RAMPS — A Technique for Resource Allocation and Multi-Project Scheduling

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INTRODUCTION

Some Recent Developments

Work planning, a never-ending management responsibility, has been aided tremendously in recent years by the development of a new technique commonly referred to as networking or arrow-diagramming. Today, the network is widely accepted by business, scientific, and governmental organizations as a worthy replacement for the Gantt chart and other less flexible and less meaningful methods of planning work.[1-3, 9, 12]

PERT,[4, 10] Critical Path Method (CPM),[7, 8] and many other similar systems[5, 6] use estimates of the time required to complete each activity as the basis for determining the work schedule. The scheduling system sequences all the activities in the network and calculates the earliest and latest completion dates for each activity. These dates are then woven together to form a schedule for the total project. In some instances the scheduling function is automated, that is, an electronic computer is used to perform the calculations; in others the schedule is determined manually and monitored with the aid of a computer.*

RAMPS, a system for *R*esource *A*llocation and *M*ulti-*P*roject *S*cheduling, was recently developed by C-E-I-R, INC. and now is an operational IBM 7090 digital computer program. RAMPS retains many of the basic concepts of its predecessors; it uses the network for work planning and relies on a careful analysis of the needs of each individual activity, but it also has unique features not found in other systems. Two of these are readily apparent in its name—Resource Allocation and Multi-Project Scheduling.

Activity Resource Requirements

Major differences among many networking systems lie in the information provided for each activity and ultimately used in the work scheduling function. In most systems, this information includes estimates of the time needed to complete each activity and the total cost of the activity or a related group of activities. Where a schedule is produced, it attempts to reflect the most desirable time-cost relationships.

While RAMPS includes time and cost considerations in its work schedules, it also incorporates the *resource requirements* of each activity and the *availability of these resources* at the time the activity is to be scheduled—both extremely vital factors in any meaningful scheduling system.

Multi-Project Schedules

A unique feature of RAMPS is its ability to schedule *simultaneously* more than one work

* A comprehensive bibliography is to be found in Voress, *et al.*[11]

project. The projects to be scheduled may differ in size, type of work, importance and starting times. They are related only in their reliance on a common pool of resources.

RAMPS recognizes and responds to established priorities for the projects and competition among activities within all projects for limited quantities of available resources. The system also strives to meet established target completion dates by applying larger quantities of available resources to critical activities within all projects.

Competition for Available Resources

In addition to defining the work and resources required by the various activities, the RAMPS user provides the system with a knowledge of the quantity of each resource type that is available to all projects. Provision is also made for using overtime or additional units of a given resource at a premium cost.

There may be many activities in all projects competing for the same resources during the same work period. RAMPS weighs the needs of each activity individually and in relation to the other activities before deciding how the resources are to be allocated.

Management Controls

Under the many constraints imposed by completion deadlines, specified resource limits and project priorities, RAMPS must weigh many factors before deciding how best to schedule each project. Frequently, there are many possible routes that RAMPS could follow, each with a different effect on the schedules produced. There is, for example, the route that minimizes project completion time, but perhaps at an increased cost because of the use of overtime. Another route may assure a minimum of idle resources throughout the lives of the projects, and another might maximize the total number of activities being worked on during each scheduled work period. In instances such as these, RAMPS relies on control information provided by the RAMPS user to determine which course of action is most desirable. This ability on the part of management to influence and guide the scheduling function is one of the major features of the RAMPS system.

ESTABLISHING THE NETWORKS

General Description

The foundation of the RAMPS system is the network—a graphic display of a plan. The network portrays an orderly step-by-step series of actions which must be performed successfully in order to reach a specific, definable objective. Simply stated, a network is a work flow diagram.

Concurrency in the Network

In almost every real situation, there are many activities that can be carried on concurrently; others must be accomplished in a purely serial fashion. By planning to allow several related efforts to proceed simultaneously and converge at the proper event, the manager is able to reach his stated objective in a much shorter period of time. Since the network is a work plan, those activities which logically can be worked on in parallel should be shown in the network as concurrent activities. The concept of serial and concurrent activities is shown in Figure 1.

