Planning and Control Techniques
For Construction Projects

Summary Lecture

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1.0 CONSTRUCTION PLANNING AND ORGANIZATION

1.1 Introduction

Project management may be described as the process of planning, executing and controlling a project, from inception to completion, in a given time, at a given cost, for a given end product, and in accordance with available human and technical resources, fig. 1.1.

The management process should be capable of accepting possible alteration at any stage that may result when:

* Basic assumptions change.
* Original estimates are no longer valid.
* New facts, changes and restrictions occur which could not be anticipated.

In general, the management process must be dynamic; its most important goal is not necessarily completion of project exactly as planned. The principal aim should be to achieve the intended objectives of the project in the best possible way and with the best possible result. Fig. 1.2 shows the main activities of the dynamic cycle of the management process.

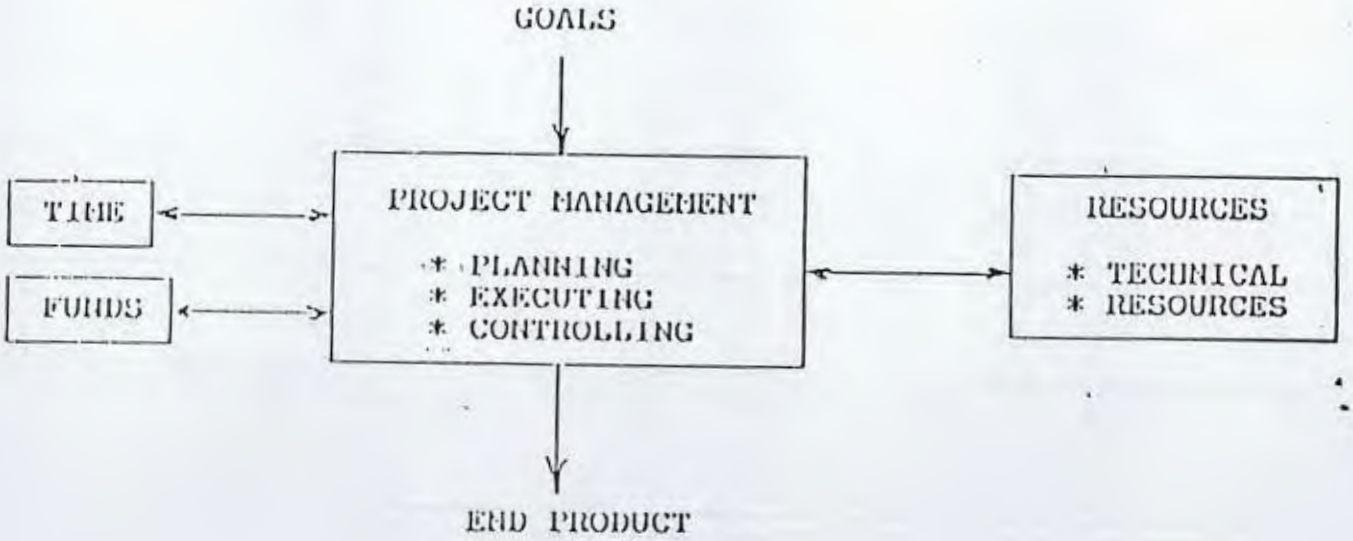
GOALS
TIME
FUNDS
PROJECT MANAGEMENT
* PLANNING
* EXECUTING
* CONTROLLING
RESOURCES
* TECHNICAL
* RESOURCES
END PRODUCT

Fig. 1.1

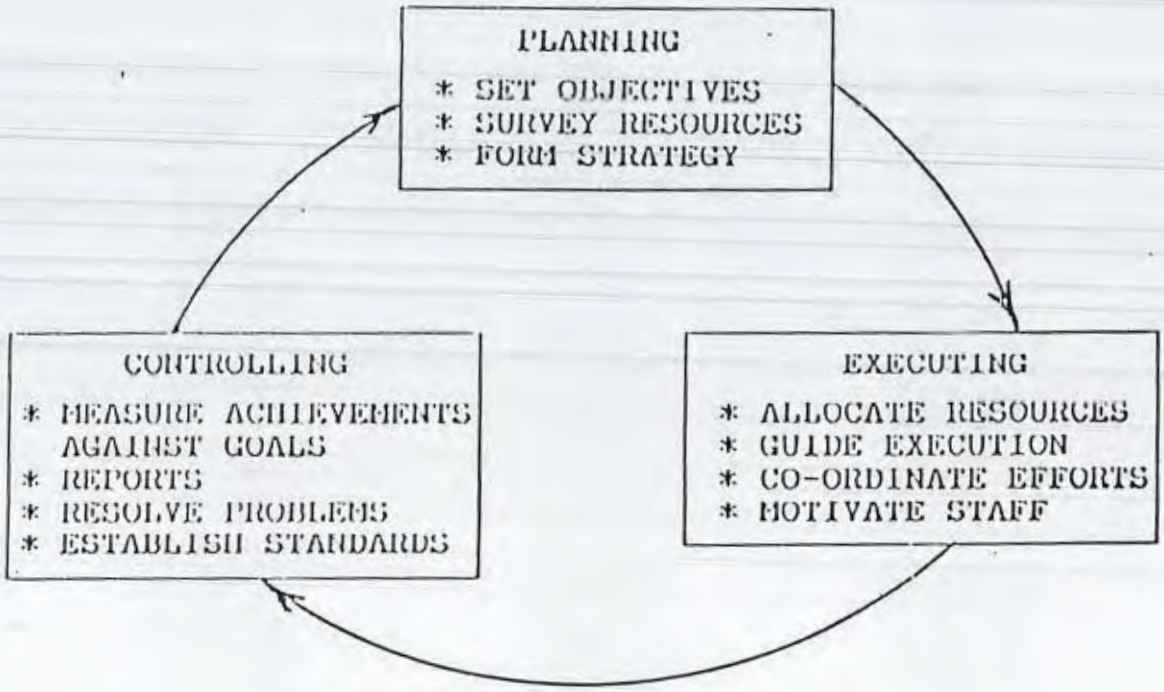
PLANNING
* SET OBJECTIVES
* SURVEY RESOURCES
* FORM STRATEGY
EXECUTING
* ALLOCATE RESOURCES
* GUIDE EXECUTION
* CO-ORDINATE EFFORTS
* MOTIVATE STAFF
CONTROLLING
* MEASURE ACHIEVEMENTS AGAINST GOALS
* REPORTS
* RESOLVE PROBLEMS
* ESTABLISH STANDARDS

Fig. 1.2

1.2 Organization and contracts:

There are numerous alternative contractual and organizational approaches to the design and construction of a project. The principal categories include the following:

* Traditional approach
* Turnkey (Design-Construct or Design-Manage)
* Owner-Builder
* Profesional Construction Management

Each has its advantages and disadvantages for a particular application, and each has developed a certain degree of flexibility so that many of the individual alternatives overlap one another. The organizational and contractual relations could be complicated in some traditional approaches, or simple and clear in proper management approach. Figs. 1.3 & 1.4 show samples of organisations and flow charts.

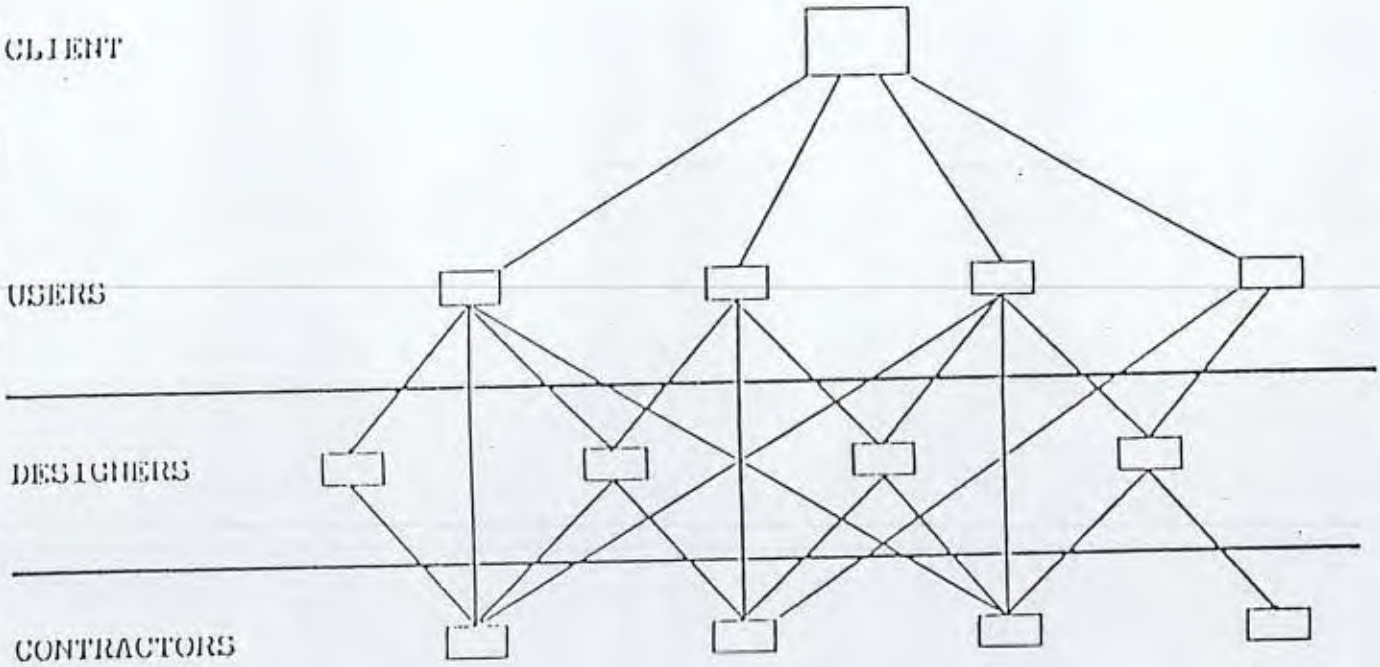

Fig. 1.3 Traditional organizational flow-chart

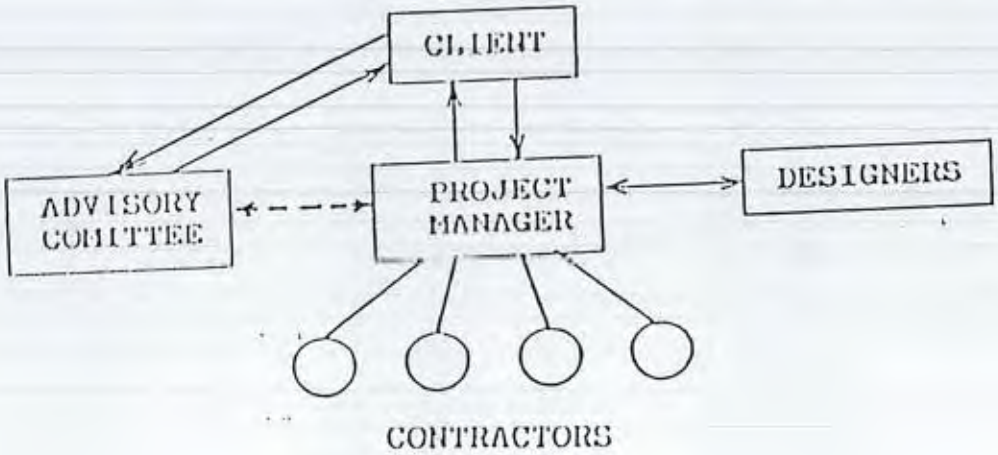

Fig. 1.4

2.0 PLANNING AND CONTROL TECHNIQUES

2.1 Introduction

Planning and control are the major twin functions of the project management responsibilities (they are the two sides of a coin). Planning and control are the most challenging tasks faced by the "Project Management".

Once the professional construction manager has been chosen, and even when fair and equitable contractual agreement have united all members of the project team and oriented them towards the owner's goals, the team will still face the most challenging part of project management: Planning and control to bring the project to completion on schedule, within budget, and in accordance with the owner's functional objectives.

This can be achieved by providing the required information to ensure the following:

* Adequate resources are available at the right moments (Manpower, Materials and Equipment)
* Adequate time is allowed for each stage in the process and that all various component activities start at the appropriate time.

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* Adequate funds are available in due time within the total budget.

For this, all participants of the project team will need the fullest understanding and control process and all practical tools that can be put at their disposal.

2.2 Planning for what ?

* Planning and control tools are the major twin functions serving all participants in the project.
* Planning aims at the best economic use of the available resources (labour, materials and equipment).
* Planning provides needed data to ensure the following:
  - Adequate resources are available at the right moment.
  - Adequate time is allowed for each stage in the process and that all various component activities start at the appropriate time.
  - Adequate funds are available in due time within the total budget.
* Proper planning makes it possible to achieve the goals of the project in accordance with:
  - Quality target
  - Given time
  - Specified funds.

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* Systems plan, Fig. 2.1, considers and interact with:
  - Client requirements
  - Project needs
  - Contractor experience
* Normally it involves all phases of the project, from concept .....Commissioning, Figs, 2.2 & 2.3.

2.3 Planning at All Stages:

Planning is applied at all project stages in varying degrees of detail, depending on the stage at which it is being carried out. For construction work, it is usually divided into pre-tender, pre-contract, construction and short term planning on site.

Pre-tender planning is done to allow the estimator to arrive to an estimate based on the proposed methods of working and an estimate of the time required to carry out the work. Programming at the pre-tender stage is usually in an outline form to consider only the phasing of the main operations.

