مشروعات الاسكان والمشروعات
ذات الطبيعة المتكررة

* تخطيط وبرمجة
* إدارة العمليات

دكتور مهندس

عادل السمادونى
دكتوراه إدارة مشروعات التشييد

أستاذ مساعد مادة إدارة مشروعات التشييد
كلية الهندسة والتكنولوجيا بالمطرية - جامعة حلوان

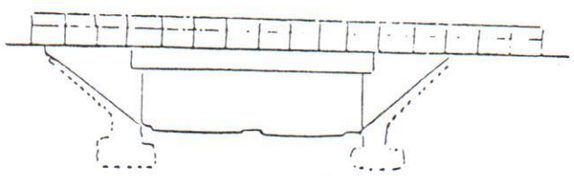
مدير عام مكتب الخبراء المصريون لادارة المشروعات

EPM
CONSULTANCY

PROBLEM

As part of an overall motorway construction project, a side road has to be directed on to the new bridge which will go over the motorway. You list the activities and estimated durations for the construction of the bridge as follows.

10	Construct precast concrete beams - off site	10 wks
20	Excavate for N abutment	4 wks
30	Excavate for S abutment	3 wks
40	Construct N abutment	8 wks
50	Construct S abutment	8 wks
60	Grade N approaches	6 wks
70	Grade S approaches	6 wks
80	Erect precast concrete beams and construct in-situ slab	5 wks
90	Surfacing & parapets etc. on bridge and approaches	2 wks



Draw networks (activity on the arrow and precedence) to keep the construction time a minimum assuming

i) Excavation on both abutment may occur simultaneously.

ii) Grading on N and S approaches may occur simultaneously but can not start until the respective abutment is complete.

iii) Construction of the N and ~~A~~ S abutments can not occur simultaneously as the same formwork is to be used for both abutments.

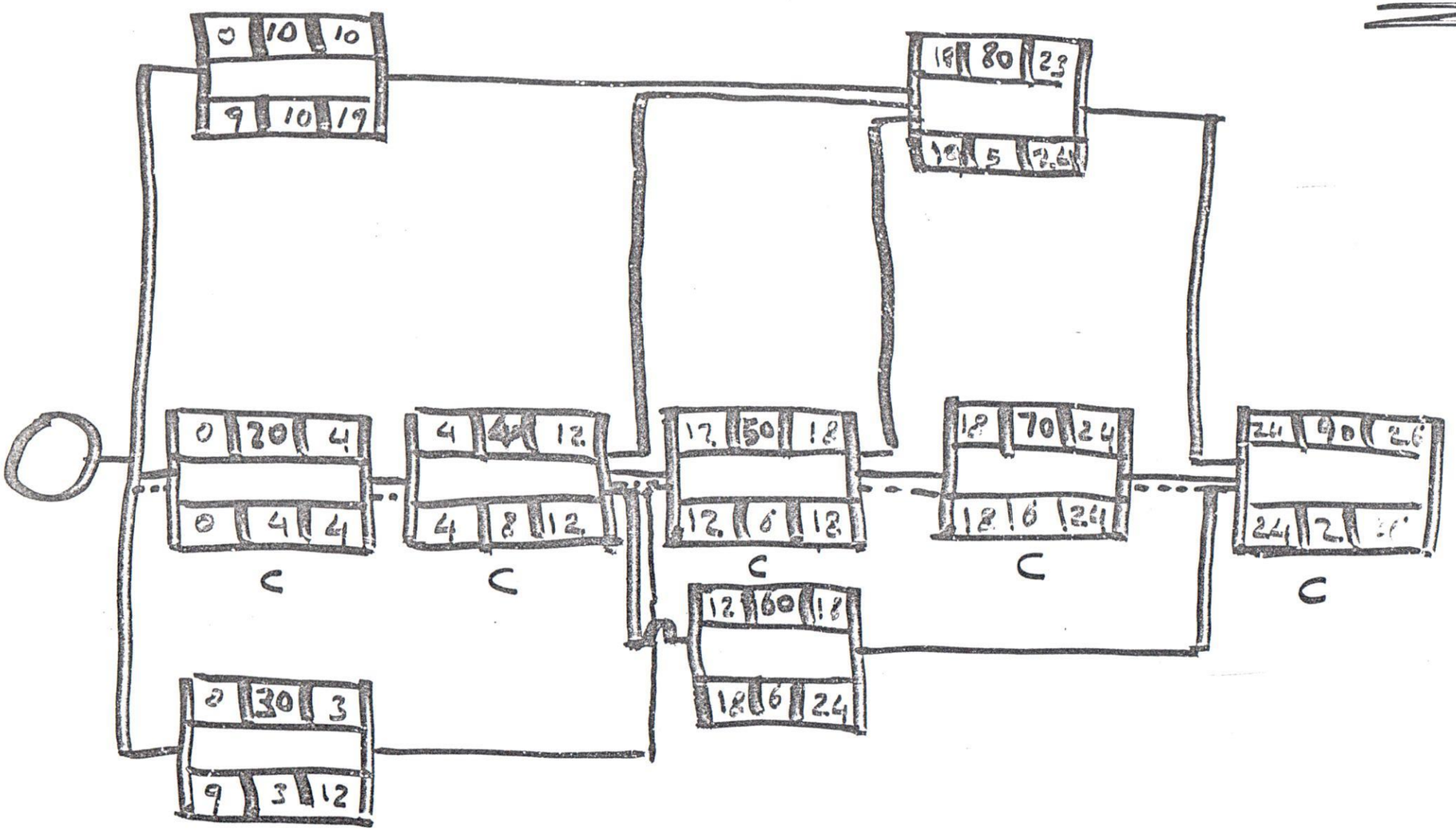
Find the critical path and the minimum construction period. How much time could be saved by using an extra set of formwork ? Would having the time on the approaches by doubling the plant be as effective?

(25 wks, 6 wks, No, only 1 wk. saved)

Act. No	Desc.	Dur. wks	Prec. Act
10		10	—
20		4	—
30		3	—
40		8	20
50		6	30+40
60		6	40
70		6	50
80		5	40, 50+10
90		2	60, 80+70

0 + 10 = 10

Case I


0 10 10
9 10 19
19 80 23
19 5 24
0 20 4
0 4 4
4 4 12
4 8 12
12 50 18
12 6 18
18 70 24
18 6 24
24 90 26
24 2 30
12 60 18
18 6 24
0 30 3
9 3 12
C
C
C
C
C

EPM
CONSULTANCY

Line Of Balance Method;

Construction of a house might reasonably be covered by a network of from 30 to 60 activities (Possibly more if all material deliveries, estate road construction, sewers, electricity and other services are included)

However if the estate includes 200 houses then the network would have six to twelve thousand activities.

There would be tremendous repetition on the network and it would be difficult to keep it updated.

It would not let anyone know management or employees, how work was proceeding and it is probable that the network would have little effect on the work.

Line of balance methods are particularly suited to repetitive work.

Illustration how progress today (week 20) can be seen at a glance from this progress chart for the construction of 50 houses.

EPM CONSULTANCY

Example of line of balance;

Your company has been awarded a contract to erect 124 pylons for the electricity board.

The Table shows the sequential operations involved in the construction of each pylon together with the estimated and required number of men per gang for each operation.

Table; Operation, manbours and number of men

Operation	Manhours	No. of men per operation per gang
A. Excavate	55	4
B. Concrete Foundations	64	4
C. Erect tower	145	8
D. Fix cantilever cable arms	90	8
E. Fix insulators	25	5

The handover rate specified is six pylons per week and this can be tacen as the target rate of build.

Prepare a line of balance schedule assuming that each gang works at its natural rhythm. State clearly the contract duration. Assume a five-day week, eight hours per day, and a minimum buffer of two days.

