Planning and Control Techniques For Construction Projects

Summery Lecture

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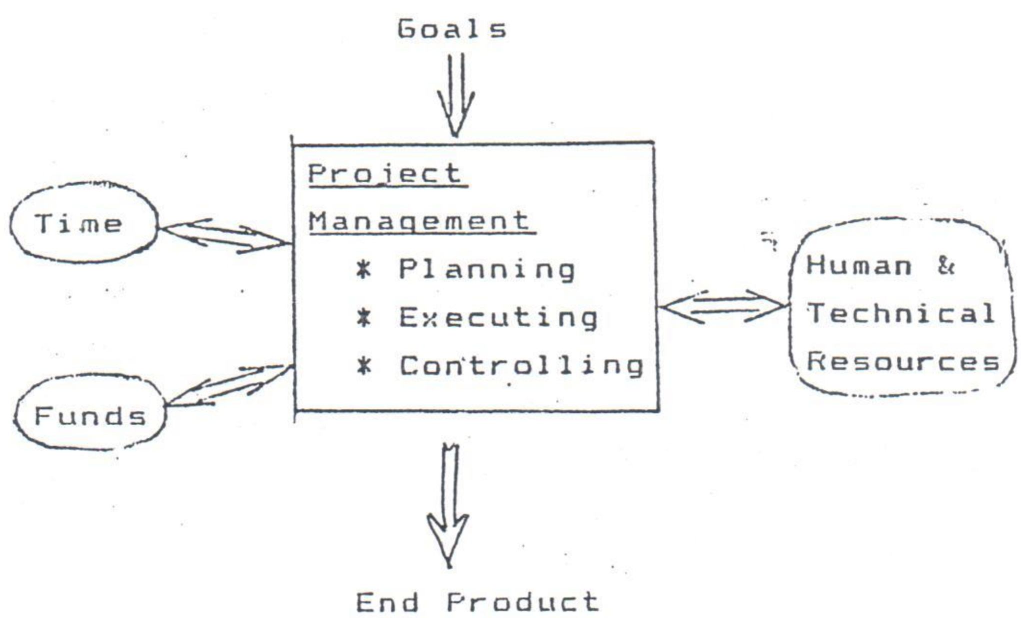
Construction Planning and Organization

1.0 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 technical and human resources.



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

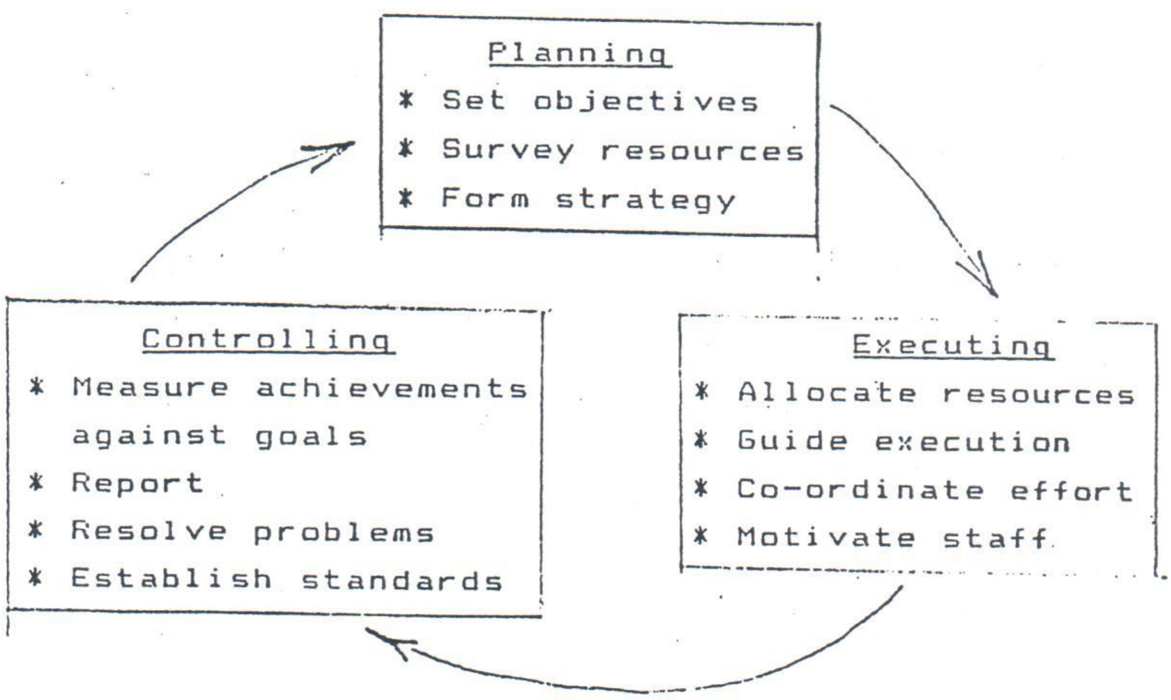
* Basic assumptions change.

* Original estimates are no longer valid.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 principle aim should be to achieve the intended objectives of the project in the best possible way and with the best possible result.

The following diagram shows the main activities of the dynamic cycle of the management process.

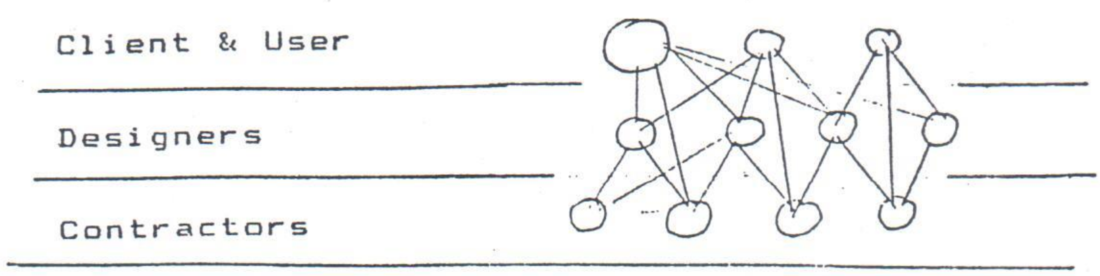


1.1 Organizations and Contracts:

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
* Professional 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.



OR

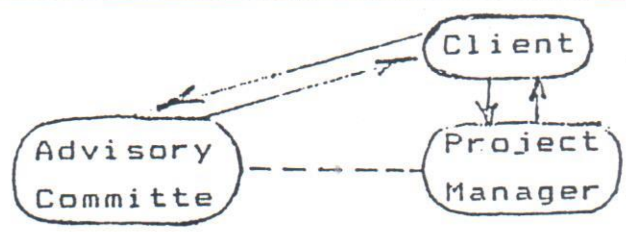


fig.1&2 show samples of organizations & flow charts

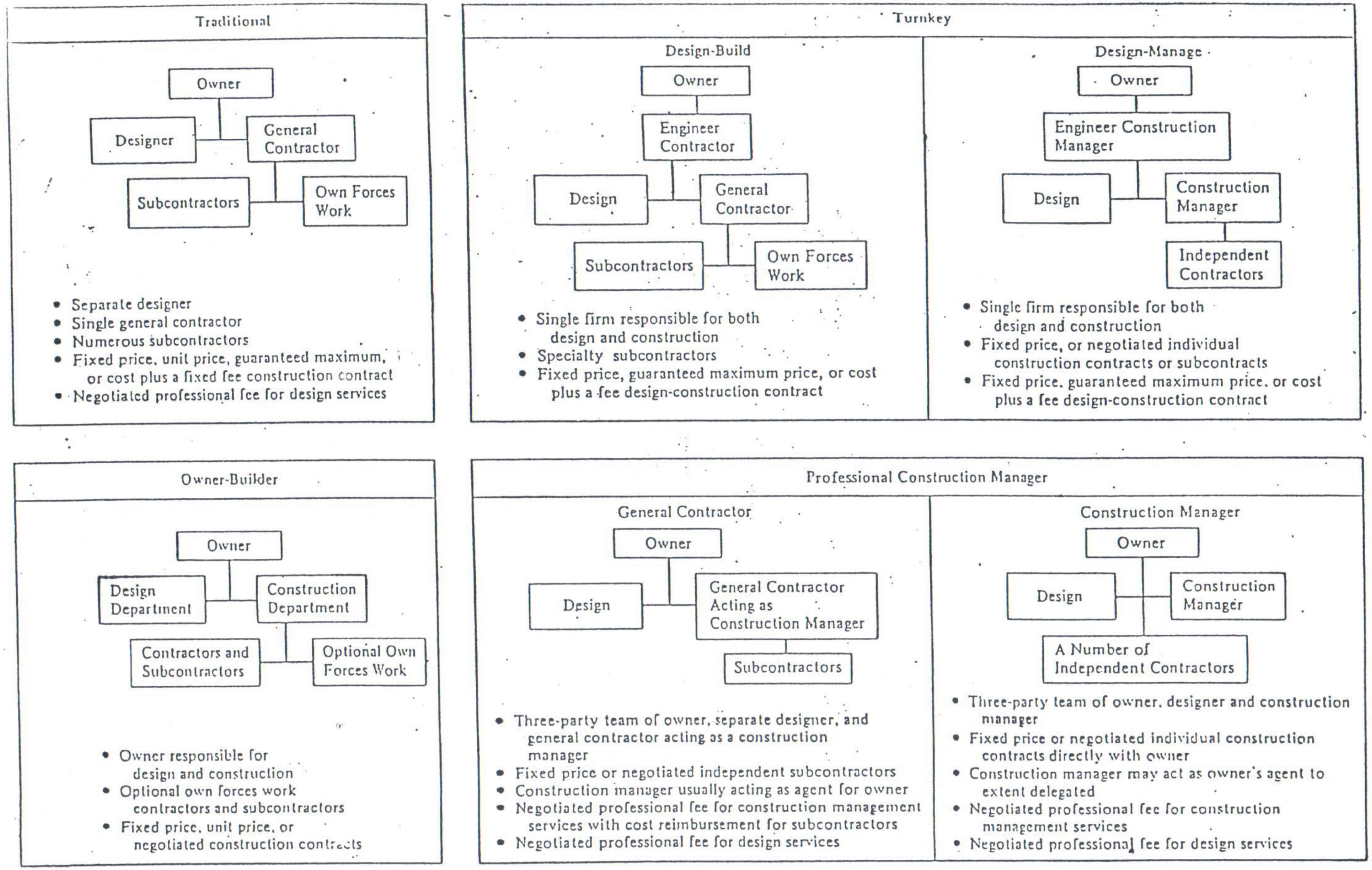


Figure 1 Alternate contractual approaches.

