ARAB REPUBLIC OF EGYPT

THE INSTITUTE OF
NATIONAL PLANNING

Memo.(1497)

A Model For Distribution Of Resources in Multi-Projects

By

Dr. Mohd. Yehia Abdel Rahman

March 1989

CAIRO
SALAH SALEM St-NASR CTTY

CONTENTS

INTRODUCTION :

(*)
" At this time, computationally feasible models for optimizing the leveling of resources do not exist "

<<<...>>>

One of the common problems which faces a production or a construction firm, is to distribute its resources on its different projects. There will be no problem, if the resources were enough to cover the needs of all projects.

The problem will arises, if one project or more could not be accomplished at its exact time. In this case, some subsidiary problems could be created; such as :

i) the posterior project/ s -if any - will be retarded;
ii) the firm may pay some overtaxes as penalties for retardation;
iii) the confidence and trust in that firm will be chaked and changed ;
iv) the total cost of the project/ s , will augment with the time (the opportunity and indirect costs are directly proportional with the time).

To overcome the preceeding problems, the firm planners have to put their hands on the bottlenecks; then reevaluate and modify their plans.

(*) Ref. (5); pp. 545

There are many reasons, that the project(s) may accomplished after its calculable time. Some of these reasons, could be summarized in the following points :

i) the absence of scientific techniques and managements;
ii) the shortage of resources during the execution ;
iii) the wrong distribution of resources on the projects;
iv) the negligence of control for some sensible and critical activities ;
v) the unavoidable and unexpected exterior factors as climate, power, ..., etc.

In this research, we will consider the PERT or CPM technique as a starting step to formulate the mathematical relations of our model. So, the first part of this research will concern to briefly expose the most important parts of PERT or CPM technique as a scientific tool for this kind of problems. An extended and very important part of this technique, is the so-called "Resource leveling and allocation"; where equipment and manpower planning will be put in consideration in this research.

In the second part, we will concentrate our attentions to generalize the use of "Resource allocation" as a preliminary step to formulate our model. In the third part, the computer output result for an example will be presented.

PART - I

PERT and CPM

Two fundamental analytic techniques proposed in the late 1950s for planning, scheduling, and controlling complex projects. PERT which is the synonym of "Project Evaluation and Research Technique" or "Performance Evaluation and Research Technique" or "Program Evaluation and Research Task"; and CPM for "Critical Path Method". Although the two techniques were developed concurrently and independently, they were nearly similar. Aside from minor differences in terminology, notation, and structure, only two major differences usefully distinguished the two methods. First, PERT acknowledged uncertainty in the times to complete activities, while CPM did not. Second, PERT restricted its attention to the time variable, whereas CPM included time - cost tradeoffs.

(I-1) PERT / TIME and PERT / COST :

The common factor in the two techniques -PERT and CPM- is the "job" or the "activity". The project managers must schedule and coordinate the various jobs or activities so that the entire project is completed in time. A complicating factor in carrying out this task is the interdependence of the activities. For example, some activities depend upon the completion of other activities before they can be started. When we realize that projects can have as many as several thousand specific activities, we see why project managers look for procedures that could help them answer questions such as the following :

a) What is the expected project completion date ?
b) What is the scheduled start and completion date for each specific activity ?
c) Which activities are "critical" and must be completed exactly as scheduled in order to keep the project on schedule ?
d) How long can "noncritical" activities be delayed before they cause a delay in the total project ?

As we know, PERT / TIME and CPM can be used to help answering the above questions.

While project time and the meeting of a scheduled completion date are of primary considerations for almost every project, there are many situations in which the cost associated with the project is just as important as time. The technique referred to as PERT / Cost can be used to help plan, schedule, and control project costs. The ultimate objective of a PERT / Cost system is to provide information which can be used to maintain project costs within a specified budget. In this term, PERT / Cost technique offers different alternatives schedules (Time vis-a-vis Cost) for achieving a project.

The first step in a PERT / Cost control system is to break the entire project in to components that are convenient in terms of measuring and controlling costs. The related activities which are under the control of one department, subcontractor, etc.; are often grouped together to form what are referred to as "work packages". By identifying costs of each work package, a project manager can use a PERT / Cost system to help plan, schedule, and control project costs.