EPAM
CONSULTANCY

The number of man-hours is

the number of men x the number of hours

ie. 5 menwoking for 11 hours is 55 man hours

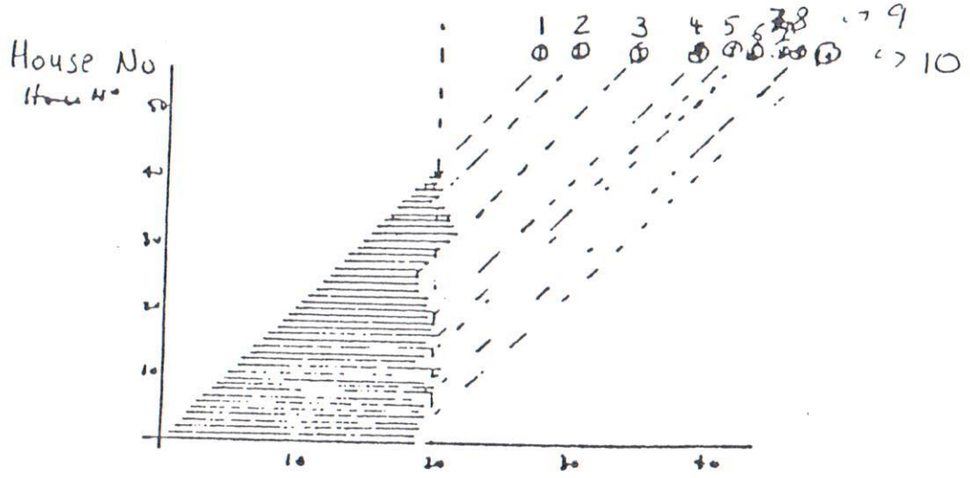
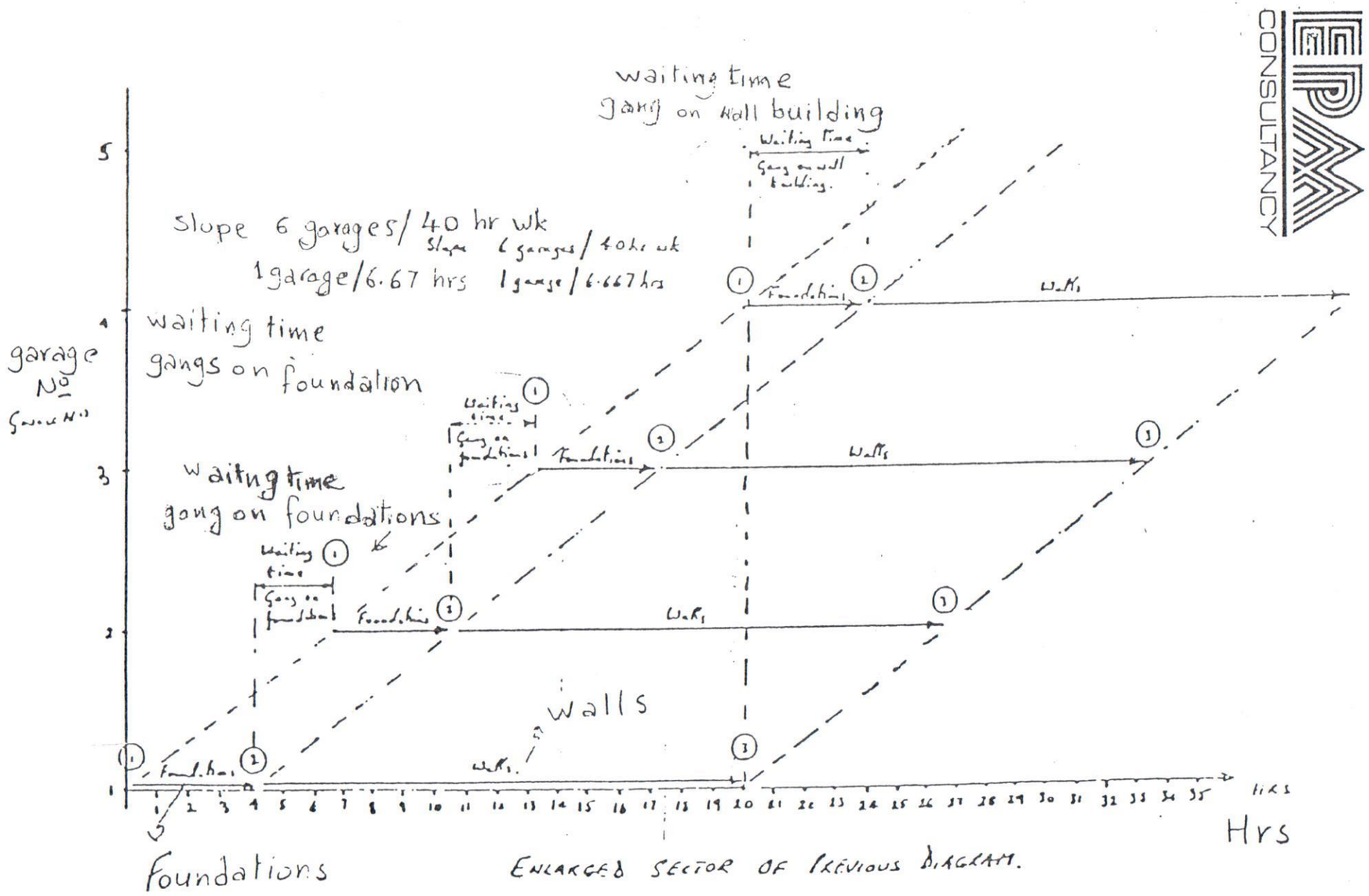


Fig-1

1-2	Substructure	6-7	Joinery finishing
2-3	Brickwork	6-9	Electrical
3-4	Joinery	6-8	Plumbing
5-6	Glazing	9-10	Painting



ENLARGED SECTOR OF PREVIOUS DIAGRAM.