Pre-contract Planning is carried out when the contract has been won and the project is considered more fully. Planning, at this stage, includes the overall programme, labour schedule, plant schedule, material schedule,..etc. The

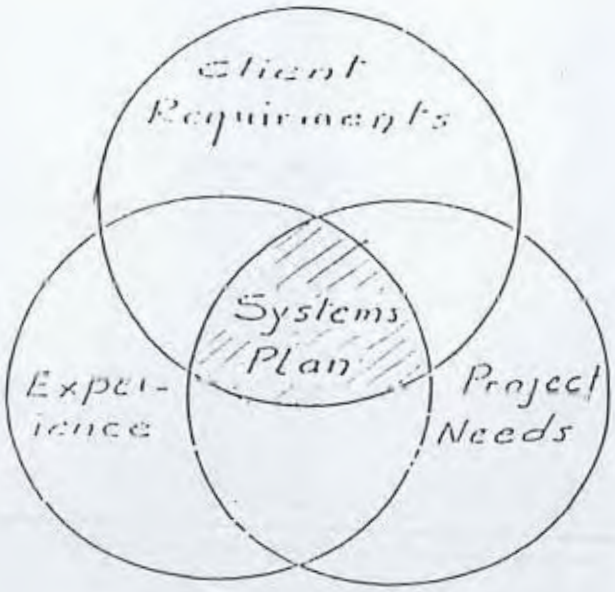

Fig. 2.1 Systems Plan

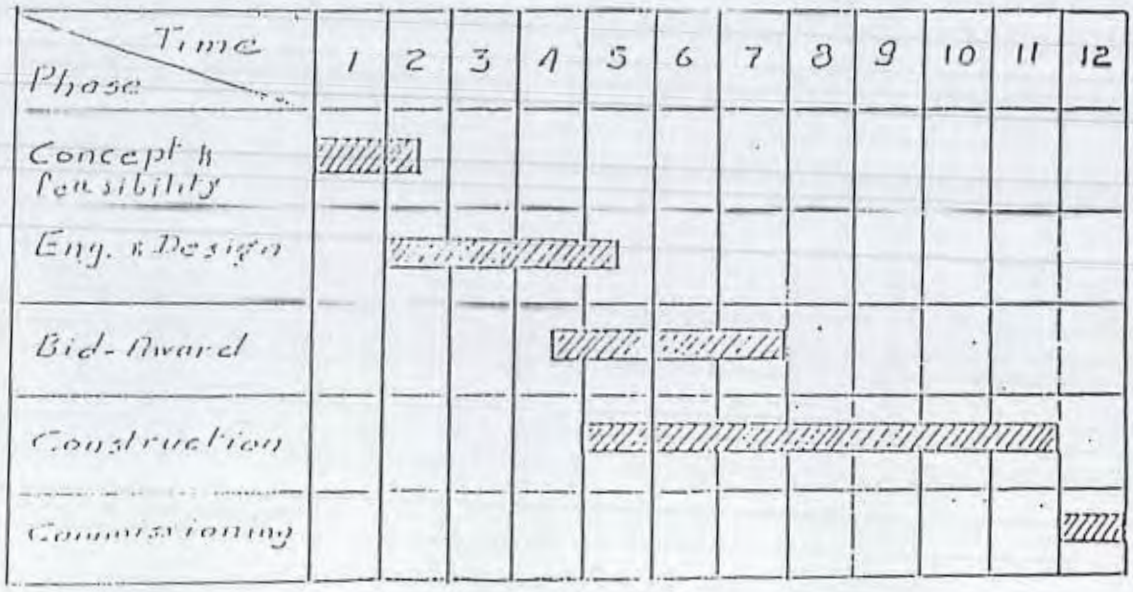

Fig. 2.2 Project Phases

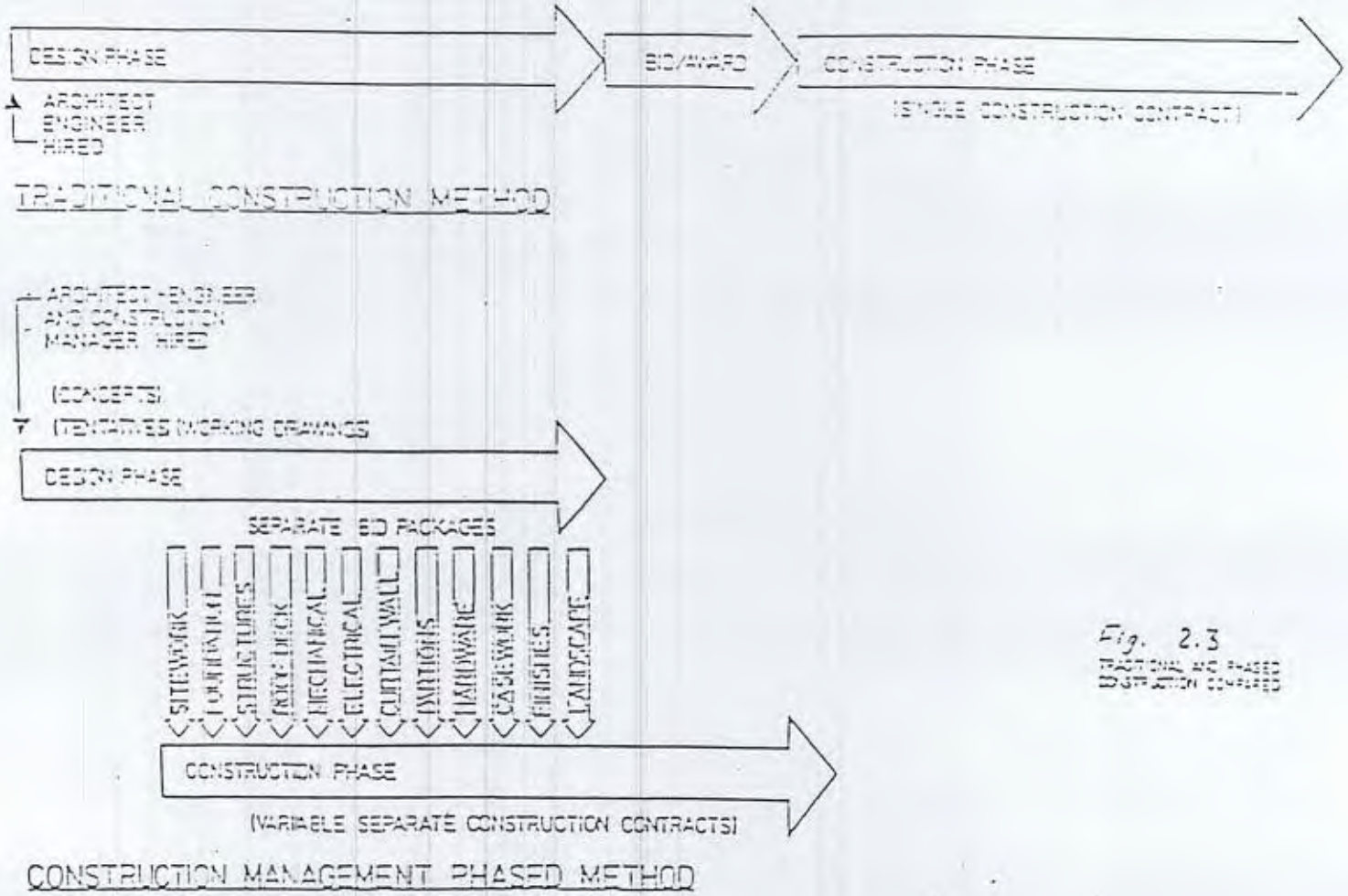
DESIGN PHASE
BID/AWARD
CONSTRUCTION PHASE
(SINGLE CONSTRUCTION CONTRACT)
ARCHITECT
ENGINEER
HIRED
TRADITIONAL CONSTRUCTION METHOD
ARCHITECT-ENGINEER
AND CONSTRUCTION
MANAGER HIRED
(CONCEPTS)
(TENTATIVES WORKING DRAWINGS)
DESIGN PHASE
SEPARATE BID PACKAGES
SITEWORK
FOUNDATION
STRUCTURES
ROOF DECK
MECHANICAL
ELECTRICAL
CURTAIN WALL
PARTITIONS
HARDWARE
CASEWORK
FINISHES
LANDSCAPE
CONSTRUCTION PHASE
(VARIABLE SEPARATE CONSTRUCTION CONTRACTS)
CONSTRUCTION MANAGEMENT PHASED METHOD

Fig. 2.3
[illegible]

overall program should not break the operations down excessively or it will become unrealistic.

Construction planning is carried out during the construction stage. It is, usually, more detailed than the pre contract planning. It can be divided into separate detailed subprograms, that can be easily interconnected in a global planning program. These programs should be flexible to allow for updating without disruption of the whole program. Monthly updating is most common.

Short term planning on site is done in greater detail and the programs at this stage are broken down much further.

Control must be carried out to make planning effective, as without control planning, losses are much of its value. It must be applied continuously to update the plans and to enable reconsideration of work ahead in the light of what has already taken place.

2.4 Characteristics of a Good Plan:

* The plan must have definite objectives.
* It should be simple, the aim is to outline complex situations in a simple way.
* It should be based on appropriate practical information.

* It should use available resources to the utmost.
* It should be flexible, it must be possible to alter certain elements of the plan without disrupting the entire plan. There must be a reasonable degree of slack built into the plan.
* It should provide propor standards of expectations, by providing identified and quantified mile stones along the way so that easy control may be exercised.

2.5 Objectives of Information System to Aid in Management Planning:

1- To provide an organized and efficient means of measuring, collecting, verifying and quantifying data reflecting the progress and status of operations on the project with respect to schedule, cost, resources, procurement and quality.

2- To provide standards against which it is possible to measure or compare progress and status. Examples of standards include CPM schedules, control budgets, procurement schedules, quality control specifications and construction working drawing.

3- To provide an organized, accurate and efficient means of converting the data from the operations into information.

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The information system should be realistic and should recognize:

* The means of processing the information (manual, computer, ..)
* The skills available, and
* The value of the information compared with the cost of obtaining it.

4- To report the correct and necessary information in a form which can best be interpreted by management, and at a level of detail most appropriate for the individual managers or supervisors who will be using it.

In keeping with the principles of management by exception, the following two objectives should be added:

5- To identify and isolate the most important and critical information for a given situation, and to get it to the correct managers and supervisors, that is, those in a position to make best use of it.

6- To deliver the information to them in time for consideration and decision making so that, if necessary, corrective action may be taken on those operations that generated the data in the first place.

2.6 Model for planning and control :

The flow chart, in fig.(5), models the operations, flow of information, and decision making process characteristic of a feed' back control system appropriate for a medium to large sized engineering construction project. Although this flow chart applies equally well in the conventional design and construction process, where the two phases are largely separated, a control system of this type can have its greatest impact in the professional construction management approach where there is a strong interplay between all aspects of the system concept; design; procurement; construction and commissioning. This approach is especially prvalent in large heavy-industrial projects, such as tunnels, refineries, power stations and in the large building field. In projects of this type, engineers involved in design and those in construction interact continuously to optimize the facilities from both points of view.

* Components of the model flow chart :

Site environment (box 1), is considered regarding major conditions that can affect the initial plan, suchas, weather and procurement delays or even unexpected good facilities on site. The initial plan (box 2), is made with consideration of the available resources, proposed budget and site environment. The initial plan is fed to (box 3), aand site operations get underway. This initial plan becomes also reference standards for control purpose (box 5). The site operations underway generate indicators or progress which are monitored and measured (box 4), (quantities in place, elapsed time, money expended, resources consumed and quality) and fed as data into a system (box 6), to produce information for decision makers.

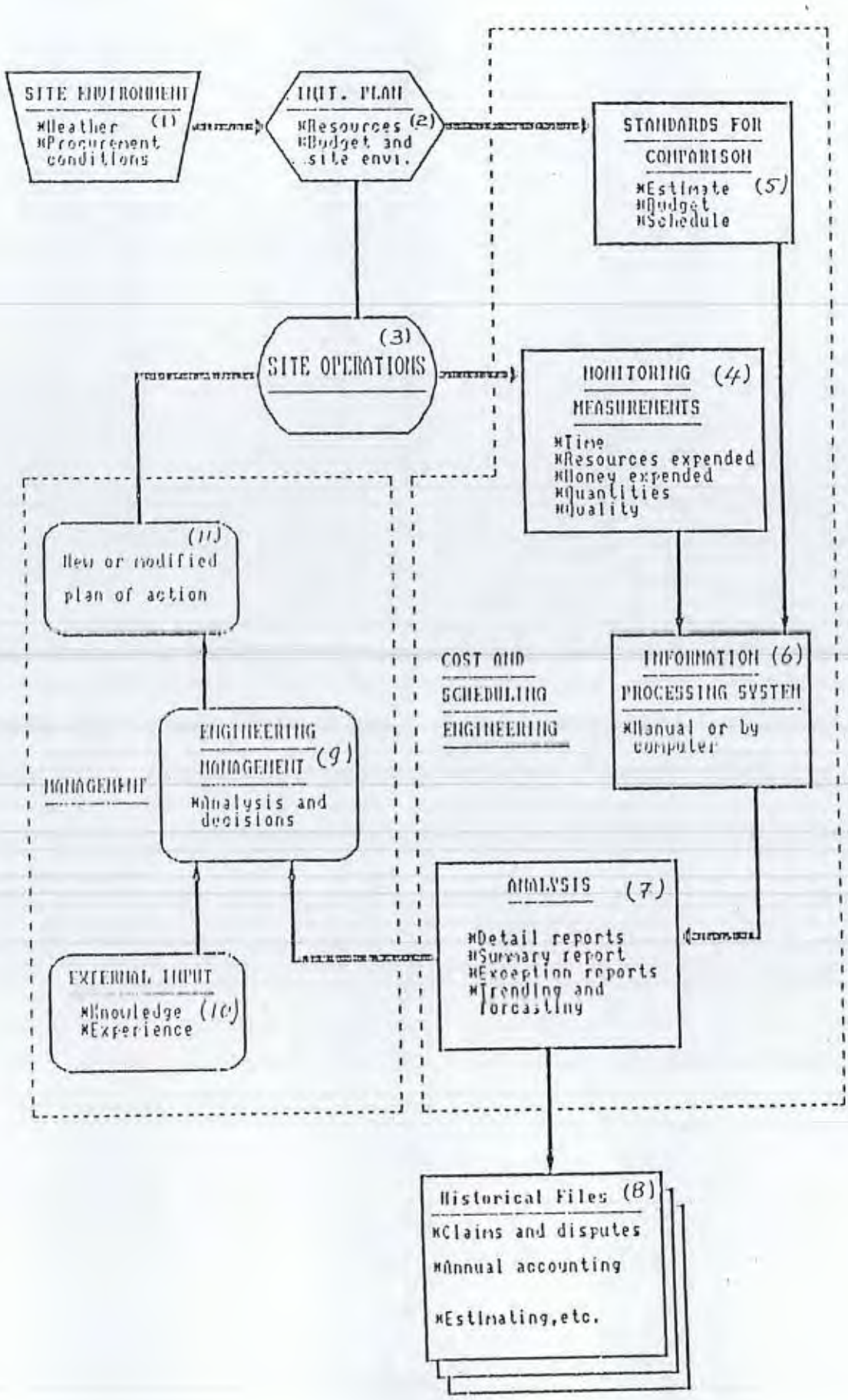


FIG 2.4 FLOW CHART FOR PROJECT CONTROL SYSTEM

* Feedback control system :

The feedback system operates continuously throughout the life of a project. Associated with it is a feedback time. Ideally, the time through parts 4,5,6 and 7 should be as short as possible so that engineering managers and suppervisors can receive accurate and up-to-date information in time to make decision and formulate plans of action so as to have maximum impact in controlling those operations which are generating the information in the first place.

