5	0	1
4, 5	3	1	0
4, 6	12	0	0
5, 6	3	0	1
6, 7	5	5	3
6, 8	3	5	5
7, 9	6	5	5
8, 9	8	5	4
9, 10	6	0	1
10, 11	4	1	1
11, 12	15	0	1

Problem Name : BCD.3

No of Activities: 21

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	12	4	3
1, 4	5	4	2
2, 3	5	3	3
2, 6	10	4	3
2, 7	15	4	2
3, 5	3	0	1
4, 8	8	4	3
5, 6	2	1	1
5, 8	2	1	1
6, 10	11	3	3
7, 12	8	0	1
8, 9	1	4	3
9, 11	7	3	0
10, 13	12	0	0
11, 12	2	3	3
12, 13	10	0	0
13, 14	18	0	0
14, 15	20	0	0
15, 16	15	3	3
15, 17	10	3	3
16, 17	20	0	0

Problem Name : BCD.2

No of Activities: 21

No of Resources : 3

Resource Limit (1) : 10

Resource Limit (2) : 9

Resource Limit (3) : 10

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	6	0	0	2
1, 4	8	0	0	6
2, 3	3	10	4	5
2, 6	9	10	8	4
2, 7	15	4	3	4
3, 5	5	10	9	6
4, 8	9	10	9	6
5, 6	2	3	7	3
5, 8	3	5	6	2
6, 10	14	0	3	1
7, 12	20	5	5	0
8, 9	14	0	0	2
9, 11	8	9	8	6
10, 13	16	8	8	6
11, 12	7	9	9	2
12, 13	8	0	0	0
13, 14	19	0	0	1
14, 15	22	0	0	2
15, 16	5	0	1	4
15, 17	12	0	1	6
16, 17	7	1	0	5

Problem Name : BCD.1

No of Activities: 18

No of Resources : 2

Resource Limit (1) : 9

Resource Limit (2) : 7

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	15	0	0
2, 3	8	0	0
2, 4	14	0	0
3, 4	6	9	7
3, 5	7	9	7
4, 6	9	9	7
5, 6	7	9	7
5, 7	7	9	7
6, 9	18	4	4
7, 8	3	0	0
7, 9	4	0	0
8, 10	9	1	1
9, 13	4	5	3
10, 11	8	9	4
10, 13	11	9	7
11, 12	1	0	3
12, 13	1	3	4
13, 14	30	0	0

Problem Name : ACD.4

No of Activities: 13

No of Resources : 1

Resource Limit (1) : 5

Activity Label	Duration	Resource Req. (1)
1, 2	5	5
2, 3	6	5
2, 6	2	4
3, 4	1	5
3, 5	4	5
4, 5	4	4
5, 7	12	5
5, 9	3	5
6, 7	1	0
7, 8	5	3
7, 9	3	2
8, 10	8	1
9, 10	10	5

Problem Name : ABCD.1

No of Activities: 19

No of Resources : 2

Resource Limit (1) : 10

Resource Limit (2) : 10

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	3	0	1
2, 3	2	0	2
3, 4	7	10	8
3, 8	19	10	10
4, 5	4	10	10
4, 7	8	9	9
4, 8	8	8	9
5, 6	3	9	10
6, 7	1	7	8
6, 8	5	8	10
7, 8	3	8	8
7, 10	11	10	9
8, 9	8	7	10
9, 10	2	0	1
10, 11	6	0	3
11, 13	4	9	9
11, 14	8	10	10
13, 14	6	10	4
14, 15	9	2	2

Problem Name : ABCD.2

No of Activities: 15

No of Resources : 2

Resource Limit (1) : 14

Resource Limit (2) : 13

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	11	14	12
1, 3	16	9	11
2, 5	18	14	13
3, 4	6	10	10
3, 6	15	12	10
4, 5	7	11	11
5, 6	2	9	8
5, 8	16	14	13
6, 7	11	14	13
6, 9	20	11	8
7, 8	3	12	12
7, 9	16	14	13
8, 9	12	11	10
9, 10	14	1	1
10, 11	13	0	1

Problem Name : ABCD.3

No of Activities: 19

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 2

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	1	0	2
2, 3	3	1	1
3, 4	6	3	2
3, 8	8	3	2
4, 5	5	3	2
4, 7	15	3	2
4, 8	5	3	2
5, 6	3	2	1
6, 7	7	2	2
6, 8	4	3	2
7, 8	8	3	1
7, 10	15	3	2
8, 9	5	2	2
9, 10	7	3	1
10, 11	2	0	1
11, 12	5	1	0
11, 13	2	1	1
12, 13	3	0	1
13, 14	2	1	1

Problem Name : ABCD.4

No of Activities: 13

No of Resources : 2

Resource Limit (1) : 4

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	4	4
1, 4	8	4	4
2, 3	3	4	3
3, 6	7	2	0
4, 5	4	4	0
5, 6	3	0	4
5, 9	15	1	4
6, 7	9	3	4
6, 8	11	4	4
6, 9	20	3	3
7, 10	12	1	0
8, 9	9	2	2
9, 10	14	1	0

Problem Name : F1

No of Activities: 18

No of Resources : 4

Resource Limit (1) : 3

Resource Limit (2) : 5

Resource Limit (3) : 4

Resource Limit (4) : 2

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	5	0	0	0	0
1, 3	8	1	0	0	1
2, 3	5	1	0	0	0
2, 5	6	3	5	1	2
2, 6	5	0	0	3	2
2, 7	20	3	5	1	0
3, 4	15	3	5	4	2
3, 6	0	0	0	0	0
4, 5	3	0	0	0	0
4, 7	5	0	0	0	0
4, 8	6	0	0	0	0
5, 7	4	1	0	0	0
5, 8	9	1	1	0	0
6, 7	10	3	5	3	1
7, 10	5	0	0	0	0
8, 9	1	0	0	0	0
8, 10	2	0	0	0	0
9, 10	1	0	0	0	0

Problem Name : F2

No of Activities: 19

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	0	5
2, 3	8	4	1
2, 4	5	5	3
3, 5	2	3	3
3, 6	10	2	5
4, 5	5	0	0
5, 7	6	2	1
5, 9	8	1	1
6, 7	3	0	0
6, 10	5	3	5
6, 11	8	2	4
7, 8	1	0	0
8, 9	3	1	5
8, 11	6	5	5
9, 11	2	4	5
9, 12	1	0	0
10, 11	5	3	5
10, 12	2	2	1
11, 12	3	3	1

Problem Name : F3

No of Activities: 14

No of Resources : 1

Resource Limit (1) : 6

Activity Label	Duration	Resource Req. (1)
1, 2	5	3
1, 3	4	4
1, 4	5	6
2, 3	8	2
3, 5	3	6
3, 6	6	6
4, 5	5	5
4, 7	2	3
5, 6	2	0
5, 7	3	1
6, 8	7	4
7, 8	4	4
7, 9	3	0
8, 9	5	6

Problem Name : F4

No of Activities: 23

No of Resources : 3

Resource Limit (1) : 4

Resource Limit (2) : 4

Resource Limit (3) : 1

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	2	1	3	0
1, 3	4	3	4	0
1, 4	3	4	4	0
2, 5	5	3	1	0
2, 6	8	3	3	0
3, 4	1	2	3	0
4, 6	5	3	1	0
4, 7	10	2	3	0
4, 9	6	2	2	1
5, 8	6	2	0	1
6, 8	7	3	2	1
7, 9	2	4	4	1
8, 10	5	0	0	0
9, 10	0	0	0	0
9, 11	2	3	0	0
10, 12	8	1	0	0
10, 13	6	3	3	0
11, 13	2	4	2	1
11, 14	5	3	0	1
12, 13	5	0	0	1
13, 14	3	1	1	0
13, 15	4	2	0	0
14, 15	5	1	0	0

Problem Name : F5

No of Activities: 16

No of Resources : 1

Resource Limit (1) : 5

Activity Label	Duration	Resource Req. (1)
1, 2	10	5
1, 3	8	2
2, 3	8	4
2, 5	7	3
3, 4	5	2
3, 5	4	5
3, 6	6	0
4, 7	8	5
5, 6	2	1
5, 10	4	3
6, 7	4	3
7, 8	10	2
7, 10	5	5
8, 9	2	1
9, 11	1	0
10, 11	15	3

Problem Name : F6

No of Activities: 14

No of Resources : 2

Resource Limit (1) : 10

Resource Limit (2) : 12

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	15	8	10
1, 4	10	5	7
1, 5	20	8	5
2, 3	10	9	8
2, 6	15	6	12
3, 4	8	10	10
3, 5	12	5	5
4, 5	3	0	0
4, 7	10	10	12
5, 8	8	2	2
6, 7	10	9	10
7, 8	8	3	3
7, 9	20	0	1
8, 9	5	5	5