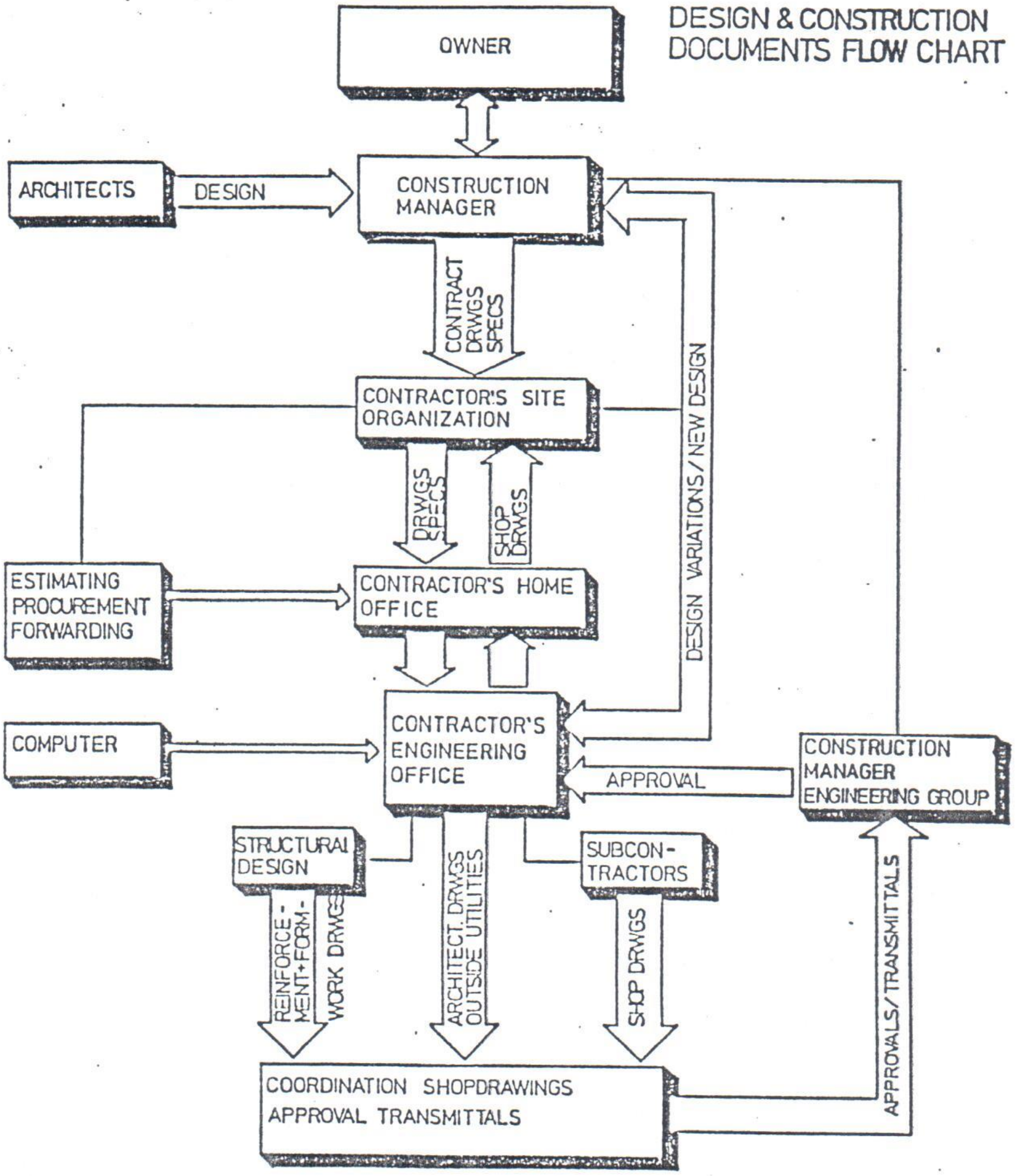
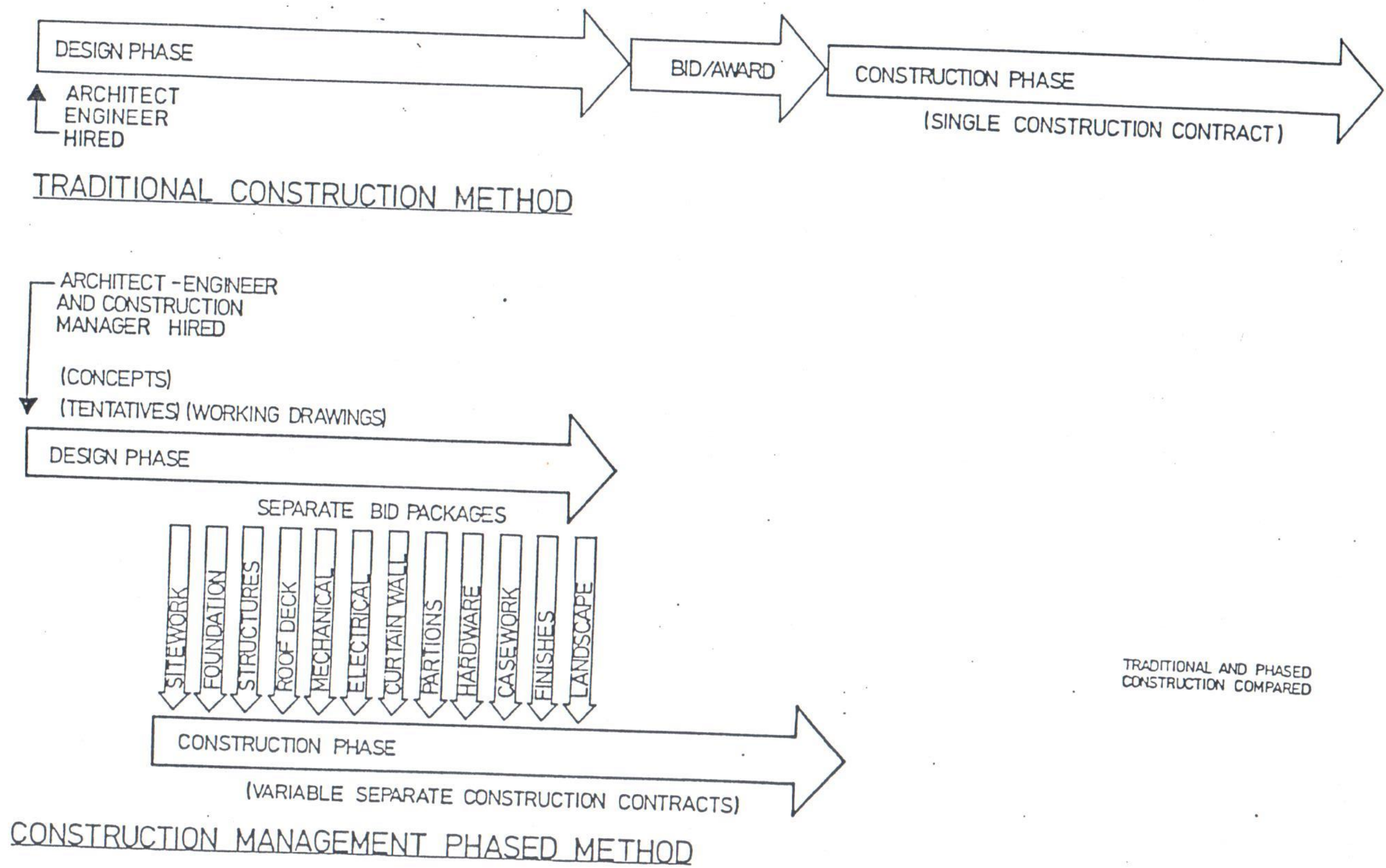


Figure 2

DESIGN & CONSTRUCTION DOCUMENTS FLOW CHART



TRADITIONAL AND PHASED
CONSTRUCTION COMPARED

Planning and Control Techniques

.0 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. For this they will need the fullest understanding and control process and all practical tools that can be put at their disposal.

2.1 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, and short term planning on site.

Pre-tender planning is done to allow the estimator to arrive at an estimate of cost 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 overall programme should not break the operations down excessively or it will become unrealistic.

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

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

Samples of pre-tender method statement
is given in fig.3

Fig. 3 Pre-tender Method Statement

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 access via 1 metre wide gate in hoarding (position shown on site layout drawing).	–	–
Accommodation	–	All accommodation to be firm's standard sectional huts (position shown on site layout drawing) Toilets provided in form of mobile unit.	2 carpenters	8
Temp. Services	–	Provide electrical, water & W.C. services as shown on site layout drawing.	3 labourers	3
			Plumber & mate	3
			Electrician & mate	2
Excavation	105 cubic metres	*Reduced level dig* Front bucket of J.C.B. 4 – easy going.	J.C.B. 4 & operator & 3 labourers	1
	140 cubic metres	*Tie beam trenches* Rear back-acter bucket of J.C.B. 4. *Internal drain trenches* 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 – within works.	2 lorries & drivers	5
General Hoisting & Transportation	–	The tower crane will be used for lifting all materials until frame is complete when it will be replaced by a 750 kg platform hoist which will be built adjacent to T.C. before it is removed. N.B. all bricks & blocks	Tower crane & driver	80
			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	420 cubic metres	*Mixing* The concrete will be mixed in a 300/200 litre electrically powered reversing drum mixer, having a built-in weigh batcher, the aggregate being delivered to the weigh batcher by a hand scraper. All 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
	420 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	–
	420 cubic metres	*Placing* The concrete is to be compacted by means of vibrator.	3 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	62½
		Plant Cutting bench, bending bench and power bender all on hard standing and covered with tarpaulin on a scaffold frame.	Power bender	

Fig.3 *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 set aside at the S.E. end of the building. A joiners' shop to be provided consisting of a scaffold tube frame covered with a tarpaulin 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 bases and edge of floor slab at ground floor.	4 carpenters	63½
	–	*Columns* 12 mm plywood sheet with 100 mm × 50 mm sawn backing, secured by column cramps (see drawing no.) supported by telescopic props.	8 carpenters	

Fig. *continued*

Item	*Quantity*	*Remarks*	*Labour & Plant*	*Time Req'd Days*
	–	*Beams* 12 mm plywood sheet with 100 × 50 mm sawn backing to soffite and sides, supported by Telescopic props.		
	–	*Slabs* 12 mm plywood sheet with 100 mm × 50 mm sawn bearers on expanding steel floor centres.		
Mortar-Mixing	–	Mortar for bricklaying will be mixed in a 150/100 litre mixer located on hard standing adjacent to the T.C. or hoist. 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	

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 planand there must be a reasonable degree of slack built into the plan.
* It should provide proper standards of expectations, by proiding identified and quantified mile stones along the way so that easy control may be exercised.

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 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.

U The information s ystem 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.

5 A model for project planning and control :

The flow chart in fig.4 models the operations, flow of information, and decision making process characteristic of a feedback control system appropriate for a medium to large sized engineering

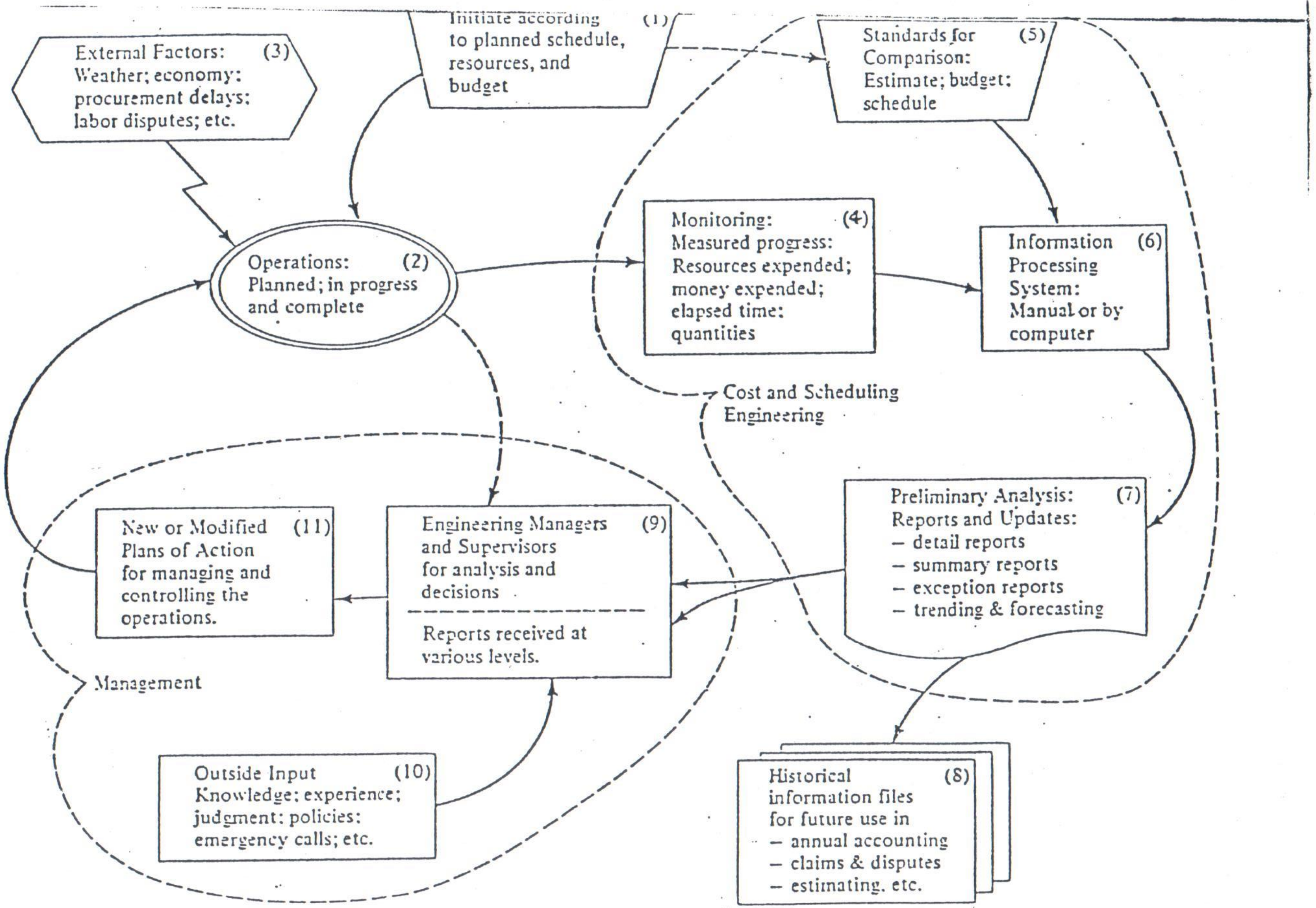


Figure 4 Flow chart of project control system *(From Boyd C. Paulson, Jr.,* "Concepts of Project Planning and Control," Journal of the Construction Division, *ASCE, vol. 102, no. CO1, March 1976, p. 71.)*

construction project. It has been designed to reflect the objectives stated in the previous section.
Note that 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 inerplay between all aspects of the system: concept; design; procurement; and construction. This approach is especially prevalent in large heavy-industrial projects, such as 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: In the flow chart, the project is initiated according to a predefined plan(box 1) and operations get underway (box 2). The plans also become reference standards for control purposes (box 5). As operations continue, external factors (box 3) such as recently imposed standards or newly available materials in design, or bad weather, procurement delays, foundation excavation problems, or even unexpectedly good conditions on thesite, may cause the course of operations to differ from the plan, or may provide opportunities for improving on the plan. The operations underway generate indicators or progress (quantities in place, elapsed time, money expended, or resources consumed) which may be measured (box 4) and fed as data into a system (box 6) to produce information for decision makers.
This information processing system refers to planned standards (box 5), such as schedules and budgets, to show deviations, variances, and trends. The information is analyzed and made available through reports (box 7), which may be stored for future

reference (box 8), or given to engineering managers and supervisors for their further analsis and decision making (box 9), or both. They combine aand compare this information with their own sknowledge, experience, policies, and other qualitative and quantitative information and judgment (box 10) in order to produce new or modified plans for continuing and controlling the project operations (box 11).

Feedback This is a feedback control system, and it operates continuously through out 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 supervisors can receive accurate and up-to-date information in time to make decisions and formulate plans of action so as to have maximum im pact in controlling those operations which are generating the information in the first place.

On a small project, it is possible to short-circuit the path from box 2 to box 9 and provide direct feedback.

On large projects, some improvement could be made through computer applications. This is mainly to improve and expedite the operations represented by boxes 4, 5, 6, and 7 on the flow chart in order to help resolve difficulties and improve the quality of information available to decision makers.