2.7 Job activities :

The project is subdivided for planning purposes into segments called activities. An activity is a single work step that has a recognizable begining and end, and requires time for its accomplishment. The following are suggested guidlines for identifying activities :

1) By area of responsibilities. Work items done by the general contractor and each of his subcontractors should be separated.
2) By category of work as distinguished by craft or crew requirement.
3) By category of work as distinguished by equipment requirement.
4) By category of work as distinguished by matorial such as concrete or steel ...etc.
5) By distinct of structural elements such as footings, walls, beams, columns or slabs.
6) By location on the project when diferent teems or different areas will be involved.
7) With regard to owner's breakdown of the work for bidding or payment purposes.
8) With regard to contractor's breakdown for estimating and cost-accounting purposes.

The activities used may represent large segments of the project or may be limited to small segments. Too little details will limit planning and control effectivness. Too much details will confuse the project manager with voluminous data that tend to obscure the significant factors and increase the cost of the management system. Planning detail valies with level of project management involved, according whether it is for top management or for the execution engineer who is responsible for a particular job.

2.9 Samples of Pre-tender Planning Method Statement :

Main objectives are to help estimators to consider alternative methods of construction and to arrive to an accurate cost. Table 2.1 shows a sample of method statement.

Table 2.

CONTRACT: AMENITY CENTRE & OFFICE BLOCK SHEET NO: COMPILED BY:

NO. OF SHEETS DATE

Item	Quantity	Remarks	Labour & Plant	Time Req'd Days
Hoarding	45 linear metres	Erected along N.E. boundary of site 2.5 metres high.	2 carpenters	2
Access	-	Vehicle access via works entrance		
	-	Cross over in S.W. footpath	2 labourers	1
	-	Workmen's access via 1 metre wide gate in hoarding (position shown on the layout drawing).	-	-
Accommodation	-	All site accommodation to be first 1 metre wide gate in hoarding (position shown on the layout drawing). Toilet provided in form of mobile unit.	2 carpenters	5
Temp. Services	-	Provide electrical, water & W.C. services as shown on site layout drawing.	3 labourers Plumber & mate	3 3
			Electrician & mate	2
Demolition	105 cubic metres	Reduced level dig. From bucket of J.C.B. 4 - easy going.	J.C.B. 4 & operator & 3 labourers	1
	140 cubic metres	Tie beam overlaid Rear back-acter bucket of J.C.B. 4. Internal drain overlaid Rear back-acter bucket of J.C.B. 4.	J.C.B. 4 & operator & 3 labourers	4
		Disposal of surplus spoil Remove to tip 400 metres distance using lorries - vehicle works.	2 lorries & drivers	5
General Hoisting & Transportation	-	The tower crane will be used for lifting all materials and frame is complete when it will be replaced by a 250 kg platform hoist which will be built adjacent to T.C. before it is removed.	Tower crane & driver	50
	1		Hoist	80

Fig. continued

Item	Quantity	Remarks	Labour & Plant	Time Req'd Days
		Lifted onto floor before crane removed. Platform hoist used for lifting materials used in finishings.		
Concreting	400 cubic metres	Mixing The concrete will be mixed in a 350/200 litre electrically powered revolving drum mixer, having a built-in weigh batcher, the aggregate being delivered to the weigh batcher by a hand scraper. AC located at south corner of site. Cement is to be stored in a 20 tonne silo located directly over the mixer.	2 labourers 300/200 litre mixer set up	75
	400 cubic metres	Transportation Mixed concrete is to be transferred to all levels by means of the tower crane using a 400 litre skip.	Tower crane 500 kg capacity 21 metre max. reach - driver	
	400 cubic metres	Finishing The concrete is to be compacted by means of vibrator.	2 labourers Immersion vibrator	
Reinforcement	37 tonnes	Work Area All reinforcing steel to be cut & bent on site in the area set aside at the east corner of the site, adjacent to the existing building. The equipment in this area consists of a scaffold rack for storage of steel when delivered, and a scaffold rack for storage of steel when processed.	3 steel fixers	42
		Fixes Cutting bench, bending bench and power bender all on hard standing and covered with tarpaulin on a scaffold frame.	Power bender	

Table 2\ continued

Item	Quantity	Remarks	Labour & Plant	Time Req'd Days
	-	*Transport* Steel lifted to the required level using the tower crane.	Tower crane	
Form-work	-	*Working Area* All formwork is to be produced on site in the area outside at the S.E. end of the building. A joinery shop is to be provided containing the saw bench which will be from covered with a temporary and having a concrete hardstanding.		
	-	*Plant* Electrically powered circular saw.	Circular saw	
	-	*Transport* Formwork lifted to required level using tower crane.	Tower crane	
	-	*Foundations* Rough boarded form-work to beam and original floor slab at ground floor.	4 carpenters	6½
	-	*Columns* 12 mm plywood sheet with 100 mm × 50 mm sawn backing, secured by column clamps (see drawing no.) supported by telescopic props.	8 carpenters	

continued

Item	Quantity	Remarks	Labour & Plant	Time Req'd Days
	-	*Beams* 12 mm plywood sheet with 100 × 50 mm sawn backing to soffits and sides, supported by Telescopic props.		
	-	*Slabs* 12 mm plywood sheet with 100 mm × 50 mm sawn bearers on expanding steel floor centres.		
Mortar-Making	-	Mortar for bricklaying will be mixed in a 150/100 litre mixer located on hard standing adjacent to the T.C. or both. A bagged cement store will be located alongside.	1 labourer	
Scaffolding	-	Scaffolding will be of independent type 1 m wide with staging at 2 m intervals and be constructed of tubular steel. A ramp will be provided at the N.W. end of the building to provide access to all platform levels.	2 scaffolders	

3.0 PLANNING AND CONTROL TOOLS

There are many different analytical tools and graphical techniques for the planning, scheduling and control of the operations and resources. They range from simple check-list and bar charts, to more complicated charts, schedules and network plans, showing the interrelation of different activities.

3.1 Check-list:

The check-list is prepared to serve the required purpose and level of planning and control. This could be for either of the following:

* Time progress
* Cost
* Quality

The level of details depends on the person who will interpret the data and take the appropriate decision, this person may vary from top management to the immediate supervisors.

The works needed to be performed to complete a project are divided into a number of activities. The activities may be global or detailed in accordance with the level of

planning and control needed.

The check-list may take the form of a spread sheet or a simple table form. For each activity in the check-list, the following is to be determined:

* The duration needed to complete the activity
* The activities needed to be completed immediately before the start of the activity into consideration (immediate preceding activities). This will form the logic sequence for performing the project activities.

Also depending on the purpose of the check-list, the following may be added:

* Building method
* Resources needed (labour, material and equipment)
* Cost estimate
* Allocation of funds

Samples of check-list is given in table 3.1

Table 3.1

Activity		Quantity	Unit	Duration	Start		Finish		Remarks
No.	Description			Days	Plan	Actual	Plan	Actual	
1	Mobil.	L.S.	L.S.	5	1-12	3-12	6-12	9-12	Delay
2	Excavation	400	m^3	10	7-12	7-12	17-12	17-12	In time
3	P.C.	200	m^3	4	18-12	18-12	22-12	24-12	Delay
4	R.C. Footing	80	m^3	4	23-12	24-12	27-12		
5	Backfill	120	m^3	2	27-12		29-12		

3.2 Bar Charts

A bar chart describes graphically a project consisting of a well defined collection of tasks or activities, the completion of which marks its end. An activity is a task or closely related group of tasks whose performance contributes to completion of the overall project. A typical activity noted in a bar chart for a building project could global as

"Foundation"

or more detailed as

"Excavate

Plain concrete

Reinforced concrete

Back fill"

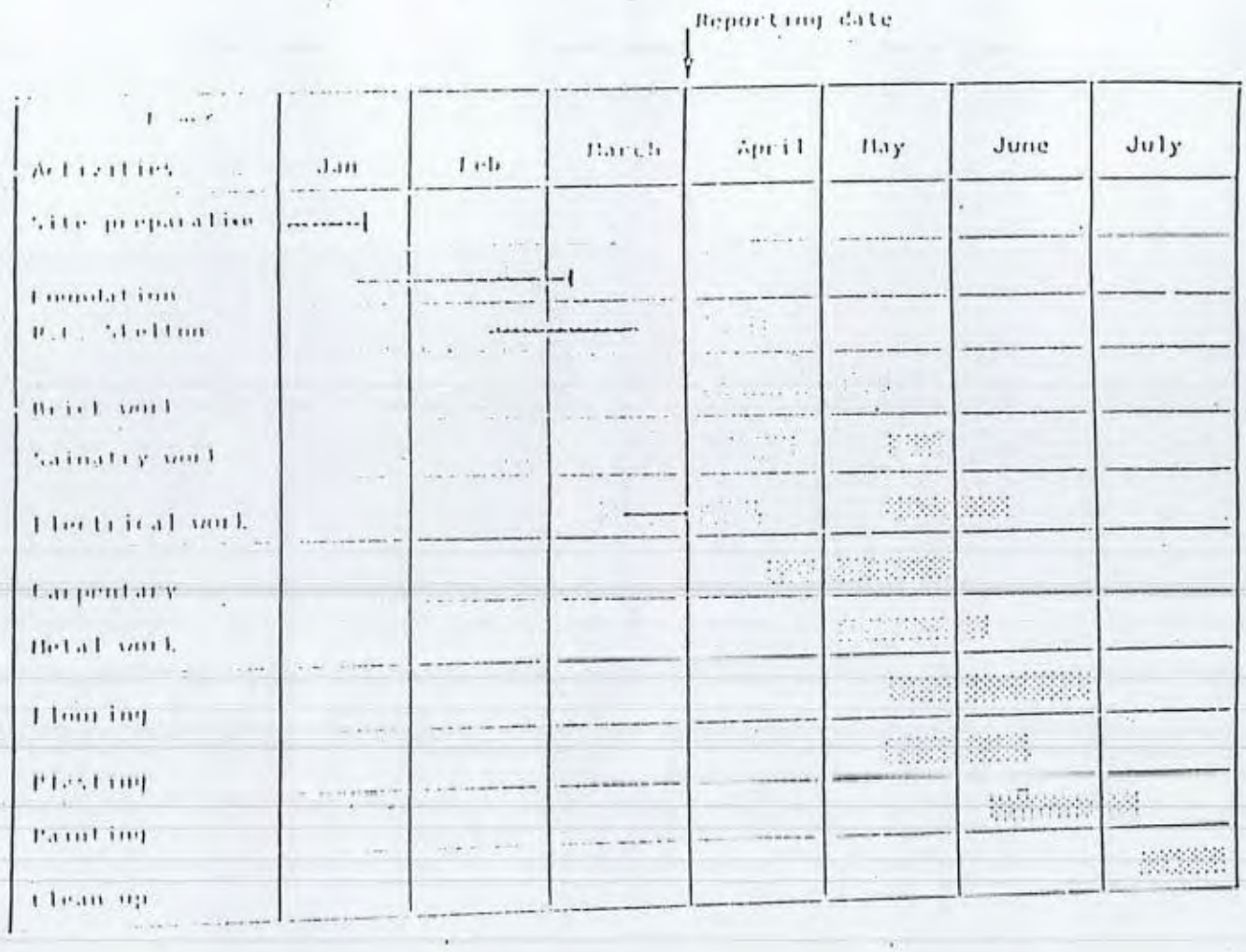
A simple bar chart for a building project is shown in fig.

3.1. Bar charts differ in the way they show planned progress on the horizontal scale and in several details of diagrammatic style. Two of the most common types will be given.

