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PERT / CPM Techniques in Planning and Monitoring Some Agricultural Projects

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Abstract :

This paper aims at providing the reader with the applications of Network Analysis Techniques to planning in general and to the Agricultural sector in particular.

It also aims to treat the lack of essential details (which are very useful details to trainees in agricultural planning) and not explored in the reference listed below .

It discusses how the process of project planning and management is performed in some agricultural projects and how PERT/CPM can be effectively used . This well be done through three case studies . These case studies are quoted (but modified here --- see later ---) from :

Maurizio Garzia ,
Project planning and monitoring using Network Analysis Techniques ,
Development policy studies and training services (ESPT) , 1982 .

The three case studies are :

1. Wailing lift irrigation projects ,
2. Terai-construction of a sawmill , and
3. Integrated area development programme .

While the first two case studies focus on the application of Network Analysis Techniques to specific sectoral projects , the third case study aims at illustrating how the same techniques could be applied to the planning of an integrated programme comprising several projects from different sectors .

The precedence relationships between the project activities were specified by using the approach named : *
An Activity-On-Arrow representation (or An Arrow Network) .

* The next paper will present a modified version named :
An Activity-On-Node representation (or A Node Network) .

Introduction :

In agricultural planning , the PROJECT may be defined as a major undertaking made up of many tasks or ACTIVITIES.

The activities are interrelated through PRECEDENCE relationships in a way such that certain activities cannot be STARTed until others are COMPLETEd. If activity A must precede activity B, we say that A is a Predecessor of B and B is a Successor of A . If no other activity comes so that B can start immediately upon COMPLETION of A , we use the term immediate Predecessor and so immediate Successor.

Network Analysis Techniques , specially the CPM (Critical Path Method) and the PERT (Program Evaluation and Review Technique) are very useful techniques for planning , scheduling , and controlling and evaluating the cost and time aspects of large complex projects. The construction of buildings or bridges , the development of new products or systems and many complex agricultural projects are typical applications of these techniques .

Usually , there are three factors influencing Project management decisions :

i, Time ,

ii, Available resources , and

iii, Cost .

i, If we have only one limited supply resource (named TIME) and sufficient other production resources (such as materials , equipment , personnel , . . . etc) available at any time to proceed with any activities whose Predecessors have all been completed , we may ask :

1. What is the Expected project COMPLETION time ?

2. What is the Scheduled START time and COMPLETION time for each activity ?

3. Which activities are CRITICAL , in the sense that if they are not completed on time , the entire project will be delayed ?

4. For each nonCRITICAL activity , how much SLACK or FLOAT time is there : i.e., how long can the activity be held up (or kept back) without delaying the project ?

The time duration of each activity may be assumed to be either precisely known (the deterministic case) or specified in terms of the following three estimates :

. An optimistic time (or shortest possible time) ,

. A pessimistic time (or longest possible time) , and

. A most likely time .

ii, Project Managers must also determine how many resources , such as People and equipment , are available for the project and how they should be allocated among the various activities . Improper management of resources can significantly delay many projects .

iii, The cost of the project must be controlled . Managers seek ways in which cost can be minimized . This is closely related to the allocation of resources through the project .

PERT was developed with an objective of being able to handle uncertainties in activity completion times .
On the other hand , CPM was developed for scheduling and controlling projects when the task or activity times were considered well known . However , CPM offered the option of reducing activity times by adding more workers and/or resources , usually at an increased cost . A distinguishing feature of the CPM was that it enabled time and cost tradeoffs for the various activities in the project .

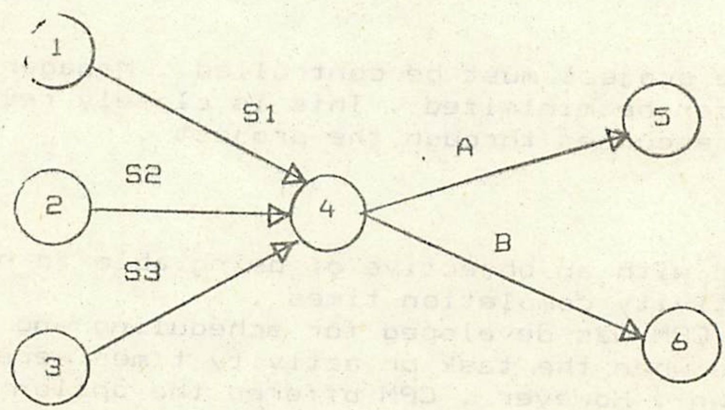
In today's usage , the distinction between PERT and CPM as two separate techniques have largely disappeared . Computerized versions of the PERT/CPM approach often contain options for considering uncertainty in activity times as well as activity time-cost tradeoffs .

Before starting the case studies , let us discuss the algorithm and solve at least one example :

The Activity-On-Arrow Approach :

With An Activity-On-Arrow approach , the project is drown as a network in which the arrows represent activities and the nodes are the events or time points at which the last of the incoming activities ends and the outgoing activities can begin . For example ,

If activities A and B can both begin only after all of three activities S1 , S2 , and S3 are complete , the Activity-On-Arrow (or the Arrow Network) can be represented as follows :



Node 4 represents the event that all of the activities S1 , S2 , and S3 have been completed ; and the activities A nd B can start .

The solution ALGORITHM :

1. In Case of Deterministic Activity Times :

The basic problem concerns of finding :

- The ES (Earliest Start) and EF (Earliest Finish) time possible for each activity ,
- The LS (Latest Start) and LF (Latest Finish) times for each activity that would not delay the project as a whole are also generated .
- The critical activities ,
- the slack times , and
- The minimum duration of the project .

2. In Case of Probabilistic Activity Times :

With probabilistic activity times , the mean and variance for each activity are obtained as follows :

If :

a_i : represents the estimate of the optimistic duration of activity i ,

m_i : represents the estimate of the most likely duration of activity i , and

b_i : represents the estimate of the pessimistic duration of activity i .

then , the mean (t_i) and the standard deviation (d_i) are computed as follows :

$$t_i = \frac{a_i + 4\,m_i + b_i}{6}$$

&

$$d_i = (b_i - a_i) / 3.2$$

Hint :

This is a technical issue involving the precise probabilistic meaning of a " pessimistic " or " optimistic " estimate , and it is also an attempt to compensate in part for a tendency of the algorithm to underestimate the variance of the project duration .