3.0 Planning and Control Tools

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

3.1 Check-list :

The check-lisst 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 interprete the data and take the appropriate decison, this person may vary from the 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, materials, equipments)
* Cost estimate
* Allocation of funds.

Samples of check-list is given in fig.5

.2 Bar Charts:

A bar chart graphically describes 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 tyspical 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.6

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 I : 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.7a

In order to report progress, a parallel bar is sometimes placed immediately below the plan bar, and is initially open also. Then as the job progress, it is shaded in

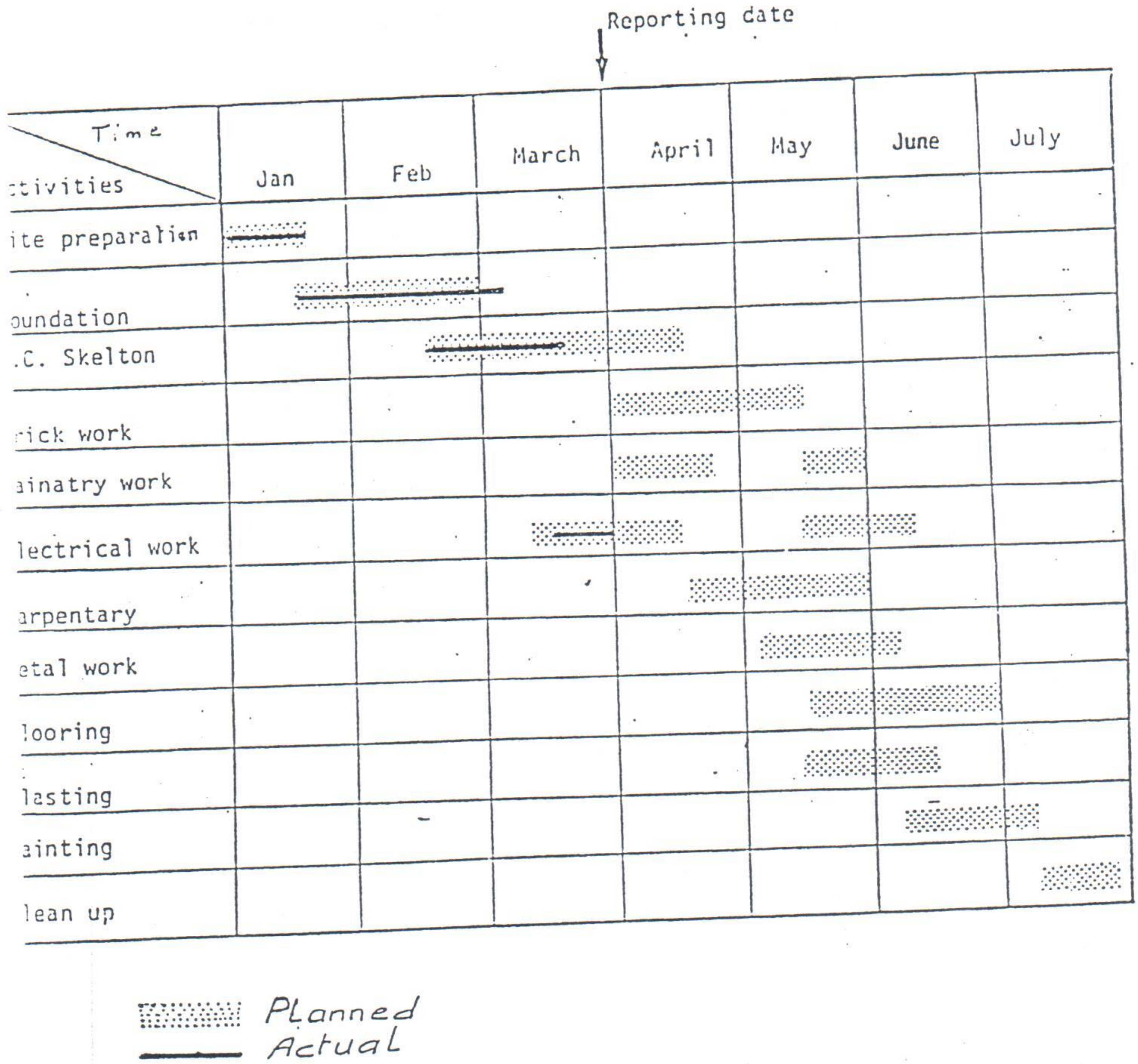
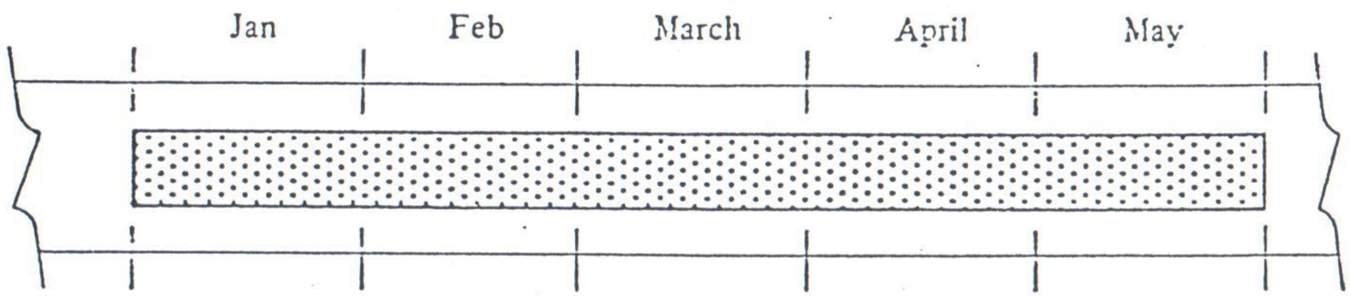
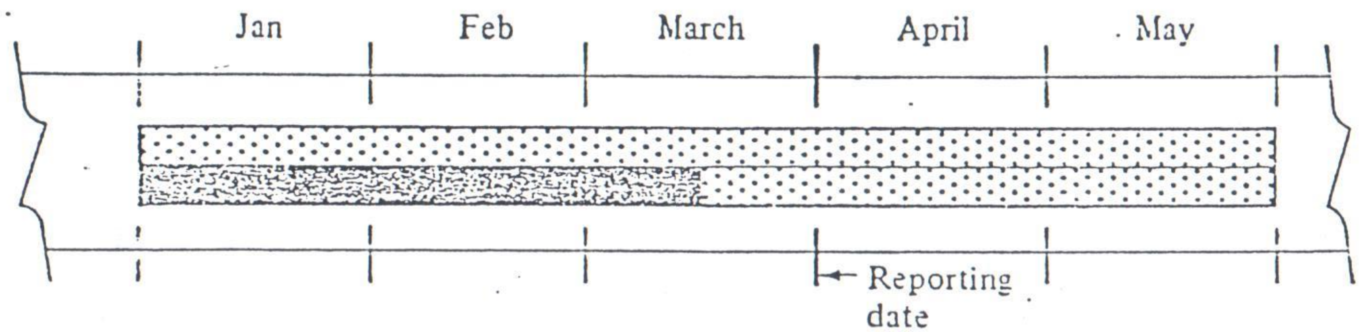


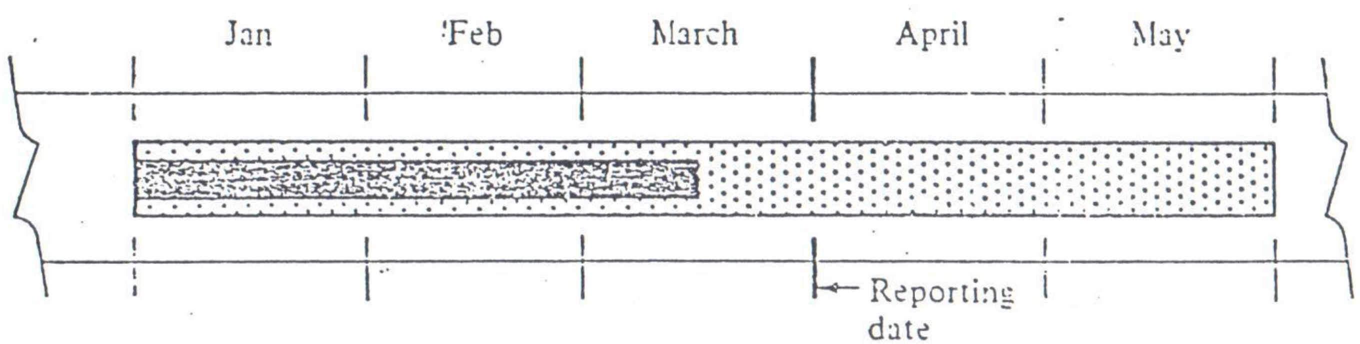
Fig. 6 Simple bar chart for a building project



(a) Type I Plan Bar



(b) Type I Reporting: Version 1



(c) Type I Reporting: Version 2

Fig.7 Type I bar chart

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.7b or 7c. 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 indication of whether the activity is behind or ahead of schedule.

The type I bar chart 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.8. In this case the actual progress will not be properly indicated.

ıe II : Time-scaled for plsnning; time-scaled for -eporting

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.9 shows typical presentation of type II bar chart.

vantages 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.

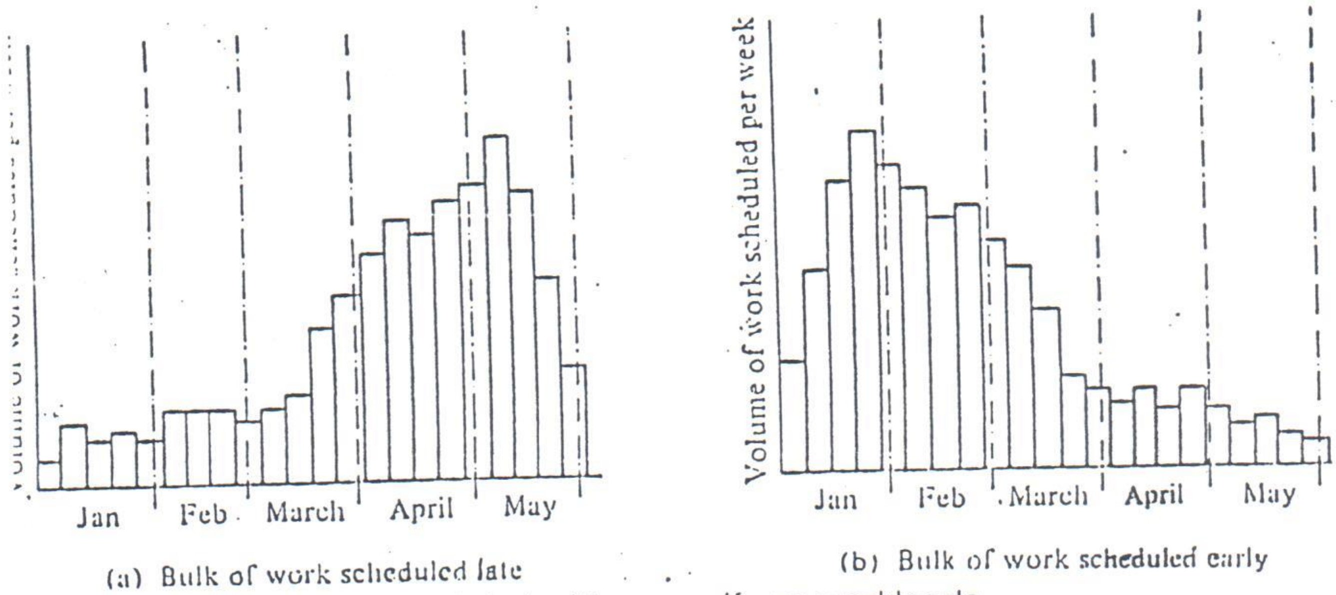


Figure 8 Activities scheduled with nonuniform workloads.