Problem Name : F7

No of Activities: 82

No of Resources : 4

Resource Limit (1) : 7

Resource Limit (2) : 11

Resource Limit (3) : 20

Resource Limit (4) : 8

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	1	0	0	5	1
1, 3	3	2	1	3	1
1, 4	8	1	3	0	0
1, 14	6	1	0	2	1
1, 18	10	5	8	15	4
2, 19	5	4	6	12	7
3, 11	7	3	1	8	4
3, 14	16	4	1	14	3
3, 15	5	2	9	6	4
4, 5	1	2	3	4	1
4, 6	4	3	3	9	2
5, 6	11	2	5	11	5
5, 7	1	0	3	16	6
5, 9	2	0	0	8	2
6, 12	9	2	2	4	2
7, 8	0	0	0	0	0
7, 10	5	1	2	4	1
8, 9	4	0	0	0	1
8, 26	3	1	1	14	1
8, 27	1	7	9	0	0
9, 12	0	0	0	0	0
9, 24	2	1	0	4	0
9, 25	1	0	0	0	4
10, 28	27	2	4	8	2
11, 12	1	0	0	0	1
11, 16	9	1	2	4	3
12, 13	6	1	1	4	3
12, 17	12	4	7	15	4

13, 24	5	2	2	4	0
14, 19	6	4	7	16	7
15, 17	8	2	0	0	0
5, 20	6	1	8	11	6
16, 22	6	0	4	18	1
17, 22	1	1	1	4	3
17, 23	4	0	0	0	5
17, 33	14	1	1	13	4
18, 19	12	3	4	11	4
19, 20	8	2	8	10	6
19, 21	7	1	1	9	6
20, 21	5	3	5	8	1
21, 34	7	3	2	1	8
21, 35	13	4	4	13	5
22, 34	28	1	2	12	5
23, 37	29	2	2	6	1
23, 46	19	1	1	18	4
24, 32	15	1	1	17	1
25, 26	0	0	0	0	0
25, 31	1	2	2	0	0
25, 32	41	2	2	5	2
25, 38	25	0	0	14	0
26, 31	7	1	2	3	1
26, 40	5	0	0	2	0
27, 30	16	3	0	1	0
27, 40	6	0	0	0	3
28, 29	4	2	1	3	1
28, 30	2	1	2	0	1
29, 41	4	1	4	1	4
29, 42	2	2	3	3	0
30, 43	7	2	2	2	2
31, 39	8	1	0	5	0
32, 38	3	2	1	4	0
32, 47	1	0	0	0	2
33, 34	6	1	1	0	0
34, 36	5	2	1	0	4
34, 37	42	3	2	9	1
35, 36	8	7	4	3	2
36, 37	6	1	0	0	0
36, 47	7	4	2	0	2
37, 46	15	1	0	2	3
37, 47	0	0	0	0	0
38, 39	3	1	3	3	4
39, 40	6	2	4	4	1
39, 45	0	0	0	0	0
40, 45	13	0	4	11	2
41, 43	10	2	3	4	1
42, 44	5	7	0	19	1
43, 44	9	0	0	9	0
43, 48	12	1	1	0	1

44, 48	17	2	6	17	1
45, 46	6	1	6	6	0
46, 48	29	3	4	11	3
47, 48	16	2	1	0	0

Problem Name : F8

No of Activities: 57

No of Resources : 4

Resource Limit (1) : 6

Resource Limit (2) : 8

Resource Limit (3) : 10

Resource Limit (4) : 10

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	1	1	1	1	1
1, 3	8	4	6	5	5
1, 5	5	3	2	6	2
1, 6	4	2	2	1	2
1, 8	3	3	4	6	4
2, 15	2	3	5	0	7
3, 4	15	1	3	1	3
3, 5	0	0	0	0	0
4, 15	1	2	0	2	0
4, 16	6	2	6	3	5
5, 13	3	5	1	5	0
5, 14	4	3	6	9	1
6, 7	6	2	4	3	1
6, 12	5	3	7	8	1
7, 10	17	2	8	1	1
7, 12	7	6	1	0	0
7, 20	0	0	0	0	0
8, 9	5	0	0	3	3
8, 10	6	0	0	2	1
9, 20	1	0	0	0	2
9, 23	4	0	0	7	8
10, 11	8	6	5	1	0
10, 22	2	0	3	1	5
11, 21	6	2	1	2	2
12, 14	13	1	0	4	0
13, 18	1	0	2	0	1
14, 18	0	0	0	0	0
14, 19	2	2	4	2	2

14, 20	3	5	1	0	0
15, 17	19	2	1	3	1
16, 18	8	0	0	0	3
17, 27	38	3	6	5	4
18, 26	6	3	5	1	5
18, 27	25	1	0	2	1
19, 25	18	3	2	1	0
20, 24	21	3	2	1	3
20, 25	8	2	4	6	1
21, 22	11	2	2	4	6
21, 34	8	1	0	2	7
22, 35	18	2	3	2	3
23, 32	1	2	0	2	1
23, 33	13	4	5	1	1
24, 32	8	2	3	3	3
25, 30	22	1	4	2	1
25, 31	5	1	5	1	0
26, 27	9	1	2	1	9
26, 28	3	6	7	0	0
27, 29	5	1	2	5	2
28, 30	1	0	0	3	0
29, 37	18	3	6	9	7
30, 37	13	1	0	2	0
31, 37	6	3	2	0	5
32, 33	6	0	0	0	5
33, 37	7	2	2	9	1
34, 37	6	1	3	5	8
35, 36	4	4	4	1	0
36, 37	1	2	5	1	1

Problem Name : F9

No of Activities: 21

No of Resources : 2

Resource Limit (1) : 7

Resource Limit (2) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	1	0	0
1, 3	5	1	0
1, 4	6	2	1
1, 5	7	1	0
1, 9	4	2	1
2, 3	3	1	1
2, 7	10	5	1
2, 9	12	1	2
3, 4	2	0	0
3, 7	8	2	2
4, 5	1	0	0
4, 6	8	1	1
4, 7	5	2	3
5, 6	2	4	1
5, 7	2	3	3
6, 7	1	1	0
6, 8	3	3	3
6, 9	5	2	3
7, 8	7	2	1
7, 9	11	4	3
8, 9	2	2	2

Problem Name : F10

No of Activities: 71

No of Resources : 3

Resource Limit (1) : 8

Resource Limit (2) : 12

Resource Limit (3) : 10

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	1	6	2	8
2, 3	7	2	2	2
2, 5	11	7	3	8
2, 7	5	1	6	0
3, 4	4	1	4	4
3, 6	13	6	11	6
4, 9	7	4	6	8
4, 10	6	1	0	1
4, 11	8	1	0	0
5, 7	1	3	3	3
5, 8	8	1	4	2
5, 18	0	0	0	0
6, 7	4	1	0	4
6, 16	5	4	2	9
7, 16	6	3	0	3
8, 17	5	1	4	8
8, 19	6	1	1	1
9, 15	13	2	8	9
10, 16	5	5	3	4
11, 14	11	6	3	3
11, 12	0	0	0	0
12, 13	5	5	5	3
13, 14	8	1	10	9
13, 23	18	2	4	8
13, 24	6	1	1	1
14, 22	7	7	6	7
14, 23	6	5	1	6
15, 20	17	1	5	2
15, 21	35	3	1	3
15, 28	10	1	6	6
16, 18	14	2	3	1

17, 19	1	3	2	1
17, 30	20	2	8	8
18, 20	12	0	5	0
19, 20	0	0	0	0
19, 29	6	3	2	1
19, 30	4	3	4	8
20, 32	41	3	2	4
21, 33	11	2	4	2
22, 27	23	2	0	2
22, 33	13	5	7	6
23, 25	19	8	0	0
24, 27	21	3	3	3
25, 26	28	1	3	1
25, 35	15	2	2	3
25, 36	32	3	4	2
26, 36	4	0	0	4
26, 38	6	6	1	1
27, 34	4	2	4	2
28, 33	6	1	4	1
29, 31	6	2	1	3
29, 32	12	4	8	6
30, 31	5	5	5	5
31, 40	1	1	1	3
31, 41	6	5	11	3
32, 40	8	2	3	4
32, 43	6	0	0	4
33, 39	9	0	9	0
34, 39	16	2	1	2
34, 43	8	0	0	1
35, 38	6	2	1	2
36, 37	6	3	0	3
37, 38	8	2	1	4
37, 43	12	6	9	7
38, 39	0	0	0	0
38, 43	7	2	3	4
39, 42	17	1	2	0
40, 41	3	2	4	6
40, 42	7	7	0	10
41, 42	7	1	4	5
42, 43	11	3	3	3

Problem Name : F11

No of Activities: 23

No of Resources : 2

Resource Limit (1) : 8

Resource Limit (2) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	6	6	2
1, 5	5	4	5
2, 3	4	3	3
3, 4	2	0	3
3, 6	12	4	5
4, 5	1	0	0
5, 6	4	2	1
5, 7	8	3	3
5, 9	10	1	0
6, 11	8	4	0
7, 8	4	1	1
7, 11	6	0	3
8, 10	5	0	1
8, 12	2	2	0
9, 12	3	0	2
9, 13	5	1	1
9, 14	6	3	1
10, 11	3	2	2
10, 15	7	3	1
11, 14	6	6	1
12, 13	1	0	0
13, 14	2	0	1
14, 15	5	3	1