The probabilistic critical path calculation is now performed using the mean time for each activity , and the project mean and variance are estimated as the sums of means and variances of critical activities .

Project duration is assumed to be normally distributed with these parameters .

Sample Problem 1 :

The following table represents the activities , with their required precedence and the estimated times (in weeks) that each activity will take , of one project (each of these activities is itself a more or less complex project , but as a first pass -- management wishes to evaluate the undertaking without further refinement) .

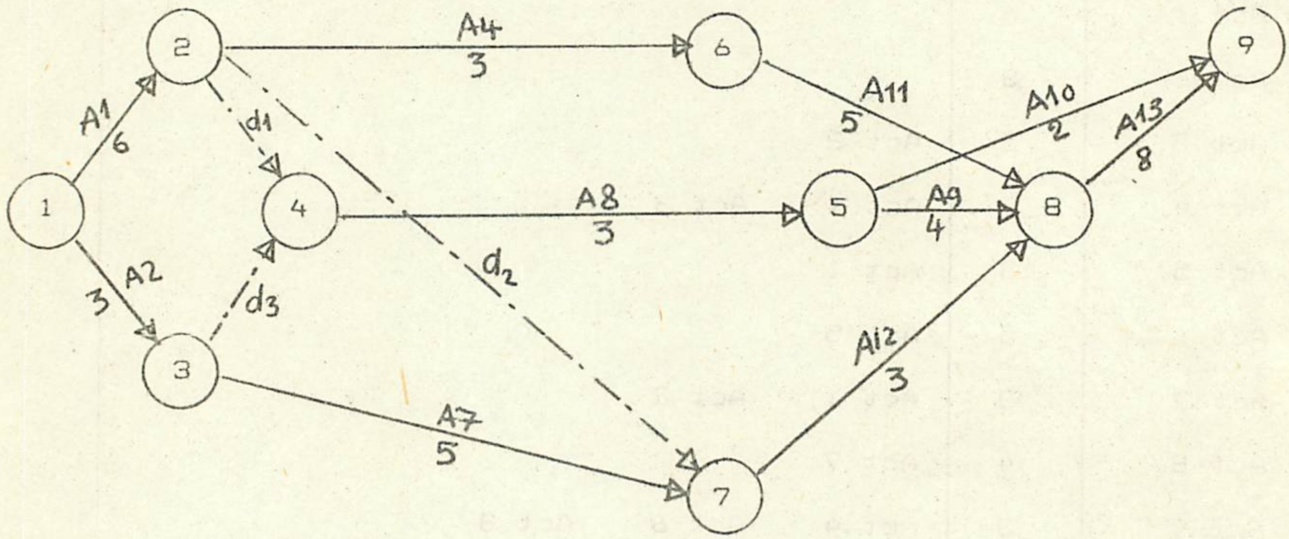
Act. code	Time	Predecessors				
		pred 1	pred 2	pred 3	pred 4	. . .
Act 1	6					
Act 2	3					
Act 3	5	Act 2				
Act 4	3	Act 1	Act 3			
Act 5	3	Act 1				
Act 6	5	Act 5				
Act 7	3	Act 1	Act 2			
Act 8	4	Act 7				
Act 9	3	Act 4	Act 6	Act 8		
Act10	2	Act 7				

a: NPROB_01.DAT

The Activity-On-Arrow Approach :

This Approach requires that an Arrow Network to be prepared as a first step .

The following figure represents the Arrow Network for this example :



The Corresponding Activity-On-Arrow Table :

Act. Code	Act. Nodes i	Act. Nodes j	Time	
Act 1	1	2	6	
Act 2	1	3	3	
d1	2	4	0	<--- dummy activity
Act 4	2	6	3	
d2	2	7	0	<--- dummy activity
d3	3	4	0	<--- dummy activity
Act 7	3	7	5	
Act 8	4	5	3	
Act 9	5	8	4	
Act10	5	9	2	
Act11	6	8	5	
Act12	7	8	3	
Act13	8	9	3	

a: APROB_01.DAT

Notice that :

- You can see that it was necessary to add 3 dummy activities : d1 , d2 , and d3 .
- Having numbered the Nodes , we need only give the Start and End nodes of each activity to specify precedence .
- All activities must be entered including dummy activities which should be assigned zero time . Thus , the number of activities has been increased accordingly .
- The Events must be numbered " left-to-right " ; i.e., each activity's End node must have a larger number than its Start node . This is to assure the absence of loops in the network and avoids any need to check for loops .

The computer input data and output results will be shown in the following pages .

DETAILED PROBLEM DATA LISTING FOR
Prblem 01 Arrow Network

ROW LABEL	SYMBOL	MEAN TIME	START NODE	END NODE
ACT 1	A01	6.	1	2
ACT 2	A02	3.	1	3
ACT 3	A03	0.	2	4
ACT 4	A04	3.	2	6
ACT 5	A05	0.	2	7
ACT 6	A06	0.	3	4
ACT 7	A07	5.	3	7
ACT 8	A08	3.	4	5
ACT 9	A09	4.	5	8
ACT 10	A10	2.	5	9
ACT 11	A11	5.	6	8
ACT 12	A12	3.	7	8
ACT 13	A13	3.	8	9

Prblem 01 Arrow Network
ACTIVITY LIST REPORT

Activity Name	Symb	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	
ACT 1	A01	0.00	6.00	0.00	6.00	0.00	c
ACT 2	A02	0.00	3.00	3.00	6.00	3.00	
ACT 3	A03	6.00	6.00	7.00	7.00	1.00	
ACT 4	A04	6.00	9.00	6.00	9.00	0.00	c
ACT 5	A05	6.00	6.00	11.00	11.00	5.00	
ACT 6	A06	3.00	3.00	7.00	7.00	4.00	
ACT 7	A07	3.00	8.00	6.00	11.00	3.00	
ACT 8	A08	6.00	9.00	7.00	10.00	1.00	
ACT 9	A09	9.00	13.00	10.00	14.00	1.00	
ACT 10	A10	9.00	11.00	15.00	17.00	6.00	
ACT 11	A11	9.00	14.00	9.00	14.00	0.00	c
ACT 12	A12	8.00	11.00	11.00	14.00	3.00	
ACT 13	A13	14.00	17.00	14.00	17.00	0.00	c