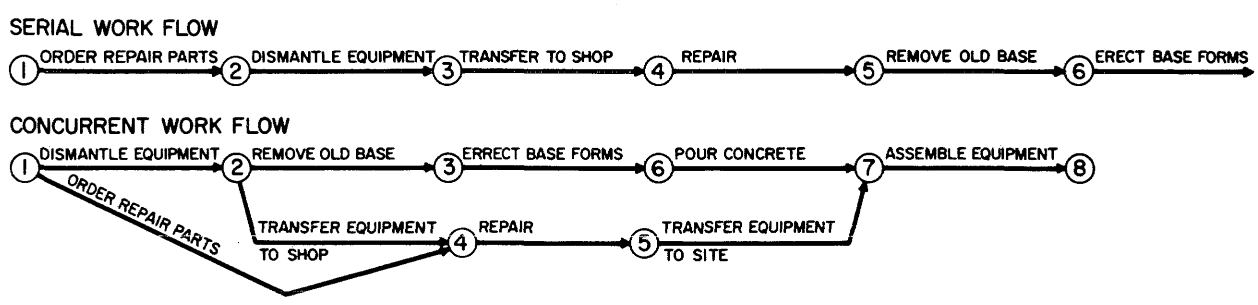

Figure 1. Concept of Concurrent Work Flow and Serial Work Flow.

It is obvious that a considerable amount of effort must be expended to determine which activities may be concurrent and which must proceed alone. But it is this effort at the planning level that saves time and money later when the actual work is done.

ESTIMATING TIME AND RESOURCE REQUIREMENTS

General Description

Although the importance of an accurate and well-planned network cannot be over-emphasized, there is perhaps no other function in the total application of RAMPS that is more important than obtaining accurate estimates of the time and resources required by *each activity*. Because RAMPS bases many of its scheduling and resource allocation decisions on this information, the validity of the schedules produced hinges on the thoroughness with which time and resource requirements are estimated. It is imperative that these estimates be made by those individuals who are most familiar with the work to be accomplished by each activity.

Determining Amount-of-Work

With the preliminary networks drawn and available as work guides, the next step in applying RAMPS can begin: determining the *amount-of-work* required by each activity in the networks.

Amount-of-work is derived from multiplying the number of unit time periods required to complete an activity under *normal working conditions* by the number of units of resource required per time period. The unit time period may be an hour, day, month, or any unit of time that defines the smallest period within which work will be scheduled and resources allocated.

Although it is not necessary to record amount-of-work in the network, it is frequently beneficial because it provides a ready visual display of the time and resource estimates for each activity as illustrated in Figure 2. The amount-of-work figures are enclosed in boxes below the activity lines. The units of resource required per time period are recorded beside the amount-of-work boxes. The estimated number of time periods needed to complete each activity can be quickly determined by dividing the units of resource figure into the amount-of-work.

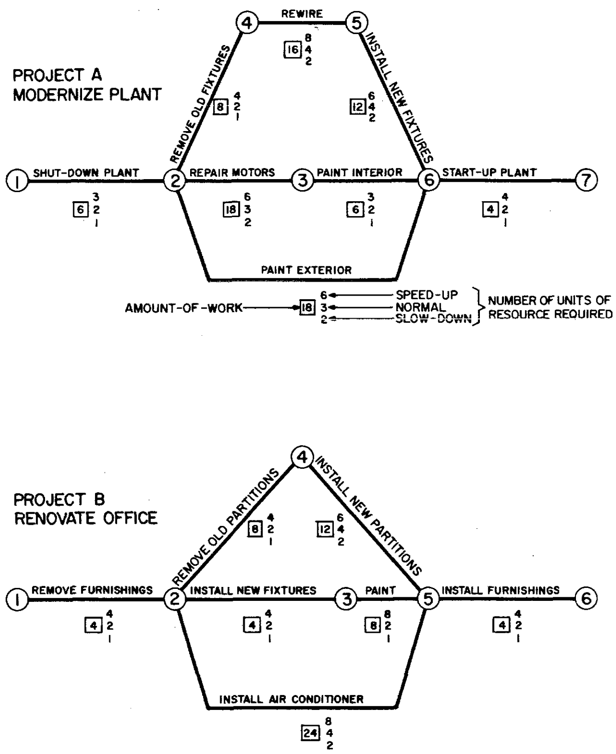

Figure 2. Amount-of-Work and Alternate Resource Utilization Rates in the Networks.

If we assume that under normal conditions activity 3-6 of Project A will require three days to be completed and will consume the work of two painters during each day, the amount of work for the activity would be six units.