Fig-2

Line of balance clrt for construction of 6 garages every 40

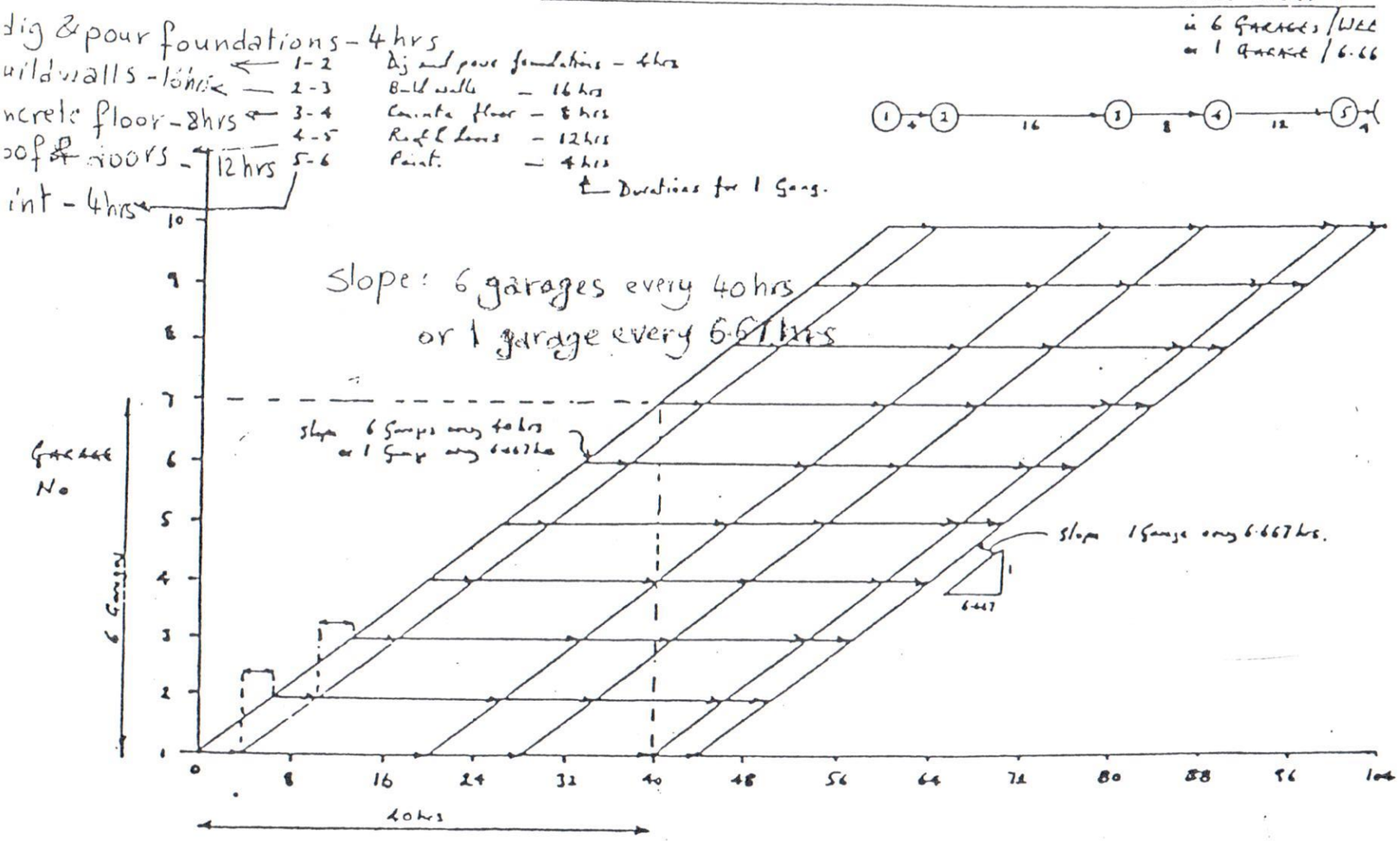


Fig-3

EPM CONSULTANCY

Resource Multiplication Factor

Resource utilization factor.

Activity	Duration		Waiting Time	Resource Utilization Factor
1-2 Dig/pour foundations	4 hrs	1	6.667 - 4 = 2.667 hrs	$\frac{4}{4+2.667} = 0.6$
2-3 Build walls	16 hrs	3	4 + 3×6.667 - 20 = 4 hrs	$\frac{16}{16+4} = 0.8$
3-4 Concrete floors	8 hrs	2	20 + 2×6.667 - 28 = 5.333 hrs	$\frac{8}{8+5.333} = 0.6$
4-5 Roof and doors	12 hrs	2	28 + 2×6.667 - 40 = 1.333 hrs	$\frac{12}{12+1.33} = 0.9$
5-6 Paint.	4 hrs.	1	40 + 6.667 - 44 = 2.667 hrs	$\frac{4}{4+2.667} = 0.6$

ACTIVITY	DURATION	RESOURCE MULTIPLICATION FACTOR	OUTPUT FOR ACTIVITY IF NO WAITING
1-2 Dig and pour foundations	4 hrs	1	1 Every 4 hrs
2-3 Build walls	16 hrs	3	1 Every = 5.33 hrs
3-4 Concrete floors	8 hrs	2	1 Every = 4 hrs
4-5 Roof and doors	12 hrs	2	1 Every = 6 hrs
5-6 Paint	4 hrs	1	1 Every 4 hrs

NATURAL RHYTHM

Activity 1-2

Start on garage at 0 + (10-1)x 4 hrs and finish at 36 + 4 = 40 hrs

Activity 2-3

Start on garage No 1 at 4 hrs. Finish on garage No 1 at 20 hrs. Start on garage No 10 at 4 + (10-1)x 5.33 = 52 hrs. Finish on garage No 10 at 52 + 16 = 68 hrs.

Activity 3-4

Start on garage No 10 at 68 hrs. Start on garage No 1 at 68-(10-1)x 4 = 32 hrs. Finish on garage No 1 at 32 + 8 = 40 hrs.

ACTIVITIES OCCURRING AT THEIR NATURAL RHYTHM (OR MULTIPLE OF THEIR NATURAL RHYTHM)

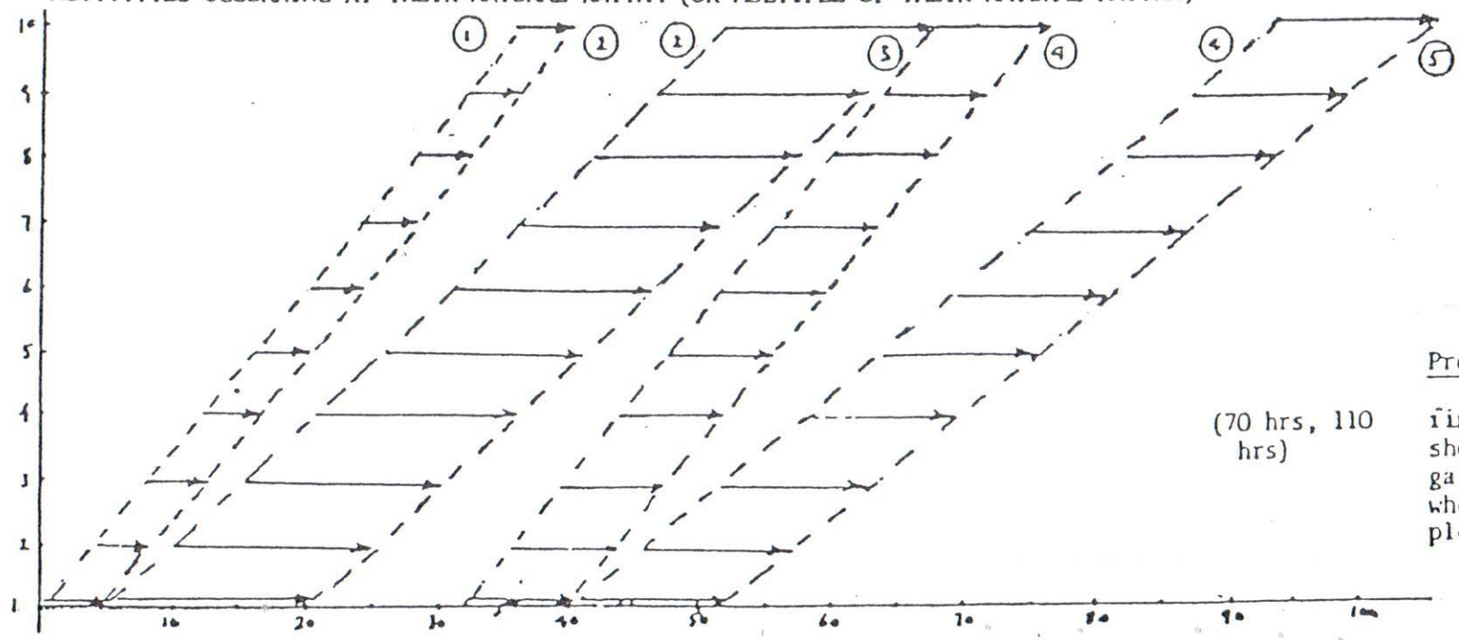


Fig-4

(70 hrs, 110 hrs)

Problem 9

Find when painters should start on garage No 1 and when they will complete garage No 10.

Operation	Man-hrs/ pylon	Ideal gang size	Duration hrs	No of gangs to obtain output closest to/every 6.667 hrs *	Time between start on first pylon and start on last
Excavate	55	4	13.75	2 when output = 1 every 6.875 hrs (= 0.859 days)	(124-1)x .859 = 105.7 days
Concrete foundations	64	4	16	2 when output = 1 every 8 hrs (= 1 day)	x 1 = 123
Erect tower	145	8	18.125	3 when output = 1 every 6.042 hrs (= 0.755 days)	x .755 = 92.9
Fix cantilever cable arms	90	8	11.25	2 when output = 1 every 5.625 hrs (= 0.703 days)	x .703 = 86.5
fix insulators	25	5	5	1 when output = 1 every 5 hrs (= 0.625)	x .625 = 76.9

* 6 pylons per week of 5 days of 8 hours = 1 pylon every 6.667 hours.