Earliest project completion time = 17.00000

```
Prblem 01 Arrow Network : Bar chart
ct.   0                                                                   17.00
------+------+------+------+------+------+------+------+------+------+------+--

01    |CCCCCCCCCCCCCCCCCCCCCCCCCCC                                             |
04    |                          CCCCCCCCCCCCC                                 |
11    |                                      CCCCCCCCCCCCCCCCCCCCCCC           |
13    |                                                            CCCCCCCCCCCC
02    |xxxxxxxxxxxxx.............                                              |
07    |            xxxxxxxxxxxxxxxxxxxxxx.............                         |
06    |            x.................                                      |
08    |                          xxxxxxxxxxxxx....                             |
03    |                          x....                                         |
05    |                          x.....................                        |
12    |                                  xxxxxxxxxxxxx............             |
09    |                                      xxxxxxxxxxxxxxxxxxx....           |
10    |                                       xxxxxxxx..........................
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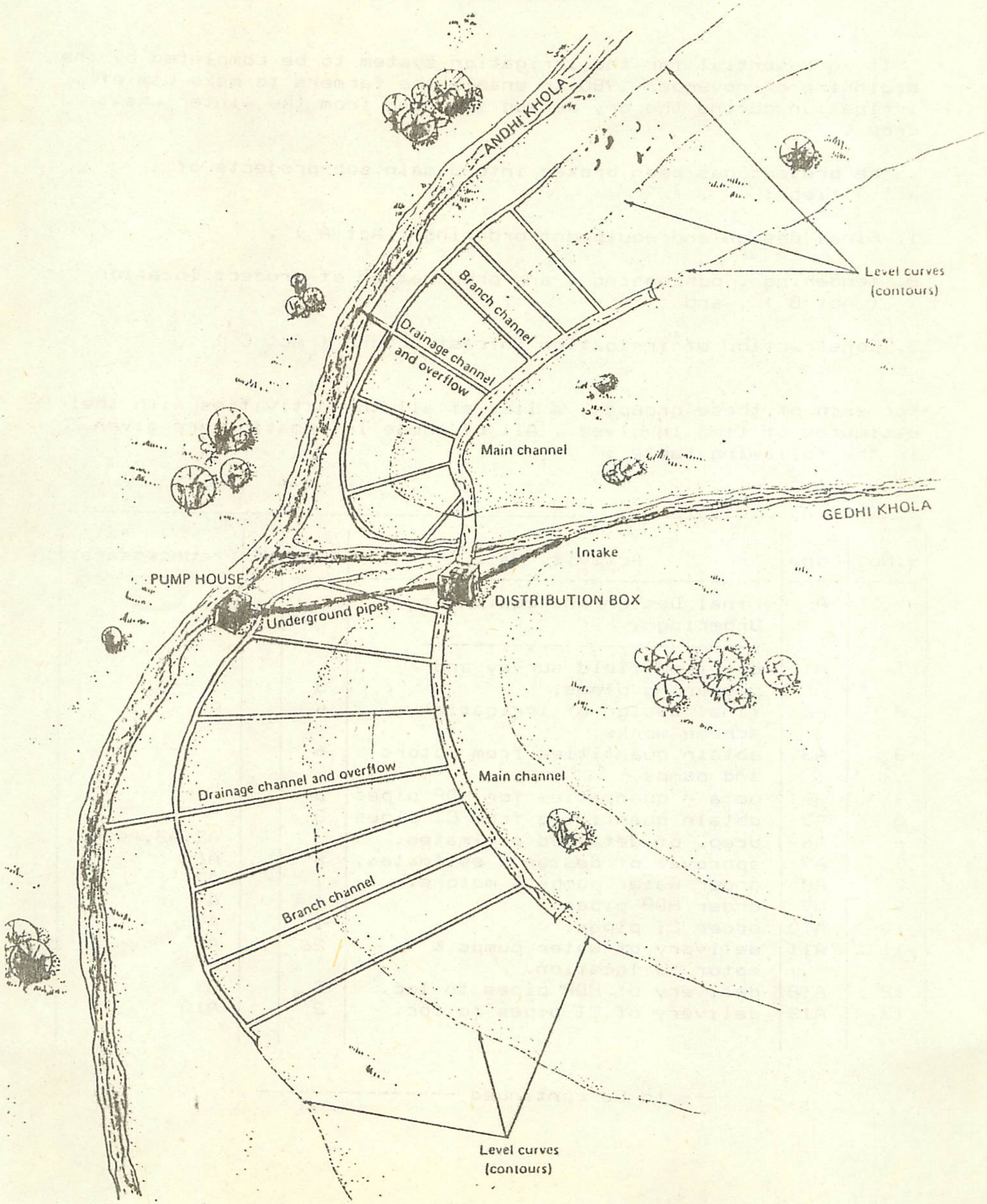
Case study No 1 :

WALING LIFT IRRIGATION PROJECT

Background Information :

On october 1 , 1979 --- the Government of NEPAL decided to finance the Waling Lift Irrigation Project (WLIPN) along the lines proposed in the feasibility study prepared by the Agricultural Projects Service Centre (APSC). The project consists of a lift irrigation infrastructure network , covering 45 ha. in the waling area --- see the figure , integrated with agricultural development activities ; i.e., improved seeds , fertilizers , pesticides , credit , training and extension .

Waling Lift Irrigation Project Diagram :



It is essential for the irrigation system to be completed by the beginning of november 1980 to enable the farmers to make use of irrigation during the dry period starting from the winter wheat crop .

The project has been broken into 3 main sub-projects of activities :

1. Final design and equipment ordering (Act A) ,

2. Tendering , purchasing , and preparation of project location (Act B) , and

3. Construction of irrigation infrastructure (Act C) .

For each of these groups , a list of all the activities with their estimates of time involved . All of these information are given in the following table :

S.No.	Code	Activity Name	Time	MP	* Predecessors
	A	Final Design and Equipment Ordering :			
1	A1	detailed field survey and preparing plans.	3		--