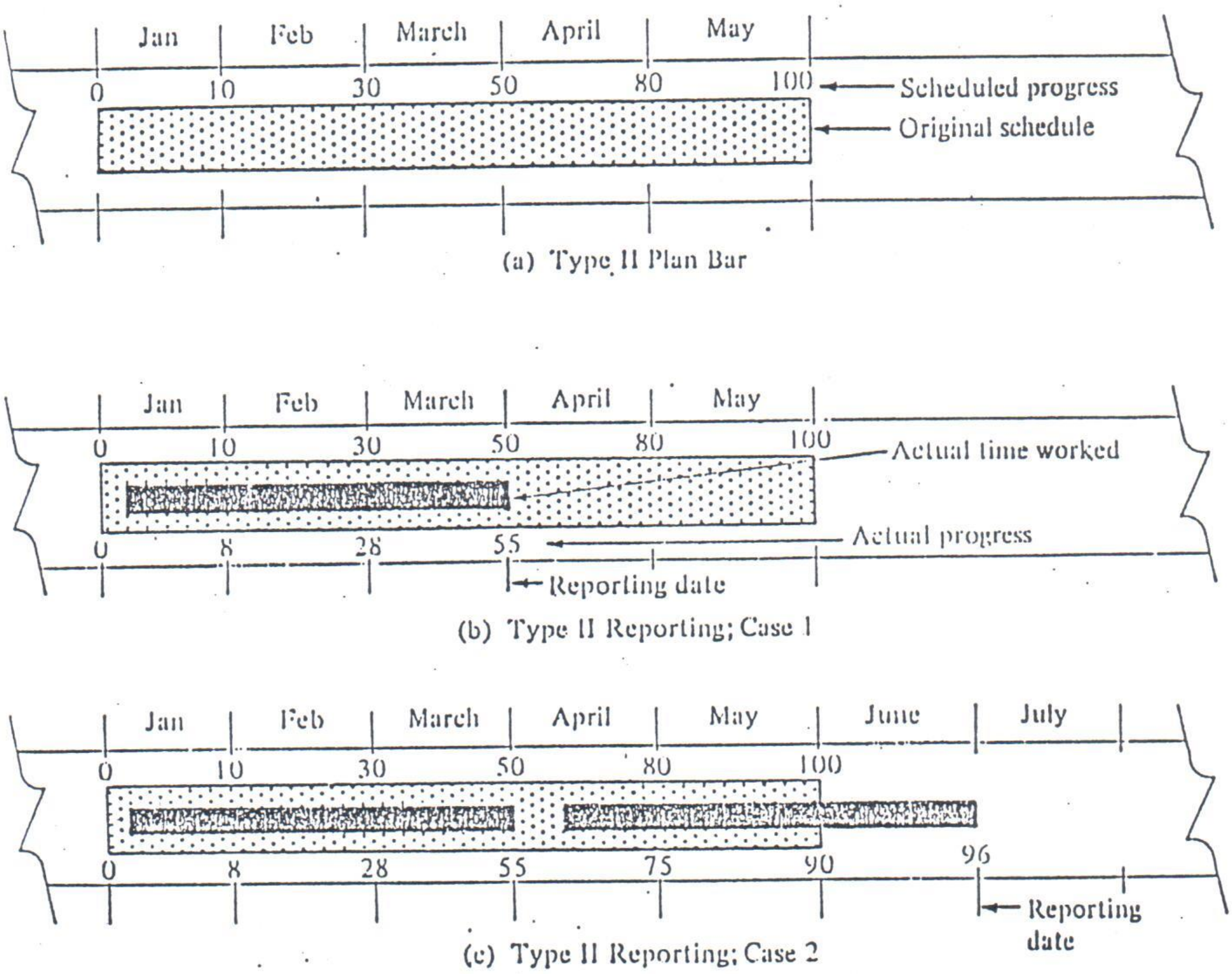


Figure 9 Type II bar charts.

* Require less revision and updating than more sophisticated systems.
* It is especially helpful in turbulent early stages of an engineering and construction project when frequent changes and revisions are a fact of life.

.imitation 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 constraints 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 scchedule, or even to project the progress of an individual activity.
* It is therefore limited as a control tool.

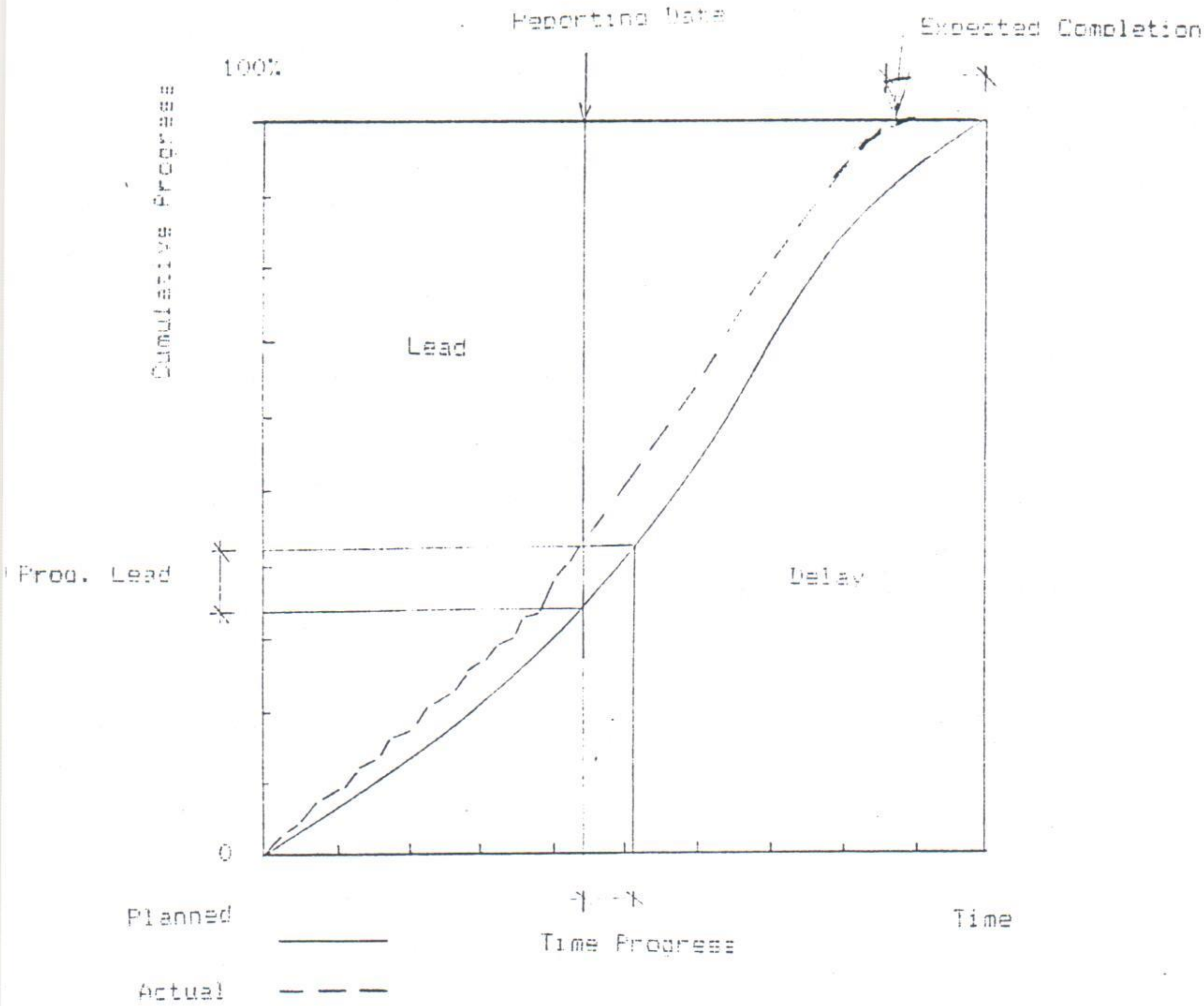
3.3 Progress Curves (S - Curves)

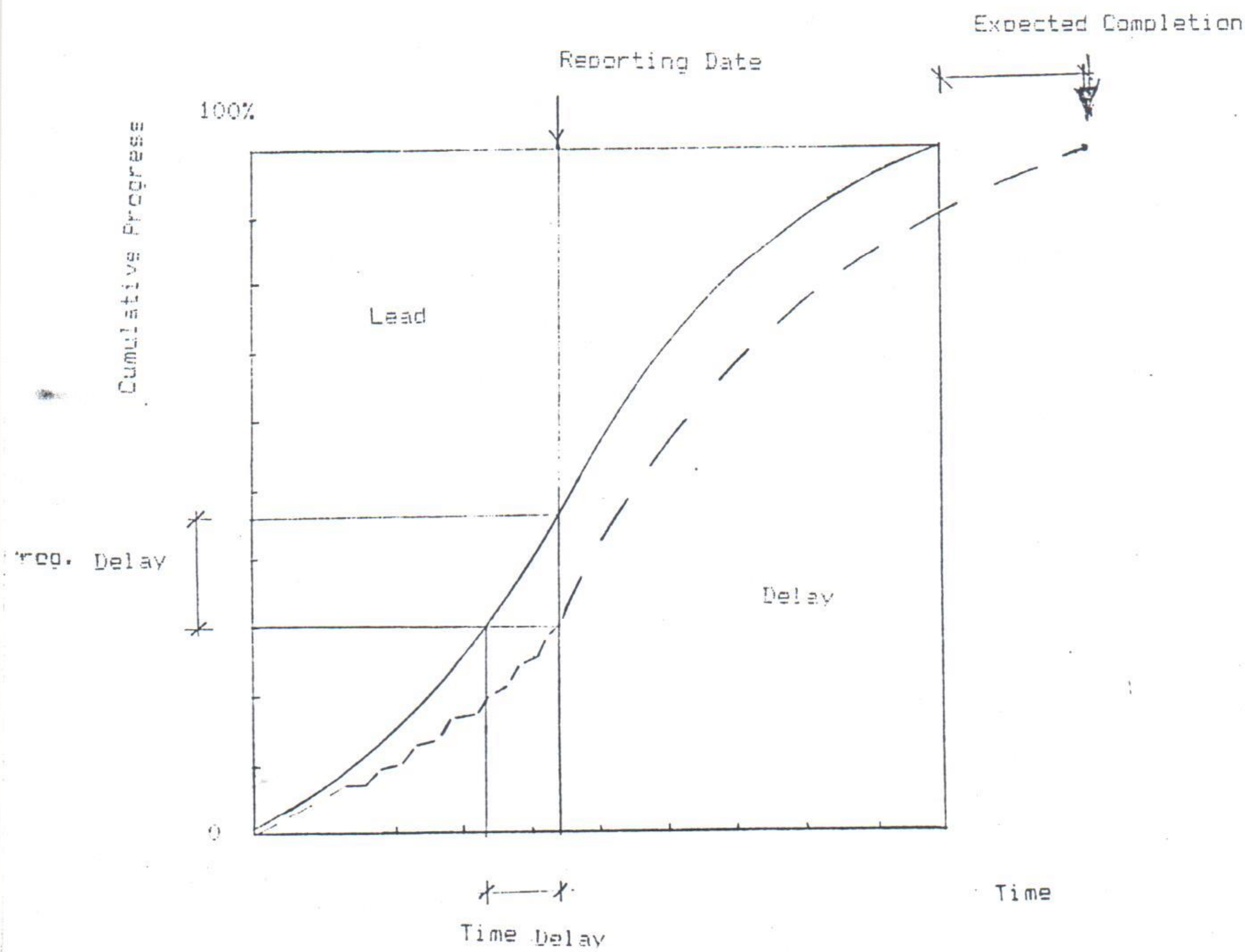
Progress curves are , also called "S" curves due to its most common graphic shape . The curve shows some measure of cumulative progress on the vertical axis against time on the horizontal axis . Progress can be measured in terms of quantity surveys of work in place , man - hours expended , money expended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

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 . Fig.(   ) shows concepts of planning , reporting and comparing .


Reporting Date
Expected Completion
100%
Cumulative Progress
Lead
Prog. Lead
Delay
0
Time Progress
Time
Planned
Actual


Expected Completion
Reporting Date
100%
Cumulative Progress
Lead
Prog. Delay
Delay
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Time Delay

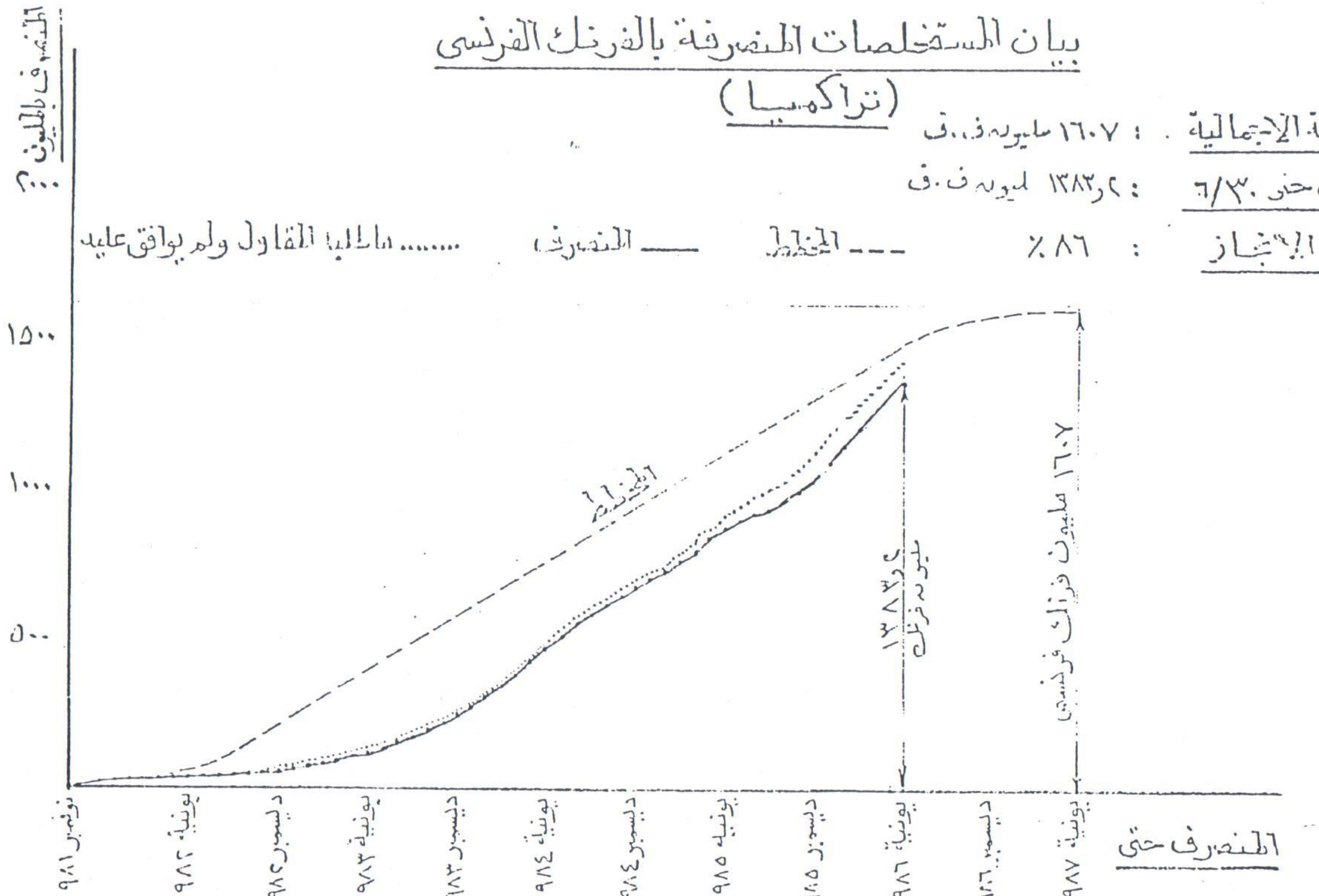
بيان المستخلصات المنصرفة بالفرنك الفرنسى

