RESOURCE CONSTRAINED

PROJECT SCHEDULING PROBLEM

(RCPSP)
Resource-Constrained Problem

- When the number of resources (e.g., people, equipment) is not adequate to meet peak demand requirements and it is impossible to obtain more, the project manager faces a resource-constrained problem.

- The trick (objective) is to prioritize and allocate resources to minimize project delay without exceeding the resource limit or altering the technical network relationships.
Allocating Limited Resources

- Allocation of limited resources to different activities is often known as "constrained resource scheduling."
- This technique is designed to produce schedules that will not require more resources than are available in any given period.
  - The project will have to be completed using the given resources even if its duration has to be extended.
- The limited resource problems are solved by two distinctly different approaches.
  - The first category includes heuristic procedures which are designed to produce good resource feasibility schedules.
  - The second category, in contrast, consists of procedures designed to produce the best (optimal) schedules.
The Heuristic Approach

- What is required in the heuristic approach is some basic criteria along with a procedure by which the resources may be allocated efficiently.
- The criteria comprise a set of predetermined priority rules.
- The combination of this procedure and the priority rules is known as the heuristic approach.
The Heuristic Approach ... cont’d

Various priority rules can be used to solve resource-constrained problems.

- Assume that the resource availability is limited to a maximum of four.
- If it is desired to allocate resources to an eligible activity having the least slack, the activity 1-2 gets preference.
- The activity 1-4 will get preference if allocation is to be made to an activity having the largest number of resources or resource days.
- If shortest imminent activity is preferred, activity 1-3 gets first priority.
- If the minimum LFT (late finish time) heuristic is chosen, activity 1-2 will be allocated resources first.
- Some of the predominant priority rules commonly used as follows:

1) Has the earliest start time.
2) Has the minimum late start time.
3) Has the minimum early finish time.
4) Has the minimum late finish time.
5) Has the least float.
6) Has the largest duration.
7) Has the shortest duration.
8) Has the most immediate successors.
9) Has most successors.
10) Has the least nonrelated activities.
11) Has the least nondependent jobs remaining.
12) Has the least immediate successors.
13) Has the least successors.
14) Can start first considering resources.
15) Has the least float per successor.
16) Has the longest path following.
17) Will finish first.
18) Has the largest resource requirement.
19) Has the largest resource days requirement.
20) Has the largest remaining resource days requirement.
The Heuristic Approach … cont’d

- In general, it is not possible to say which combination of priority rules will give the best results for a given project.
- A set of priority rules that performs poorly for a given problem may do well for others.
- However, the following combination of priority rules is used generally:
  1. Allocate resources to the activity having the least float.
  2. Allocate to activity requiring the largest number of resource days.
  3. Allocate to activity using largest number of resources (people or machines).
  4. Allocate to an activity that precedes the largest remaining resource days requirement.
  5. If a tie, allocate to the activity with the lowest sequence (i - j value).

- These priority rules may be employed throughout the two alternative methods. These are the series method and parallel method.
The Series and Parallel Methods

- The basic allocation procedure is a method of scheduling work by balancing need with availability of resources at a given time.

- The **series method** accomplishes this by allocating resources to activities in series (one activity at a time from start to finish).

- The **parallel method** allocates resources to activities one day at a time. An activity may be allocated resources one day but delayed the next day, while another activity using the resources is executed.
Optimal Procedures

- The heuristic approach is an approximate procedure, or it is just a combination of priority rules and procedure that guides the allocation exercise and hence cannot give an optimal solution.
- The optimal procedures that have been developed can be divided into two groups:
  1. Procedure based on Linear Programming (LP).
  2. Procedure based on enumerative and other mathematical techniques.
- These procedures attempt to get the optimal solution by going through all possible solutions.
- Since many variables are involved in resource allocation problems, these procedures cannot be adopted for large networks or for projects where the number of resources required are many.
- Hence heuristic procedures are widely used and are the only available means of solving the complex problems that occur in practice. However, the increased availability of more powerful computer systems may improve the usage of optimal procedures.
Unlimited Resource Allocation

- If ample quantities of all required resources are available, still it may have to be seen how best they can be used.
- We have three options for scheduling the activities.
- They can be scheduled at
  - their earliest start time,
  - their latest start time,
  - or at any time between these two.
- The objective in unlimited resource scheduling is to lower the project cost as much as possible.
  - This may be achieved by resource leveling.
Resource Leveling - Unlimited Resource Case

In the resource-leveling procedure the resources are allocated in such a way that the resource profile is gradually built up to a peak and slowly brought down to the end without another rise, see figures below. Generally speaking, the smoother the resource profile, the lower is the overall cost.