2	A2	final design of irrigation scheme works.	4		A1
3	A3	obtain quantities from motors and pumps.	6		--
4	A4	obtain quantities for HDP pipes	6		--
5	A5	obtain quantities from CI pipes	3		--
6	A6	prep. of detailed estimates.	3		A2,A3,A4,A5
7	A7	approval of design & estimates.	8		A6
8	A8	order water pumps & motors.	1		A7
9	A9	order HDP pipes.	1		A7
10	A10	order CI pipes.	1		A7
11	A11	delivery of water pumps & motor to location.	26		A8
12	A12	delivery of HDP pipes to loc.	8		A9
13	A13	delivery of CI pipes to loc.	2		A10

---- to be continued ---------------

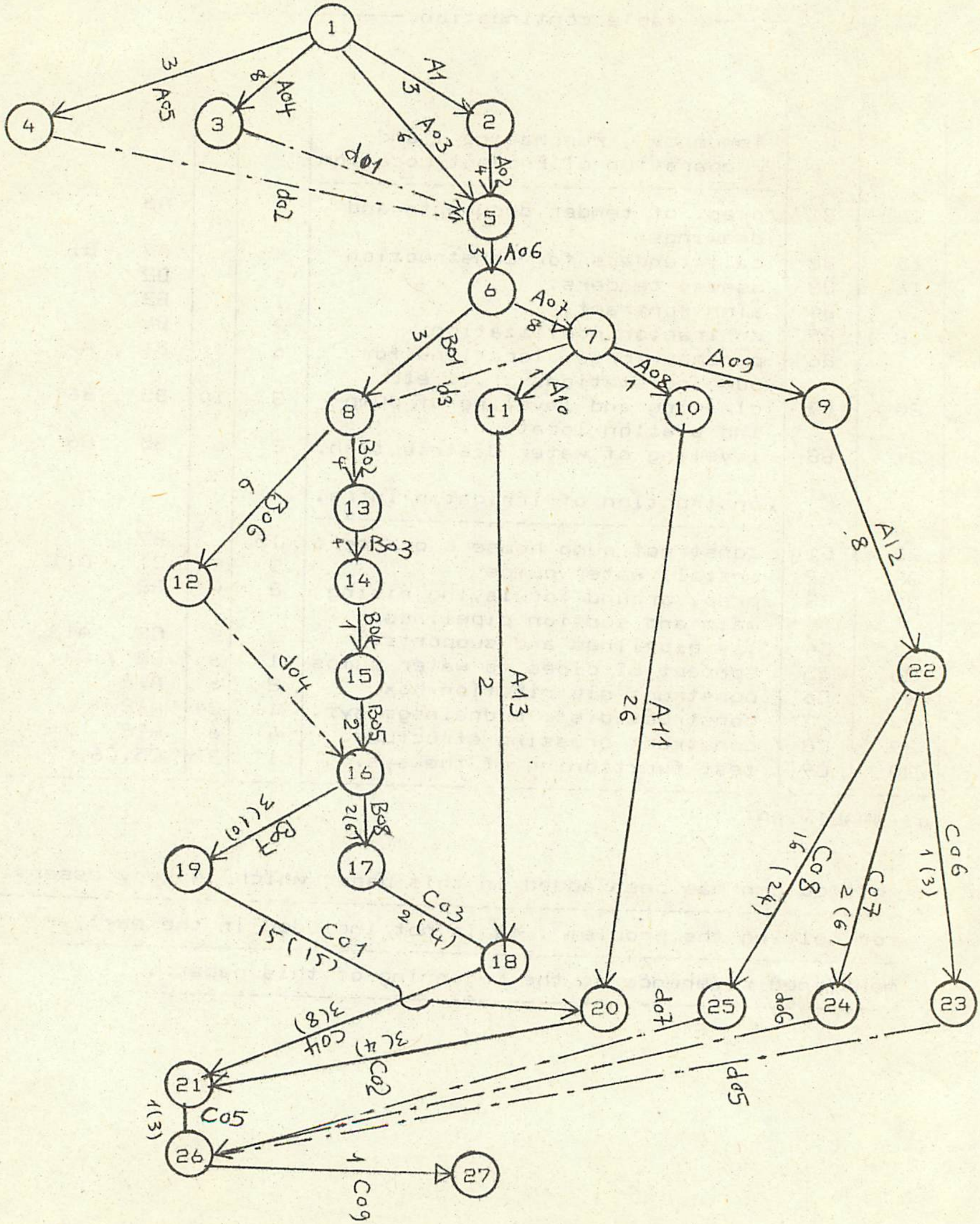
---- table continuation --------------

	B	Tendency , Purchasing , and Preparation of Project Location			
14	B1	prep. of tender documents and drawings.	3		A6
15	B2	call tenders for construction	4		A7 , B1
16	B3	assess tenders.	4		B2
17	B4	sign contract.	1		B3
18	B5	contractor mobilization.	2		B4
19	B6	purchase proj. locations for pumping stations , ... etc.	6		B1 , A7
20	B7	clearing and leveling of pumping station location.	3	10	B5 , B6
21	B8	leveling of water distribution.	2	6	B5 , B6
	C	Construction of irrigatin Infra.			
22	C1	construct pump house & quarters	15		B7
23	C2	install water pumps	3	4	C1 , A11
24	C3	prep. ground for laying rising main and suction pipelines.	2	4	B8
25	C4	lay pipelines and supports.	3	8	C3 , A13
26	C5	connect CI pipes to water pumps	1	3	C2 , C4
27	C6	construct distribution box.	2	6	A12
28	C7	construct dist. & drainsge sys.	16	24	A12
29	C8	construct crossing structure.	4	6	A12
30	C9	test functioning of the sys.	1	2	C5,C6,C7,C8

a: NWALIP.DAT

* this column has been added in this paper which is very essential for solving the problem . it is not included in the earlier mentioned reference at the beginning of this paper .

The Activity-On-Arrow Network :



List of Project Activities For Computer Purposes :

S.No.	Act.Nodes i	j	Time	Code	MP	Predecessors *
1	1	2	3	A1		--
2	1	3	6	A4		--
3	1	4	3	A5		--
4	1	5	6	A3		--
5	2	5	4	A2		A1
6	3	5	0	d1		
7	4	5	0	d2		
8	5	6	3	A6		A2,A3,A4,A5
9	6	7	8	A7		A6
10	6	8	3	B1		A6
11	7	8	0	d3		
12	7	9	1	A9		A7
13	7	10	1	A8		A7
14	7	11	1	A10		A7
15	8	12	6	B6		A7
16	8	13	4	B2		A7,B1
17	9	22	8	A12		A9
18	10	20	26	A11		A8
19	11	18	2	A13		A10
20	12	16	0	d4		
21	13	14	4	B3		B2
22	14	15	1	B4		B3
23	15	16	2	B5		B4
24	16	17	2	B8	2	B5,B6
25	16	19	3	B7	10	B5,B6
26	17	18	2	C3	4	B8
27	18	21	3	C4	8	C3,A13
28	19	20	15	C1	15	B7
29	20	21	3	C2	4	C1,A11
30	21	26	1	C5	3	C2,C4
31	22	24	2	C6	6	A12
32	22	23	1	C7	24	A12
33	22	25	16	C8	6	A12
34	23	26	0	d5		
35	24	26	0	d6		
36	25	26	0	d7		
37	26	27	1	C9	12	C5,C6,C7,C8

a: AWALIP.DAT

* only the first 4 columns are needed as input data for the computer program: (Activity-On-Arrow Approach).

DETAILED PROBLEM DATA LISTING FOR

ROW LABEL	SYMBOL	MEAN TIME	START NODE	END NODE