In this technique, three categories of cost could be identified for any given project :

1) **Direct costs :**

Associated with the commitment of resources (labor, materials, equipment, and so forth) to activities ;

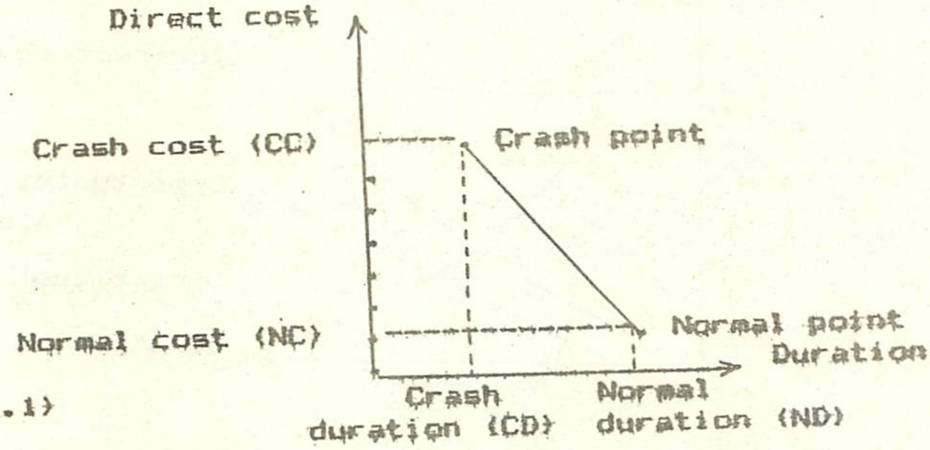
2) **Indirect or Overhead costs :**

Such as expenses associated with utilities, administration, and supervision; and

3) **Opportunity costs :**

Such as penalties for completing a project beyond a certain date or bonuses (benefits or negative costs) for completing a project prior to a specified date.

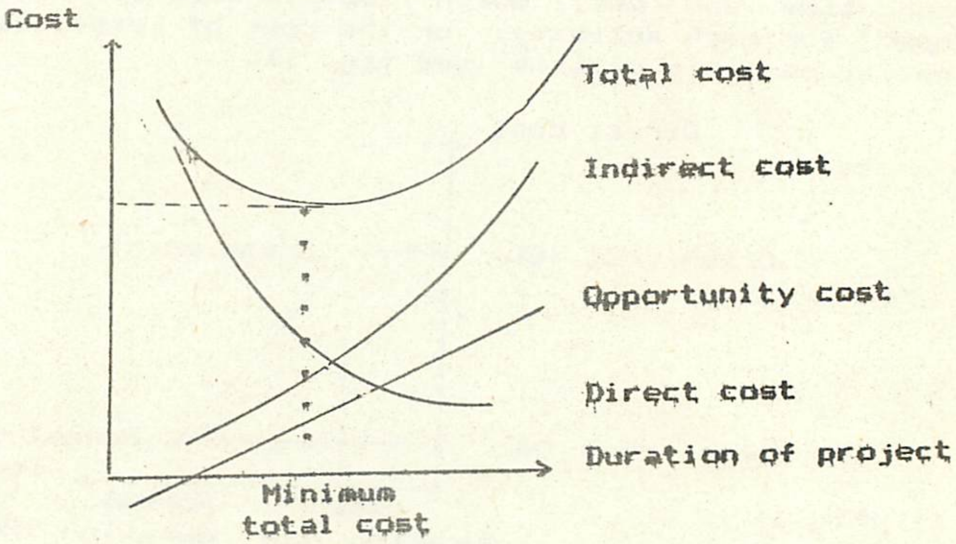
In this approach, for every job or activity there are four data items must be associated. However; its normal, crash time and cost, which leads to calculate the "Cost slope" for each activity, or the cost of expediting this activity per unit of time (see fig. 1).



(Fig.1)

$$\text{Cost slope} = \left| \frac{CC - NC}{CD - ND} \right|$$

Given the determination of a critical path based on normal times, the act of "crashing" involves the sequential time compression of critical activities from normal durations to crash durations. The end result of this effort is a set of schedules yielding direct cost as a discrete function of project duration. When this function is combined with the indirect and opportunity cost functions, a discrete version of the total cost function can be constructed;(Fig. 2).