Excavation

Start at day 0 on first pylon and finish on day $\frac{13.75}{8} = 1.7$

Start at day 0+105.7 = 105.7 on pylon No 124 and finish on day $105.7 + \frac{13.75}{8} = 107.4$

(Note:- the accuracy of calculation is overdone in view of likely accuracy of input data - theoretically we have assumed that excavation gang 2 starts after 0.859 days - not a very sensible assumption but then the accuracy is being overdone. If gang 2 starts excavation at day 0 the answers will be only marginally affected.)

Concrete foundations

Start at day 1.7 + 2 (buffer) = 3.7 say day 4 and finish on day $4 + \frac{16}{8} = 6$ for pylon No 1

Start at day 4 + 123 = 127 on pylon No 124 and finish on day $127 + \frac{16}{8} = 129$

Erect towers

Start at day 129 + 2 (buffer) = 131 on pylon No 124 and finish on day $131 + \frac{18.125}{8} = 133.3$

Start at day 131 - 92.9 = 38.1 say 38 on pylon No 1 and finish on day $38 + \frac{18.125}{8} = 40.3$

Fix cantilever cable arms

Start at day 133.3 + 2 (buffer) = 135.3 say day 136 and finish on day 136 + $\frac{11.25}{8}$ = 137.4 for pylon No 124

Start at day 136 - 86.5 = 49.5 say day 49 on pylon No 1 and finish on day 49 + $\frac{11.25}{8}$ = 50.4

Fix insulators.

Start at day 137.4 + 2(buffer) = 139.4 say day 140 and finish on day 140 + 5/8 = 140.6 for pylon No 124

Start at day 140 - 76.9 = 63.1 say day 63 and finish on day 63 + 8 = 63.6 for pylon No 1

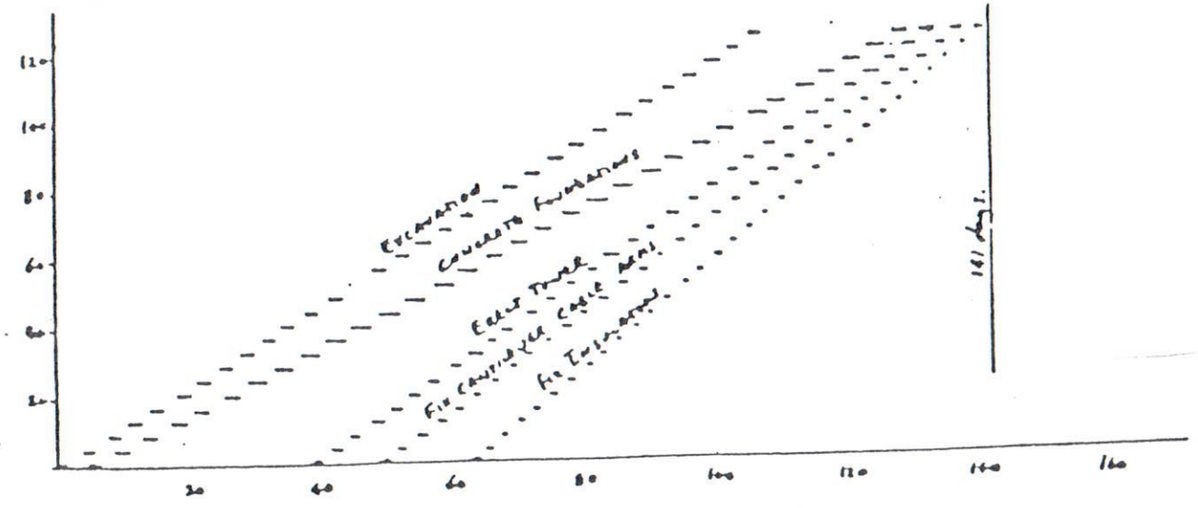
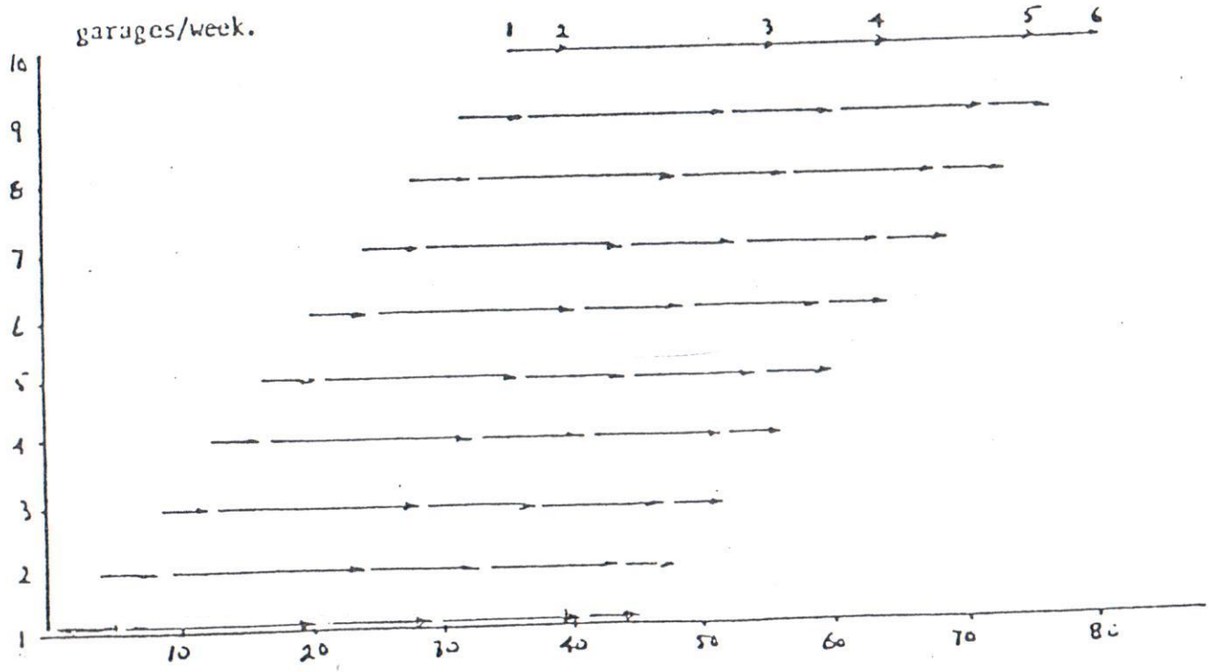


Fig-6

FULLY BALANCED & PARTIALLY BALANCED ACTIVITY SEQUENCES.

Activity	Duration	Resource Multiplication factor	Output for activity if no waiting
1-2 Dig and pour foundations	4 hours	1	1 Every 4 hours
2-3 Build walls	16 hours	4	1 Every 4 hours
3-4 Concrete Floors	8 hours	2	1 Every 4 hours
4-5 Roof and doors	12 hours	3	1 Every 4 hours
5-6 Paint	4 hours	1	1 Every 4 hours

By increasing resources it may be possible to obtain a partially balanced activity sequence or even (as in this case) a fully balanced activity sequence. Since each activity duration is a multiple of 4 hours by having 4 gangs for activity 2-3, 3 gangs for 4-5 a fully balanced activity sequence can be obtained. Note that the rate is 1 every 4 hours for all activities - ie. output = 10 garages per 40 working hours or 10 garages/week.



It is desirable to have production running at same rate for every item.

(a) avoids waiting time - more efficient less waste.
(b) easier management
(c) better labour relations
(d) better pricing
(e) better bonus scheme possible?