ACT 1	A01	3.	1	2
ACT 2	A04	6.	1	3
ACT 3	A05	3.	1	4
ACT 4	A03	6.	1	5
ACT 5	A02	4.	2	5
ACT 6	d01	0.	3	5
ACT 7	d02	0.	4	5
ACT 8	A06	3.	5	6
ACT 9	A07	8.	6	7
ACT 10	B01	3.	6	8
ACT 11	D03	0.	7	8
ACT 12	A09	1.	7	9
ACT 13	A08	1.	7	10
ACT 14	A10	1.	7	11
ACT 15	B06	6.	8	12
ACT 16	B02	4.	8	13
ACT 17	A12	8.	9	22
ACT 18	A11	26.	10	20
ACT 19	A13	2.	11	18
ACT 20	d04	0.	12	16
ACT 21	B03	4.	13	14
ACT 22	B04	1.	14	15
ACT 23	B05	2.	15	16
ACT 24	B08	2.	16	17
ACT 25	B07	3.	16	19
ACT 26	C03	2.	17	18
ACT 27	C04	3.	18	21
ACT 28	C01	15.	19	20
ACT 29	C02	3.	20	21
ACT 30	C05	1.	21	26
ACT 31	C06	2.	22	24
ACT 32	C07	1.	22	23
ACT 33	C08	16.	22	25
ACT 34	d05	0.	23	26
ACT 35	d06	0.	24	26
ACT 36	d07	0.	25	26
ACT 37	C09	1.	26	27

The output Results :

S.no.	i	j	dur.	EStime	EFtime	LStime	LFtime	T.F.	
1	1	2	3.0	0.0	3.0	0.0	3.0	0.0	C
2	1	3	6.0	0.0	6.0	1.0	7.0	1.0	
3	1	4	3.0	0.0	3.0	4.0	7.0	4.0	
4	1	5	6.0	0.0	6.0	1.0	7.0	1.0	
5	2	5	4.0	3.0	7.0	3.0	7.0	0.0	C
6	3	5	0.0	6.0	6.0	7.0	7.0	1.0	
7	4	5	0.0	3.0	3.0	7.0	7.0	4.0	
8	5	6	3.0	7.0	10.0	7.0	10.0	0.0	C
9	6	7	8.0	10.0	18.0	10.0	18.0	0.0	C
10	6	8	3.0	10.0	13.0	15.0	18.0	5.0	
11	7	8	0.0	18.0	18.0	18.0	18.0	0.0	C
12	7	9	1.0	18.0	19.0	26.0	27.0	8.0	
13	7	10	1.0	18.0	19.0	20.0	21.0	2.0	
14	7	11	1.0	18.0	19.0	44.0	45.0	26.0	
15	8	12	6.0	18.0	24.0	23.0	29.0	5.0	
16	8	13	4.0	18.0	22.0	18.0	22.0	0.0	C
17	9	22	8.0	19.0	27.0	27.0	35.0	8.0	
18	10	20	26.0	19.0	45.0	21.0	47.0	2.0	
19	11	18	2.0	19.0	21.0	45.0	47.0	26.0	
20	12	16	0.0	24.0	24.0	29.0	29.0	5.0	
21	13	14	4.0	22.0	26.0	22.0	26.0	0.0	C
22	14	15	1.0	26.0	27.0	26.0	27.0	0.0	C
23	15	16	2.0	27.0	29.0	27.0	29.0	0.0	C
24	16	17	2.0	29.0	31.0	43.0	45.0	14.0	
25	16	19	3.0	29.0	32.0	29.0	32.0	0.0	C
26	17	18	2.0	31.0	33.0	45.0	47.0	14.0	
27	18	21	3.0	33.0	36.0	47.0	50.0	14.0	
28	19	20	15.0	32.0	47.0	32.0	47.0	0.0	C
29	20	21	3.0	47.0	50.0	47.0	50.0	0.0	C
30	21	26	1.0	50.0	51.0	50.0	51.0	0.0	C
31	22	24	2.0	27.0	29.0	49.0	51.0	22.0	
32	22	23	1.0	27.0	28.0	50.0	51.0	23.0	
33	22	25	16.0	27.0	43.0	35.0	51.0	8.0	
34	23	26	0.0	28.0	28.0	51.0	51.0	23.0	
35	24	26	0.0	29.0	29.0	51.0	51.0	22.0	
36	25	26	0.0	43.0	43.0	51.0	51.0	8.0	
37	26	27	1.0	51.0	52.0	51.0	52.0	0.0	C

Total project time = 52

C means Critical Activity . . .

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Waling Lift Irrigation Project : Bar chart
Act.   0                                                                 52
-------+------+------+------+------+------+------+------+------+------+----

A01    ICCCCC
A02    I    CCCCCC
A06    I         CCCCC
A07    I             CCCCCCCCCCCC
B02    I                        CCCCCCC
B03    I                              CCCCCC
B04    I                                   CC
B05    I                                    CCCC