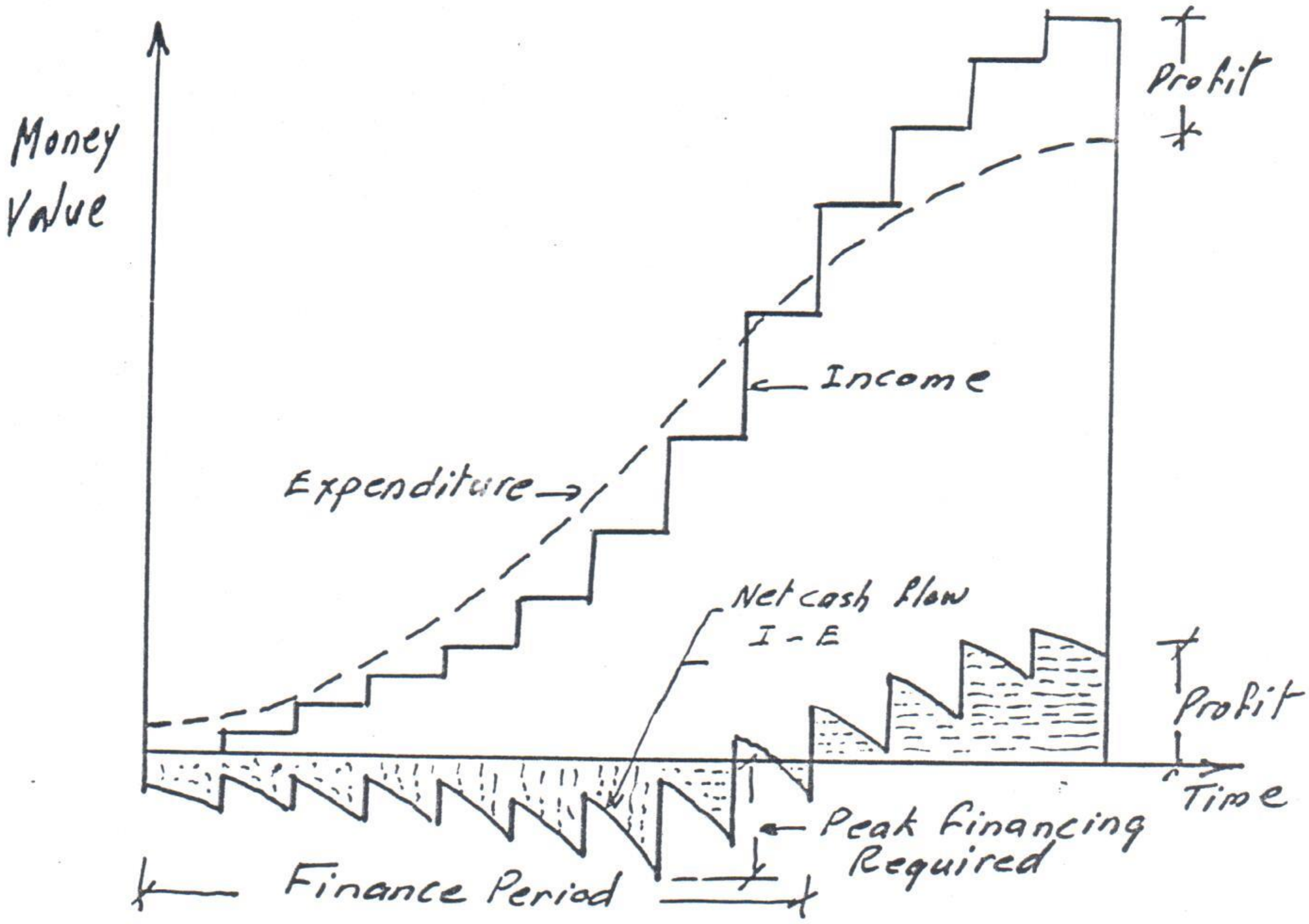
(تراكميا)

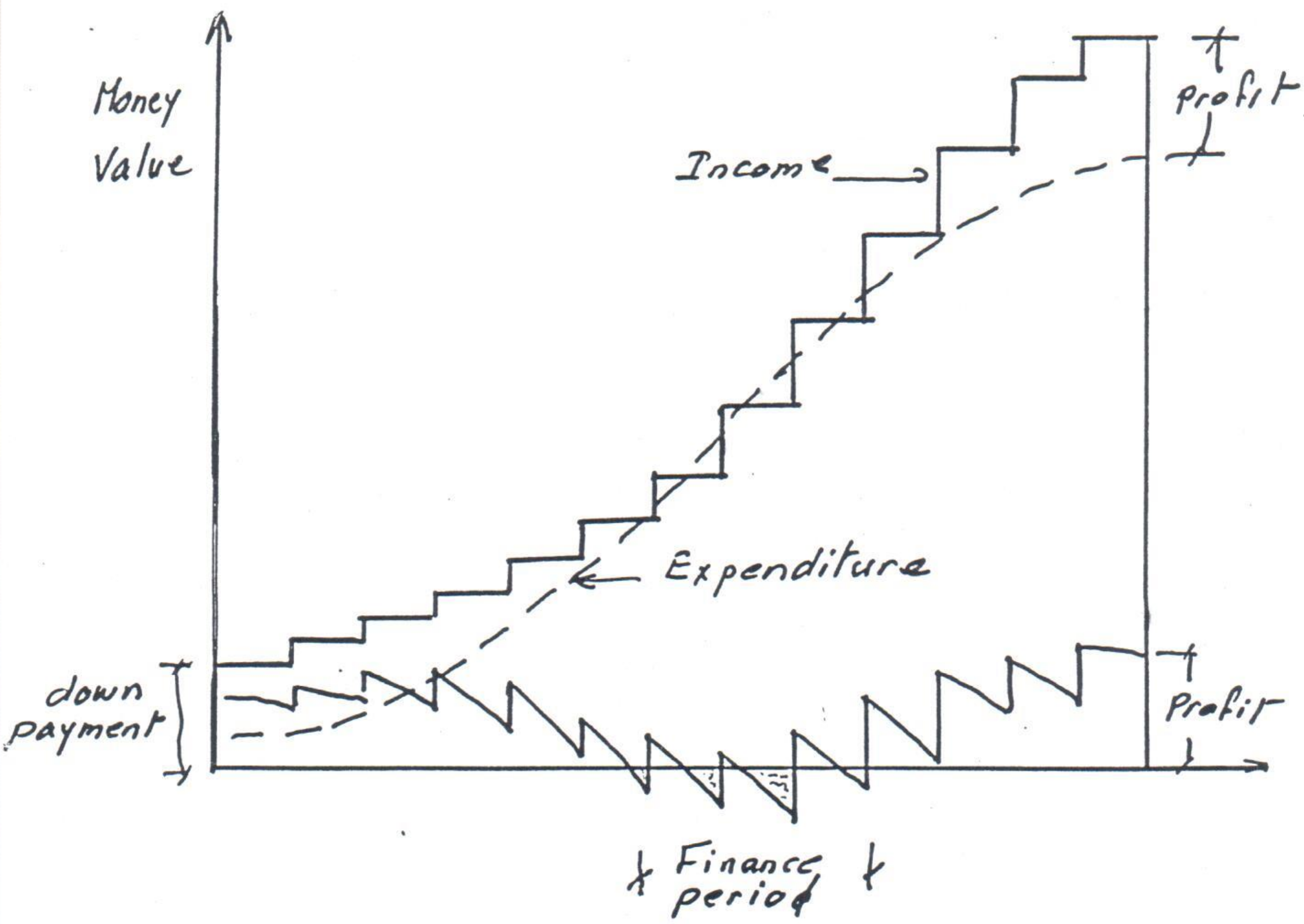
القيمة الإجمالية : ١٦٠٧ مليون ف.ف

المنصرف حتى ٦/٣٠ : ١٣٨٣٫٢ مليون ف.ف

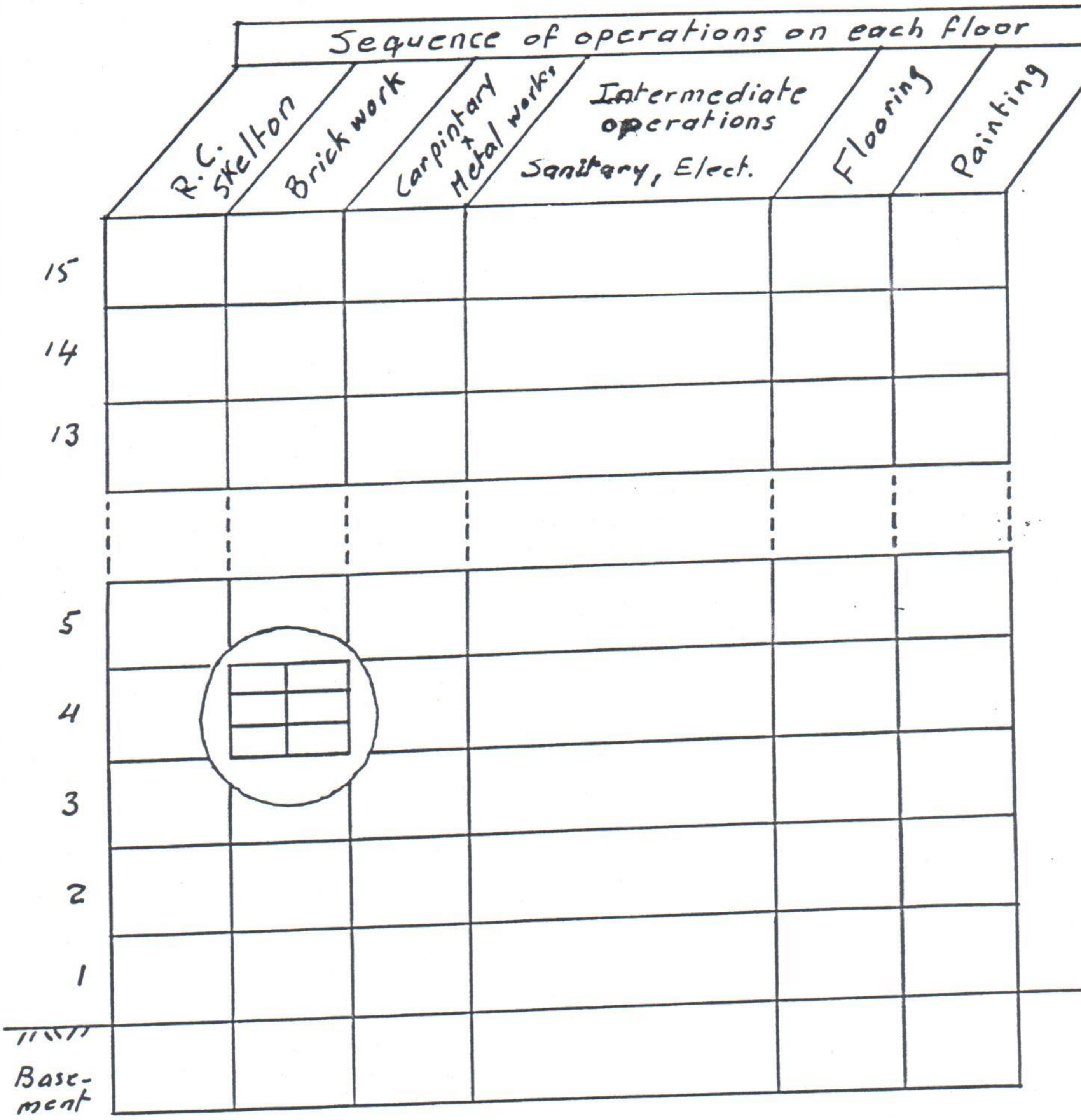
نسبة الإنجاز : ٨٦ ٪




Money Value
Profit
Income
Expenditure
Net cash flow I - E
Profit
Time
Peak financing Required
Finance Period


Money Value
profit
Income
Expenditure
down payment
Profit
Finance period

Cash Flows



Matrix Schedule for high rise building

planned start	17.4.81	20.4.81	Actual start
planned finish	21.4.81	25.4.81	Actual finish
Duration	4	5	Duration

5.0 Network Planning

5-1 Introduction :

Project planning and control are the most challenging tasks and responsibilities for the project manager.

Project managers need a management tool that enables them to manipulate large numbers of job activities and complicated sequential relationships in a simple and understandable fashion. The network diagram is a simple and effective medium for communicating complex job interdependencies. It serves as a basis for the calculation of work schedules and provides a mechanism for controlling project time as the work progress.

The network is a three phase procedure consisting of: Planning, Scheduling, and Time monitoring.

* Planning construction operations involves the determination of what must be done, how it is performed and the sequential order in which it will be carried.

* Scheduling determines calendar dates for the start and completion of project completion.

* Time monitoring is the process of comparing actual job progress with the programmed schedule.

5-2 The planning phase :

Planning is the most challenging task faced by the "project management". Normally, it involves all stages from briefing, designing, construction and commissioning.