(Fig. 2)

(I - 2) Kinds of floats :

Every activity in a project is defined or characterized by two event (point of time), the first determines its start and the second for its finish. At every event, there are two types of times to be calculated, **Earliest Event Time (EET)** and **Latest Event Time (LET)**. For critical activities, these types of times are equal.

Suppose an activity of starting event i, finishing event j and of **duration** D_{ij}. There are three kinds of floats can be calculated (if desired). Namely ;

a) **Total float**

Which is the maximum time by which the activity may be expanded without affecting project completion.

i.e ; $\text{Total float} = LET - EET_{i} - D_{ij}$

b) **Free float**

Which is the maximum time by which the activity may be expanded without affecting any subsequent activity.

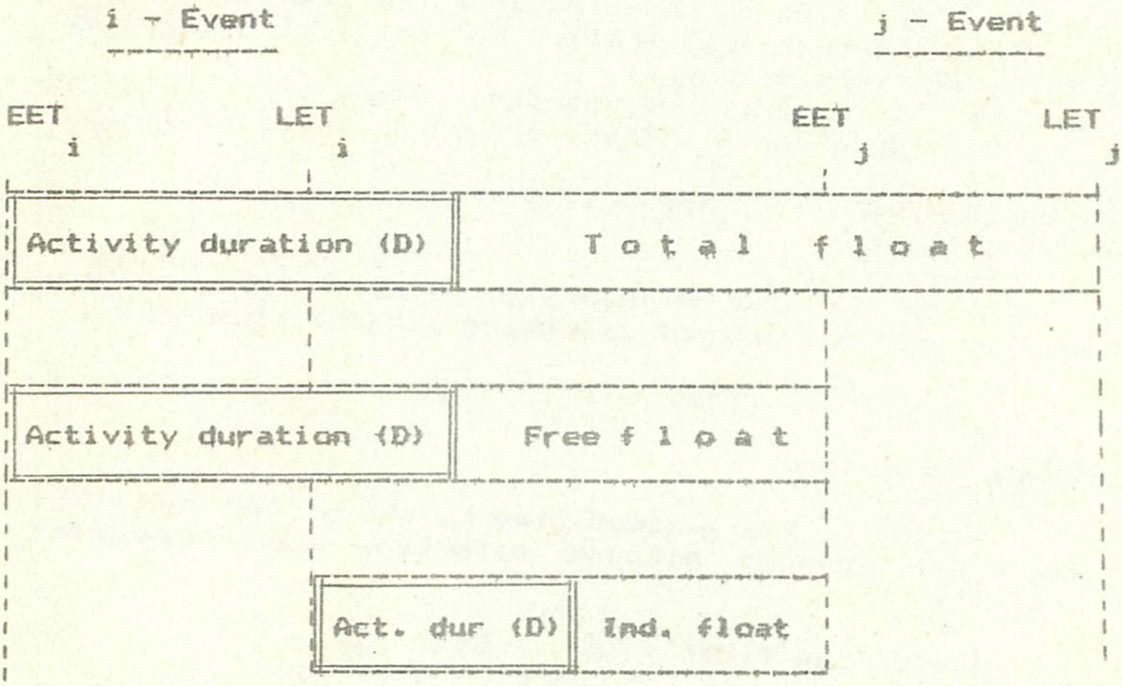
i.e ; $\text{Free float} = EET_{j} - EET_{i} - D_{ij}$

c) **Independant float**

Which is the maximum time by which the activity may be expanded without affecting any other activity.

i.e ; $\text{Independant float} = EET_{j} - LET_{i} - D_{ij}$

The above three kinds of floats could be represented graphically as follow (*) :