B07    I                                       CCCCC
C01    I                                           CCCCCCCCCCCCCCCCCCCCC
C02    I                                                               CCCCC
C05    I
C09    I
A03    Ixxxxxxxxx.
A04    Ixxxxxxxxx.
A05    Ixxxxx.....
B01    I             xxxxx.......
A08    I                        xxx..
B06    I                        xxxxxxxxx.......
A09    I                        xxx..........
A10    I                        xxx...................................
A11    I                          xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..
A12    I                          xxxxxxxxxxx...........
A13    I                          xxx...................................
C07    I                                    xxxxxxxxxxxxxxxxxxxxxxx.......
C08    I                                    xxxxxxx........................
C06    I                                    xxxx...........................
B08    I                                       xxxx...................
C03    I                                          xxx...................
C04    I                                            xxxxx.................
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Case study No 2 :

THE CONSTRUCTION OF A SAWMILL

Background Information :

The Government of NEPAL decided to build a new modern Sawmill in a Terai District (see the diagram) . It is essential to get the mill into operation as quickly as possible because of the Government's commitment to supply a foreign Investor with a large portion of the output of the mill for a box factory to be built adjacent to the sawmill .

The box plant is planned for completion in 12 months ; the mill's profits from sales to it are projected to be about RS 10 000 per week .

To lay out the total project so as to insure against leaving the job undone and so that APSC (Agricultural Projects Service Centre) could see at a glance what has to be done next , APSC has to use the Network Analysis Techniques .

The project has been broken down into three main groups of activities :

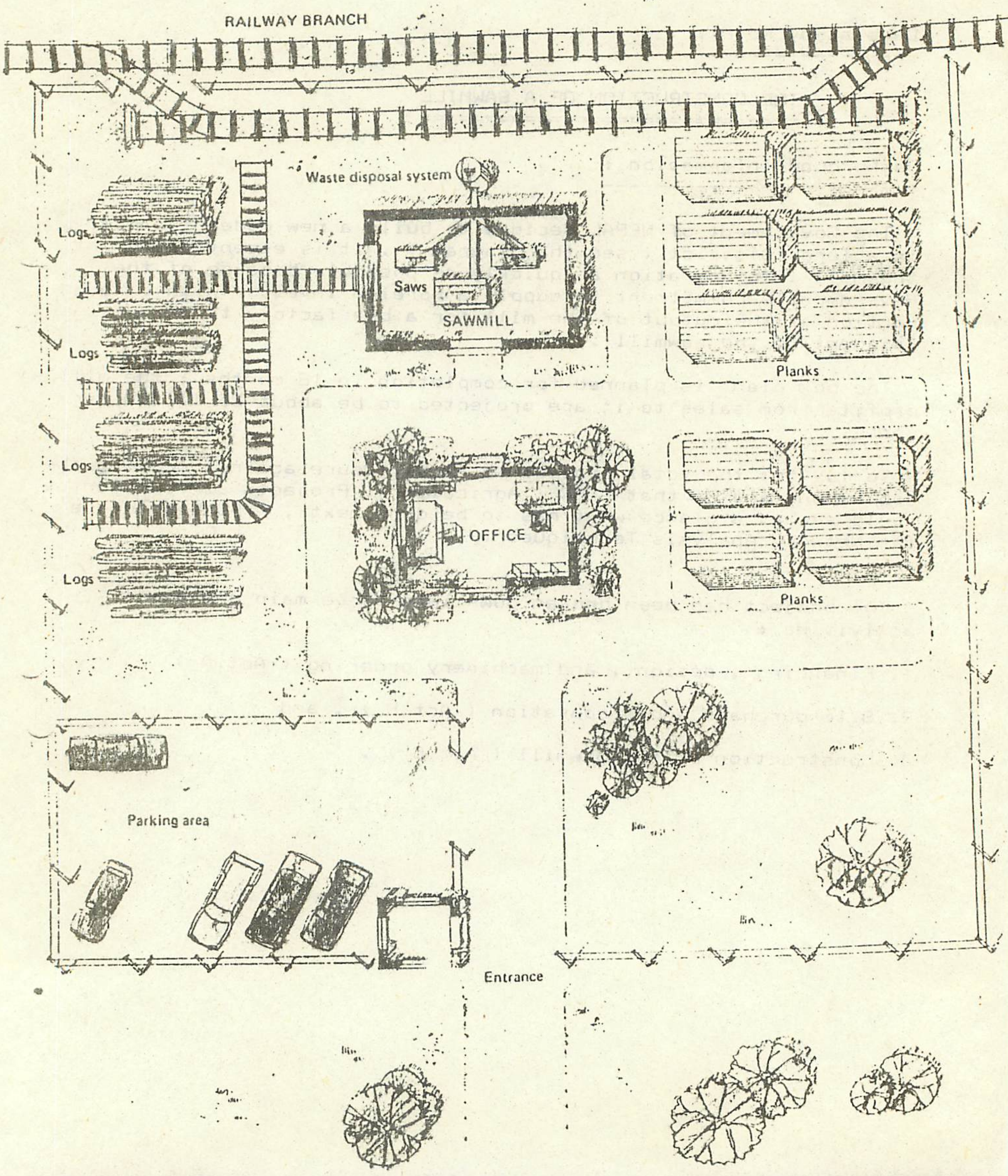
1. Financing , design , and machinery ordering (Act A) ,

2. Site purchase and preparation (Act B) , and

3. Construction of the Sawmill (Act C) .

TERAI - CONSTRUCTION OF A SAWMILL

Diagram



For each of these groups , the list of activities to be carried out and the best estimate of the time involved was also prepared . These information are given in the following table :

S.No.	Code	Activity Name	Time	MP	Predecessors *
	A	Financing , design , & machine Ordering :			
1	A1	Negotiation and signing the loans from financing agency to finance the project.	3		--
2	A2	Design of the Mill.	12		A1
3	A3	Approval of the design.	1		A2