Fig-5

EPM CONSULTANCY

Question 2; Line of balance

The construction plan for a house is shown in Fig.5 Table 5 gives the manhours required and the team size for each operation.

Prepare a line of balance schedule for a contract of 30 houses using a target rate of build of four houses per week and each team working at their natural rate.

Assume a minimumbuffer time of five-days between operations and five 8-hour days per week.

What is the overall duration of the project and when will the first team of bricklayers (superstructure operation)leave the site ?

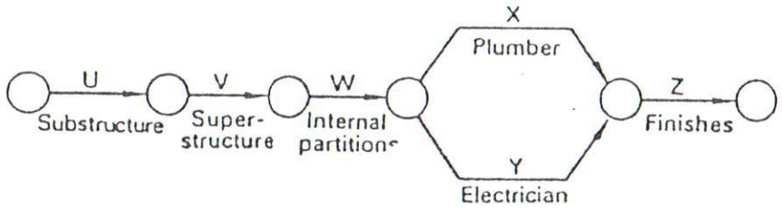


Fig. 5 Construction plan for one house.

EPM CONSULTANCY

Table 5; Manhours and team size;

Operation	U	V	W	X	Y	Z
Manhours per house	120	290	250	40	30	220
Men per team	3	6	4	3	2	5

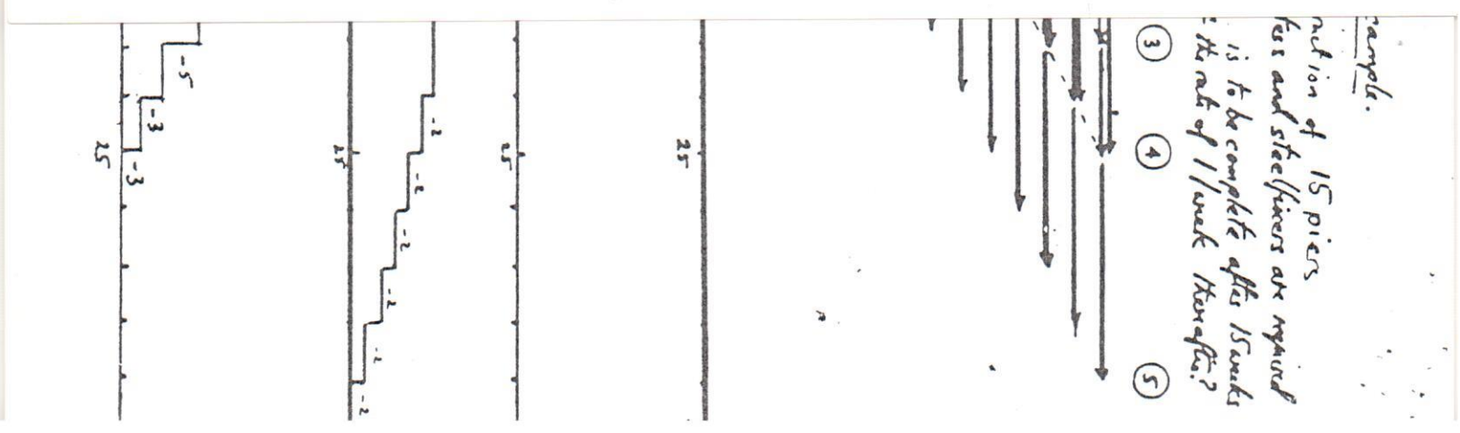
uestion 3; Line of balance

Prepare a line of balance schedule for a small contract of 15 houses pased on a rate of build of three houses per week assuming five 8-hour days per week.

A minimum buffer of five days should be assumed .Table 6 shows the operations together with the estimated manhours and optimum number of men for each operation.

Table 6; Operations, manhours and number of men

Operations	Manhours	Optimum number of men per operation
A Substructure	160	6
B Brickwork	320	4
C Joiner, 1st fix	200	4
D Tilers	60	2
E Glazing	40	2
F Joiner, 2nd fix	120	3
G Electrician	80	2
H Plumber	100	2
I Painter	40	3



Primavera & Lotus 1,2,3

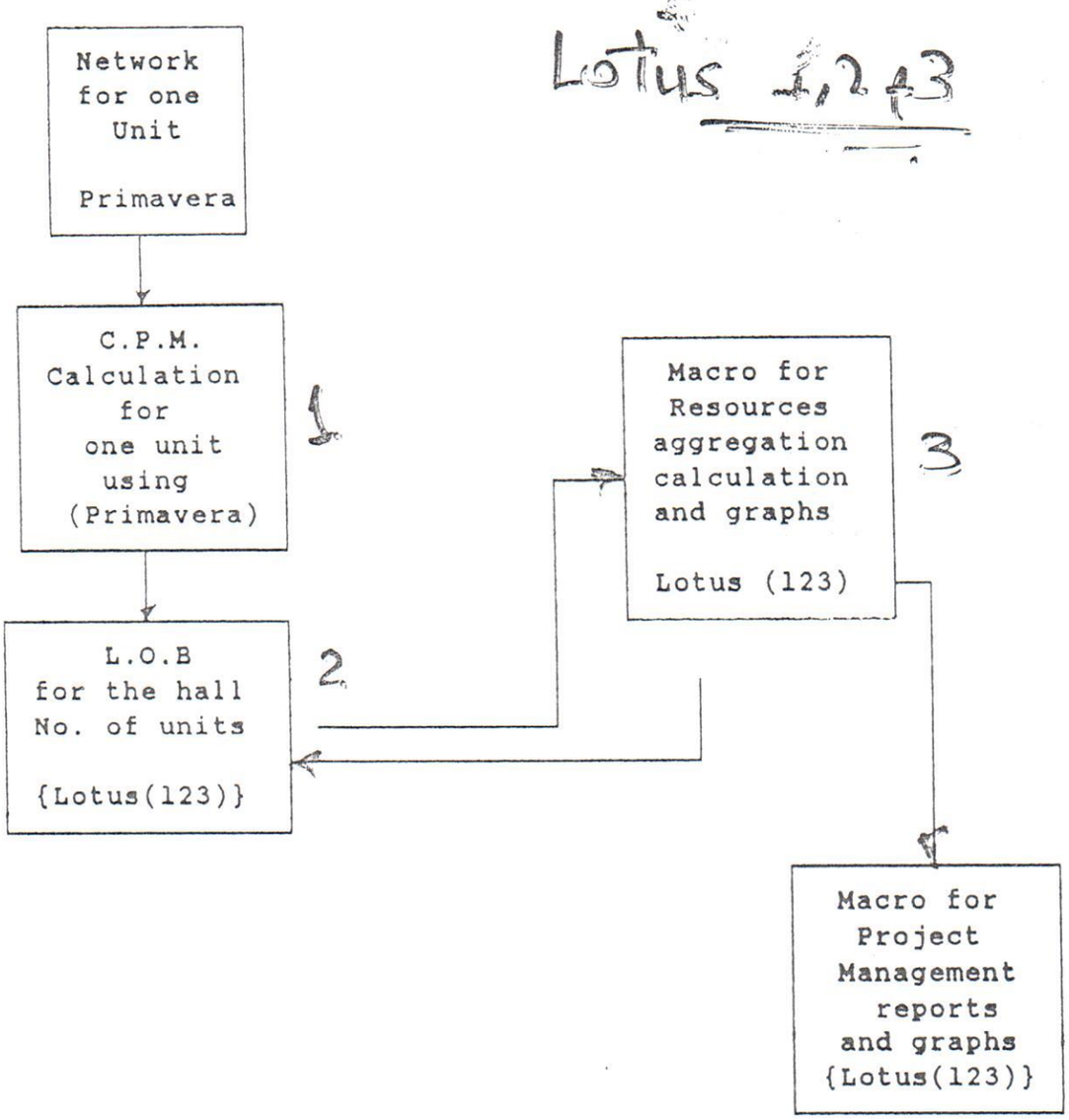


Fig (1)