The planning function is accomplished by dividing the project into many components or time-consuming steps called "activities" and establishing the planning diagram is important because all the data calculated and all the reports produced, no matter how sophisticated a system or how large a computer may be used, are only as valid as this model on which they are based.

This, makes it essential that the construction planning must be done by people who are experienced and thoroughly familiar with the type of field work involved. It is of necessity, that one person must construct the job network, but input information from many sources must be sought. Guidance from key people involved with project such as estimators, project manager, site superintendent and field engineer can be obtained from a planning meeting, or a series of such got together. The network serves as a medium whereby the job plan can be reviewed, criticized, modified and improved. As particular problems arise, consultations with individuals can clear up specific questions. The important point here is that there should be full group participation in the development of the network and collective views must be solicited.

Participation by Key subcontractors is also vital to the development of a workable plan. Normally, the prime contractor sets the general timing reference for the overall project. Then, individual subcontractors review the portions of the plan relevant to their work. An important side effect is that this procedure brings subcontractors and the prime contractor together to discuss the project. Problems are detected early and steps toward their solutions are started well in advance.

It must be recognized that the project plan represents the best thinking available at the time it is conceived and implemented. However, no such scheme is ever perfect, and the need for changes is inevitable as the work goes along.

The project program must be viewed as a dynamic device that is continuously modified to reflect the progressively more precise thinking of the field management team.

Construction planning may be said to consist of three steps:

1) Determination of the job steps or "activities" that must be performed to construct the project.

2) Ascertainment of the sequential relationships among these activities.

3) Presentation of the planning information in the form of a network.

5-3 Job activities :

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

1) By area of responsibility. 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 material such as concrete or steel, ...

5) By distinct structural elements such as footings, walls, beams, columns or slabs.

6) By location on the project when different times or different crews 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 steps. Too little details will limit planning and control effectiveness. 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 varies with the level of project management involved, according whether it is for top management or for the execution engineer who is responsible for a particular job.

5-4 Job logic :

Job logic refers to the determined order in which the activities are to be accomplished in the field. The start of some activities obviously depends on the completion of others. On the other hand, many activities are independent of one another and can proceed concurrently. Much of job logic follows from well-established work sequences that are usual and standard in the trade. Nevertheless, for a project of any consequence, there is always more than one general approach and no unique order of procedure exists. It is the planner's responsibility to select the most suitable alternatives.

Planning by C.P.M.

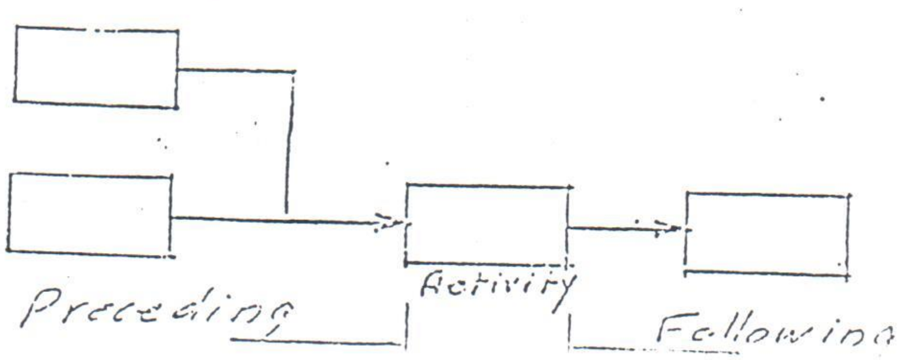
- The works needed to be performed to complete the project are divided into a number of activities.

- 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 : $ES + D = EF$

  Backward Path : $LF - D = LS$

The total float

$$= LF - EF$$

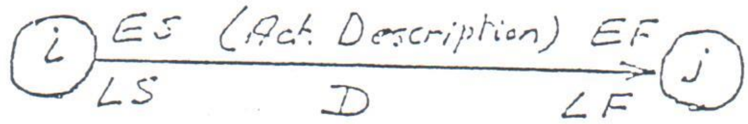
If total float is zero

the activity is critical

The critical path is the one giving the max. duration

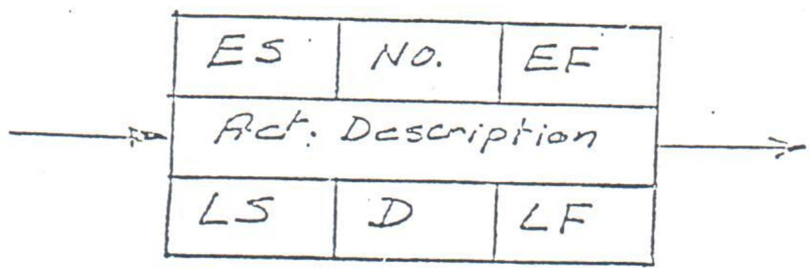
The basic graphical presentation of the network for the activities is made by either:

- <u>Arrow</u> – <u>i-j Notations</u>



OR

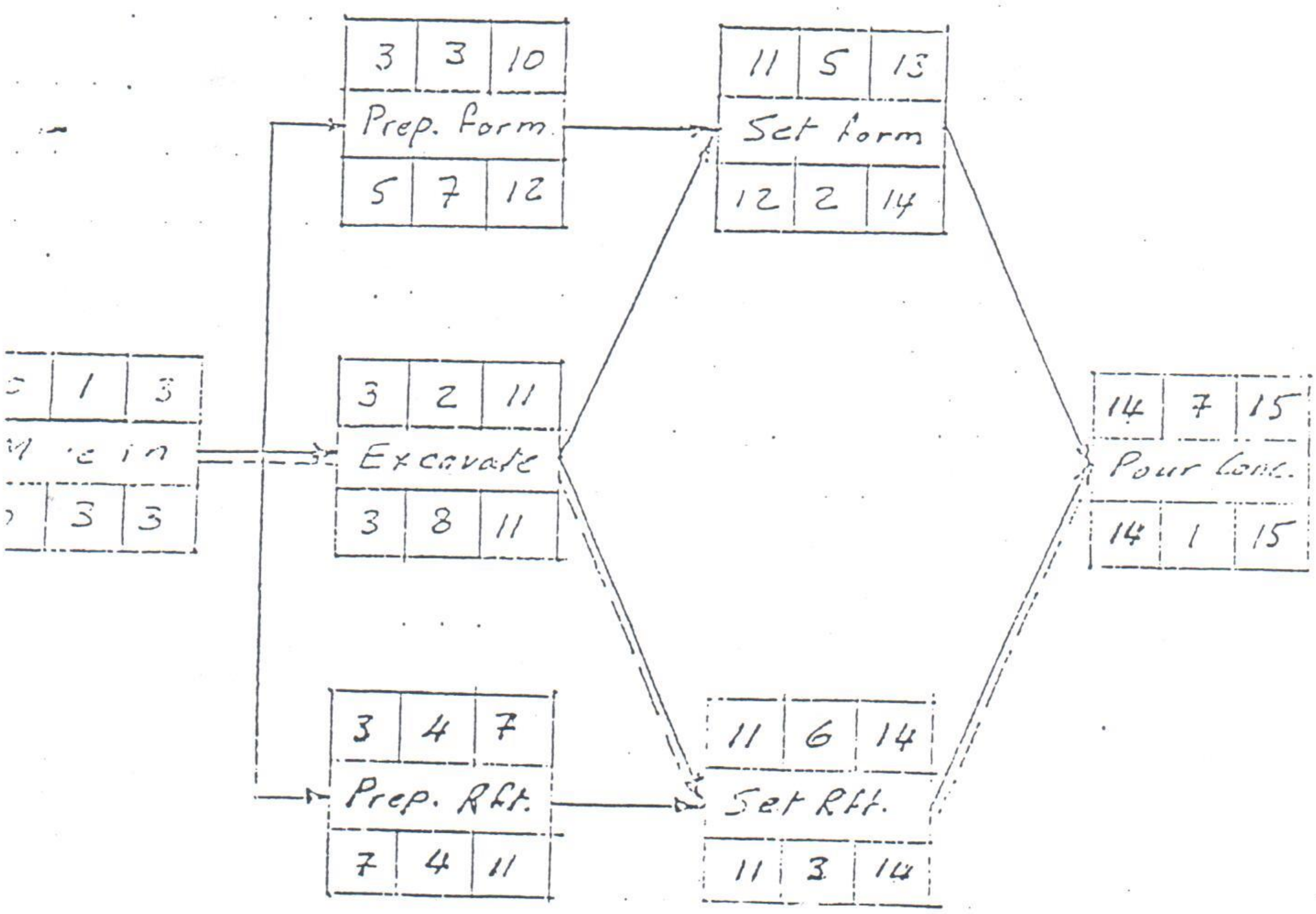
- <u>Precedence</u> – "<u>Activity-on-node</u>



Example:

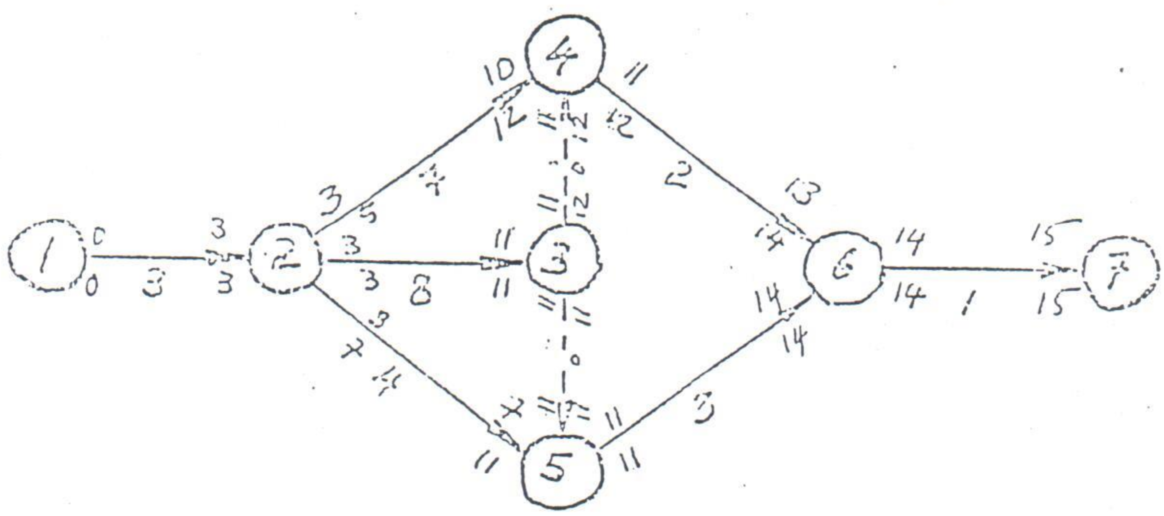
Draw the net work for the given activities :-

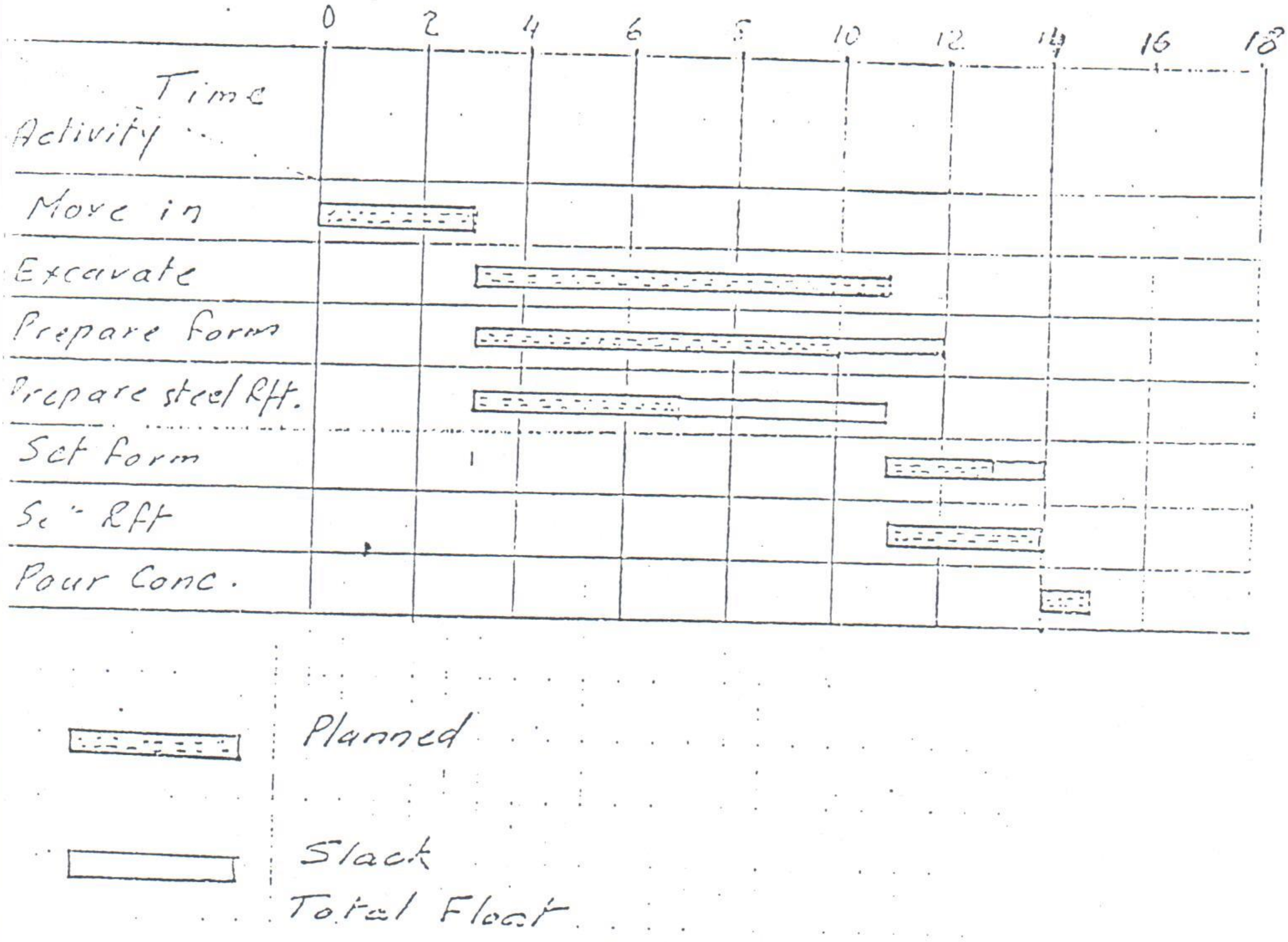
Activities No.	Description	Duration days	Preceding Activities
1	Move in	3	—
2	Excavate	8	1
3	Prepare form	7	1
4	Prepare steel Rft.	4	1
5	Set form	2	2, 3
6	Set Rft	3	2, 4
7	Pour Concrete	1	5, 6
		28 days.	