The amount-of-work concept provides the system with unique flexibility in work scheduling and resource allocation. By including two additional resource utilization rates to the normal rate already established, this flexibility can be further increased.

Establishing Alternate Utilization Rates

Under normal conditions, activity 3-6 would require three time periods to be completed and would use two painters per time period. To provide for the possibility of doing the job faster or slower than normal, one can provide two other estimates. The first is a resource utilization rate under accelerated work conditions, *speed-up;* the second is a resource utilization rate under relaxed or extended work conditions, *slow-down.* The work efficiency at other than the normal rate is introduced to account for the absence of precise linear relationships.

Once the amount-of-work has been determined for an activity, it should be the guiding factor in determining desirable speed-up and slow-down utilization rates. It is necessary to "tailor" utilization rates and work efficiencies for a given resource to the individual activity to which the resource is to be applied. Each activity in the network and the resources it needs are considered as autonomous units for purposes of estimating amount-of-work, resource utilization rates, and work efficiency at the three utilization rates.

Scheduling and Allocating Flexibility

The three rates of resource utilization provide RAMPS with great flexibility in manipulating time and resources requirements of each activity to meet *resource availability levels.* The same flexibility extends from the activity level to the project level where the speed-up, normal, and slow-down rates allow the system to adjust work accomplishment rates to meet project completion deadlines.

As shown in Figure 3, Project A could be completed in as few as 9 time periods at the speed-up rate, or as many as 32 time periods at the slow-down rate. At the normal rate, the project could be completed in 16 time periods. Note that the use of each rate requires a different peak work force. The total work force required reaches peaks of 20 men during period 5 at speed-up, 10 men during period 8 at normal, and 6 men during period 15 at slow-down rates.

If all the needed resources were available, it is likely that RAMPS would schedule a project at the speed-up rate. However, in real situations, all the needed resources are rarely available at all times, especially when there are several projects involved.

Let us assume, therefore, that only 7 men are available for work on Project A. Under this restriction, we can examine the steps taken by RAMPS in developing a schedule for that project considered in isolation. We will also see how the three utilization rates are intermixed in the schedule produced.

Determining the Critical Path

One of the first uses RAMPS makes of the amount-of-work values is in determining the *critical path* within each project. The critical path is the longest path or sequence of activities, in terms of *total time required,* from the starting to the ending activity.

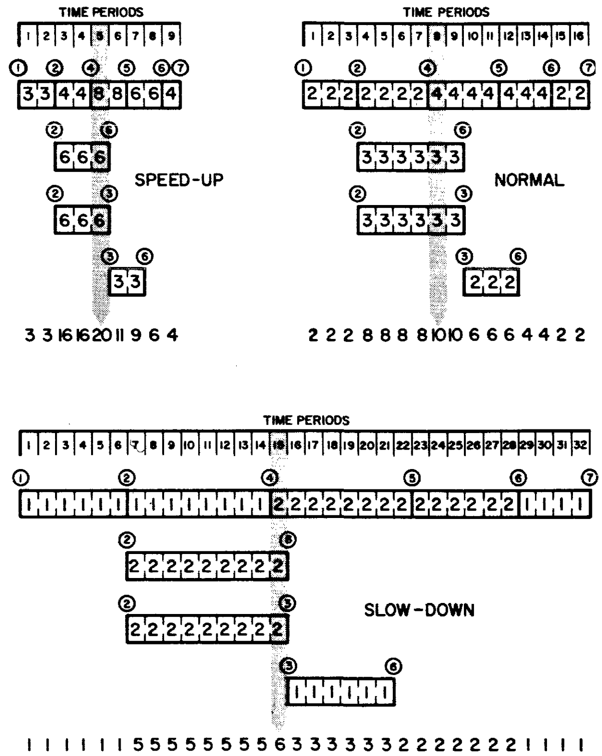

Figure 3. Possible Project Completion and Workforce Requirements at each Rate of Homogeneous Resource Utilization (Project A, Figure 2).