Type 1 : Linear time scaled for planning and linear progress scaled for reporting

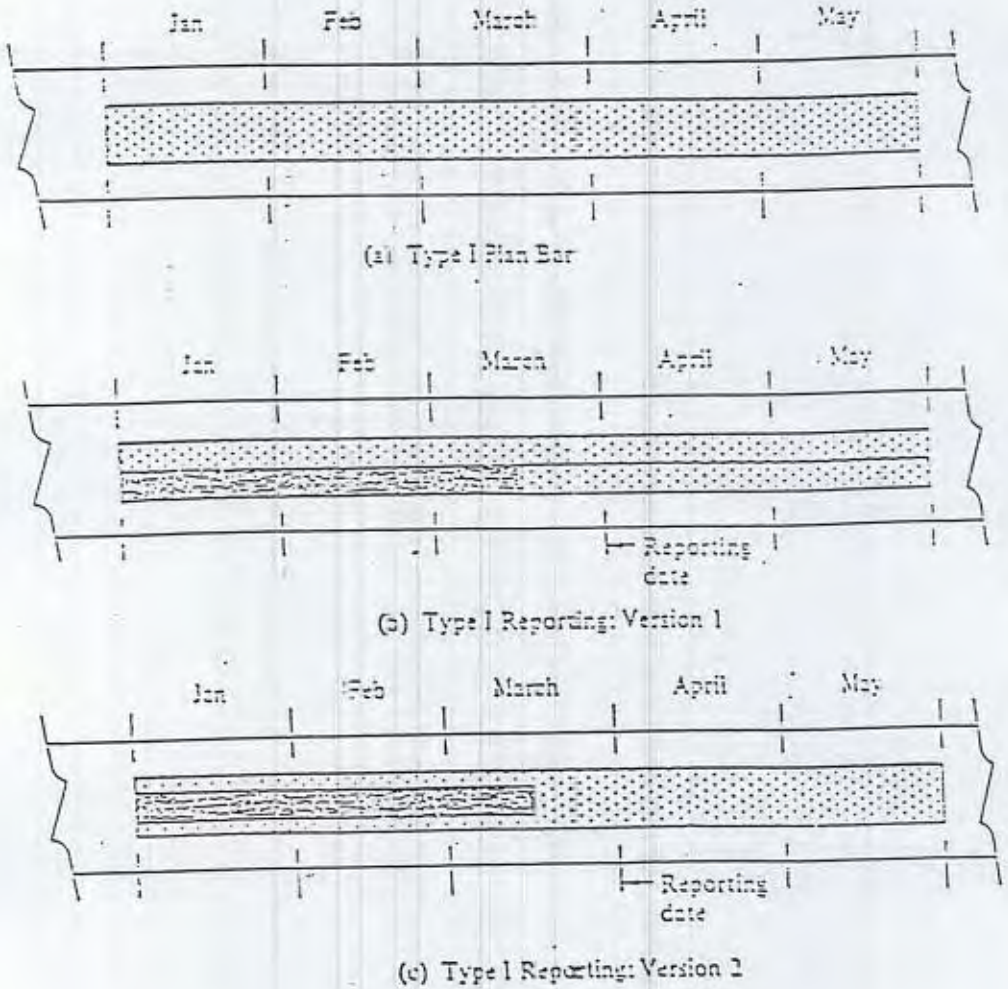
In this type, it is assumed that the progress on an activity is a direct linear function of elapsed time. Therefore, in planning, no attempt is made to show the physical percentage completion at any point on the bar representing an activity. The basic form is the open bar shown on fig. 3.2.

In order to report program, a parallel bar is sometimes placed immediately below the plan bar, and it is initially open also. Then as the job progresses, it is shaded in direct proportion to physical work completed on the activity (not necessarily elapsed time). This can be presented on the plan bar as shown in fig. 3.2 b or c. Note that the current physical progress, a work function, does not necessarily coincide with the current reporting date, a time function. By comparing the shaded reporting bar with the open plan bar and with the current date, one obtains only a rough



Planned
Actual in progress
Actual completed

Fig 3.1 Sample bar chart for a building project



(a) Type I Plan Bar

(b) Type I Reporting: Version 1

(c) Type I Reporting: Version 2

Fig.3a Type I bar chart

indication of whether the activity is behind or ahead of schedule.

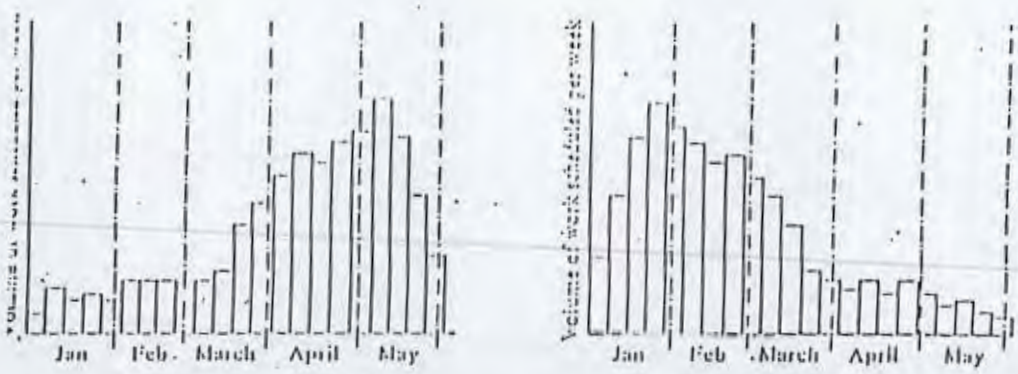
The type I bar reflects activity status accurately only when cumulative progress is indeed a direct linear function of time. However, it is quite possible that the bulk of work was scheduled late or early as shown in fig. 3.3. In this case the actual progress will not be properly indicated.

Type II : Time-scaled for planning; time-scaled for reporting

In this type, the planned cumulative progress percentage are written at the end of each basic time interval (day, week, month, .. etc.). The progress percentage may be expressed in terms of physical work completed, man hour expended, money value, etc.. Fig. 3.4 shows typical presentation of type II bar chart.

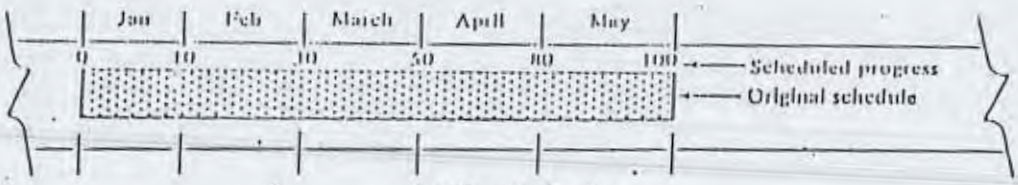
Advantages of bar charts:

* Simple graphical presentation results in easy general comprehension.
* Good form of communication in the building industry with basic understanding usually found at all levels of management.
* Require less revision and updating than more sophisticated systems.

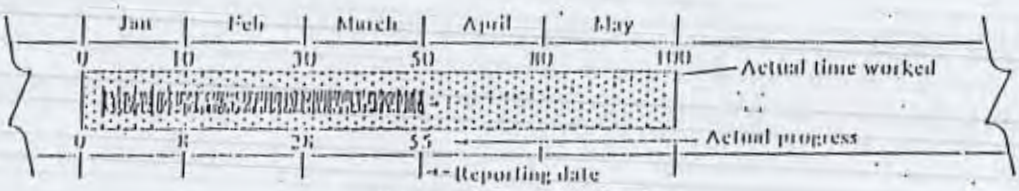


(a) Bulk of work scheduled late (b) Bulk of work scheduled early

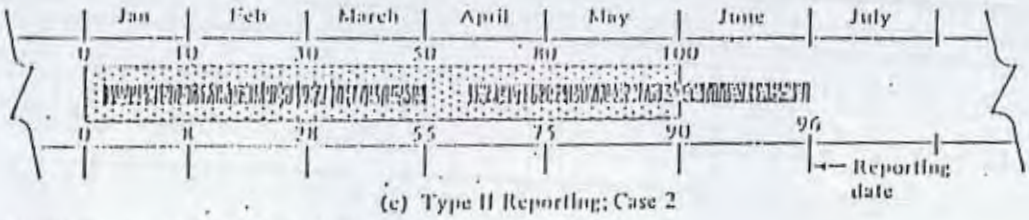
Figure 3.3 Activities scheduled with nonuniform workloads.



(a) Type II Plan Bar



(b) Type II Reporting; Case 1



(c) Type II Reporting; Case 2

Figure 3.4 Type II bar charts.

* It is especially helpful in turbulent early stages of an engineering and construction project when frequent changes and revisions are a fact of life.

Limitation of Bar Charts:

* Because of their broad planning nature, they become very cumbersome as the number of line activities, or bar increases.
* Logic sequence, interconnections and constrains of various activities in the project is not expressed in the diagram.
* It is difficult to use it for forecasting the effects that changes in a particular activity will have on the overall schedule, or even to project the progress of an individual activity.
* It is therefore limited as a control tool.

3.3 Progress Curves (S - Curves)

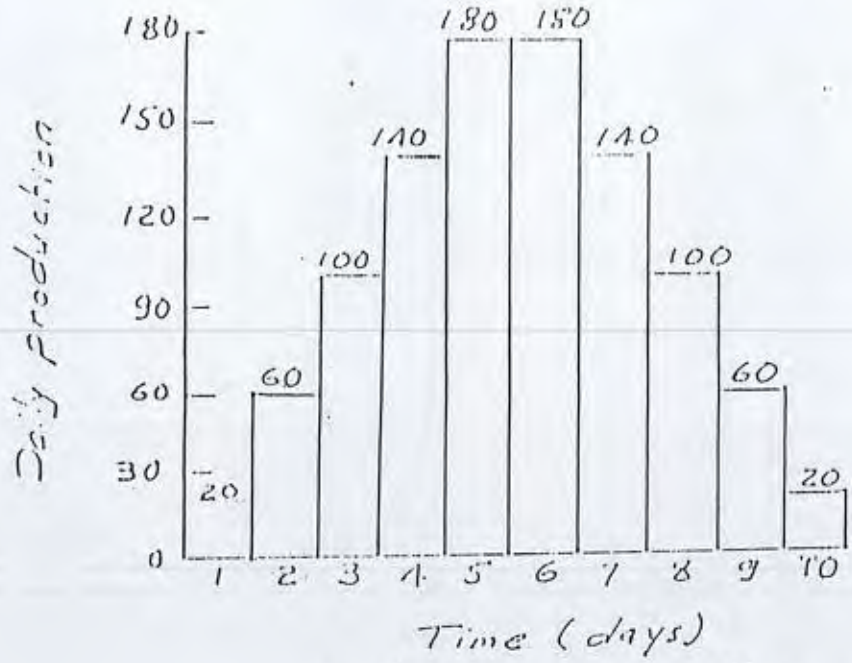
Progress curves are also called "S" curves due to its most common graphical shape. The curve shows some measure of cumulative progress on the vertical axis against time on the horizontal axis. Progress can be measured in terms of quantity surveys of work in place, man-hour expended, money expended or any other measure which makes sense. This can be

expressed either in terms of actual units (L.E., m^2, m^3, m'...) or as a percentage of the estimated total quantity to be measured.

The shape of a typical S-curve results from integrating progress per unit of time in order to obtain cumulative progress. On most projects, works tend to start slowly, build up, then taper off near the end. Fig. 3.5 shows the normal daily production pattern and the cumulative production against time S-curve.

The planned progress curve can be made from preliminary estimates, previous experience, or from properly network analysis as will be discussed later.

Once the planned progress is plotted, it can be compared with the actual progress. It is also possible to make projections based on the slope of the actual progress curve. Such projections, however, should neither be made nor interpreted without a good understanding of the reasons for deviations, if any, from planned progress, and of the current and future plans of project management. Figs. 3.6 and 3.7 show concepts of planning, reporting and comparing. Figs. 3.8, 3.9, 3.10, 3.11 show practical applications of the S-curves in Cairo Metro Project. Fig. 3.12 shows the use of the S-curve to illustrate the cash flow situation.



Daily production [Normal distribution]