Critical Path ― ― ― ―

Activities No.	Description	Duration days	Proceeding Activities
1-2	Move in	3	—
2-3	Excavate	8	1-2
2-4	Prepare form	7	1-2
2-5	Prepare Rft	4	1-2
4-6	Set form	2	2-3, 2-4
5-6	Set Rft	3	2-3, 2-5
6-7	Pour Conc.	1	4-6, 5-6




Time
Activity
0
2
4
6
8
10
12
14
16
18
Move in
Excavate
Prepare form
Prepare steel/Rft.
Set form
Set Rft
Pour Conc.
Planned
Slack
Total Float

Activity	No.	Duration (days)	Preceding Activity
Move in	10	2	--
Survey&general layout	20	1	10
Locate & clear (4 km)	30	16	20
Excavate (4 km)	40	20	30
Prepare pipe (4 km)	50	12	30
Lay pipe (4 km)	60	24	40,50
Locate pipes (4 km)	70	4	60
Foundation for control room	80	10	20
Finishing control room	90	19	80
Install control equipments	100	5	90
Test C.R. with pipeline	110	3	70,100
Clean up	120	2	110
Contingency	130	5	120

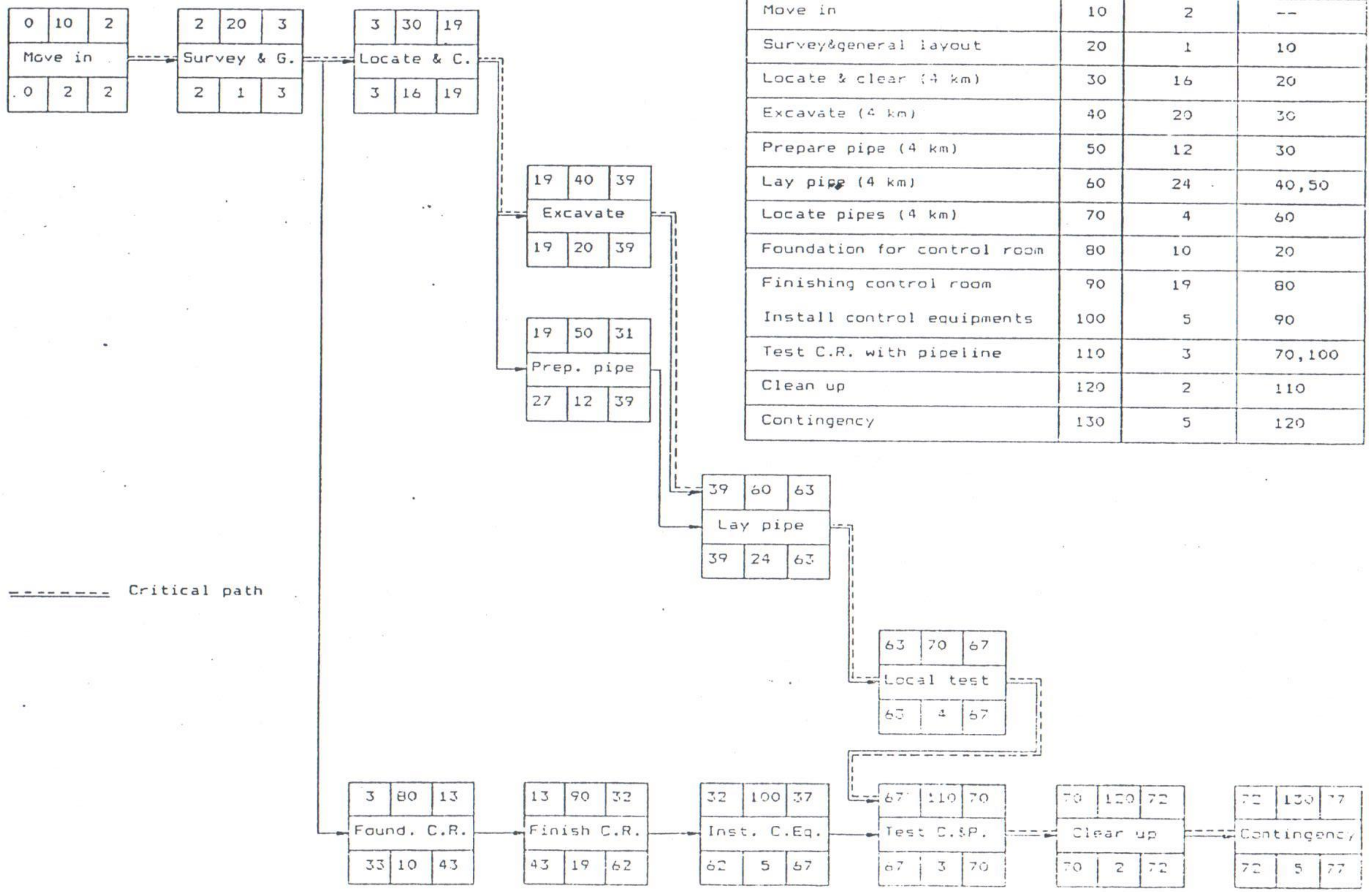


Fig (6.7) The precedence diagram scheduling for the relocation of 4 km pipeline and a control room , general job plan

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

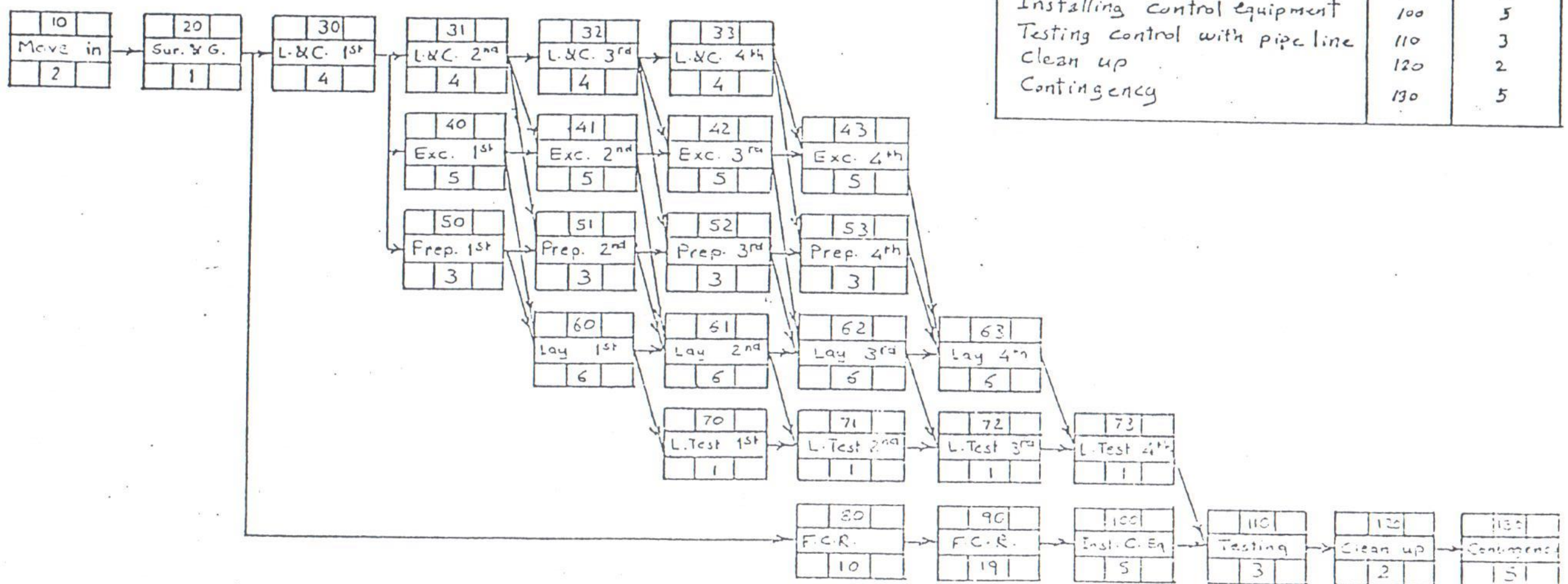
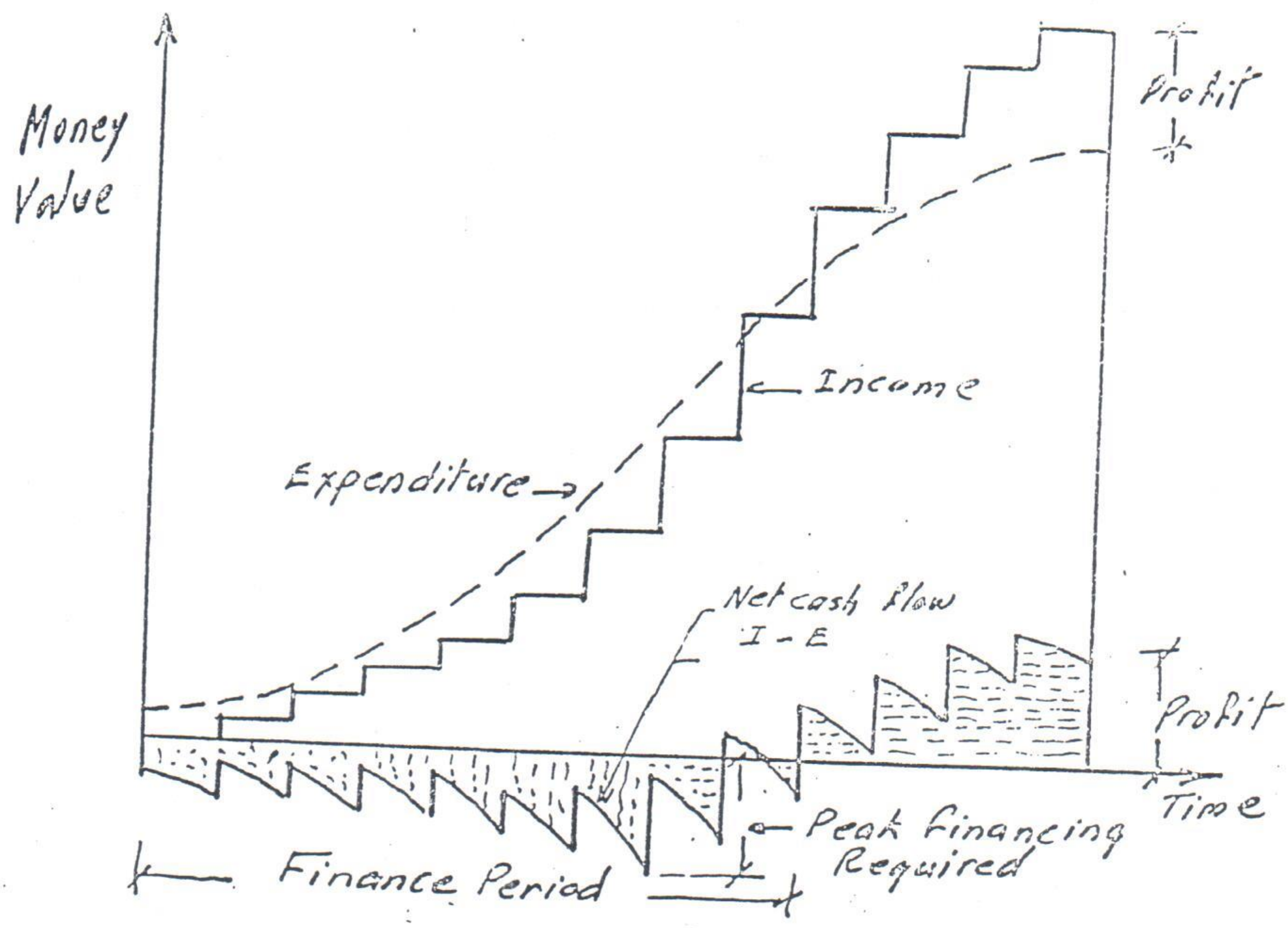
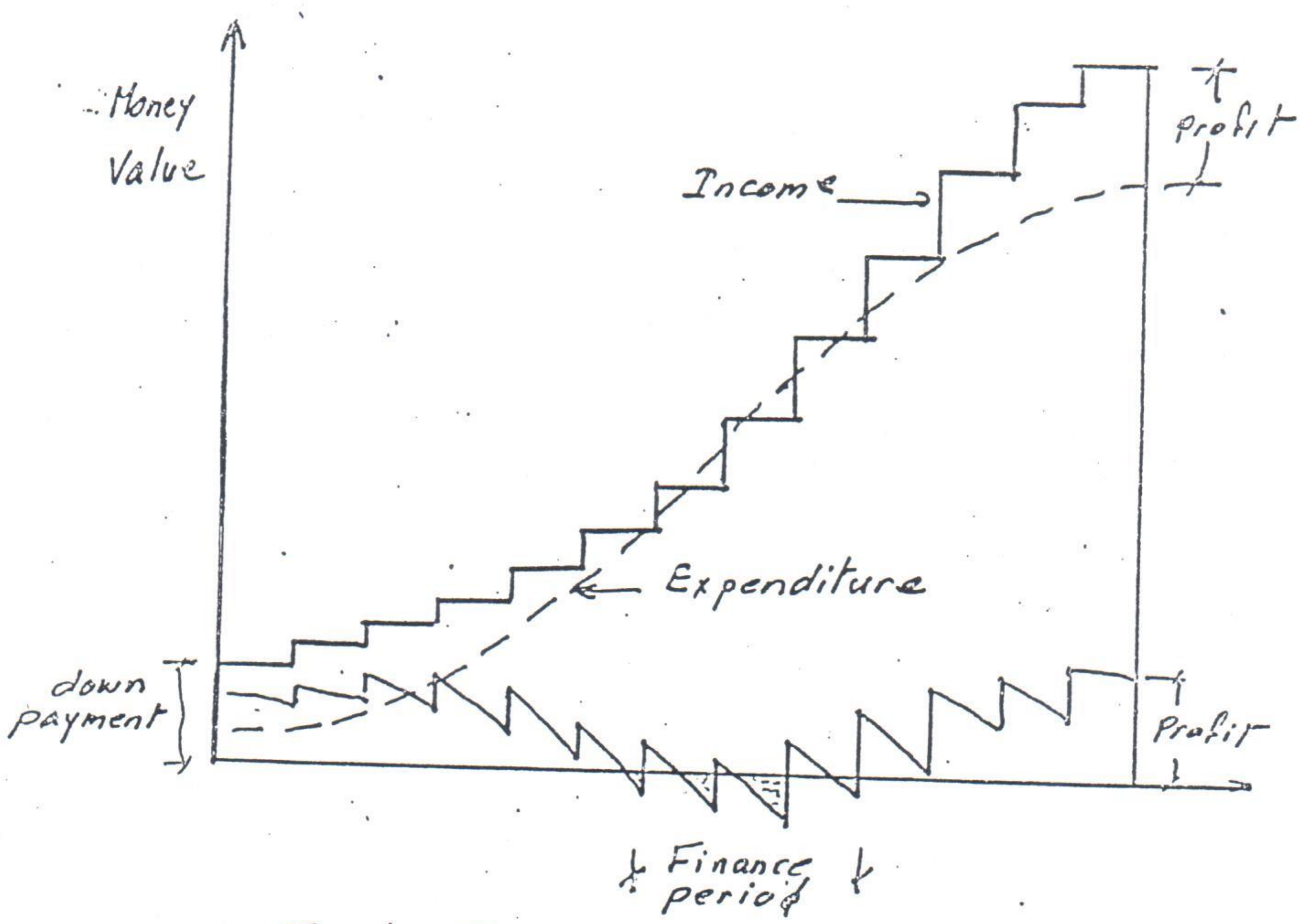