All activities on the critical path are *critical activities.* As shown in Figure 2, there are three possible work paths in Project A, the longest of which requires 16 time periods at normal rates and travels through events 1, 2, 4, 5, 6, and 7. This path is the critical path; any delay in the completion of a critical activity will cause an equal delay in completion of the project. If any or all of the activities *not* on the critical path are completed ahead of schedule, there could be no time gained in project completion. On the other hand, time gained along the critical path means time gained in project completion. Thus, the critical path calculation provides the following information:

1. The duration of the project if all activities on the critical path are scheduled at the normal resource utilization rate, and
2. The identity of those activities which are critical and therefore must receive *preference* when they are competing for a limited resource with activities that are *not* on the critical path.

Therefore, the next step in developing a schedule is determining when there will be competition between critical and non-critical activities for the 7 men that are available. This is done by establishing the earliest possible *start times* for the non-critical activities so that the *total resource requirements* for all activities *in each time period* can be determined. Figure 3 shows the earliest periods at which work on each activity in the project can begin. Note that beginning in period 4, the resources required at normal rates exceed the quantity available.

It can be seen that by using the slow-down utilization rates during periods 4 through 9, a schedule could be produced that stays within the limits of the available resources. However, this can be done only at the expense of extending the project completion time.

Since RAMPS strives to complete each project as quickly as possible, the use of slow-down rates on critical activities is essentially a last resort. Therefore, another alternative must be considered: delaying the start of the non-critical activities so that the resources they would otherwise consume can be diverted to the critical activities. This is called "floating" an activity.

Determining Activity Float

Activity float is the difference in time periods between the earliest time an activity *can* be completed and the time it *must* be completed without extending the project completion time. An activity float analysis for Project A is shown in Figure 4. Note that the critical activities have zero float—they cannot be delayed without delaying project completion.

The float for activity 2-6 is five time periods. The earliest time it can be completed is period 9; it must be completed during period 14 to preclude a delay in the start of activity 6-7. This kind of float is called *free float* because the activity can be delayed without interfering in any way with the float of other activities.

Conversely, activity 2-3 has two periods of *interfering float*. Since it must be completed before activity 3-6 can begin, 2-3 can be delayed one or two time periods, but only with an equal reduction in the float of activity 3-6. For this reason, the float of activity 2-3 is said to interfere with the float of an activity that is to be started later.

Producing a Schedule

With the combined power of the float analysis and the three rates of resource utilization, RAMPS is now equipped to produce an efficient schedule that meets the work requirements of each activity, minimizes project completion time, and stays within the limits of available resources. An idea of how this power is used can be gained from Figure 5 which shows the schedule produced for Project A.

By delaying the start of activity 2-6 and using the speed-up and slow-down rates where necessary, RAMPS has scheduled the project for completion in 15 time periods using a total work force of only 7 men. Note, too, that idle resources have been minimized where possible.

Although this small example serves to illustrate how RAMPS schedules work, a better idea of the scheduling power of RAMPS can be gained when one considers that this example takes into account only one project and only

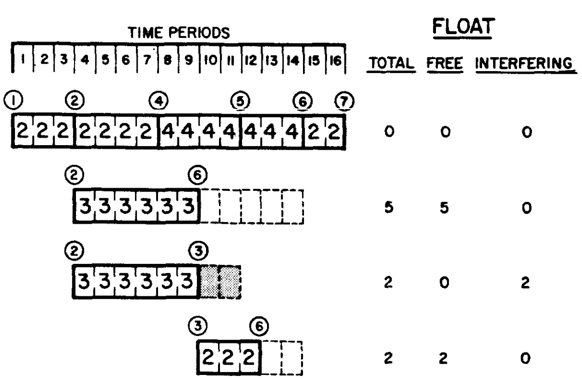

Figure 4. Activity Float Analysis.

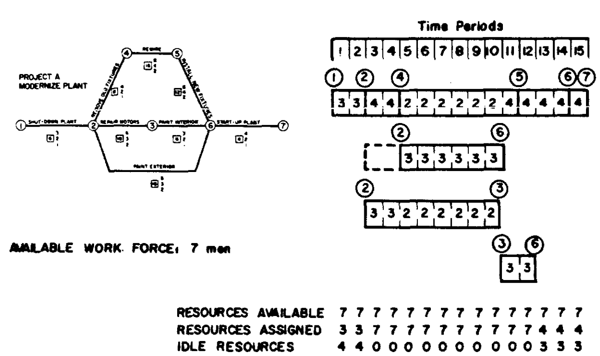

Figure 5. Derived Work Schedule for Project A Using Float and Combined Resource Utilization Rates.

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