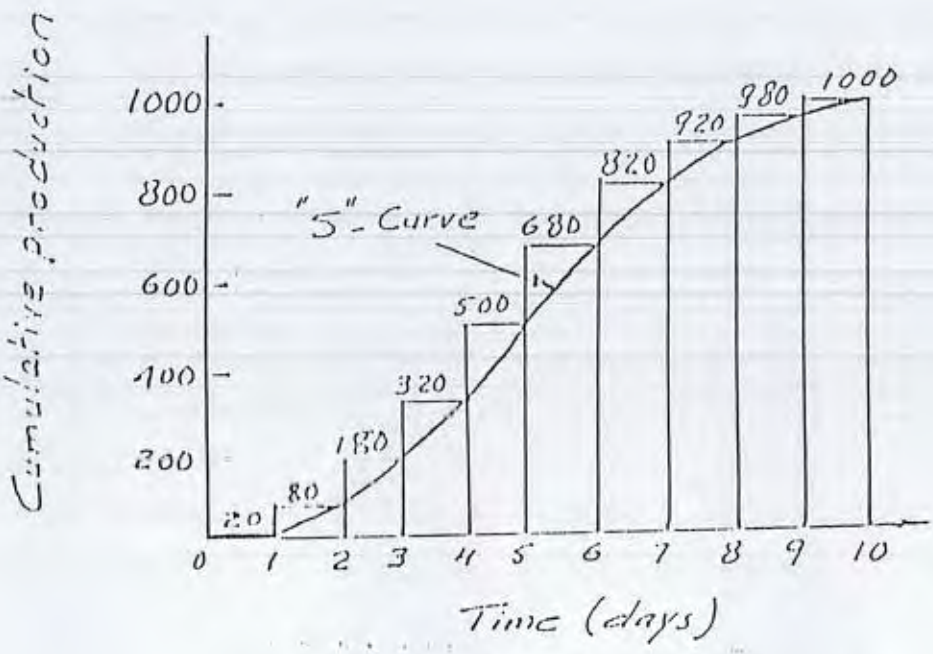


Fig. 3.5 Development of progress curve

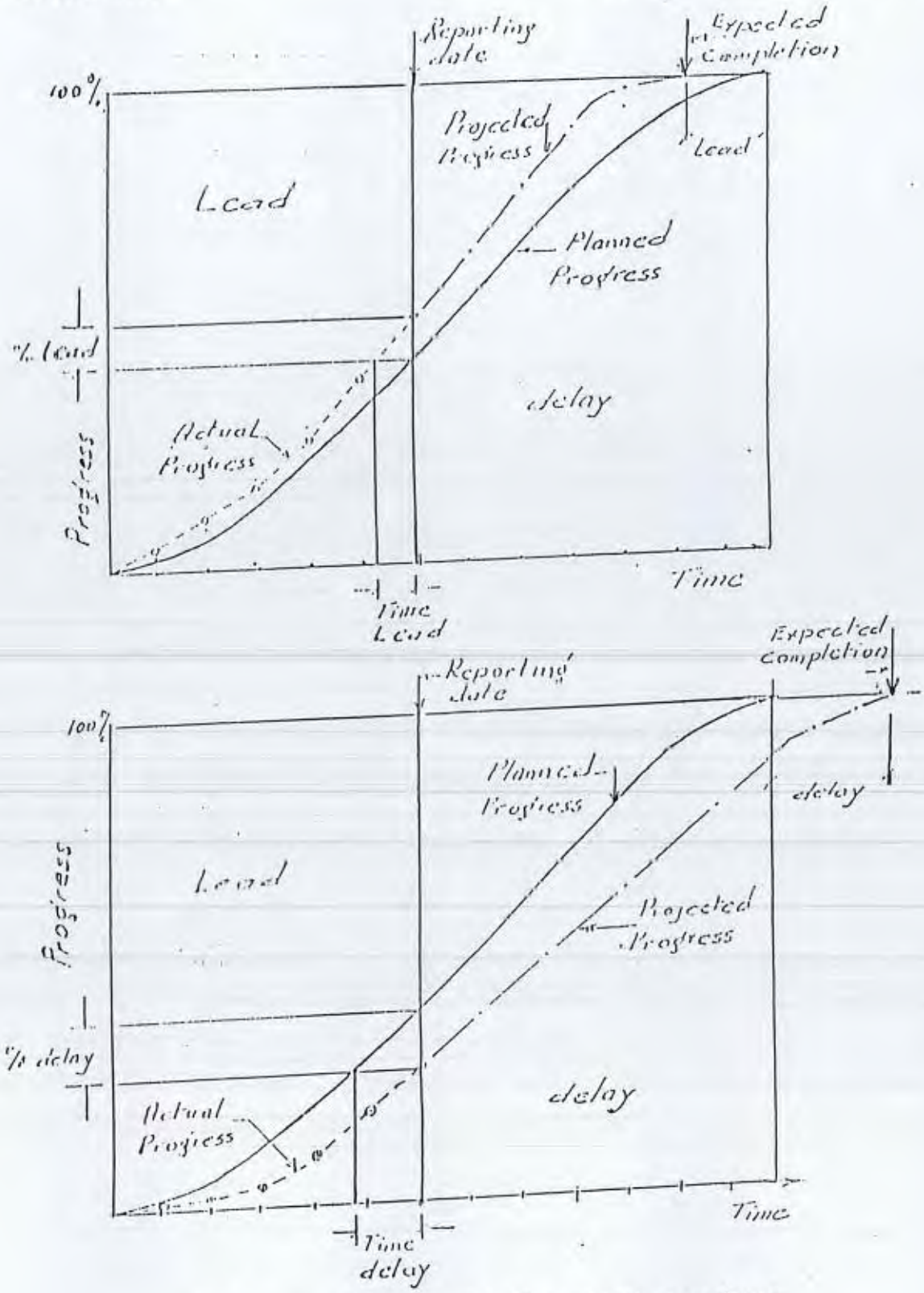
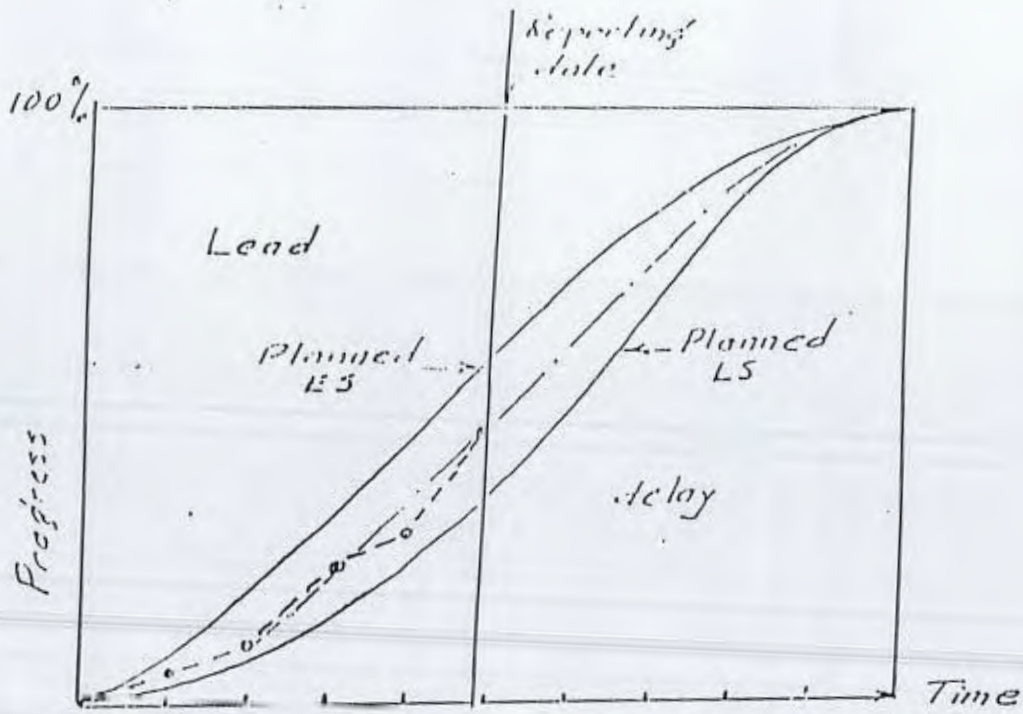


Fig. 3.6 Planning & Reporting progress



---- Actual progress within Limits of ES & LS.