Problem Name : F12

No of Activities: 65

No of Resources : 4

Resource Limit (1) : 6

Resource Limit (2) : 6

Resource Limit (3) : 9

Resource Limit (4) : 9

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	7	3	0	9	7
1, 16	6	4	5	1	0
1, 19	12	3	4	7	6
2, 3	8	1	1	6	6
2, 4	13	4	4	2	2
3, 16	0	0	0	0	0
3, 17	11	3	2	5	7
3, 20	6	2	3	5	8
4, 5	13	3	3	2	3
4, 8	5	4	1	0	1
4, 20	19	3	2	4	4
5, 6	4	1	0	4	1
5, 27	6	2	5	0	7
6, 7	7	3	4	7	7
6, 8	3	2	1	3	0
6, 9	13	2	4	0	0
7, 9	6	3	1	0	4
7, 27	12	1	1	4	2
8, 10	6	0	0	7	8
8, 11	17	2	2	3	3
8, 27	0	0	0	0	0
9, 11	6	5	1	8	0
9, 13	6	2	4	1	2
9, 25	15	1	2	2	0
10, 11	1	1	1	0	0
10, 12	4	2	4	6	0
10, 14	5	1	3	4	3
11, 12	18	3	2	1	4

11, 13	22	0	0	1	3
11, 25	1	1	3	1	3
12, 13	0	0	0	0	0
12, 15	12	2	3	0	0
13, 15	6	1	3	4	9
13, 25	8	6	0	0	0
14, 15	35	2	4	2	2
14, 30	18	1	1	4	6
15, 25	7	1	1	2	2
15, 30	3	3	3	1	3
16, 18	5	5	5	0	0
17, 19	6	3	1	3	0
18, 19	17	1	0	1	0
18, 20	8	3	5	7	0
19, 20	1	0	0	9	9
19, 21	4	2	2	0	4
20, 22	4	3	1	1	1
20, 24	28	2	2	6	1
20, 27	1	4	6	0	1
21, 23	1	3	2	0	0
21, 26	18	2	0	1	2
21, 28	6	6	0	0	0
22, 24	11	1	1	3	4
22, 26	13	0	1	2	1
23, 26	19	2	3	6	8
23, 28	26	3	1	0	1
23, 29	12	2	1	1	1
24, 26	0	0	0	0	0
24, 29	5	1	1	3	3
25, 29	4	1	4	5	7
25, 30	18	0	0	2	1
26, 28	7	2	6	1	1
26, 29	5	1	0	2	0
27, 29	16	1	3	8	1
28, 29	3	1	3	2	1
28, 30	6	2	2	2	2
29, 30	1	2	3	4	5

Problem Name : F13

No of Activities: 23

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	5	0
1, 4	2	1
1, 6	3	2
2, 3	10	1
2, 7	4	0
2, 10	8	2
3, 4	7	0
3, 6	5	0
3, 9	15	2
4, 5	2	3
4, 6	2	1
4, 8	3	1
5, 7	1	2
6, 11	3	1
7, 10	3	2
7, 12	1	3
8, 11	6	2
9, 10	18	1
10, 11	20	1
10, 13	2	3
11, 12	12	2
11, 13	6	4
12, 13	10	3

Problem Name : F14

No of Activities: 15

No of Resources : 2

Resource Limit (1) : 3

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	3	3	3
1, 3	5	1	0
1, 4	7	2	1
2, 3	2	1	0
3, 5	12	3	2
4, 5	2	0	0
4, 6	6	3	3
5, 6	12	1	1
5, 7	20	2	0
6, 7	8	3	3
6, 8	5	1	0
7, 9	12	3	3
8, 9	2	0	0
8, 10	7	1	1
9, 10	8	3	3

Problem Name : F15

No of Activities: 53

No of Resources : 3

Resource Limit (1) : 5

Resource Limit (2) : 4

Resource Limit (3) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	19	3	3	3
2, 3	2	4	1	1
2, 4	3	4	1	1
2, 5	12	3	2	2
3, 6	6	0	1	2
3, 7	16	2	1	1
4, 9	6	0	0	1
4, 13	12	1	0	4
5, 6	7	1	1	3
6, 7	0	0	0	0
6, 10	8	2	2	3
6, 13	1	5	1	1
6, 15	6	1	4	1
7, 8	8	2	2	1
8, 15	18	1	2	1
8, 18	6	0	1	0
9, 12	28	2	2	2
10, 11	6	1	1	1
11, 12	16	2	1	2
11, 13	18	3	1	1
11, 21	24	0	2	2
12, 21	32	1	1	0
12, 22	18	2	0	0
13, 14	15	1	0	1
14, 15	0	0	0	0
14, 16	6	0	0	2
14, 17	4	1	4	0
15, 18	9	1	2	2
16, 21	6	1	2	2
16, 24	13	3	3	3
17, 18	10	2	0	0

17, 19	6	0	2	0
17, 24	3	2	1	2
17, 25	1	5	0	0
18, 19	1	1	1	1
18, 20	13	0	0	2
19, 20	7	2	1	2
19, 26	16	2	0	0
20, 26	1	2	1	2
21, 24	5	3	2	3
22, 23	8	1	1	1
22, 24	15	1	3	2
23, 24	17	2	4	1
23, 28	6	0	1	0
23, 29	8	1	0	2
24, 27	11	0	0	2
25, 26	4	2	2	1
25, 27	6	0	0	3
26, 27	7	0	0	4
27, 30	1	2	0	2
28, 29	2	3	0	0
28, 30	1	0	3	0
29, 30	5	4	3	0

Problem Name : F16

No of Activities: 101

No of Resources : 6

Resource Limit (1) : 3

Resource Limit (2) : 5

Resource Limit (3) : 7

Resource Limit (4) : 10

Resource Limit (5) : 3

Resource Limit (6) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)	Resource Req. (5)	Resource Req.(6)
1, 2	1	1	4	1	9	1	0
1, 3	4	2	3	3	6	1	3
1, 7	12	0	1	0	5	1	4
1, 8	0	0	0	0	0	0	0
2, 3	1	3	5	0	0	0	0
2, 4	6	0	0	0	0	0	4
3, 4	0	0	0	0	0	0	0
3, 5	13	3	1	1	8	1	2
3, 6	2	2	2	2	3	1	2
3, 8	0	0	0	0	0	0	0
4, 5	6	1	1	3	1	2	2
4, 17	8	0	0	7	7	0	0
5, 6	14	1	4	1	0	0	0
5, 17	0	0	0	0	0	0	0
5, 19	4	0	0	3	0	0	0
5, 20	6	2	1	4	4	1	4
6, 18	3	3	0	0	0	0	1
6, 19	5	3	5	0	0	0	0
6, 22	11	1	2	4	0	2	1
7, 8	0	0	0	0	0	0	0
7, 9	6	2	4	2	0	0	2
7, 12	8	3	3	3	1	3	1
7, 14	21	2	2	2	1	0	0
8, 14	1	0	0	0	2	0	0
8, 18	18	0	2	5	6	0	3

9, 10	0	0	0	0	0	0	0
9, 11	7	0	0	6	0	0	4
9, 12	4	1	2	1	1	0	0
10, 11	5	1	1	0	9	1	1
10, 12	16	1	2	2	0	2	1
11, 13	0	0	0	0	0	0	0
11, 26	13	2	0	2	0	2	1
12, 13	6	1	4	1	2	3	1
12, 14	0	0	0	0	0	0	0
12, 15	0	0	0	0	0	0	0
12, 16	5	2	5	7	0	0	0
12, 18	30	1	1	0	1	0	0
13, 24	14	1	3	3	1	0	1
13, 25	6	1	4	0	0	0	0
13, 26	22	0	1	5	8	1	3
14, 15	12	2	4	1	0	0	0
14, 18	8	0	0	2	0	0	0
15, 16	9	1	2	3	7	1	3
15, 22	18	1	2	1	1	1	1
15, 23	16	2	0	2	1	1	1
16, 23	0	0	0	0	0	0	0
16, 24	3	3	4	6	1	1	1
16, 25	13	1	0	0	1	1	2
17, 20	0	0	0	0	0	0	0
17, 31	27	1	3	4	8	1	1
18, 22	12	0	2	0	8	1	0
18, 23	0	0	0	0	0	0	0
19, 20	6	1	1	6	6	1	1
19, 21	1	0	2	6	0	0	0
19, 22	2	1	1	1	0	2	4
19, 30	2	0	0	0	10	3	0
20, 30	6	2	2	3	1	1	4
20, 31	8	1	1	2	1	0	0
21, 22	0	0	0	0	0	0	0
21, 30	29	1	2	3	1	2	4
21, 32	9	2	2	2	0	2	3
22, 23	0	0	0	0	0	0	0
22, 28	31	1	3	4	1	0	0
22, 29	5	1	1	3	1	1	3
23, 28	6	0	0	0	2	0	2
23, 34	16	1	0	0	0	2	0
24, 25	0	0	0	0	0	0	0
24, 27	5	1	1	1	0	0	0
25, 26	0	0	0	0	0	0	0
25, 27	18	1	2	1	0	1	0
25, 35	9	1	2	2	4	1	1
26, 27	0	0	0	0	0	0	0
26, 35	39	2	1	5	8	0	0
26, 36	21	1	1	0	1	0	1
27, 34	11	2	3	4	1	0	0