L.O.B. DIAGRAM

(OUTPUT OF L.O.B. MACRO)

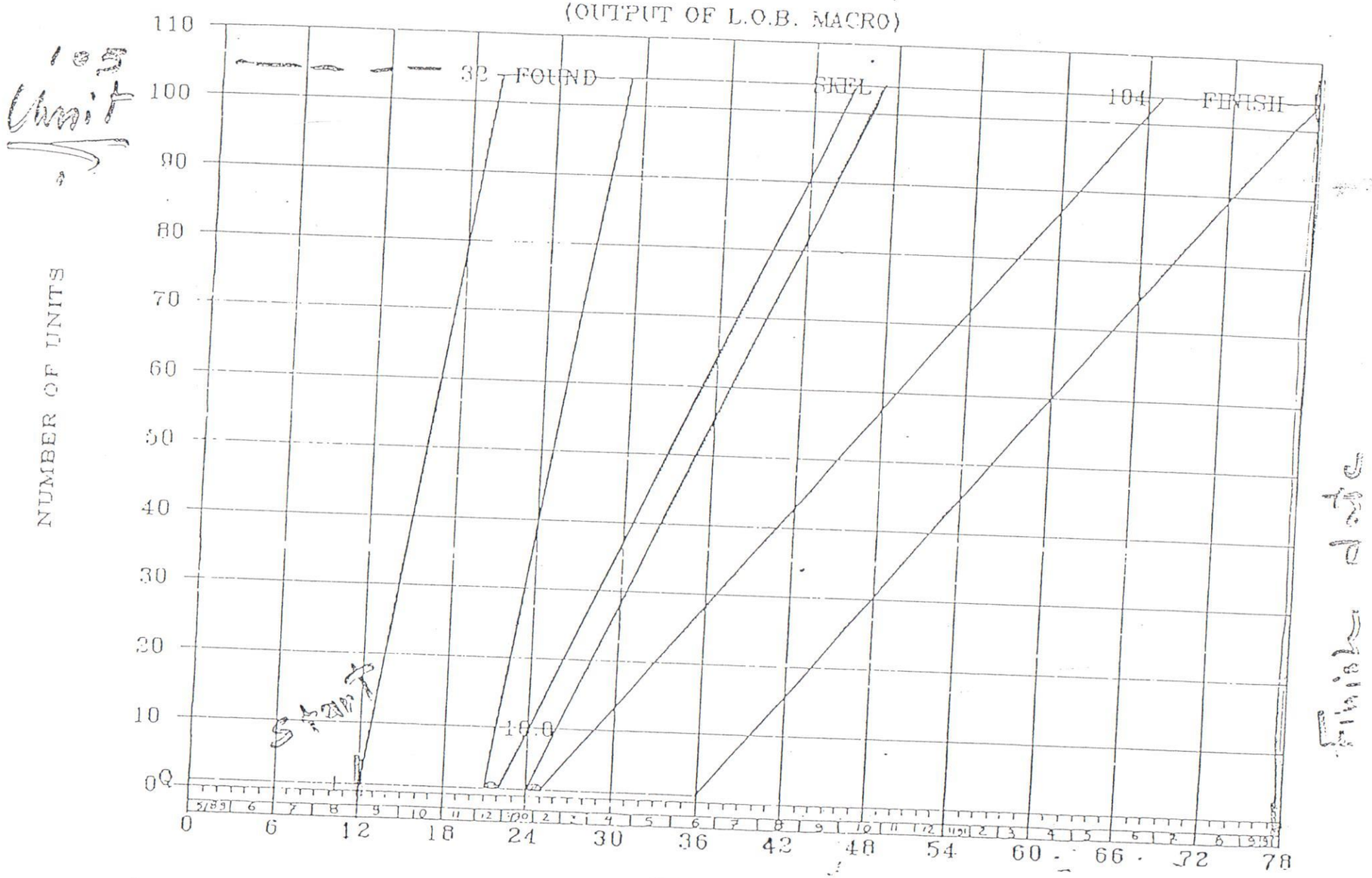


Fig. (2)

2- Resource Macro :

The programme calculates and graphically presents the different resources for the project, taking into consideration the number of units to be constructed in the same time and derived by the line of balance in order to give the monthly utilization profile. See Fig.(3).

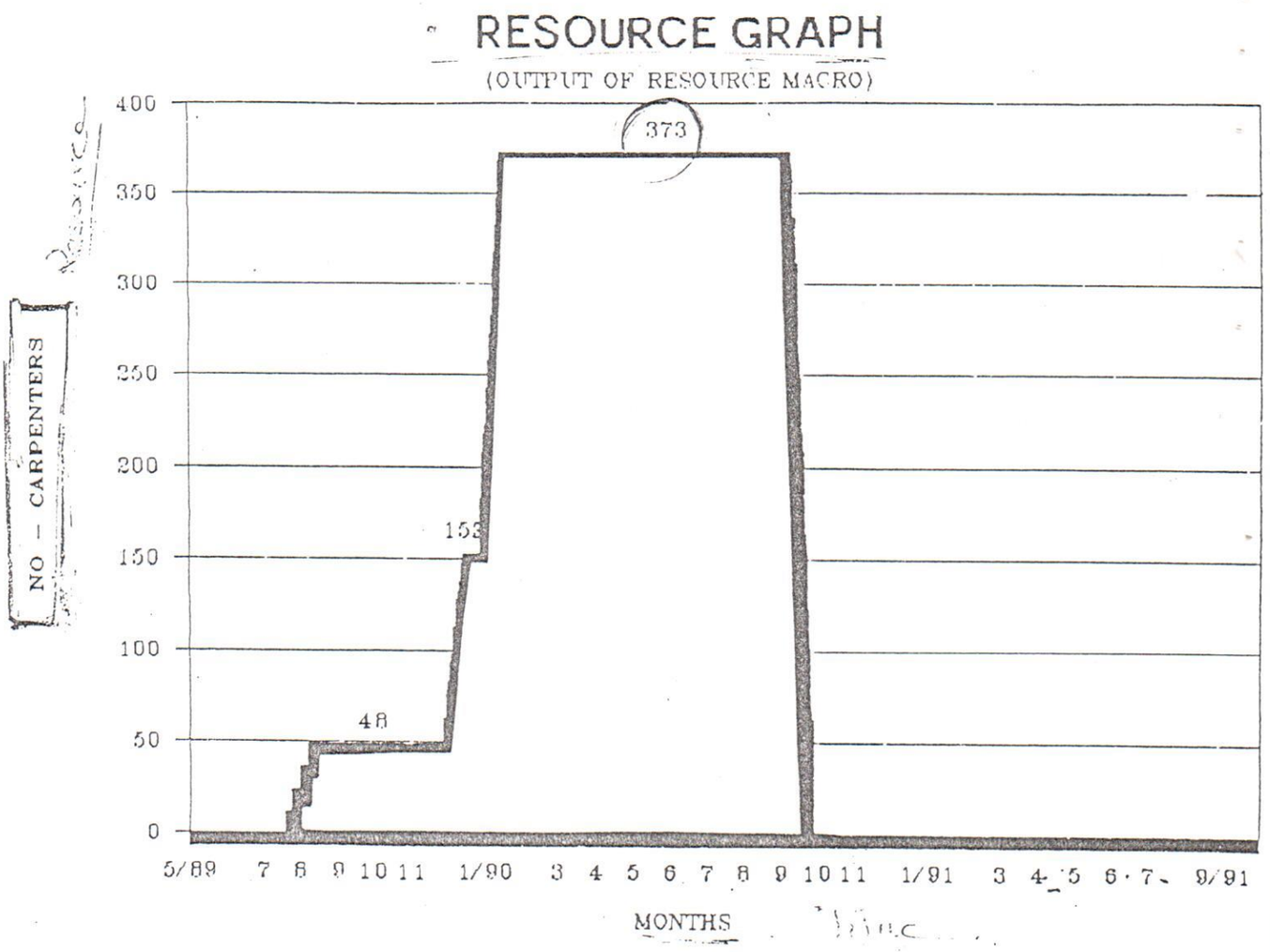


Fig. (3)

3- Distribution Macro :

The programme distributes the monthly rates (either money or quantity) among their working months for every item of the bill of quantity. All these values are added to provide the monthly profile and cumulative S-curve till the end of the project.