Fig (6·8) The detailed network for the relocation of 4 km pipe line and a control room.


Money Value
Profit
Income
Expenditure
Net cash flow I - E
Profit
Time
Peak financing Required
Finance Period


Money Value
profit
Income
Expenditure
down payment
Profit
Finance period

Cash Flows

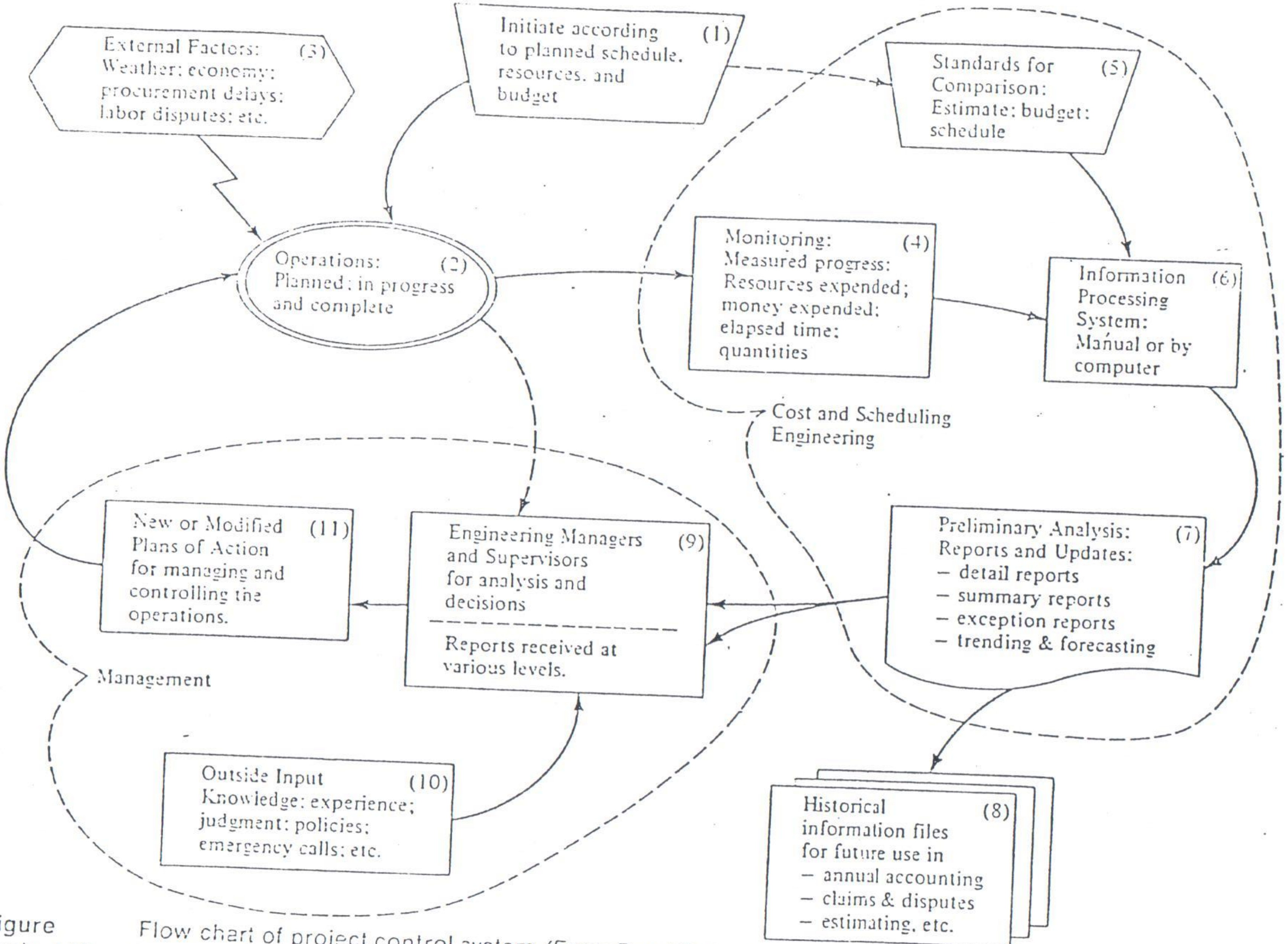


Figure Flow chart of project control system *(From Boyd C. Paulson, Jr., "Concepts of Project Planning and Control," Journal of the Construction Division, ASCE, vol. 102, no. CO1, March 1976, p. 71.)*

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).

8-2 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.

*) 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

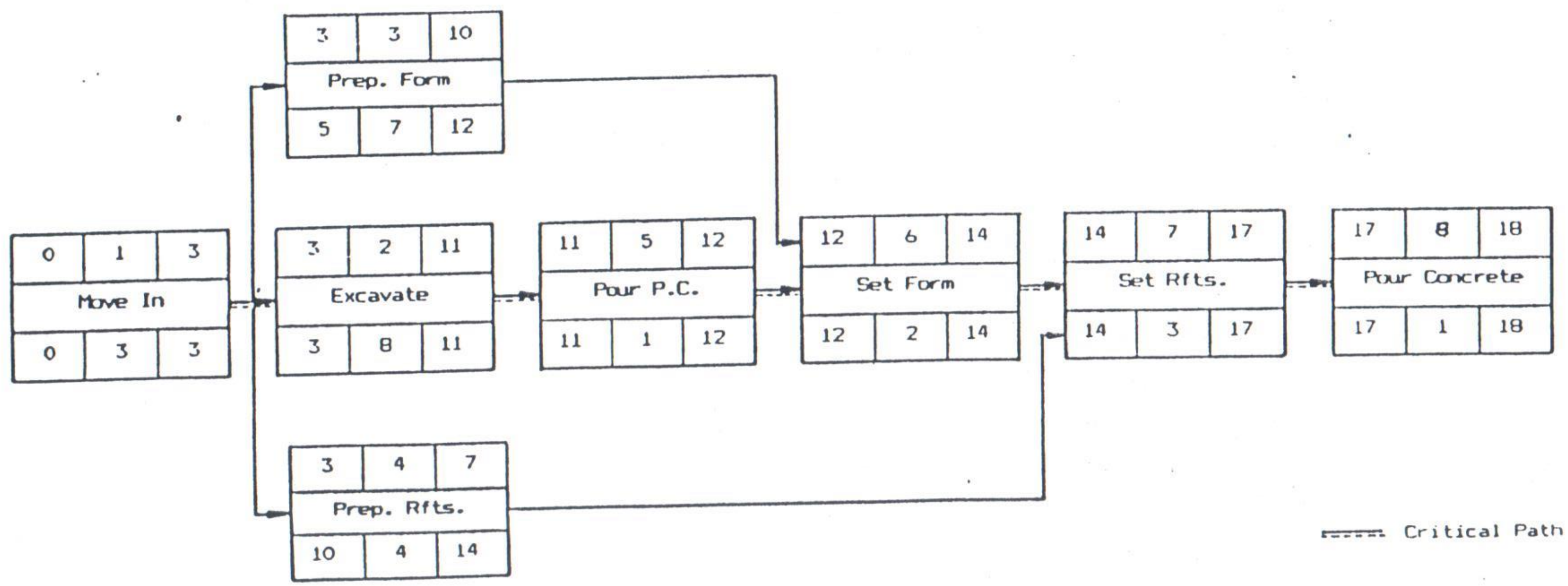


Figure (6.4) R.C. footing, precedence diagram schedule

Act. No.	Activity	Duration	ES	EF	TF	FF	Resource Rate/day	Resource 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

	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		4																
	2 Excavation	8							8											
	5 .Pour P.C.	4												4						
	6 Set form	4													4					
	7 Set rfts.	4																4		
	8 Pour conc.	4																		4
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															act. 4					
						-6	-6	-6	-6				+6	+6	+6	+6				
Σ 1		Total = 170	4	4	4	14	14	14	14	14	14	14	14	10	10	10	4	4	4	4

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 Leveling under limited resource allocation :

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																		
	2 Excavation	8																		
	5 Pour P.C.	4																		
	6 Set form	4																		
	7 Set rfts.	4																		
	8 Pour conc.	4																		
Non critical activities	3 Prep. forms	6																		
	4 Prep. rfts.	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																			

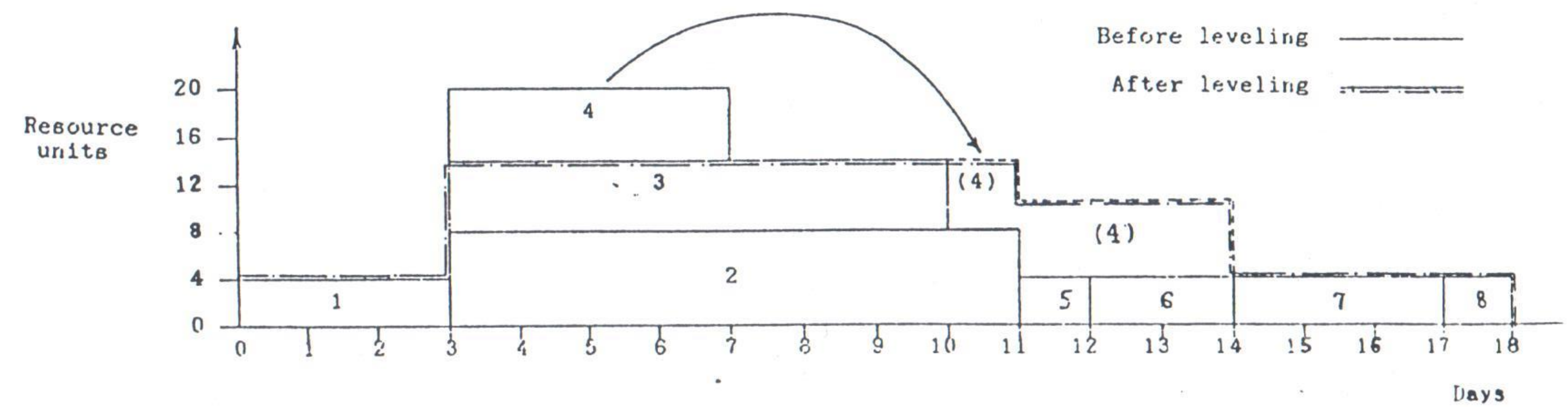


Figure (8.2) Bar chart & resource histogram for the R.C. footing , before and after leveling (Unlimited resource leveling)