27, 35	1	0	0	0	0	0	3
27, 37	0	0	0	0	0	0	0
28, 33	25	2	2	0	0	0	0
29, 32	4	2	1	2	1	3	1
29, 39	23	3	1	5	6	1	1
30, 31	3	0	0	1	2	1	0
30, 32	0	0	0	0	0	0	0
30, 40	18	1	3	1	1	0	2
31, 40	4	1	2	4	7	1	0
32, 33	0	0	0	0	0	0	0
32, 39	8	1	2	0	0	0	0
32, 40	12	2	1	4	7	1	1
33, 34	14	1	2	1	2	2	3
33, 37	0	0	0	0	0	0	0
33, 38	0	0	0	0	0	0	0
33, 39	2	1	2	3	0	1	1
34, 35	13	0	0	5	7	0	0
34, 37	0	0	0	0	0	0	0
34, 38	4	0	4	0	1	0	0
35, 36	6	3	0	3	0	0	0
35, 37	5	2	1	2	0	0	0
36, 37	2	1	2	0	0	2	1
37, 38	4	1	4	4	0	0	0
37, 39	17	1	2	3	4	0	0
38, 39	8	2	1	0	0	1	2
39, 40	15	1	3	5	8	1	3

Problem Name : F17

No of Activities: 19

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	2	0
1, 3	1	2
1, 5	5	3
2, 3	3	1
2, 4	1	2
2, 5	2	1
2, 8	7	0
3, 5	6	3
4, 5	4	3
4, 6	2	0
4, 7	1	1
4, 8	2	0
5, 6	6	3
6, 7	5	1
6, 8	9	2
7, 8	4	2
8, 9	1	0
8, 10	10	3
9, 10	6	1

Problem Name : F18

No of Activities: 18

No of Resources : 2

Resource Limit (1) : 8

Resource Limit (2) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	5	2
1, 3	10	7	3
2, 3	5	3	3
2, 5	14	3	3
3, 4	6	5	1
3, 6	8	6	0
4, 5	3	6	2
4, 7	5	3	0
5, 8	11	3	1
6, 8	12	6	3
7, 9	5	2	0
8, 10	7	0	0
8, 11	12	0	1
9, 10	5	1	0
9, 11	10	0	1
10, 12	11	1	1
11, 13	15	2	0
12, 13	5	0	3

Problem Name : F19

No of Activities: 17

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	8	2
1, 3	5	4
1, 4	2	0
2, 3	3	1
2, 5	9	4
3, 5	5	0
4, 5	3	1
4, 7	2	0
4, 9	12	4
5, 6	1	1
5, 7	4	2
5, 8	8	2
6, 7	6	2
6, 8	3	0
7, 8	8	4
7, 9	2	1
8, 9	3	4

Problem Name : F20

No of Activities: 23

No of Resources : 3

Resource Limit (1) : 3

Resource Limit (2) : 3

Resource Limit (3) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	5	1	1	1
1, 3	2	0	0	0
1, 4	5	1	0	0
1, 5	25	2	3	3
2, 3	6	0	1	0
2, 4	10	1	0	1
2, 5	11	0	0	1
3, 4	3	1	0	1
3, 6	3	2	1	0
4, 5	6	2	0	1
4, 6	1	3	1	1
4, 7	7	2	0	2
4, 8	9	0	0	1
5, 6	1	0	0	0
5, 8	4	0	1	2
6, 7	2	3	2	0
6, 8	3	1	2	0
6, 9	12	0	1	2
7, 8	1	1	0	1
7, 10	4	1	2	1
8, 9	2	1	2	1
8, 10	6	1	0	1
9, 10	1	1	0	0

Problem Name : F21

No of Activities: 17

No of Resources : 1

Resource Limit (1) : 4

Activity Label	Duration	Resource Req. (1)
1, 2	8	1
2, 3	1	1
2, 4	1	2
2, 6	3	4
3, 7	6	0
4, 5	1	0
4, 6	2	0
4, 7	6	1
5, 6	1	1
5, 7	5	3
6, 8	10	3
6, 10	22	1
7, 8	6	1
7, 9	2	2
8, 9	2	1
8, 10	12	2
9, 10	3	2

Problem Name : F22

No of Activities: 21

No of Resources : 5

Resource Limit (1) : 6

Resource Limit (2) : 4

Resource Limit (3) : 7

Resource Limit (4) : 10

Resource Limit (5) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)	Resource Req. (5)
1, 2	5	4	2	5	8	2
1, 3	2	0	0	0	1	3
1, 4	6	1	0	3	1	0
1, 5	8	1	1	1	0	0
2, 4	7	2	3	7	9	5
2, 6	3	3	1	0	1	0
3, 5	11	0	0	0	0	2
3, 7	2	0	0	0	0	0
3, 9	5	2	1	3	2	5
4, 5	2	1	1	0	0	0
4, 6	3	0	0	6	1	2
4, 8	1	5	3	7	10	4
5, 6	5	2	2	3	5	0
5, 7	2	0	0	1	0	3
5, 8	3	3	1	2	5	0
6, 8	2	6	0	0	0	1
6, 10	6	0	0	7	0	0
7, 9	10	2	1	3	0	0
7, 10	8	1	1	0	0	5
8, 10	1	0	0	1	0	1
9, 10	12	0	0	7	0	1

Problem Name : F23

No of Activities: 36

No of Resources : 1

Resource Limit (1) : 10

Activity Label	Duration	Resource Req. (1)
1, 2	2	5
1, 3	8	0
1, 4	5	8
1, 6	1	1
2, 3	8	5
2, 8	12	1
3, 4	6	6
3, 6	11	5
3, 9	20	3
4, 5	2	4
4, 7	1	5
5, 6	2	2
5, 7	4	4
5, 8	3	3
6, 7	1	0
6, 9	6	5
6, 10	3	2
7, 8	10	1
7, 9	2	6
7, 11	9	2
8, 9	3	2
8, 10	1	1
8, 12	20	0
8, 13	14	3
9, 12	8	7
9, 15	6	8
10, 11	10	6
10, 13	5	0
10, 14	15	5
11, 12	8	4
11, 13	7	3
11, 14	5	1
12, 14	2	0
12, 15	5	9
13, 14	10	10
14, 15	5	3

Problem Name : F24

No of Activities: 18

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 8

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	5	3	5
1, 3	8	1	0
1, 4	6	1	1
2, 4	5	2	5
2, 6	2	3	3
3, 5	2	5	1
4, 6	3	1	5
5, 6	1	0	0
5, 8	5	3	4
6, 7	6	3	3
6, 9	10	2	6
7, 9	11	3	2
7, 10	5	5	1
8, 9	4	0	1
8, 10	5	1	3
8, 11	8	3	5
9, 11	7	2	2
10, 11	2	0	2

Problem Name : F25

No of Activities: 14

No of Resources : 3

Resource Limit (1) : 4

Resource Limit (2) : 4

Resource Limit (3) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	5	1	3	0
1, 4	8	2	1	2
2, 3	2	2	3	1
2, 5	1	0	0	1
3, 4	3	0	3	2
4, 5	12	4	0	1
4, 6	6	0	4	3
5, 6	2	3	3	1
5, 7	4	1	0	3
6, 7	8	1	2	0
6, 9	3	3	1	2
7, 8	3	2	1	2
7, 9	6	4	0	0
8, 9	2	0	1	0

Problem Name : F26

No of Activities: 48

No of Resources : 5

Resource Limit (1) : 5

Resource Limit (2) : 5

Resource Limit (3) : 5

Resource Limit (4) : 5

Resource Limit (5) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)	Resource Req. (5)
1, 2	12	2	3	5	0	0
1, 3	4	1	0	0	3	5
1, 4	5	3	1	0	0	0
1, 12	8	4	3	1	0	0
2, 4	3	3	3	3	1	1
2, 5	4	3	1	0	0	1
2, 6	6	0	0	5	0	2
3, 4	2	4	1	0	1	0
3, 6	1	0	0	5	0	0
3, 7	8	0	0	2	3	1
3, 8	9	1	2	0	0	5
3, 15	20	0	0	1	0	2
4, 6	2	1	2	1	0	0
4, 7	1	2	1	0	0	1
5, 6	1	0	3	1	0	0
5, 11	6	2	2	0	0	0
5, 12	5	0	0	0	1	3
5, 13	8	0	1	1	1	2
6, 7	2	0	0	0	0	0
6, 10	18	3	1	5	0	1
6, 11	15	2	1	0	3	2
7, 8	3	0	1	2	0	1
7, 9	1	0	0	2	0	1
7, 14	4	0	3	2	1	1
8, 9	2	1	2	3	0	1
8, 11	7	5	1	4	0	1
9, 10	2	1	0	1	2	1

