MULTI-PROJECT RESOURCE ALLOCATION — THE STATE OF THE ART

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Summary

The traditional project network techniques have been extended to address the problem of resource allocation in a multi-project system.

Because of the excessive computational effort required by even the best of the analytic approaches, heuristic programming has been favoured for the multi-project, multi-resource problem. The programs developed use a combination of priority rules based on time or resource usage to minimize project slippage while achieving good cost performance and resource utilization.

Exciting potential exists at the Project Management/Economic Planning interface. Here this extension of project network techniques could be used to complement the conventional economic planning techniques in developing countries by facilitating the development and efficient execution of feasible public sector investment programs which require careful integration of several mutually dependent projects.

1. INTRODUCTION

The Resource problems associated with project scheduling [1] can be grouped into the following three categories:-

— Time/Cost trade off.....in which project completion time is reduced by an optimum amount by allocating additional resources to certain critical activities.
— Resource Levelling...in which resources are unlimited and are assigned to maintain a constant usage within a constraint on project duration.
— Resource Allocation...in which resources are limited and are allocated to project activities in an attempt to find the shortest project schedule consistent with fixed resource limits.

This paper attempts to review the efforts made to address the problem of Resource Allocation in the Multi-project situation [2]. An assessment is also made of the possible application of this extension of Network Analysis to Economic Planning.

2. PRACTICAL SIGNIFICANCE

This extension of Network Analysis takes account of the practical situations facing Project Managers. Resources are often available only in limited amounts and this directly influences planning objectives, time and cost estimates, scheduling and progress control.

The following examples illustrate this point:

— The Engineering and Construction Division of a large industrial company has responsibility for planning and executing several maintenance and construction projects all competing for limited common resources and having tight completion deadlines. Realistic project completion schedules (time, cost) have to be set for each project and resources have to be allocated to achieve efficient resource utilization while ensuring that on-time and cost performance is maintained.

— A developing country has a large industrial investment program as a central feature of its rolling five year national economic plan. The program requires the planning and implementation of several large related projects. Given the inevitable constraints on management time, manpower skills, materials available, foreign exchange, domestic financing, great importance must be attached to the setting of realistic project schedules (completion dates, project costs) and allocation of critical resources to each project. Constant review and revision of the Economic Plan would be required as new projects are added and other conditions change (project priority, resource constraints etc.)

3. SOLUTION TECHNIQUES

3.1 General Approach

Solution techniques for the resource — constrained project scheduling problems [3], [4 & 5], have been proposed using linear and integer programming, dynamic programming, implicit enumeration, bounded enumeration (branch and bound) and heuristic programming.

The computational effort required by even the best of the analytic approaches to cope with the large projects encountered in the real world has caused these techniques to be of no more than general interest to project managers. Instead, the problem of resource allocation in the multi-project situation has been tackled by the development of powerful computerized heuristics [6].

3.2 RAMPS Program[1]

Typical of these is RAMPS (Resource Allocation and Multi-Project Scheduling), one of the most elaborate and universally applicable heuristic computer programs for handling the resource allocation problem in multiple projects.

For each scheduling period, the program evaluates possible scheduling combinations by delaying or interrupting tasks. From these combinations, those compatible with the resource constraints are accepted and judged as a function of:-

- a priority combination of objectives (such as start and finish each task as soon as possible; give priority to critical activities; maximize tasks simultaneously in process, etc.)
- the corresponding cost
- the indicated total delay for each project
- the relative importance of the various projects under construction

Three sets of input data are required for each activity viz — amount of resource required, time required, cost of splitting an activity once it has begun. The program also requires project information such as start date, desired completion date and dollar-penalty rate, or a project priority rating. The output consists of a work schedule for each project including costs and resources and a summary of resources used in each time-period, classified by resource type.

3.3 Other Multi-Project Systems

Several other multi-project planning and scheduling systems have been developed. These include:-

— SPAR 1[2] (Wiest, 1963)

The SPAR 1 program (Scheduling Program for Allocation of Resources) developed by Wiest is capable of handling single or multiple projects. The basic program uses the following three heuristics:-

1. Serial allocation of resources, period by period, to jobs based on their early start times.
2. When several jobs compete for the same resources, preference is given to the jobs with the least total slack.

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1. See Reference [3], p. 271.
2. See Reference [1], p. 120-123.

3. Whenever possible, non-critical jobs are re-scheduled in order to free resources for scheduling to critical or non-slack jobs.

Modifications to the basic program include the addition of scheduling heuristics or sub-routines generally designed to increase resource utilization and/or reduce project duration.

— Multi-Project Scheduling System (Fendley, 1968)

This is a complete multi-project scheduling system [7] consisting of a series of procedures for the allocation of scarce resources to activities at the appropriate point in time such that the projects are completed by their due dates (or as close to the due date as possible), while utilizing resources efficiently. The minimum-slack first priority rule is used for sequencing individual jobs such that total costs at least approach a minimum. Realistic due dates are set by calculating the total resources load factors created by both in-progress and in-coming projects and calculating the amount of slippage that must occur to perform all projects with fixed resources.

— NHK — SMART[3] (Oshima)

The NHK-SMART program (Scheduling Managment and Allocation Resources Technique) proposed by Oshima allocates the so-called key resources first and then attempts to allocate the other ones without changing key resource assignments. In handling the resources, consideration is given to the schedule time and the slack time of activities. Computational experience is not reported in the literature.