As in the case of constrained resource allocation, the leveling problems can be solved by heuristic as well as optimal procedures. The optimal procedures are normally not adopted because they are too expensive.

The idea of a heuristic approach centers around rescheduling the activities within the limits of available float in order to achieve better distribution of resource usage. This can be done by rescheduling all the critical jobs first followed by selective scheduling of the noncritical jobs to obtain the leveled profile.

The heuristic rules normally adopted may be summed up as follows:

1. Schedule all the critical jobs first.
2. Start the noncritical jobs whenever there is a rise up to the point where the peak is reached.
3. Start the noncritical jobs whenever there is a drop so that no ups and downs occur in the resource profile.

![Figure 9.7: General Resource Profiles](image)
Multi-Resource Leveling

- Multi resource leveling problems are clearly more complicated than single resource ones.
- Since each activity may require different quantities of several resources for its execution, attempts at balancing one resource type may spoil the balance of the others.
- If manual solutions are desired, this problem can be solved by applying a weighting factor to each type of resource and computing the optimum solution.
- However, if even one of the resources' availability is limited, then the problem has to be treated as one of resource constrained allocation.
General Remarks

- The best leveling may be obtained by a trial and error procedure, applying different heuristics for the same problem and choosing the best.
- It should be noted that leveling can produce several alternative solutions. These solutions are acceptable if one peak is maintained, and buildup to the peak and the subsequent decline are gradual.
- If it is desired to determine which alternative schedule presents the most leveled solution, a comparison can be made of the sum of squares of resource requirements within each time unit. The lowest sum of squares indicates the most leveled solution.
Multi-Project Resource Allocation

- When an organization is responsible for several projects, its objective is to make the most efficient possible use of the resources required for these projects.
- Resources that become surplus on one project are transferred to other projects in the organization.
- The procedure that simulates such a situation is called **multi-project resource allocation**.
Multi-Project Resource Leveling

- **Some resources may be shared among projects.** The question is which resources and how much of them.
  - For small projects in a relatively close vicinity some staff and equipment may be shared.
  - Project managers must make decisions when the situation looks like a borderline case:
    - for instance, would it be more efficient to have someone travel between two jobs or to hire another person even though the person will not be occupied 100% of the time?
    - same argument holds for equipment.

- **In general, convenience and simple economics are mostly the driving criteria.**
  - However, other issues may be considered, such as
    - the short- and long-term need;
    - future market expectations;
    - staff morale, fatigue, and satisfaction;
    - relationships with vendors and subcontractors; and so forth.
Multi-Project Resource Leveling

The approach to multi-project resource scheduling is fairly direct.

- All project networks are linked together, showing one initial event and one terminal event.
- Where necessary, key sequencing dummies are introduced to effect transferring of major crew or equipment from project to project.
Multi-Project Resource Leveling

- In a multi-project environment, project priorities may be superimposed over activities of a certain project because of its relative importance to the organization.
- Such activities receive higher priority over all other activities competing for resources at the same time.
Prioritizing Resource Allocations in Multi-Project Environments

• **First come** first served
• Greatest resource **demand**
• Greatest resource **utilization**
• Minimum **late finish** time
• **Mathematical programming**
Computer-aided Resource Allocation

- The methods of resource allocation involve simple arithmetic and data manipulation.
- It is obvious, however, that to perform complete resource allocation manually even for a summary level network for an average-sized project would be impractical and almost impossible for a large project.
- Fortunately, there are many computer programs available to do this type of network analysis.
- When using resource allocation programs, it is first necessary to perform a time analysis on the network.
- The schedule is then combined with additional data on resource requirements and limitations to produce a daily resource requirement schedule and a modified project schedule.
Other Uses of Resource Scheduling

- Besides being useful for projects, resource scheduling is also carried on in factory or manufacturing planning, to optimize the investment in capital equipment based on sales forecasts and projections.
  - For already established plants the technique can generate an optimal schedule for the fixed number of machines available.

- Another use of the resource allocation exercise is to simulate generation of resources and to assign them according to availability.
READING ASSIGNMENT

YOU CAN FIND MORE INFORMATION ABOUT THE SERIES AND PARALLEL METHODS FROM THE PAPER:

“RESOURCE ALLOCATION THE SERIES AND PARALLEL METHODS”

IT IS ON THE COURSE WEB SITE UNDER SUPPLEMENTARY MATERIAL!
Questions?