9, 14	16	2	1	0	0	0
9, 15	8	1	5	0	5	0
9, 16	2	1	1	2	1	1
10, 13	5	1	2	0	1	2
11, 12	6	1	2	1	0	4
11, 14	2	0	0	1	0	0
12, 13	2	0	2	0	2	0
12, 17	8	1	0	1	0	1
12, 18	5	0	0	3	0	3
12, 19	1	1	2	0	0	0
13, 14	5	4	0	5	0	0
13, 19	10	3	4	0	0	0
14, 15	3	5	0	0	0	0
14, 17	15	0	0	0	4	5
14, 18	2	4	1	3	0	0
15, 16	1	0	0	0	0	1
15, 17	2	0	1	0	2	3
16, 17	2	5	0	0	1	0
16, 18	5	0	4	0	1	0
17, 18	6	2	0	3	0	0
18, 19	1	0	2	0	3	1

Problem Name : F27

No of Activities: 37

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	12	4	4
1, 4	3	2	2
1, 5	8	1	2
2, 3	5	3	1
2, 4	11	2	1
2, 11	15	0	1
3, 4	1	0	3
3, 5	6	2	4
3, 6	5	1	1
4, 5	6	1	1
4, 6	10	1	0
4, 7	9	2	2
4, 11	3	2	0
5, 6	5	2	0
5, 7	2	6	0
5, 8	2	1	3
5, 10	1	0	2
6, 7	8	1	2
6, 9	10	2	0
6, 11	21	3	1
7, 8	2	1	0
7, 9	15	1	0
7, 10	13	2	2
8, 10	4	0	2
9, 10	4	1	2
9, 11	6	1	2
9, 12	2	1	0
9, 13	5	2	0
9, 14	3	1	1
10, 12	6	1	1
10, 14	12	0	1
11, 12	13	0	1
11, 13	20	1	2
11, 14	9	1	2

12, 13	11	2	1
12, 14	10	1	1
13, 14	5	0	1

Problem Name : F28

No of Activities: 21

No of Resources : 3

Resource Limit (1) : 4

Resource Limit (2) : 4

Resource Limit (3) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	3	1	0	0
1, 3	4	2	1	0
1, 4	12	2	2	2
2, 3	2	3	1	2
2, 4	1	0	1	0
3, 5	4	2	1	0
3, 6	8	2	0	2
4, 5	3	1	1	0
4, 7	5	0	2	4
4, 8	1	4	1	0
5, 6	15	3	1	2
5, 9	12	0	0	1
6, 7	6	0	4	0
6, 8	1	0	2	3
6, 9	7	1	0	1
6, 10	6	0	2	0
7, 8	1	1	1	1
7, 10	2	0	0	2
8, 9	1	0	0	0
8, 10	5	1	1	0
9, 10	1	1	0	1

Problem Name : F29

No of Activities: 21

No of Resources : 1

Resource Limit (1) : 5

Activity Label	Duration	Resource Req. (1)
1, 2	1	1
1, 3	6	4
1, 4	9	2
1, 5	8	1
2, 3	2	0
2, 4	1	3
2, 6	8	4
2, 9	12	5
3, 4	3	5
3, 7	15	1
4, 5	2	1
5, 6	6	1
5, 7	8	2
5, 8	7	1
5, 9	6	2
6, 7	3	5
6, 8	1	4
6, 9	2	1
7, 8	1	0
7, 9	5	5
8, 9	10	2

Problem Name : F30

No of Activities: 25

No of Resources : 1

Resource Limit (1) : 3

Activity Label	Duration	Resource Req. (1)
1, 2	6	1
1, 4	1	1
2, 3	7	3
3, 4	2	2
4, 5	6	2
4, 7	1	0
5, 6	4	1
6, 7	3	3
6, 8	5	2
7, 9	8	1
8, 9	3	2
8, 10	8	3
9, 12	10	2
9, 14	3	1
10, 11	5	3
11, 12	6	3
12, 13	7	1
13, 14	3	2
14, 15	5	1
14, 17	2	0
15, 16	1	1
16, 17	2	2
17, 18	3	1
17, 19	1	1
18, 19	2	2

Problem Name : F31

No of Activities: 20

No of Resources : 2

Resource Limit (1) : 5

Resource Limit (2) : 8

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	12	3	4
1, 3	5	3	2
1, 4	2	0	1
2, 5	6	3	7
3, 7	2	1	5
4, 5	3	0	1
4, 6	7	1	2
5, 8	8	2	6
6, 9	3	0	1
7, 8	10	1	4
7, 9	5	2	2
8, 10	1	0	1
9, 10	15	2	6
10, 11	5	2	2
11, 12	9	4	0
11, 13	6	0	8
12, 15	11	4	5
13, 14	5	1	3
14, 15	1	1	1
15, 16	2	0	5

Problem Name : F32

No of Activities: 21

No of Resources : 3

Resource Limit (1) : 4

Resource Limit (2) : 3

Resource Limit (3) : 2

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	8	1	3	2
1, 4	5	0	2	0
2, 3	4	1	1	0
2, 6	6	4	0	1
2, 7	5	0	2	1
3, 5	3	2	0	2
4, 8	10	1	1	1
5, 6	2	0	1	2
5, 8	1	0	1	0
6, 10	2	0	3	0
7, 12	9	1	2	2
8, 9	5	1	2	2
9, 11	4	1	0	1
10, 13	1	4	1	2
11, 12	1	0	1	1
12, 13	3	1	3	2
13, 14	1	0	1	1
14, 15	2	1	2	2
15, 16	5	0	0	1
15, 17	3	3	0	0
16, 17	7	1	0	2

Problem Name : F33

No of Activities: 24

No of Resources : 2

Resource Limit (1) : 6

Resource Limit (2) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	1	6	4
1, 3	3	2	2
1, 4	7	3	1
1, 5	11	1	0
2, 3	1	2	3
2, 6	5	0	2
2, 7	4	1	1
2, 8	2	0	0
2, 9	12	3	3
3, 4	5	3	3
3, 7	10	0	2
4, 5	1	0	1
4, 7	6	4	1
5, 8	8	1	2
5, 10	6	2	0
6, 7	2	1	1
6, 9	8	1	0
6, 10	6	2	4
7, 8	2	0	1
7, 9	1	3	3
7, 10	15	1	0
8, 10	1	0	3
9, 10	3	1	3
10, 11	12	6	2

Problem Name : F34

No of Activities: 22

No of Resources : 2

Resource Limit (1) : 8

Resource Limit (2) : 10

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)
1, 2	2	4	4
1, 3	3	1	1
1, 4	6	5	2
1, 6	12	0	2
2, 3	5	5	0
2, 4	2	1	4
2, 5	13	1	1
3, 4	4	1	4
3, 5	2	3	3
4, 5	5	1	2
4, 6	6	1	2
5, 6	6	3	3
5, 8	7	1	2
5, 9	11	1	5
5, 10	15	1	0
6, 7	1	0	0
6, 8	2	4	4
7, 8	5	1	2
7, 9	6	3	0
7, 10	12	1	0
8, 9	1	0	1
9, 10	2	1	0

Problem Name : F35

No of Activities: 13

No of Resources : 4

Resource Limit (1) : 4

Resource Limit (2) : 4

Resource Limit (3) : 3

Resource Limit (4) : 2

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	3	0	1	0	2
1, 4	5	1	1	0	0
2, 3	2	3	3	1	0
2, 5	11	1	0	1	0
2, 6	8	2	4	0	2
3, 5	5	1	3	1	0
4, 6	18	2	2	1	2
4, 7	15	3	0	3	1
4, 8	12	0	0	3	0
5, 8	7	0	0	0	2
6, 7	3	1	1	1	1
6, 8	10	2	1	0	0
7, 8	4	1	4	1	0

Problem Name : F36

No of Activities: 39

No of Resources : 4

Resource Limit (1) : 10

Resource Limit (2) : 10

Resource Limit (3) : 12

Resource Limit (4) : 12

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	15	9	7	11	10
1, 4	6	2	5	10	8
1, 9	20	6	7	10	11
2, 3	11	1	5	8	9
3, 4	1	0	0	2	1
3, 6	20	1	10	11	12
3, 7	15	8	8	7	0
4, 5	10	5	5	0	0
5, 6	8	9	8	9	0
5, 8	22	1	10	5	5
6, 7	8	1	0	8	1
6, 9	15	2	0	10	0
7, 10	25	8	10	0	0
7, 11	18	6	3	8	8
8, 9	9	0	0	1	3
9, 13	12	2	0	11	12
9, 14	18	5	5	4	3
10, 13	8	8	8	1	0
10, 15	17	1	10	0	0
10, 16	19	8	5	6	2
11, 12	7	0	5	8	9
11, 15	15	10	5	5	0
12, 15	12	2	4	10	4
12, 19	2	0	1	2	12
13, 14	9	9	8	6	1
13, 17	18	6	6	3	4
14, 16	28	1	0	5	4
14, 20	16	4	0	4	0

14, 21	5	7	6	4	8
15, 17	4	5	4	3	1
16, 18	6	1	0	5	4
17, 18	12	1	3	5	6
17, 19	20	8	0	9	5
18, 19	18	2	0	5	0
18, 21	9	5	5	0	0
18, 22	8	2	10	5	0
19, 22	7	9	0	11	5
20, 21	8	0	0	3	9
21, 22	6	1	5	7	0