— ASTRA-DISK[4] (Combe)

This program described by Combe uses an activity sorting based on priority, latest start time, earliest start time and duration.

— Multi-Project Planning Program[5] (Frere et al)

This program can handle 300 different resources and 5,000 tasks where each task may be allocated a maximum of 8 resources. Priority heuristics such as critically etc. are used to allocate resources.

3.4 Commercial Packages

Walton and Staffurth [8] identified in their survey of commercially available Network Analysis programs several which attempted to address the Resource Allocation problem. Several computer software suppliers offer commercial program packages based on a heuristic approach. An example is PROJECT/2, a comprehensive project management system being marketed by Boeing Computer Services (BCS).

Project planning and control is regarded as a dynamic process which must match real world conditions where unpredictable calamities occur and where planning proceeds with the project. PROJECT/2 allows for economical updating of network logic and provides superior scheduling procedures and algorithms.

Multi-project analysis of two or more projects is also available. Resources can be constrained across several projects and feasible resource schedules generated.

4. THE PROJECT MANAGEMENT/ECONOMIC PLANNING INTERFACE

4.1 Network Analysis in Economic Planning

The extension of Network Analysis to deal with Resource Allocation in a multi-project situation can be a useful technique in economic planning. Carruthers and Battersby [9] showed how the original 5-Year plans for India could be schematized by a rudimentary network.

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3. See Reference [3], pp. 271.
4 & 5. See Reference [3], p. 271.

They outlined a dynamic programming formulation for the disjunctive problem in which two or more activities may compete for the same resource that is available only in one unit. This approach would require a considerable amount of information to be stored, and the authors suggested the use of Lagrange multipliers to reduce dimensionality.

Szuprowicz [10] gave a more practical application by illustrating the use of networks to plan and control the wide variety of projects, often mutually dependent, in Nigeria's national plan. The plan was presented as a series of networks for different sectors of the economy linked through interfaces on a multi-project basis.

Networks were proposed for use at the project, sectoral and national levels to plan and maintain the development program and facilitate centralized control. The project network represented the lowest level, for example, the construction of a steelmill or highway. Each project network formed a part of a large sector in the development programme, for example, Industry, Health, Transport. A sectoral network would therefore represent the intermediate network level grouping individual project networks and showing the dependence and relationships of project within a sector. At the national level, there would be a supra-network, summarizing all sectoral networks and providing the central planning authority with an invaluable tool for monitoring the implementation of the development program.

4.2 Some Reservations

Carruthers and Battersby report the findings of a working party of a Critical Path Analysis Study Group which examined the application of Network Techniques to economic planning in a developed country — the United Kingdom. The group felt that some form of modern technique of national planning was desirable and that network techniques could be useful in the creation of economic plans. However, they envisaged problems of defining resources and quantifying resource limits and recognized the need for a better dynamic technique to handle the complex resource problems.

Reservations have also been expressed on the operational value of a programming model for resource allocation in a developing country. Mc Carthy [11] acknowledges that the industrial investment programs of developing countries often include a series of projects which are so interdependent that bottlenecks occur unless effective coordination exists. Hoever, generalising from his experiences in Botswana, he suggests that the shortage of data and administrative capacity to implement any solution present insurmountable obstacles.

The mathematical programming approaches [12] utilized primarily in centrally planned economies offer some promise. In the Soviet Union, for example, input-output techniques are used to complement the method of "material balances" to achieve an internally consistent and coherent national plan. Material balances are drawn up on the basis of input coefficients derived from past experience, modified by anticipated consequences of technical change.

It is an administrative operational tool, designed to reshuffle resources among particular users in the light of priorities and bottlenecks, the operation being conducted mainly in quantitative, physical terms, and related to the administrative sub-divisions of the economy which seldom conform to product designations. The Input-Output table records and helps to anticipate the sectoral requirements of a given increase in output.

Chenery [13] suggests that modifications of these techniques are necessary to enable their application in developing countries. Some work has already been initiated in this area in Trinidad and Tobago. Lewis [14] has developed a preliminary Input-Output table for the construction sector while Gardiner [15] has developed a static resource demand model to assess the resource implications of a particular public sector investment program.

An attempt has also been made by Chin et al [16] to address the multiproject resource allocation problem in the construction sector by developing DEMON (A DEvelopment Scheduling MOdel for TriNidad and Tobago), a computerized scheduling model. Computational experience is not given.

4.3 Future Development

Notwithstanding the reservations expressed by some writers, the extension of the resource allocation network models developed for multiproject scheduling to complement the traditional techniques of economic planning e.g. Input-Output Analysis, creates an interface full of exciting prospects.

Adaptation of the RAMPS system or Fendley's Multi-Project scheduling system using computerized heuristics to provide a dynamic system of resource allocation would provide a powerful tool in economic planning. This would facilitate the setting of realistic completion dates for projects and achieving efficient allocation and utilization of resources.

This development could provide substantial benefits to developing countries and would require:-

- preparation of individual project networks
- assigning of a priority rating to each project
- definition of resources and quantification of resource limitations
- preparation of project schedules showing project completion dates, costs, resources allocated etc.
- development of reporting and review systems for monitoring and periodic updating of networks.
- review of plan as new projects are introduced and other changes occur (e.g. resource availability varies; project priorities change)

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