4	A4	Final Equipment and machinery specification.	2		A2
5	A5	Approval of machinery specification by the ministry.	1		A4
6	A6	Order of European machinery.	1		A5
7	A7	Order of local machinery.	1		A5
8	A8	Delivery of European machinery.	24		A6
9	A9	Delivery of local machinery.	8		A7
10	A10	Blueprints of final mill design	1		A3
11	A11	Call tenders for mill construction.	2		A10
12	A12	Sign contract for mill constr.	1		A11

---- to be continued ----------------

---- table continuation ----------

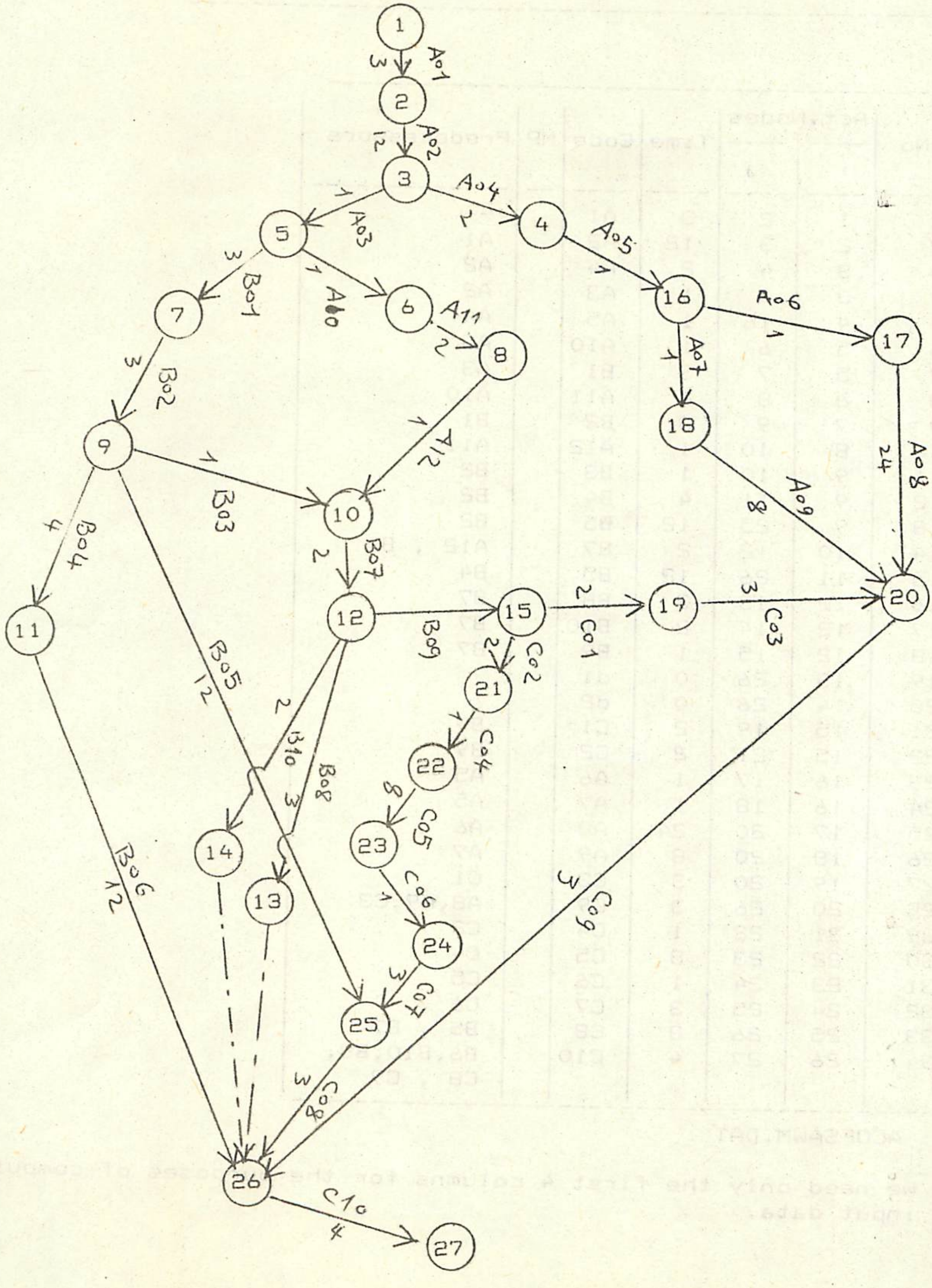
	B	Site purchase and preparation.		
13	B1	Locate suitable site for mill construction.	3	A3
14	B2	Negotiate and purchase site.	3	B1
15	B3	Survey and leveling of site.	1	B2
16	B4	Negotiate and order of a railway branch to the site.	4	B2
17	B5	Order and installation of necessary services(water,elect.	12	B2
18	B6	Construct railway branch.	12	B4
19	B7	Clearing and grading of site.	2	A12 , B3
20	B8	Fencing property.	3	B7
21	B9	Survey the foundation for mill.	1	B7
22	B10	Construction of roads and parking lots.	2	B7
	C	Construction of the sawmill.		
23	C1	Construct foundation of the three saws.	2	B9
24	C2	Construct foundation for mill building.	2	B9
25	C3	Let saw foundation dry. rising	3	C1
26	C4	Let mill build. foundation dry.	1	C2
27	C5	Construct mill building structure excluding exterior walls.	8	C4
28	C6	Install waste disposal system.	1	C5
29	C7	Erect exterior walls (after waste disposal system in place)	3	C6
30	C8	Connect outside services (electricity, water,..)previously ordered and installed.	3	B5 , C7
31	C9	Install machinery(saws, conveyors, and control boxes.	3	A8 ,A9 , C3
32	C10	Set up machinery to make it ready for operation.	4	B6,B8,B10, C8,C9

a: NCOFSAWM.DAT

---

* this column has been added in this paper which is very essential for solving the problem . it is not included in the earlier mentioned reference at the beginning of this paper .

The Activity-On-Arrow Network :



List Of Project Activities For Computer purposes :

S.No	Act.Nodes i	j	Time	Code	MP	Predecessors *
1	1	2	3	A1		--
2	2	3	12	A2		A1
3	3	4	2	A4		A2
4	3	5	1	A3		A2
5	4	16	1	A5		A4
6	5	6	1	A10		A3
7	5	7	3	B1		A3
8	6	8	2	A11		A10
9	7	9	3	B2		B1
10	8	10	1	A12		A11
11	9	10	1	B3		B2
12	9	11	4	B4		B2
13	9	25	12	B5		B2
14	10	12	2	B7		A12 , B3
15	11	26	12	B5		B4
16	12	13	3	B8		B7
17	12	14	2	B10		B7
18	12	15	1	B9		B7
19	13	26	0	d1		
20	14	26	0	d2		
21	15	19	2	C1		B9
22	15	21	2	C2		B9
23	16	17	1	A6		A5
24	16	18	1	A7		A5
25	17	20	24	A8		A6
26	18	20	8	A9		A7
27	19	20	3	C3		C1
28	20	26	3	C9		A8,A9,C3
29	21	22	1	C4		C2
30	22	23	8	C5		C4
31	23	24	1	C6		C5
32	24	25	3	C7		C6
33	25	26	3	C8		B5 , B7
34	26	27	4	C10		B6,B10,B8, C8 , C9

a: ACOFSAWM.DAT

* we need only the first 4 columns for the purposes of computer input data.