Problem Name : F37

No of Activities: 74

No of Resources : 5

Resource Limit (1) : 8

Resource Limit (2) : 8

Resource Limit (3) : 10

Resource Limit (4) : 10

Resource Limit (5) : 12

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)	Resource Req. (5)
1, 2	8	1	5	10	8	8
1, 3	8	0	6	6	1	2
1, 4	6	0	0	10	0	0
1, 6	3	6	2	5	7	11
1, 7	1	0	0	0	3	0
2, 3	10	1	0	5	0	5
2, 5	2	0	0	0	5	0
3, 4	5	4	3	2	0	0
3, 6	1	2	5	8	0	0
3, 9	12	3	2	1	0	0
4, 5	2	1	7	0	0	0
4, 9	13	1	0	5	0	3
5, 6	5	1	1	2	0	0
5, 9	4	1	0	2	0	5
5, 10	18	2	2	2	0	0
5, 19	9	4	0	4	0	1
6, 11	0	0	0	0	0	0
6, 12	6	6	6	0	0	0
7, 8	2	0	5	0	0	5
7, 13	11	8	0	0	5	0
8, 14	8	3	5	0	5	11
8, 15	5	2	2	0	0	0
9, 20	6	1	1	0	1	1
9, 34	7	5	1	9	10	0
10, 19	6	6	0	8	2	8
10, 20	15	0	0	2	1	0
10, 21	7	1	2	3	0	4

11, 12	6	2	1	0	5	4
11, 18	4	4	3	1	0	3
11, 19	5	7	0	1	3	6
12, 17	18	3	3	0	4	6
12, 24	13	1	1	0	5	1
13, 16	12	0	1	0	1	2
14, 15	6	1	3	1	0	0
14, 16	5	0	5	0	5	0
15, 26	7	0	2	2	0	0
15, 28	11	2	1	3	1	0
16, 25	5	4	2	0	3	4
16, 26	8	1	0	2	4	4
16, 27	10	0	0	5	0	4
17, 24	12	0	0	5	10	0
17, 25	1	5	7	0	9	0
18, 22	0	0	0	0	0	0
18, 23	1	2	2	5	0	0
18, 24	0	0	0	0	0	0
19, 22	1	0	0	2	0	5
20, 21	5	1	3	2	0	1
20, 33	10	5	0	0	4	3
21, 22	1	1	0	5	3	2
22, 33	3	0	0	5	0	7
23, 32	8	1	2	0	6	6
24, 31	0	0	0	0	0	0
24, 31	0	0	0	0	0	0
24, 36	5	1	0	1	4	2
25, 30	12	6	2	10	1	11
25, 31	5	1	4	0	0	0
26, 28	5	2	5	0	0	0
26, 29	0	0	0	0	0	0
27, 30	7	7	7	0	0	0
28, 38	8	8	0	1	8	1
29, 37	11	6	6	0	1	0
29, 38	0	0	0	0	0	0
30, 31	1	3	0	5	0	1
30, 37	6	0	0	2	4	0
31, 37	9	0	0	1	0	0
32, 33	3	3	2	4	5	6
32, 36	6	1	5	0	6	1
32, 37	13	8	6	9	10	0
33, 34	8	0	0	0	1	0
33, 35	12	1	5	8	0	2
34, 35	1	0	5	10	0	0
35, 36	5	1	0	5	6	0
36, 37	2	2	4	0	0	4
37, 38	8	1	8	1	1	0

Problem Name : F38

No of Activities: 66

No of Resources : 4

Resource Limit (1) : 5

Resource Limit (2) : 6

Resource Limit (3) : 10

Resource Limit (4) : 8

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	9	1	0	6	4
1, 8	6	1	2	0	3
2, 3	1	1	0	1	2
2, 5	5	0	4	0	0
3, 4	3	3	0	3	1
3, 5	8	1	0	4	1
4, 5	7	2	2	1	2
4, 6	6	1	4	1	0
4, 15	2	1	2	3	4
5, 6	8	1	4	9	0
5, 7	4	0	1	0	1
5, 9	0	0	0	0	0
6, 9	1	0	1	5	5
6, 14	18	0	1	3	2
6, 15	7	1	2	0	1
6, 16	0	0	0	0	0
7, 8	1	0	0	0	1
7, 9	2	0	0	0	1
8, 10	8	1	1	7	1
8, 11	4	2	2	1	4
8, 13	15	2	2	0	1
9, 13	6	0	0	2	1
9, 14	18	1	2	4	6
9, 18	5	4	1	3	4
10, 12	5	3	5	1	0
10, 13	4	0	4	0	1
11, 12	0	0	0	0	0
11, 21	2	0	0	9	1

12, 19	11	2	0	4	7
13, 18	13	3	3	0	0
13, 20	4	0	1	0	4
14, 15	0	0	0	0	0
14, 16	5	0	1	0	2
14, 17	0	0	0	0	0
14, 18	6	4	3	1	1
15, 17	12	1	0	2	4
16, 17	5	1	0	1	2
16, 25	14	0	0	1	1
16, 27	16	3	1	0	2
17, 18	7	3	2	1	0
18, 19	8	4	2	7	1
18, 25	0	0	0	0	0
19, 23	12	2	4	0	1
19, 25	10	0	0	5	4
20, 22	18	2	4	2	0
20, 24	0	0	0	0	0
21, 22	5	5	6	0	7
22, 23	4	4	3	1	0
22, 32	11	5	0	0	8
22, 33	8	0	6	7	1
23, 26	1	0	0	10	7
23, 29	20	1	0	5	1
23, 30	8	3	2	1	1
23, 31	10	5	4	5	3
24, 26	2	5	0	5	3
25, 27	8	1	1	3	1
26, 28	6	2	3	5	4
27, 28	1	0	0	5	1
28, 29	2	0	0	5	6
29, 34	1	0	0	0	8
30, 33	8	1	3	0	7
30, 34	5	3	3	2	2
31, 32	0	0	0	0	0
31, 33	2	1	2	1	2
32, 34	6	1	5	9	0
33, 34	3	3	3	2	3

Problem Name : F39

No of Activities: 75

No of Resources : 3

Resource Limit (1) : 8

Resource Limit (2) : 8

Resource Limit (3) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	12	3	5	2
1, 3	22	5	5	4
2, 4	4	0	0	1
2, 5	12	2	0	4
2, 6	5	1	0	0
2, 7	18	4	6	6
3, 4	1	0	0	4
3, 14	13	4	0	2
4, 5	2	1	1	0
4, 13	3	0	0	3
4, 14	1	5	2	0
5, 10	8	1	2	4
5, 11	6	3	3	2
5, 12	7	1	1	0
5, 13	15	2	2	0
6, 7	0	0	0	0
6, 8	2	2	2	3
6, 10	6	1	0	6
6, 18	4	0	1	0
7, 10	3	1	0	1
7, 19	4	2	0	1
8, 9	1	1	1	1
8, 19	7	7	0	1
9, 18	3	3	8	0
9, 19	4	2	0	1
10, 11	4	3	2	1
10, 18	6	8	0	1
11, 12	7	0	2	1
11, 17	1	0	0	2
11, 18	6	8	0	1
12, 16	4	3	3	1

12, 17	9	1	2	1
12, 25	12	2	2	0
13, 15	4	0	4	1
13, 16	27	1	0	1
13, 26	15	2	2	0
14, 15	6	3	2	1
14, 27	0	0	0	0
14, 28	0	0	0	0
15, 26	12	1	1	1
16, 17	4	1	3	1
16, 26	2	3	1	0
17, 18	3	0	1	0
17, 20	4	0	0	1
17, 24	6	1	8	2
17, 25	12	8	4	3
18, 19	0	0	0	0
18, 23	8	1	0	1
19, 21	5	3	5	1
19, 22	0	0	0	0
20, 21	1	0	0	5
20, 22	2	1	2	4
21, 33	4	1	2	3
22, 23	2	1	2	2
22, 33	3	0	3	3
23, 33	4	0	1	1
24, 31	4	0	0	0
24, 32	5	1	1	1
25, 26	0	0	0	0
25, 30	12	1	1	0
25, 31	15	0	1	0
26, 27	4	0	0	4
26, 29	2	1	2	3
26, 35	1	0	1	0
27, 28	2	1	1	2
27, 29	1	0	0	0
28, 29	3	0	1	3
29, 35	4	0	1	0
30, 34	4	1	1	0
31, 32	0	0	0	0
31, 35	2	1	2	2
32, 33	0	0	0	0
32, 34	1	0	0	1
33, 34	10	1	2	1
34, 35	2	3	3	3