The Macro draws the monthly profile and cumulative S-curve graphs. See Fig. (4 & 5).

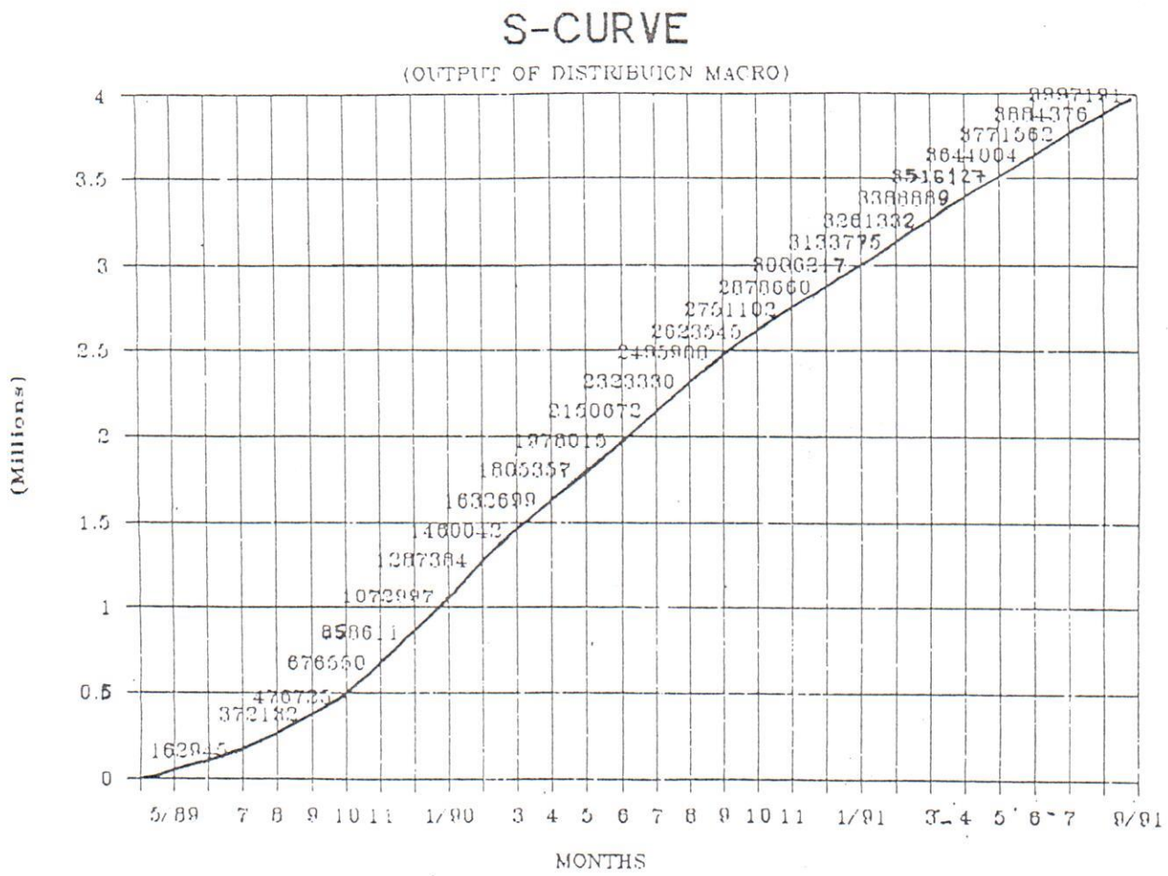


Fig. (4)

4- Master Distribution Macro :

This Macro adds up the monthly profiles which were provided from the distribution Macro for each building seperateley.

Having added the monthly profiles the macro draws the global monthly profile and global cumulative S-curve .See Fig.(6 & 7).

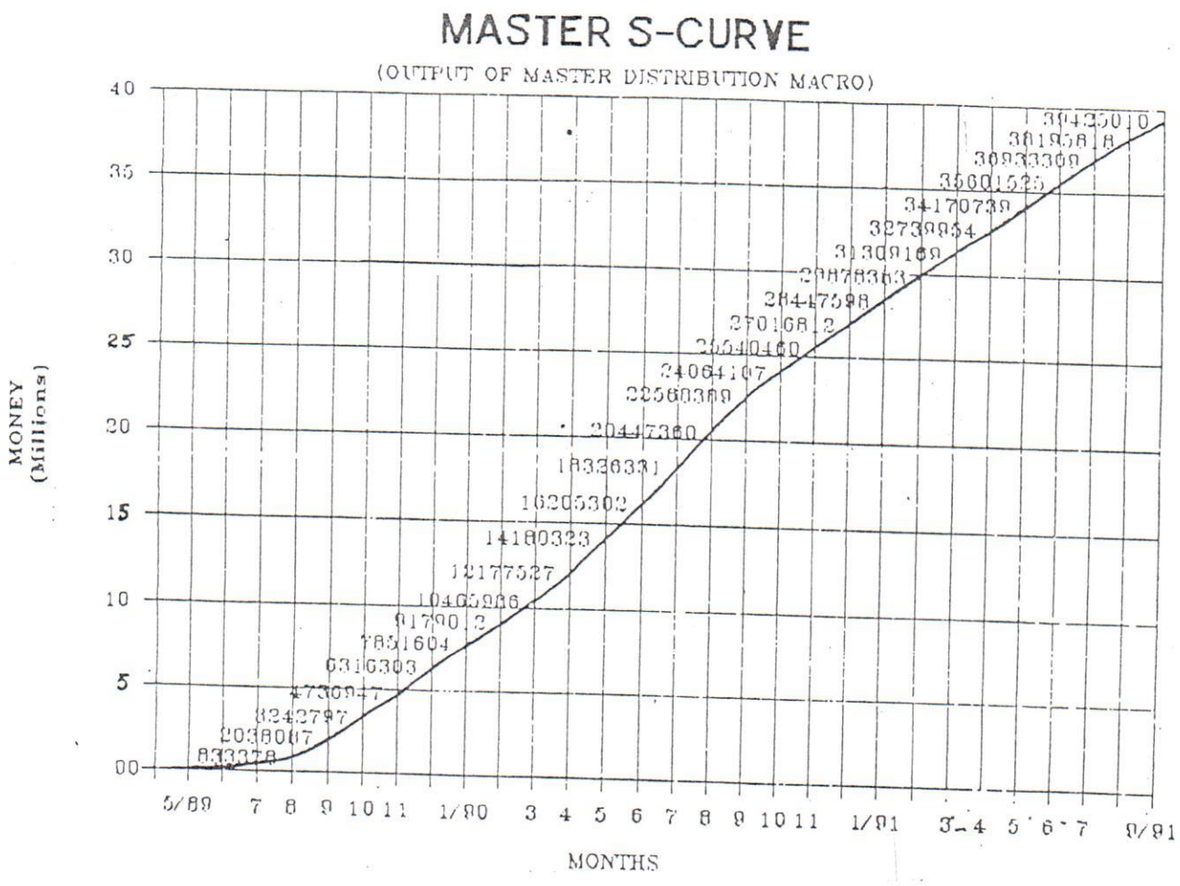


Fig. (6)

MASTER MONTHLY MONEY PROFILE

(OUTPUT OF MASTER DISTRIBUTION MACRO)