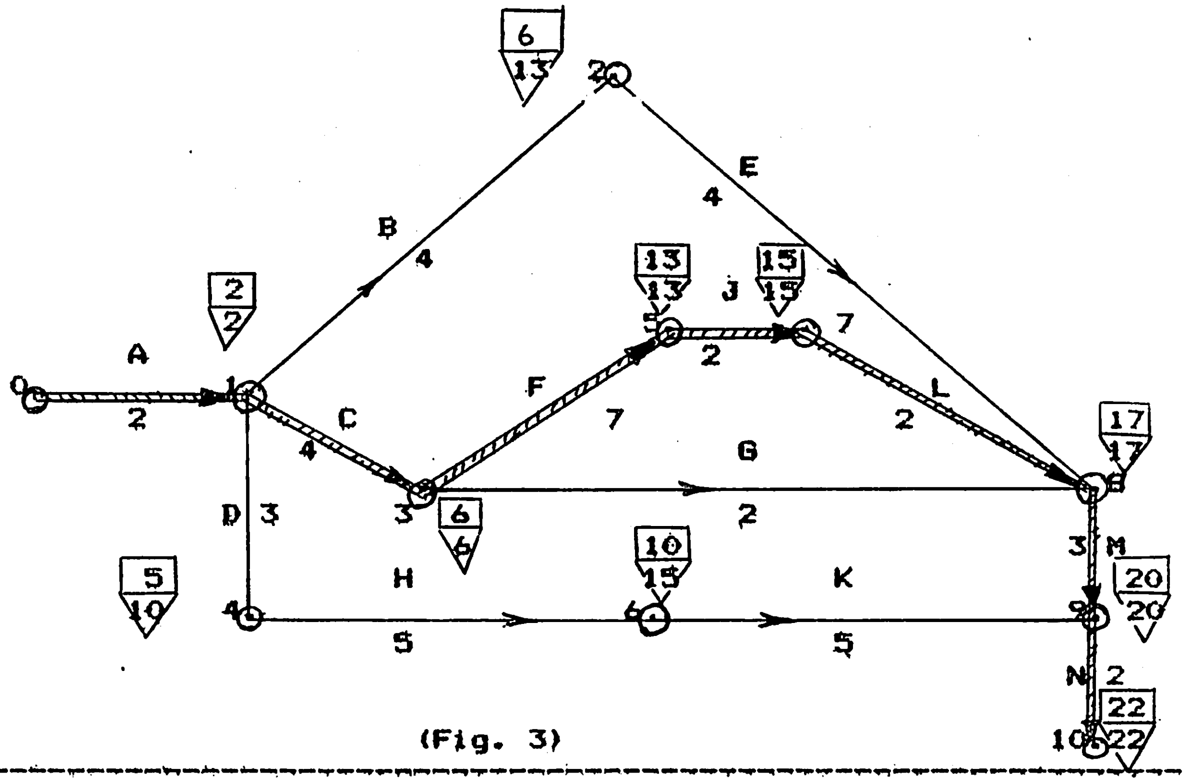
For any critical activity, the three kinds of float are equal to zero.

(*) Patrick O. Malone ,"The basics of critical path method", course notes CN. 821. September 1976 - International Bank for Reconstruction and Development.

(I - 3) Time Chart :

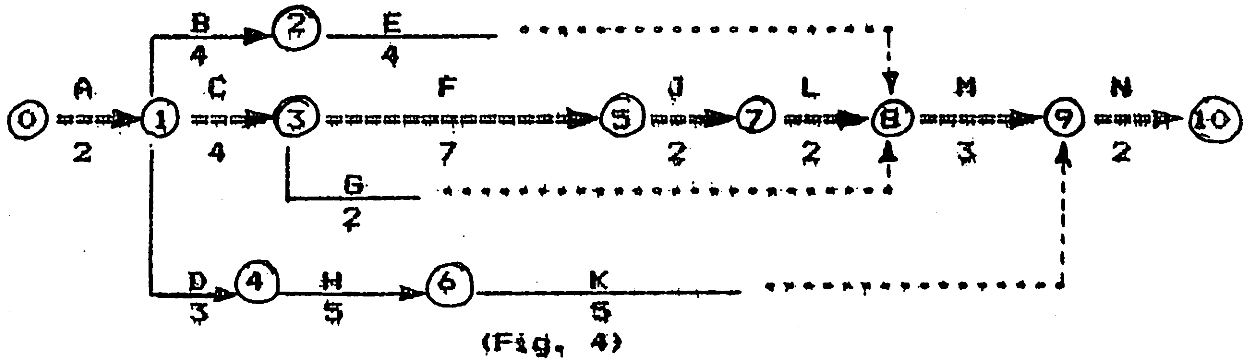
The time chart readily identifies scheduling flexibilities because of the visual case in identifying the total float associated with each non critical activity. The first step to design the time chart is the scheduling of critical activities. These activities are located as those having zero total float. Then they are plotted sequentially, the length of each line corresponds to the duration of the corresponding activity. The dummy activities need not be plotted, as they take up zero time. Each non critical activity is plotted separately. The beginning and end of each line correspond, respectively, to the earliest starting time (EET_i) and the latest finishing time (LET_j) for the given activity. The total float for each non critical activity is represented by a dotted line.