Problem Name : F40

No of Activities: 47

No of Resources : 4

Resource Limit (1) : 2

Resource Limit (2) : 5

Resource Limit (3) : 10

Resource Limit (4) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	6	0	1	5	2
1, 3	12	1	4	0	1
2, 3	0	0	0	0	0
2, 9	6	1	5	4	1
3, 4	1	0	0	1	2
3, 7	4	1	2	4	3
3, 8	0	0	0	0	0
4, 5	2	0	0	1	0
4, 6	12	2	4	6	4
5, 6	0	0	0	0	0
5, 7	2	2	0	1	0
6, 11	4	0	1	0	1
6, 12	8	1	4	8	3
6, 13	2	2	0	1	5
7, 10	7	1	0	0	1
7, 11	0	0	0	0	0
8, 9	22	2	0	1	2
8, 16	13	1	1	1	0
9, 17	18	0	2	8	2
10, 14	15	0	4	10	5
10, 15	3	1	2	4	1
10, 17	0	0	0	0	0
11, 14	13	1	1	0	0
12, 13	2	2	5	0	0
12, 14	1	0	0	1	0
13, 14	0	0	0	0	0
13, 22	5	1	2	4	1
14, 21	12	0	2	7	3

15, 19	9	1	0	4	3
15, 20	2	1	1	0	0
16, 17	1	0	0	0	0
16, 18	5	2	0	7	5
17, 18	3	1	3	3	1
17, 24	0	0	0	0	0
18, 19	2	1	0	3	1
18, 24	6	0	4	5	4
19, 23	14	1	0	5	3
19, 24	18	1	1	0	0
20, 21	2	1	0	0	1
20, 23	0	0	0	0	0
21, 22	4	1	1	10	5
21, 25	0	0	0	0	0
22, 23	6	0	5	9	0
22, 25	12	2	0	1	4
23, 26	4	0	4	4	0
24, 26	8	1	1	6	1
25, 26	1	0	0	2	2

Problem Name : F41

No of Activities: 90

No of Resources : 5

Resource Limit (1) : 3

Resource Limit (2) : 3

Resource Limit (3) : 4

Resource Limit (4) : 5

Resource Limit (5) : 3

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)	Resource Req. (5)
1, 2	3	3	1	4	1	0
2, 3	1	0	0	4	5	3
2, 5	2	1	1	0	1	0
2, 6	6	2	2	4	0	0
3, 4	12	1	1	0	1	0
3, 6	2	2	2	0	0	0
4, 7	10	2	1	0	1	2
4, 8	8	1	0	3	4	3
4, 9	6	2	0	1	3	1
5, 12	4	3	0	0	0	0
5, 13	5	1	1	0	3	3
5, 14	12	2	2	0	1	0
6, 7	3	0	0	4	4	0
6, 12	4	1	0	0	2	1
6, 13	7	1	0	0	4	1
7, 8	16	1	1	0	0	0
7, 11	8	2	0	3	0	1
7, 12	0	0	0	0	0	0
8, 9	2	1	1	0	1	0
8, 10	9	0	3	0	4	2
8, 11	6	2	3	0	0	1
9, 10	13	1	0	2	1	2
9, 20	0	0	0	0	0	0
9, 21	26	3	0	0	2	0
9, 22	21	1	1	0	0	0
10, 19	12	1	0	3	4	2
10, 20	8	0	0	4	0	3

11, 18	17	2	1	0	1	0
11, 19	11	2	3	1	1	1
12, 17	0	0	0	0	0	0
12, 18	12	2	0	2	0	2
12, 25	14	1	0	2	0	1
13, 16	2	3	0	3	0	0
13, 17	6	1	0	4	0	1
14, 15	4	0	3	4	0	1
14, 16	8	1	1	0	0	3
15, 26	7	1	0	1	2	1
16, 25	8	1	2	0	3	3
16, 27	17	2	2	1	0	0
17, 18	0	0	0	0	0	0
17, 26	1	0	0	0	1	0
18, 19	23	1	0	0	2	1
18, 24	19	3	0	0	3	1
18, 25	0	0	0	0	0	0
19, 20	1	0	0	0	2	0
19, 23	4	0	0	0	4	3
19, 24	6	1	0	0	2	1
19, 31	0	0	0	0	0	0
20, 21	1	2	0	0	2	0
20, 22	0	0	0	0	0	0
20, 23	18	0	3	0	0	4
21, 22	2	2	0	0	0	3
21, 33	4	1	1	0	0	2
22, 34	32	1	0	0	2	0
22, 36	10	3	0	0	3	2
23, 32	12	0	0	0	3	3
23, 33	8	1	1	0	0	1
24, 25	0	0	0	0	0	0
24, 29	16	1	2	0	0	1
24, 30	0	0	0	0	0	0
24, 31	4	0	3	0	0	0
25, 26	3	3	1	0	1	0
25, 28	0	0	0	0	0	0
25, 29	11	1	3	0	1	0
26, 27	1	3	0	1	3	1
26, 28	2	1	2	1	2	0
27, 28	0	0	0	0	0	0
27, 40	1	2	3	1	0	1
28, 40	8	1	3	0	4	3
29, 39	9	0	0	4	1	1
30, 39	0	0	0	0	0	0
31, 32	1	0	0	0	4	3
31, 39	1	0	0	1	0	0
32, 38	16	0	1	2	0	0
32, 39	7	0	1	0	2	2
33, 37	13	3	0	1	0	1
33, 38	6	1	1	0	1	2

34, 35	8	1	1	0	1	0
34, 36	0	0	0	0	0	0
34, 37	5	1	0	1	0	3
35, 36	12	1	0	3	1	3
36, 37	7	1	2	0	0	0
36, 42	6	1	2	1	0	0
37, 42	11	0	0	1	0	0
38, 41	19	1	0	1	4	1
38, 42	2	0	0	0	0	3
39, 40	1	1	1	0	0	0
39, 41	8	0	0	0	3	0
40, 41	3	1	0	1	2	2
41, 42	4	0	1	0	2	2

Problem Name : F42

No of Activities: 41

No of Resources : 3

Resource Limit (1) : 5

Resource Limit (2) : 6

Resource Limit (3) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	6	1	2	1
1, 3	8	3	5	6
2, 4	3	1	3	3
2, 8	2	0	6	1
2, 9	5	1	1	1
3, 4	21	1	1	4
3, 5	17	2	1	3
3, 6	7	2	2	4
4, 5	13	3	0	0
4, 7	8	2	1	3
4, 8	6	5	1	1
5, 6	6	1	4	4
5, 7	0	0	0	0
6, 7	11	2	1	2
6, 13	12	1	3	0
7, 8	7	1	3	0
7, 10	0	0	0	0
7, 12	18	2	2	2
7, 13	6	1	2	4
8, 11	1	0	3	0
8, 15	5	1	1	1
9, 10	6	1	2	0
9, 16	9	2	1	3
10, 15	12	2	2	2
10, 16	3	3	4	2
11, 12	7	1	0	1
11, 14	6	1	2	1
11, 15	8	1	3	1
12, 14	3	1	3	0
12, 17	4	3	3	2
13, 14	14	2	1	0

14, 17	2	1	3	4
14, 18	8	5	1	1
15, 16	1	1	0	0
15, 20	5	1	2	0
16, 20	7	1	0	1
17, 19	18	3	1	3
17, 20	4	0	4	0
18, 19	6	1	2	0
18, 20	12	0	3	1
19, 20	1	0	4	2

Problem Name : F43

No of Activities: 48

No of Resources : 3

Resource Limit (1) : 5

Resource Limit (2) : 5

Resource Limit (3) : 5

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	5	0	4	1
1, 3	4	4	3	1
1, 12	12	0	0	4
2, 3	6	1	2	4
2, 12	11	2	2	3
2, 13	4	0	4	0
3, 4	0	0	0	0
3, 5	5	2	1	3
3, 6	7	1	2	2
4, 5	6	1	4	1
5, 6	2	1	2	1
5, 8	11	1	2	1
5, 14	5	0	5	0
6, 7	7	1	3	1
6, 13	0	0	0	0
6, 15	6	1	0	2
6, 16	13	2	0	2
7, 8	5	1	2	0
7, 9	25	2	1	2
7, 16	6	1	3	1
8, 9	2	1	2	3
8, 10	13	3	0	0
8, 17	7	1	2	4
9, 10	4	4	1	4
9, 17	1	0	2	1
9, 19	6	1	3	5
10, 11	8	1	0	0
10, 18	8	1	5	1
10, 19	13	1	2	1
11, 20	4	1	4	1
11, 21	3	3	3	1

11, 22	5	1	5	4
12, 13	7	5	1	0
12, 15	18	1	1	1
13, 14	12	0	1	4
14, 15	4	1	4	1
15, 16	11	3	3	3
15, 17	2	4	2	4
16, 17	12	2	3	1
17, 18	6	1	1	5
18, 19	21	1	0	2
18, 20	7	2	0	3
18, 21	1	3	3	3
19, 20	6	1	0	2
19, 21	2	3	4	1
20, 21	3	2	1	3
20, 22	2	4	1	4
21, 22	1	1	1	1