Fig 3.7 Planning ES & LS, Reporting progress

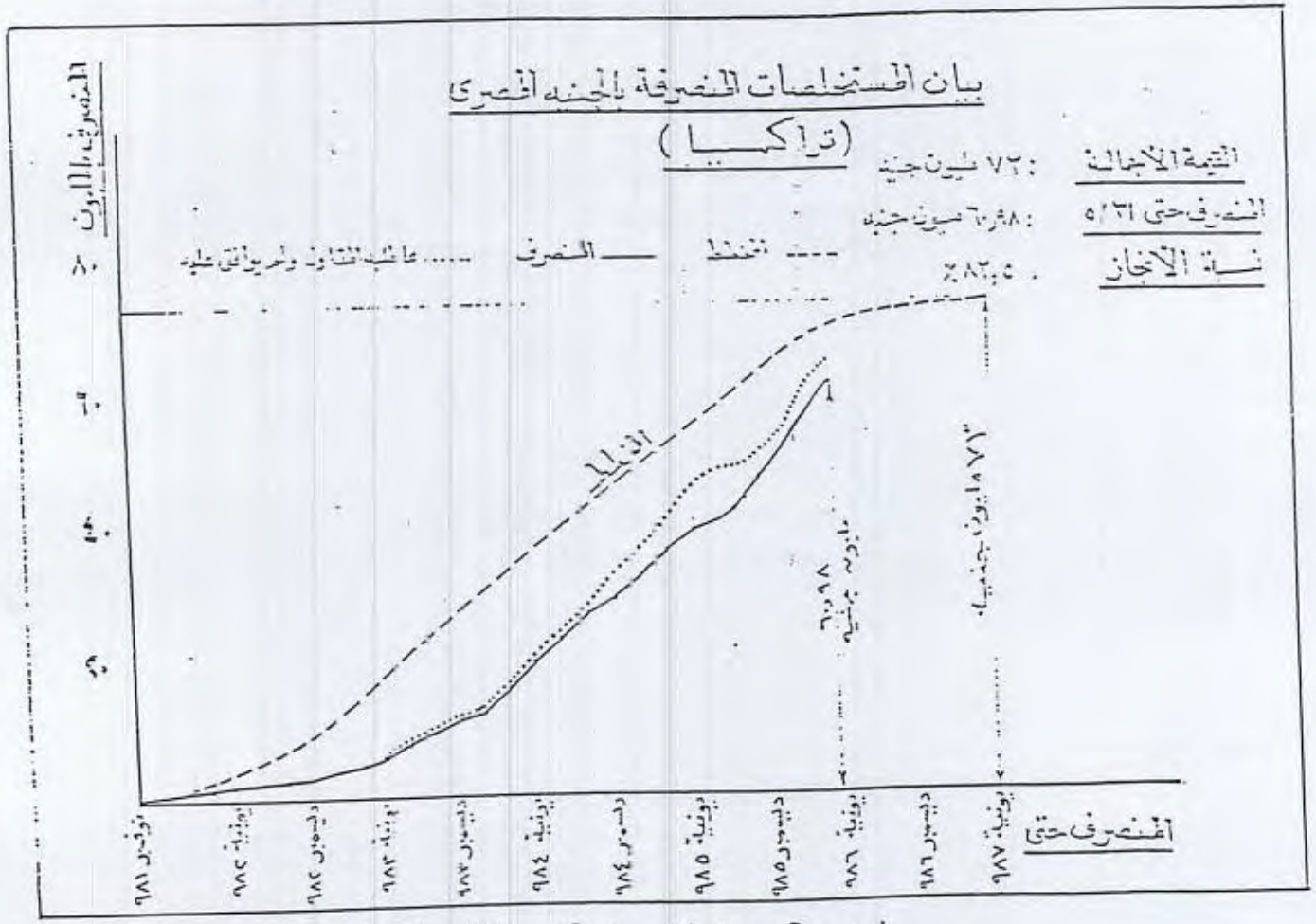


Fig. 3.8 Cairo Metro Project

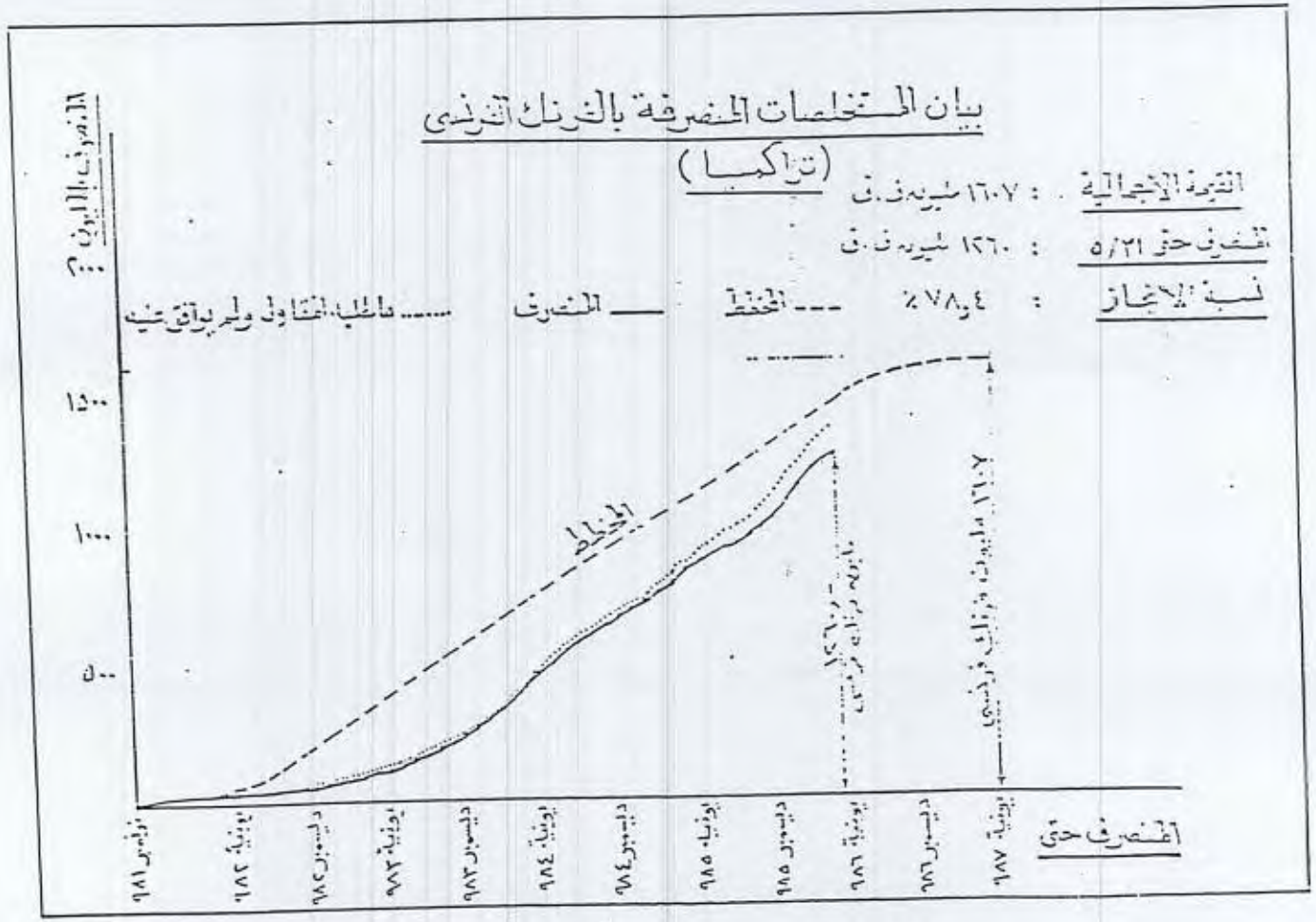


Fig. 3.9 Cairo Metro Project

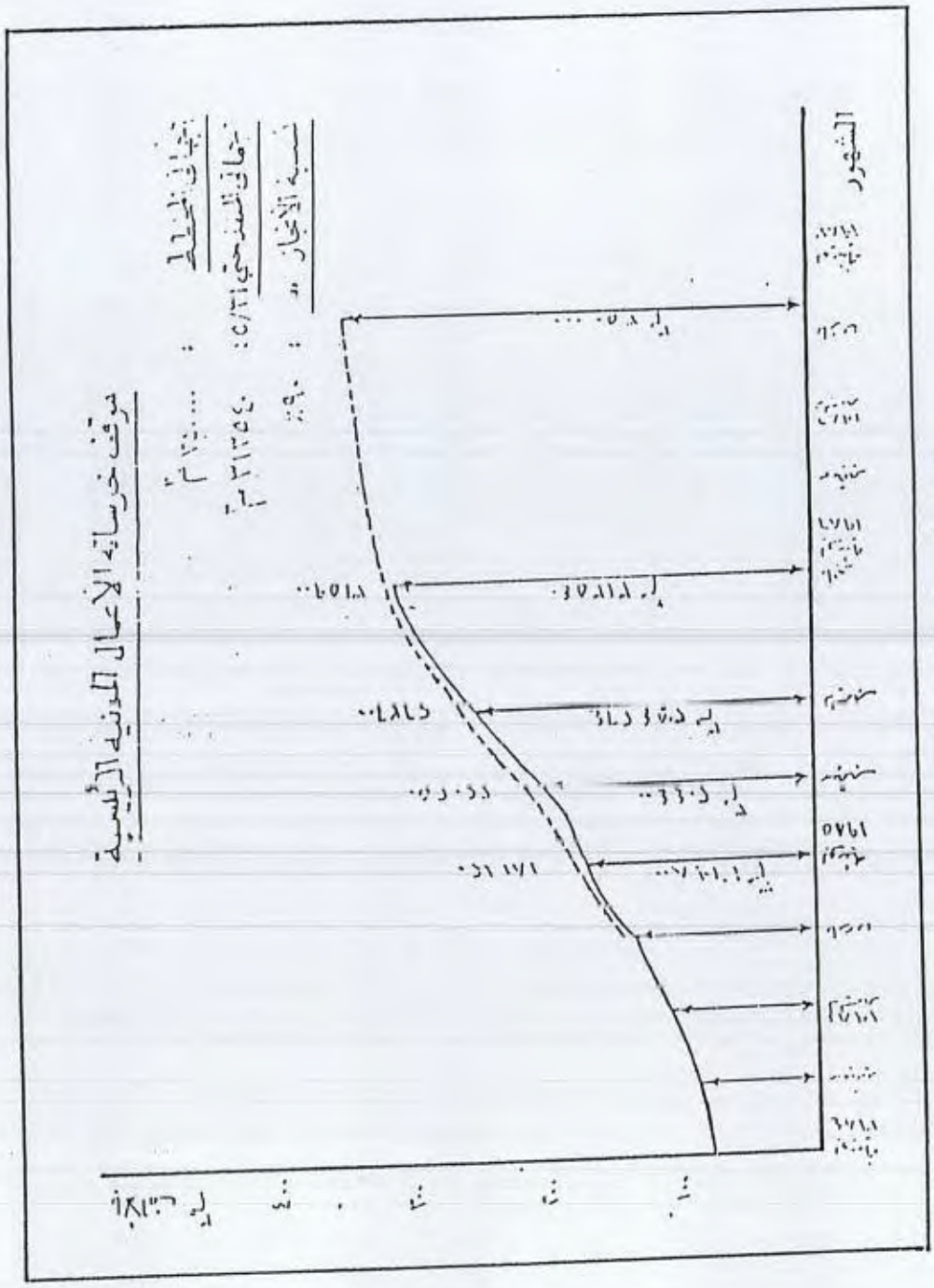


Fig. 3.10 Cairo Metro Project

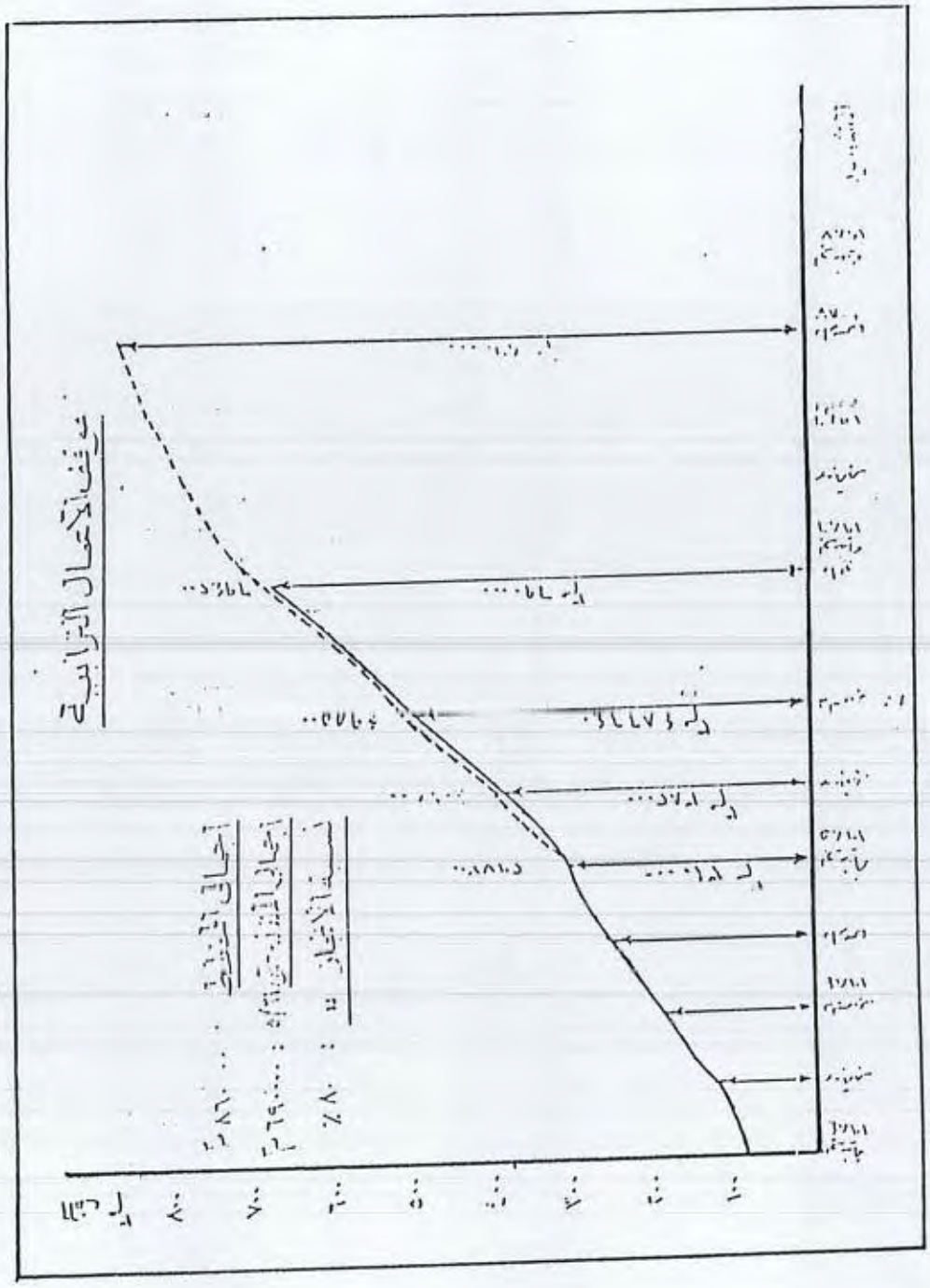


Fig. 3.11 Cairo Metro Project

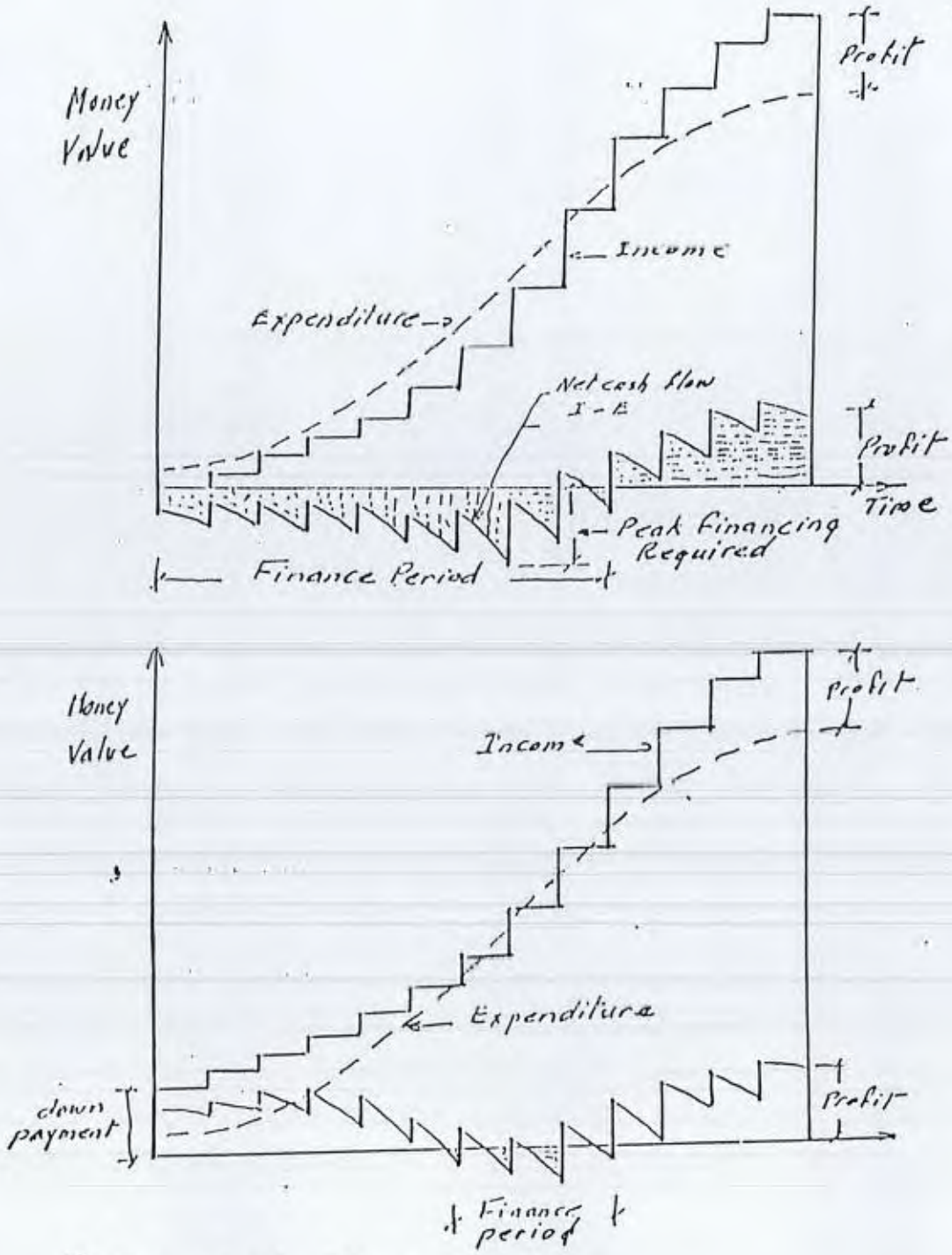


Fig. 3.12 Cash Flows

Planning by CPM

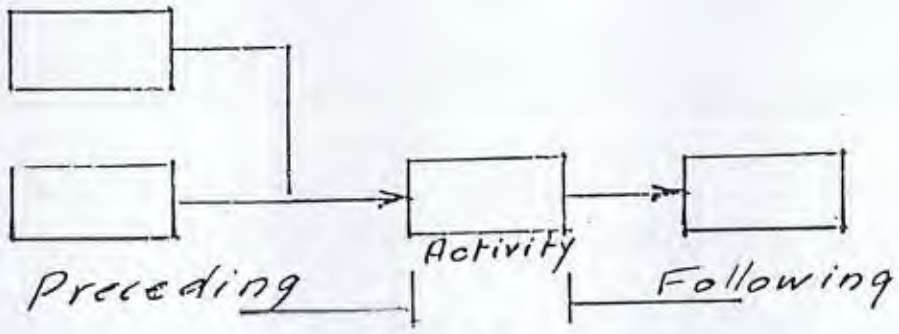
- The works needed to be performed to complete the project are divided into a number of activities.

- The activities may be global or detailed in accordance with the level of planning (Example)

- The Logic sequence for performing the different activities is determined and clearly defined by the specialists (Consultants, Site Engineers, chief site workers, other technical assistants mechanical, Electrical --- etc..)

- The adequate needed duration for each activity is also fixed.

- For each activity, the immediate preceding and following activities are clearly defined.



- For each activity, we have the following notations and relations.