For example, consider the following network of a project (Fig. 3). After calculating the total completion time of the project, and identifying both critical and non critical activities, a horizontal line with a scale proportional to that time, is plotted.
This line (doubled line) is divided in to parts. Each part represent a critical activity. The non critical activities are represented by continuous thin lines. Their lengths were taken by the same scale of the critical path (Fig. 4).



6
13
2
B
4
E
4
2
2
A
0
1
2
C
4
13
13
5
J
15
15
7
2
F
7
L
2
G
2
17
17
8
D 3
3
6
6
5
10
4
H
5
10
15
6
K
5
3 M
20
20
9
N 2
22
22
10

(Fig. 3)



0
A
2
1
B
4
2
E
4
C
4
3
F
7
5
J
2
7
L
2
8
M
3
9
N
2
10
G
2
D
3
4
H
5
6
K
5

(Fig. 4)

The role and importance of time chart will be evident in calculating the total resources required at every period during the execution of the project. It is also essential in PART II, when we have to formulate the proposed model for leveling the resources.

(I - 4) Resource leveling and allocation :

Basic models assume unlimited resource availability, which is clearly unrealistic for many enviroments. Activities on parallel paths in a network, may compete for the same resources. Consequently, limited resources may force sequential scheduling of activities which are not related by precedence relationships.

There are two basic approaches to scheduling with limited resources : resource leveling and resource allocation. In resource leveling, peak resource requirements are smoothed to reduce maximum capacity needs - consistent with meeting the scheduled completion date.

In resource allocation the duration of the project is minimized (usually beyond the scheduled completion date provided by the basic model) subject to appropriate resource and sequential constraints.

The basic issue involves scheduling non critical path activities at times which minimize fluctuations in expected needs for the resource. The resources that are to be leveled or allocated will be of different types (for example, money, labor, machinery, and so forth). Furthermore, capacities in various work centers (each resource is a work center) may or may not be transferable to other work centers or activities.

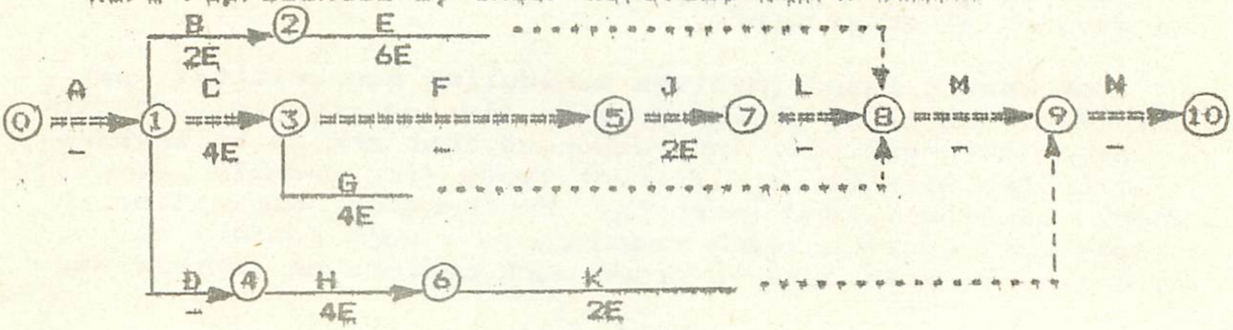
For example, a particular type of skilled labor may be appropriate only for certain activities.

As mentioned before, that leveling of resources depends on the float of the non critical activities of the project. The idea is to shift or to alleviate the resources from the points which have a high density of resources (peaks) to less density points via the non critical activities.

For example, suppose the number of engineers required at every unit of time in the previous project, like the following :

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
–	–	6	6	6	10	14	14	10	10	2	2	2	4	4	–	–	–	–	–	–	–

(Figure 5) represent the time – chart, and the activity requirements from the engineers as resources. The activities were represented by their earliest start times.



(Fig. 5)