Problem Name : F44

No of Activities: 57

No of Resources : 4

Resource Limit (1) : 4

Resource Limit (2) : 4

Resource Limit (3) : 5

Resource Limit (4) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)
1, 2	1	0	0	0	4
1, 4	3	2	3	2	1
1, 5	2	1	1	1	1
1, 8	12	3	2	3	4
2, 3	0	0	0	0	0
2, 5	8	1	3	4	0
3, 6	3	0	3	0	6
3, 7	5	4	3	1	5
3, 9	18	1	1	0	4
4, 6	5	0	0	3	3
4, 10	11	2	4	1	0
5, 10	19	2	1	1	0
5, 11	7	2	1	2	1
5, 12	5	1	1	1	1
6, 9	9	4	0	0	0
6, 10	6	1	0	1	0
7, 8	2	1	3	1	0
7, 9	29	1	0	0	4
8, 15	13	2	2	0	0
8, 17	17	1	1	1	0
9, 10	4	1	4	0	4
9, 15	2	1	3	4	1
9, 16	22	2	4	0	1
10, 11	8	0	0	1	0
10, 13	12	0	0	0	1
10, 14	14	2	0	0	1
11, 13	5	2	1	2	1
11, 14	6	3	1	3	1

12, 13	4	1	4	2	1
13, 20	17	3	1	4	5
13, 21	13	1	0	0	1
14, 15	1	0	0	2	6
14, 20	7	0	0	5	1
15, 18	9	1	0	1	2
15, 19	4	1	0	1	2
15, 20	3	3	3	1	1
15, 25	6	1	2	1	0
16, 18	19	2	1	3	1
16, 26	28	2	1	0	0
17, 18	0	0	0	0	0
17, 25	45	1	1	0	1
18, 19	18	0	0	1	1
18, 25	24	1	0	2	1
19, 23	4	1	2	0	2
19, 24	1	3	1	1	0
19, 27	6	4	0	5	0
20, 21	16	1	0	0	2
20, 23	22	2	2	0	3
21, 22	4	4	4	0	0
21, 23	2	3	1	2	0
22, 23	31	1	2	1	1
23, 24	1	0	1	0	2
23, 27	14	1	2	1	0
24, 27	6	2	1	2	0
25, 26	2	1	0	1	0
25, 27	1	0	0	0	6
26, 27	8	1	0	2	1

Problem Name : F45

No of Activities: 40

No of Resources : 3

Resource Limit (1) : 6

Resource Limit (2) : 6

Resource Limit (3) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	5	5	4	3
1, 3	5	3	5	2
1, 4	3	5	2	2
2, 3	0	0	0	0
2, 5	0	0	0	0
3, 5	0	0	0	0
3, 10	4	4	1	4
4, 6	1	5	5	4
4, 8	6	3	5	2
5, 9	2	2	4	4
6, 7	0	0	0	0
6, 12	0	0	0	0
7, 18	3	3	3	2
8, 11	0	0	0	0
8, 12	0	0	0	0
9, 11	0	0	0	0
9, 12	0	0	0	0
10, 11	0	0	0	0
10, 13	1	4	1	4
11, 15	6	3	2	2
12, 15	3	3	2	4
13, 14	6	2	2	2
14, 22	3	3	2	3
15, 16	3	1	4	4
15, 20	0	0	0	0
16, 17	3	5	3	3
17, 22	0	0	0	0
17, 25	4	1	0	4
18, 19	4	1	5	4
19, 21	0	0	0	0
19, 24	1	2	4	6

20, 21	3	5	5	4
21, 23	4	4	5	4
22, 26	4	1	6	2
23, 24	0	0	0	0
23, 26	1	2	2	1
24, 26	6	3	2	1
25, 26	0	0	0	0
25, 27	3	2	2	2
26, 27	3	0	1	3

Problem Name : F46

No of Activities: 76

No of Resources : 3

Resource Limit (1) : 6

Resource Limit (2) : 6

Resource Limit (3) : 6

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)
1, 2	4	1	3	2
1, 3	1	4	4	4
1, 14	6	5	1	4
1, 21	12	3	1	3
2, 3	8	1	0	0
2, 5	13	2	1	4
2, 15	28	1	0	2
3, 4	1	1	1	1
3, 6	5	3	5	3
4, 6	18	2	0	2
4, 15	4	1	0	4
5, 6	4	2	1	2
5, 7	6	1	0	4
5, 15	0	0	0	0
5, 17	7	5	2	3
6, 7	6	1	3	2
6, 8	7	2	1	2
6, 10	12	0	1	0
7, 8	8	3	0	0
8, 9	4	0	0	2
8, 10	6	3	4	3
8, 17	0	0	0	0
9, 10	11	0	2	1
9, 12	15	3	3	0
9, 19	5	1	1	1
10, 11	1	0	4	2
11, 12	18	1	2	0
11, 19	0	0	0	0
11, 34	25	3	1	0
12, 13	5	5	5	0
12, 20	0	0	0	0

12, 19	13	1	0	2
13, 20	0	0	0	0
13, 31	0	0	0	0
13, 34	1	2	5	5
14, 15	2	0	0	2
14, 16	1	0	0	4
14, 22	1	0	0	0
14, 25	3	3	1	4
15, 17	6	1	6	1
16, 17	22	1	0	2
16, 18	18	0	2	0
16, 25	0	0	0	0
17, 18	13	4	0	0
17, 19	31	1	0	1
18, 19	1	0	0	6
18, 34	2	2	2	2
19, 20	4	1	3	1
20, 29	0	0	0	0
20, 34	23	2	0	0
21, 22	14	1	4	1
21, 23	0	0	0	0
21, 24	23	3	1	2
22, 23	3	0	0	4
22, 25	0	0	0	0
23, 24	1	0	1	2
23, 25	17	2	3	2
23, 26	8	6	1	0
24, 26	5	1	4	2
24, 28	8	2	2	2
25, 27	11	0	0	3
26, 27	0	0	0	0
26, 28	3	3	2	3
26, 29	2	6	6	1
27, 28	0	0	0	0
27, 29	17	2	2	0
27, 31	6	1	4	3
28, 30	7	6	0	0
29, 30	11	0	2	1
30, 32	1	1	2	0
30, 33	18	0	0	5
31, 33	6	2	0	2
31, 34	7	1	4	3
32, 33	3	1	1	6
32, 34	1	0	0	4
33, 34	12	2	3	0

Problem Name : F47

No of Activities: 67

No of Resources : 5

Resource Limit (1) : 6

Resource Limit (2) : 6

Resource Limit (3) : 5

Resource Limit (4) : 5

Resource Limit (5) : 4

Activity Label	Duration	Resource Req. (1)	Resource Req. (2)	Resource Req. (3)	Resource Req. (4)	Resource Req. (5)
1, 2	1	0	0	0	2	0
1, 3	2	5	1	1	4	3
1, 4	3	4	1	2	3	2
1, 22	18	1	1	0	1	2
1, 23	5	0	0	5	0	0
2, 5	12	0	0	2	0	2
3, 6	5	3	4	3	0	0
4, 7	0	0	0	0	0	0
4, 8	3	1	3	0	1	1
5, 6	23	1	0	0	1	0
6, 9	18	0	0	0	0	3
7, 9	1	0	2	1	0	3
8, 10	5	1	2	4	1	0
8, 11	17	2	0	0	0	3
8, 29	0	0	0	0	0	0
9, 12	32	1	4	3	0	1
10, 13	1	0	0	0	0	0
10, 36	9	1	4	2	3	1
11, 14	2	0	3	1	4	1
11, 15	1	6	1	0	0	0
12, 16	15	0	2	0	0	0
13, 37	6	2	4	2	4	0
14, 17	6	2	1	3	1	4
14, 18	13	2	0	1	3	0
15, 17	0	0	0	0	0	0
15, 20	4	3	0	0	0	0
16, 20	7	3	2	0	4	0

17, 19	1	0	1	0	1	0
18, 19	5	3	5	3	0	0
19, 21	1	2	1	2	1	2
19, 43	15	0	0	3	0	3
20, 21	8	1	0	2	0	1
21, 43	8	1	2	0	3	0
22, 24	1	0	0	0	0	2
22, 25	0	0	0	0	0	0
22, 29	9	2	2	3	4	1
23, 24	5	4	4	0	0	0
23, 25	3	0	0	2	0	0
23, 26	0	0	0	0	0	0
23, 27	8	1	1	2	3	1
24, 29	8	2	3	2	1	0
25, 28	8	0	0	2	0	0
25, 31	9	1	2	5	1	0
26, 32	12	2	2	3	5	1
27, 33	13	1	0	1	0	1
27, 34	6	1	2	4	1	4
28, 31	18	0	1	0	2	0
29, 30	6	0	0	0	1	2
29, 36	8	1	0	2	0	1
30, 36	13	4	2	4	1	4
31, 38	13	1	2	0	1	1
32, 35	11	0	1	2	0	2
32, 39	19	0	0	1	2	3
33, 40	14	4	2	0	0	2
34, 39	5	0	1	2	0	0
35, 38	7	3	3	0	0	0
35, 40	28	1	1	0	2	1
35, 42	6	1	4	5	0	0
36, 43	2	0	1	2	0	2
37, 43	8	1	1	1	0	0
38, 43	25	0	4	0	0	0
39, 41	0	0	0	0	0	0
39, 44	3	3	3	3	0	3
40, 41	7	3	1	0	0	0
41, 44	21	0	2	4	0	0
42, 44	11	1	0	2	0	0
43, 44	16	2	6	1	1	0

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