Early start	ES
Early finish	EF
Late start	LS
Late finish	LF
Duration	D

- Time computation is made by both:

  Forward Path : $\underline{ES + D = EF}$

  Backward Path : $\underline{LF - D = LS}$

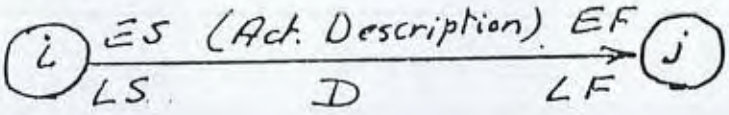
- The total float
  $= LF - EF$

- If total float is zero
  the activity is critical

- The critical path is the one giving the max. duration

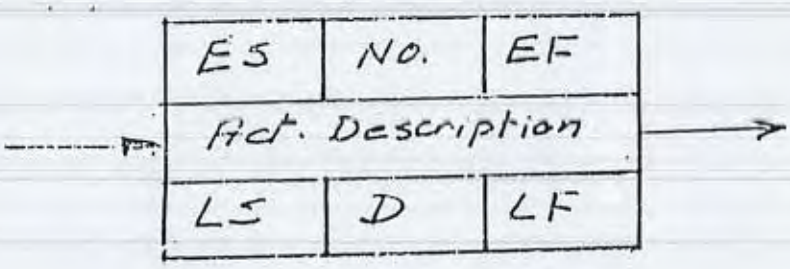
- The basic graphical presentation of the network for the activities is made by either:

  - Arrow - i-j Notations



OR

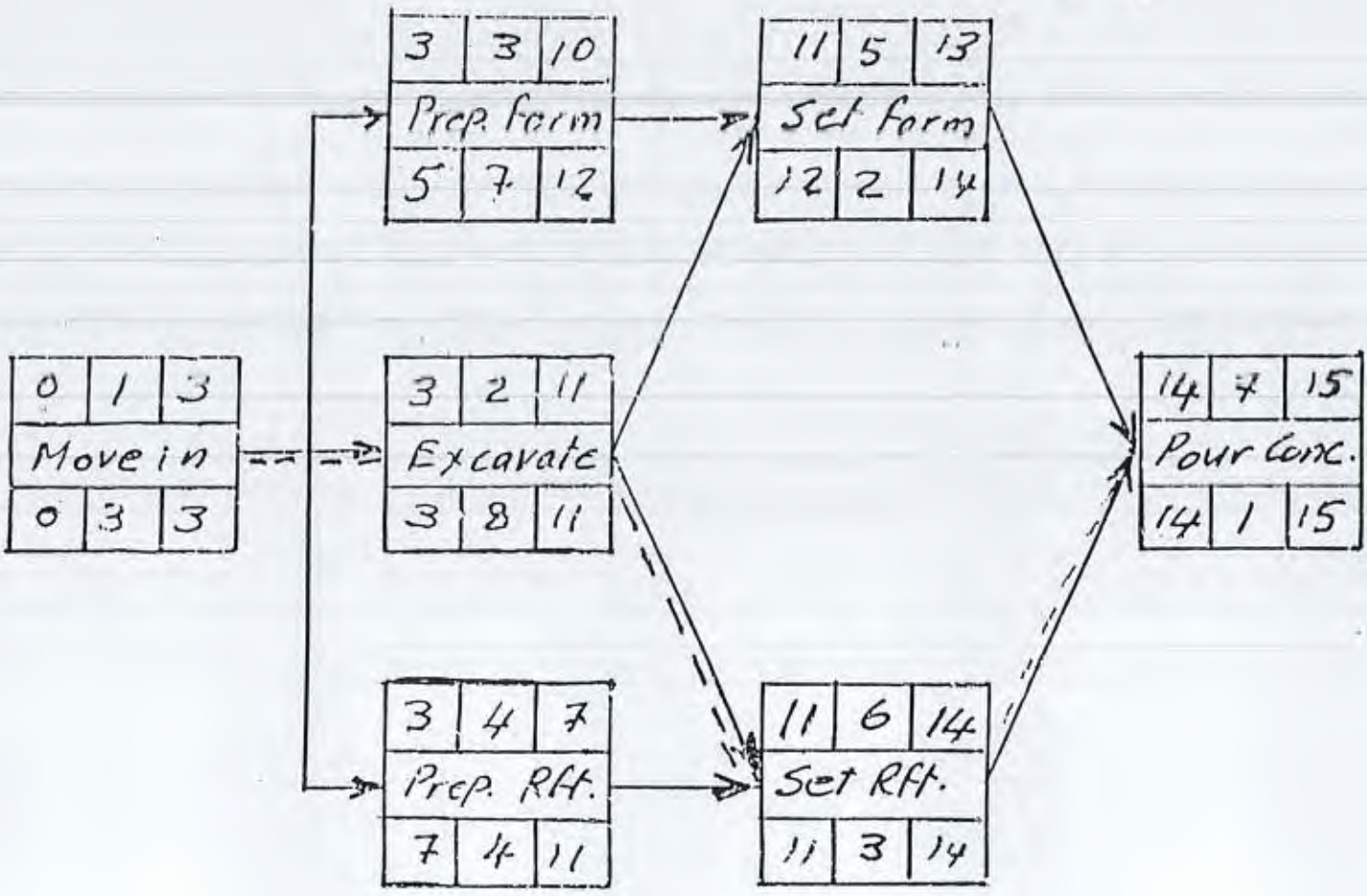
  - Precedence - Activity-on-node



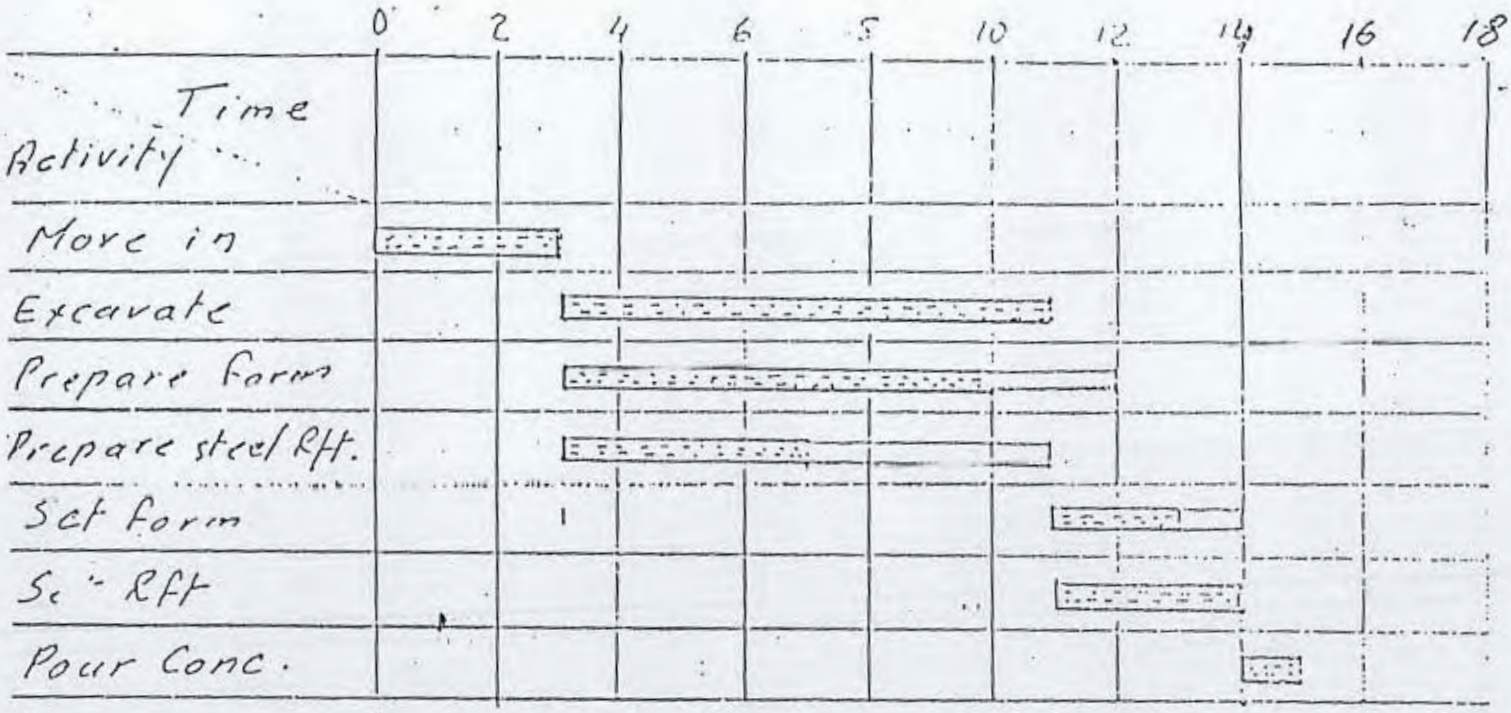
Example:

Draw the network for the given activities:-

Activities No.	Description	Duration days	Preceding Activities
1	Move in	3	—
2	Excavate	8	1
3	Prepare form	7	1
4	Prepare steel Rft.	4	1
5	Set form	2	2,3
6	Set Rft.	3	2,4
7	Pour Concrete	1	5,6
		28 days.	



Critical Path - - - - - - - -



Planned

Slack

Total Float

Activity	No.	Duration (days)
Move in	10	2
Survey and general Layout	20	1
Locate and clear (1 Km)	30	4
Excavate (1 Km)	40	5
Prepare pipes for (1 km)	50	3
Lay pipes for (1 km)	60	6
Local test for (1 km)	70	1
Foundation for Control room	80	10
Finishing Control room	90	19
Installing Control equipment	100	5
Testing control with pipe line	110	3
Clean up	120	2
Contingency	130	5

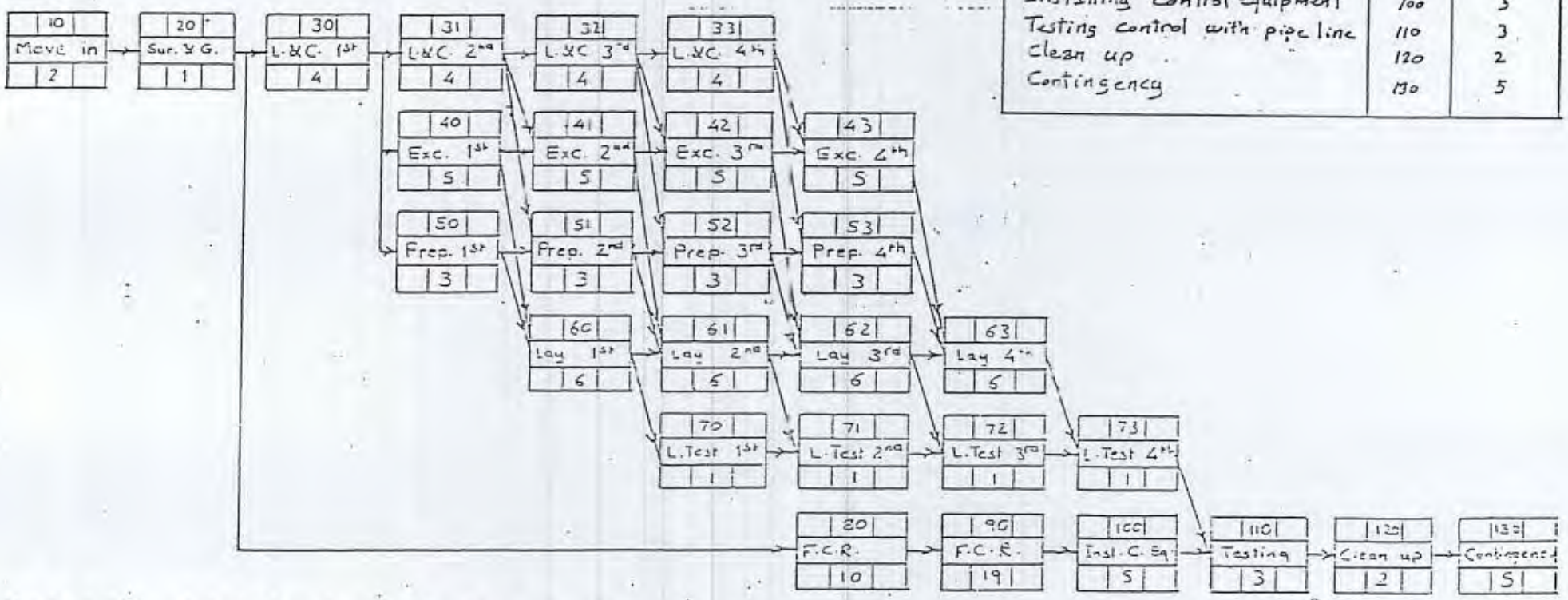


Fig (6.8) The detailed network for the relocation of 4 Km pipe line and a control room.

8.0 Resource Leveling

8-1 Introduction :

Resource leveling is the process of reducing the demand for the resources on the various project dates by re-scheduling the non-critical activities to suit the minimum resource requirement.

Leveling applies to all types of projects and is independent of the type of network being used. Common resources to be considered for leveling personnel, material, equipment and finance, to keep demands at a minimum. Also constraint on any of the resource items should be considered such as limited site storage area ....etc.

In modern projects, particularly very large ones, the need for leveling is more pronounced than in smaller projects because there is a greater economic gain in making the adjustment. In these large projects the quantity of resource is often large. Furthermore, some of the resources may be large and quite expensive to obtain and operate. Contractors working in more than one project may need to level resources in order to keep with the demand of each one of them especially if the resources were distributed among the projects. Therefore, many attempts have been made to find a satisfactory method to level resources.

A study of modern operations research techniques suggests that linear programming can be applied to solve the problem. However, due to the big number of variables in the resources of

construction projects, the use of computers will be essential. Hand calculations are not feasible in most cases to get accurate solutions for resource allocation and cost optimization. Attention has turned to the development of simplified procedure designed to give good answers while recognizing that the results may not be optimal.

The simplified procedure consists of a set of rules-of-thumb designed to progressively lead the user to a feasible solution.

There have been two approaches to these simplified solutions :

a) One sets as its objectives the minimization of the levels, and thereby the costs, of the resource while holding to the CPM project duration (Unlimited resource leveling).

b) The other takes as its objective the minimization of the duration time of the project while keeping the resource units fixed (Limited resource allocation).

B-2 Leveling Objectives :

The reasons for resource leveling can be grouped into three major categories :

First : The need to meet the physical limits of a resource. For example if limited number of workers or equipments are available, leveling will assist in reducing their daily demands so that they cope with the limits. The same thing happens when there is limited daily funds.

Second : The need to avoid the day-to-day fluctuations in resource demands. The rise and fall in the demand level is very undesirable, especially when the resource is labor. Hiring and releasing of workers on a short-term basis is troublesome, inefficient, and costly. It is not conductive to attracting and keeping top-quality workers. There are also costs that are due to work inefficiencies because new employees need time to learn their tasks and even previously employed persons need time to readjust to the working conditions of a particular job.

Third : The need to maintain an even flow of application for the resource. This appears when the project employs high-cost resource units as cranes, patching plants, ...etc. Such equipment should be able to work continuously due to their ownership costs which are involved even if they stand idle on the job site.

8-3 The traditional leveling approach :

This approach begins with the addition on every project day of the resource rates for each activity scheduled in its early start schedule position. These sums are called the daily resource sums and represent the demands for the resource over the time duration of the project.

Table (8.1) shows the early start, early finish, total float, free float, resource rates and the total resources required for each activity in the construction of reinforced concrete footing discussed previously.

II Example :

Draw the network for the given activities .