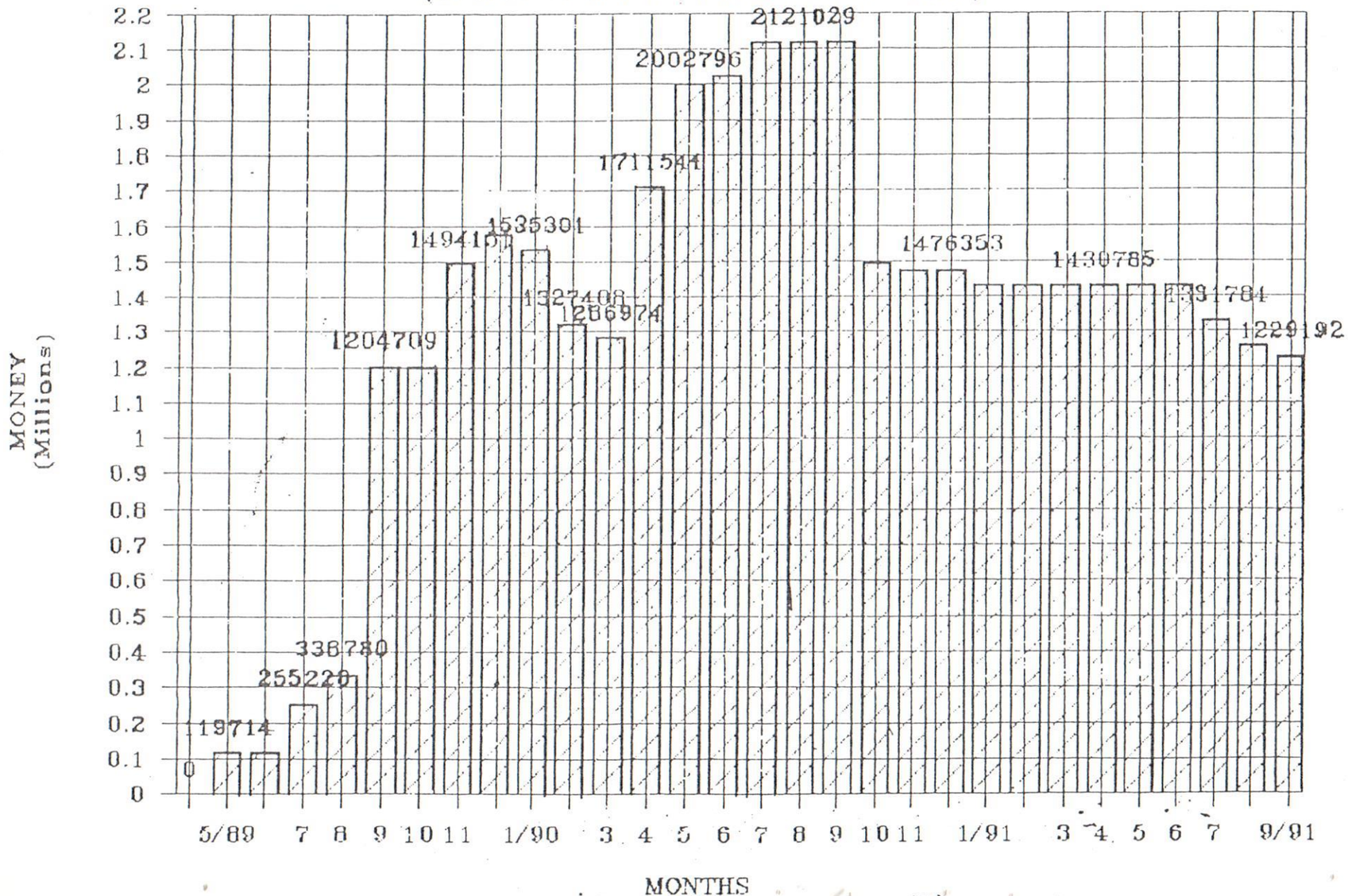


Fig. (7)

5- Cash Flow Macro :

The programme calculates the cash flow of the project taking into account the downpayment retention,..etc

The macro draws the cash flow. the graph shows the cash-in and cash-out values to give the estimated values of profit or loss during the project.See Fig.(8).

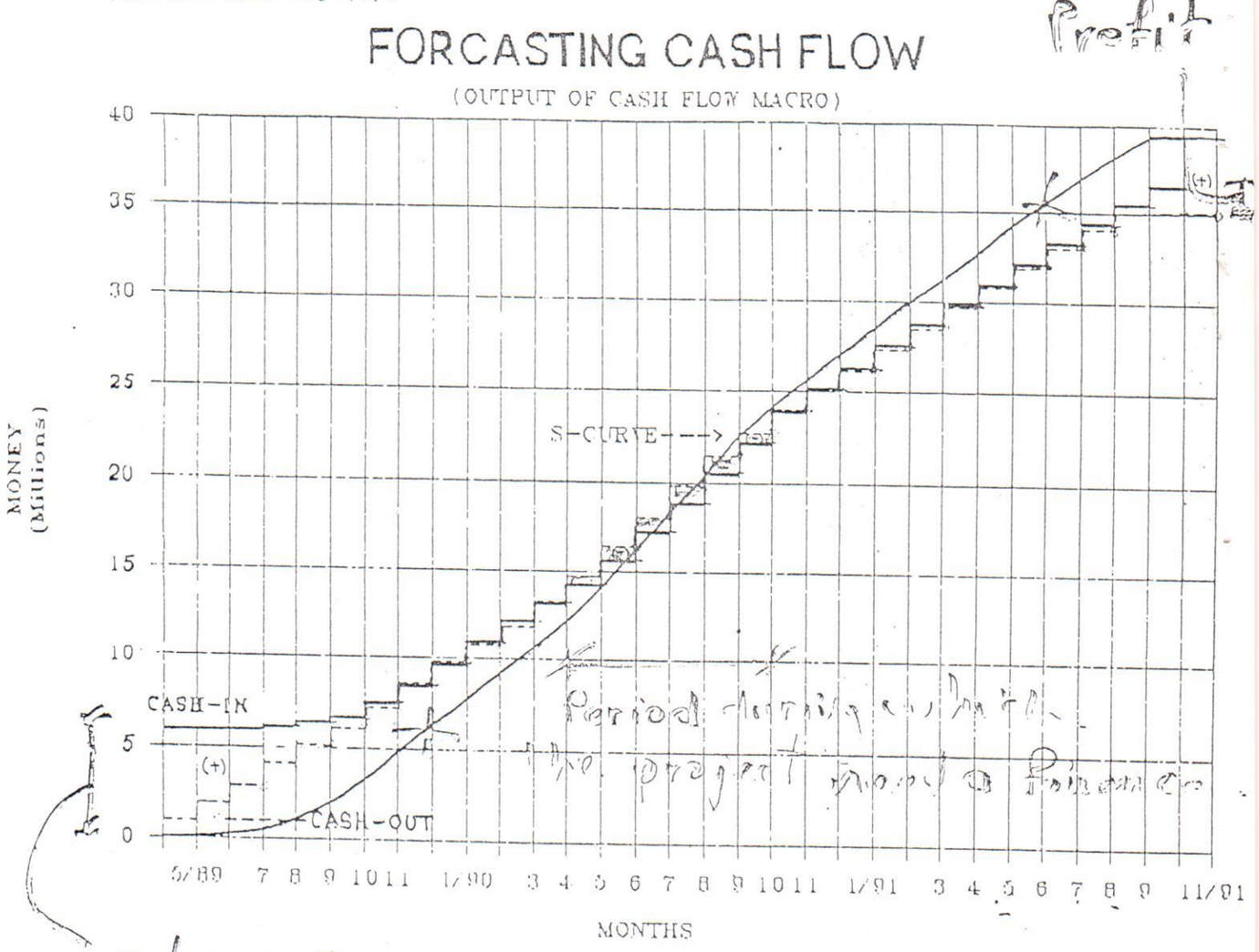


Fig. (8)