No.	Activities	Duration (Days)	Preceding Activities
1	Move in	3	--
2	Excavate	8	1
3	Prepare form	7	1
4	Prepare steel rfts.	4	1
5	Pour plain concrete	1	2
6	Set form	2	3,5
7	Set rfts.	3	4,6
8	Pour concrete	1	7

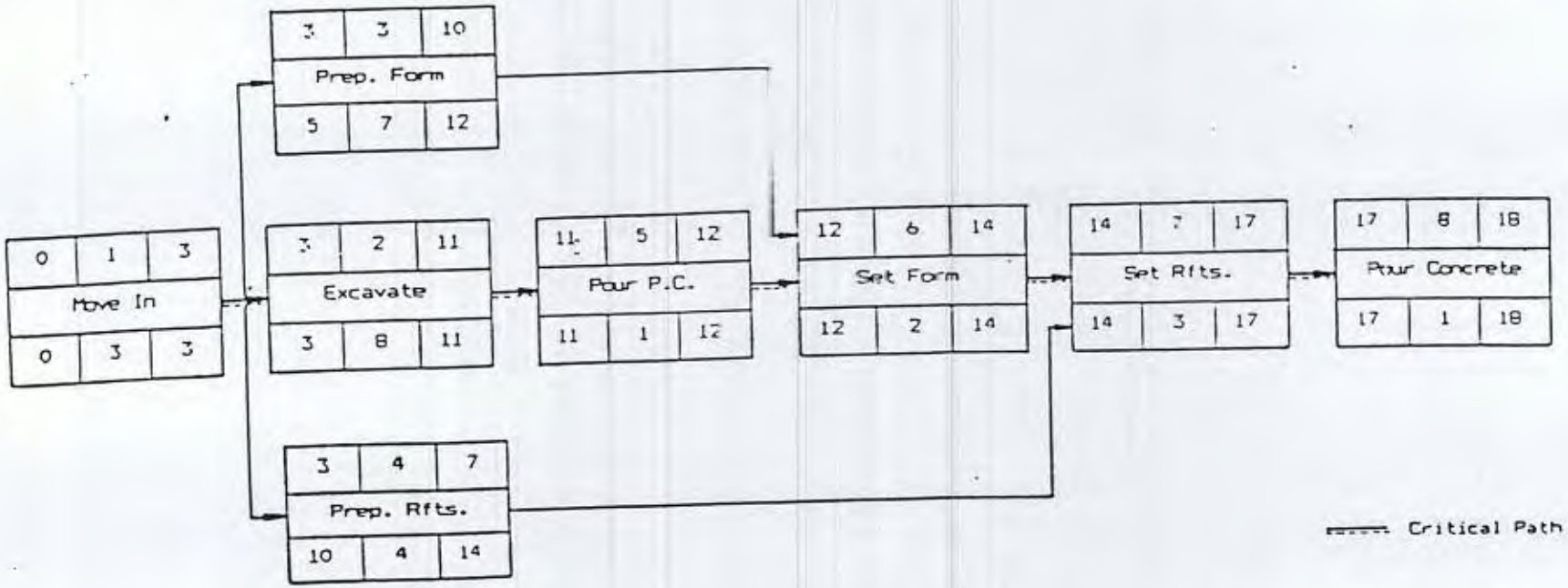


Figure (6.4) R.C. footing, precedence diagram schedule

Act. No.	Activity	Duration	ES	EF	TF	FF	Resource Rate/day	Resourc days
1	Move in	3	0	3	0	0	4	12
2	Excavation	8	3	11	0	0	8	64
3	Prep. forms	7	3	10	2	2	6	42
4	Prep. rfts.	4	3	7	7	7	6	24
5	Pour P.C.	1	11	12	0	0	4	4
6	Set form	2	12	14	0	0	4	8
7	Set rfts.	3	14	17	0	0	4	12
8	Pour concrete	1	17	18	0	0	4	4
							Total =	170

Table (8.1) R.C. Footing

8-3-1 Unlimited resource leveling :

Figure (8.1) shows the bar chart and the resource leveling for the reinforced concrete footing. Above each bar is the resource rate of the activity. As a rule of thumb in order to keep the same total duration of the project, the leveling of resources is made by moving the non-critical activities within their float. The critical activities have been plotted first in

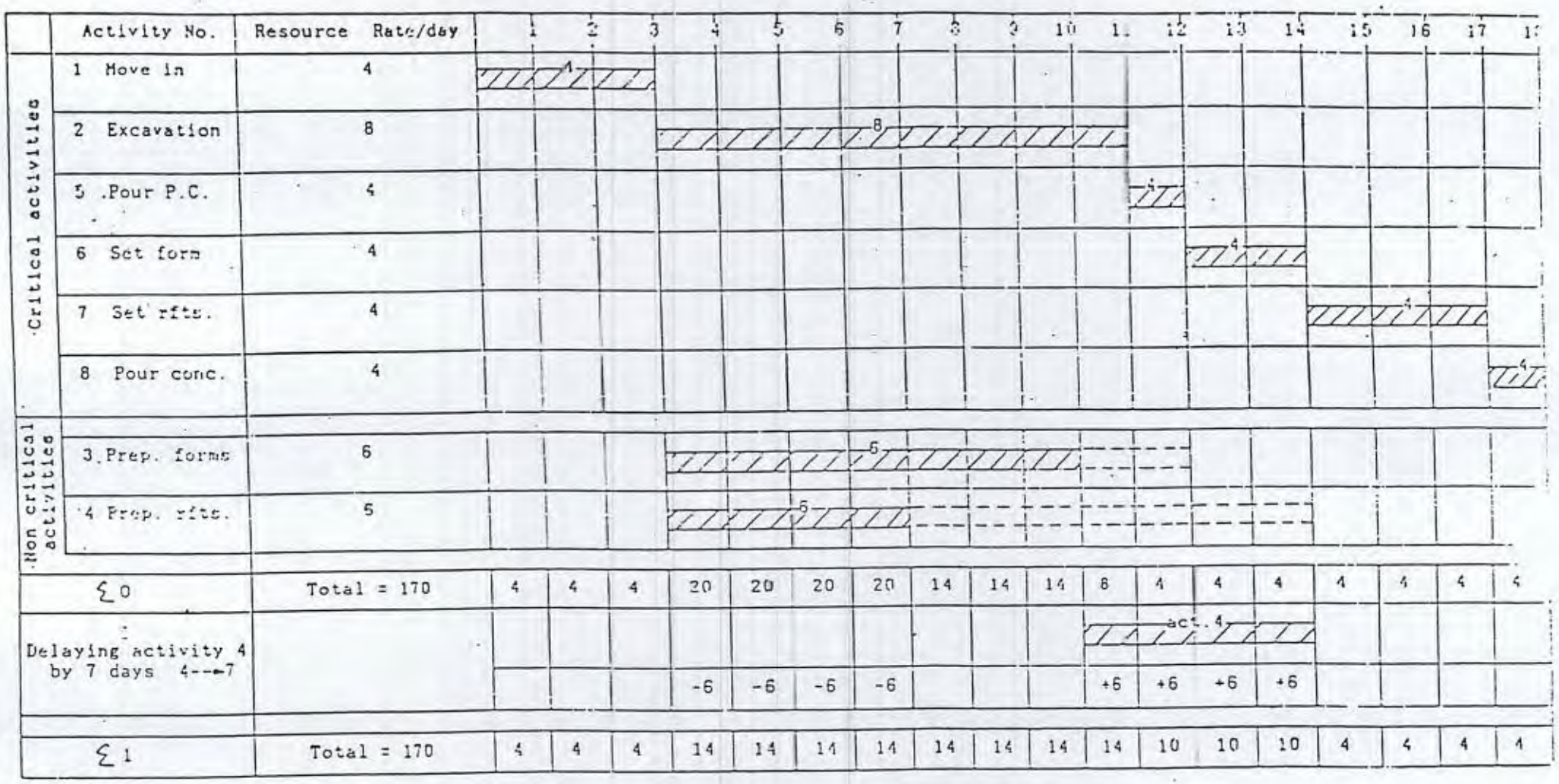


Figure (8.1) Bar chart & resource leveling for the reinforced-concrete footing

order to quickly identify the non-critical activities with floats as they are the ones which could be shifted during leveling. The daily resource sums appear in the line E0 below the bar chart. The total of the daily resource sums is 170 resource days. For an ideal resource level the sums would average 170/18 = 9.4 resource units. However, the minimum resource level must be equal or bigger than the average daily resource demand (Total resource sums / duration of the project) and/or the maximum resource rate for an activity.

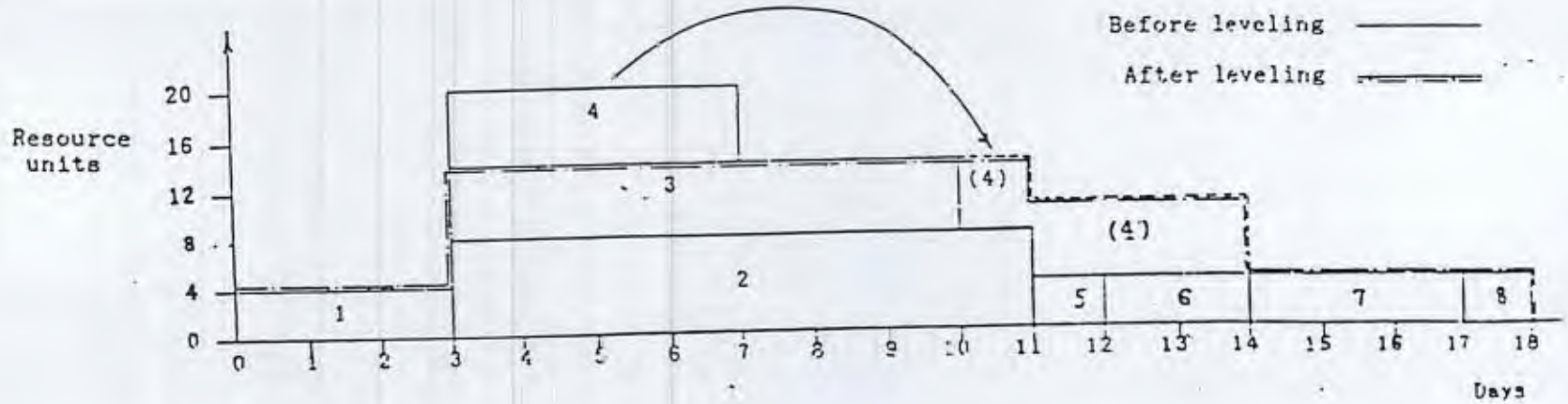
It is noticed from figure (8.1) that the maximum daily resource sums, before leveling, is 20 units and is needed in days 4, 5, 6 and 7. In order to reduce this value one or both of the non-critical activities must be shifted. Shifting activity 3 will not cause any reduction in the maximum daily resource sum in view of the fact that there will still be overlapping between the three activities 2, 3 and 4. In the same time shifting activity 4 by less than 7 days will not reduce the maximum daily resource units required. Therefore, the suitable position to give the best leveling of the resource without extending the project duration, would be by shifting activity 4 seven days. The results of this shifting is shown in line E1, where the maximum daily resource sum is reduced to 14 units.

Figure (8.2) shows another presentation for resource leveling, where it shows the bar chart and resource histogram for the same example.

8-3-2 <u>Leveling under limited resource allocation</u> :

Figure (8.3) shows the bar chart after resource leveling for the same example, but under constraint that the maximum daily resource is equal to 12 units. This results that more leveling is

	Activity No.	Resource Rate/day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Critical activities	1 Move in	4	1																	
	2 Excavation	3				3														
	5 Pour P.C.	4											1							
	6 Set form	4												4						
	7 Set rfts.	4														4				
	8 Pour conc.	4																	1	
Non critical activities	3 Prep. forms	6				6														
	4 Prep. rfts.	6				6														
Σ 0		Total = 170	4	4	4	20	20	20	20	14	14	14	8	4	4	4	4	4	4	4
Delaying activity 4 by 7 days 4---→7														4						



Efficiency factors

In building operations, labour and equipments do not work 60 minutes an hour. the theoretically computed cycle time which represents ideal conditions, needs to be corrected by working efficiency depending mainly on

job conditions

management conditions

Job efficiency factors

Job efficiency factors pertain to the physical conditions of the job apart from type of materials to be handled. These factors can be classified in the following categories:

1- Site topography and working conditions including working space available and factors like depth of cut, distance and grades for material movement.

2- Surface and climate conditions (drainage of surface and ground water ....).

3- Geology of the area affecting the nature of soil and method of excavation.

4- Specifications of the work including the sequence of construction and testing procedure (ex. of back fill ....)

Management efficiency factors

The management efficiency factors pertain to stability of organizational set up and efficiency of operation of staff and workmen. These factors include :

1- Personnel who operate the equipment, their honesty, diligence and skill, as also the incentive plans of management.

2- Selection of equipment and its operation.

3- Job planning, including plant layout, supervision and maintenance of equipment, roads, communications etc. ...

From a study in USA by frank A. Nikrik the range of efficiency factors were grouped in the following matrix

	Management factors			
Job factors	Excellent	Good	Fair	Poor
Excellent	0.84	0.81	0.76	0.70
Good	0.78	0.75	0.71	0.65
Fair	0.72	0.69	0.65	0.60
Poor	0.63	0.61	0.57	0.52

From a study for actual working hours for wheel and track type equipment the following efficiency factors were recommended :

Type of equipment	Working hour	Efficiency factor
Day operation		
Track type	50 min/hour	0.83
Wheel type	.45 min/hour	0.75
Night operation		
Track type	45 min/hour	0.75
Wheel type	40 min/hour	0.67

From a study in USA on productivity the time utilization in a waste water project for labours was as follows :

Working hours / Week	40.00 hr.	
Productive hours	12.80	32.0 %
Lost hours were due to		
Lack of materials	6.27	15.7 %
Lack of tools	3.80	9.5 %
Access to work	3.29	8.2 %
Lack of instructions	2.14	5.3 %
Waiting inspection & Redoing of work	11.00	27.5 %
Absentecism	0.70	1.8 %
	---	---
	27.20	68.0 %