DETAILED PROBLEM DATA LISTING FOR

ROW LABEL	SYMBOL	MEAN TIME	START NODE	END NODE
ACT 1	A01	3.	1	2
ACT 2	A02	12.	2	3
ACT 3	A04	2.	3	4
ACT 4	A03	1.	3	5
ACT 5	A05	1.	4	16
ACT 6	A10	1.	5	6
ACT 7	B01	3.	5	7
ACT 8	A11	2.	6	8
ACT 9	B02	3.	7	9
ACT 10	A12	1.	8	10
ACT 11	B03	1.	9	10
ACT 12	B04	4.	9	11
ACT 13	B05	12.	9	25
ACT 14	B07	2.	10	12
ACT 15	B05	12.	11	26
ACT 16	B08	3.	12	13
ACT 17	B10	2.	12	14
ACT 18	B09	1.	12	15
ACT 19	d01	0.	13	26
ACT 20	d02	0.	14	26
ACT 21	C01	2.	15	19
ACT 22	C02	2.	15	21
ACT 23	A06	1.	16	17
ACT 24	A07	1.	16	18
ACT 25	A08	24.	17	20
ACT 26	A09	8.	18	20
ACT 27	C03	3.	19	20
ACT 28	C09	3.	20	26
ACT 29	C04	1.	21	22
ACT 30	C05	8.	22	23
ACT 31	C06	1.	23	24
ACT 32	C07	3.	24	25
ACT 33	C08	3.	25	26
ACT 34	C10	4.	26	27

The output Results :

S.no.	i	j	dur.	EStime	EFtime	LStime	LFtime	T.F.	
1	1	2	3.0	0.0	3.0	0.0	3.0	0.0	C
2	2	3	12.0	3.0	15.0	3.0	15.0	0.0	C
3	3	4	2.0	15.0	17.0	15.0	17.0	0.0	C
4	3	5	1.0	15.0	16.0	17.0	18.0	2.0	
5	4	16	1.0	17.0	18.0	17.0	18.0	0.0	C
6	5	6	1.0	16.0	17.0	21.0	22.0	5.0	
7	5	7	3.0	16.0	19.0	18.0	21.0	2.0	
8	6	8	2.0	17.0	19.0	22.0	24.0	5.0	
9	7	9	3.0	19.0	22.0	21.0	24.0	2.0	
10	8	10	1.0	19.0	20.0	24.0	25.0	5.0	
11	9	10	1.0	22.0	23.0	24.0	25.0	2.0	
12	9	11	4.0	22.0	26.0	30.0	34.0	8.0	
13	9	25	12.0	22.0	34.0	31.0	43.0	9.0	
14	10	12	2.0	23.0	25.0	25.0	27.0	2.0	
15	11	26	12.0	26.0	38.0	34.0	46.0	8.0	
16	12	13	3.0	25.0	28.0	43.0	46.0	18.0	
17	12	14	2.0	25.0	27.0	44.0	46.0	19.0	
18	12	15	1.0	25.0	26.0	27.0	28.0	2.0	
19	13	26	0.0	28.0	28.0	46.0	46.0	18.0	
20	14	26	0.0	27.0	27.0	46.0	46.0	19.0	
21	15	19	2.0	26.0	28.0	38.0	40.0	12.0	
22	15	21	2.0	26.0	28.0	28.0	30.0	2.0	
23	16	17	1.0	18.0	19.0	18.0	19.0	0.0	C
24	16	18	1.0	18.0	19.0	34.0	35.0	16.0	
25	17	20	24.0	19.0	43.0	19.0	43.0	0.0	C
26	18	20	8.0	19.0	27.0	35.0	43.0	16.0	
27	19	20	3.0	28.0	31.0	40.0	43.0	12.0	
28	20	26	3.0	43.0	46.0	43.0	46.0	0.0	C
29	21	22	1.0	28.0	29.0	30.0	31.0	2.0	
30	22	23	8.0	29.0	37.0	31.0	39.0	2.0	
31	23	24	1.0	37.0	38.0	39.0	40.0	2.0	
32	24	25	3.0	38.0	41.0	40.0	43.0	2.0	
33	25	26	3.0	41.0	44.0	43.0	46.0	2.0	
34	26	27	4.0	46.0	50.0	46.0	50.0	0.0	C

total project time = 50

C means Critical Activity . . .

Case Study No 3 :

INTEGRATED AREA DEVELOPMENT PROGRAMME

The purpose of this case study is to provide an example of the applicability of Network Work Analysis Techniques to the planning of area (Sub-regional) development programme .

Background Information :

At the request of NEPAL Government , an integrated programme for the economic development of the area existing over a few hill and Terai Destricts . The programme represents one strategic means of implementing the Government's overall development policy based on geographical integration , on export promotion in agricultural and agro-industrial sectors and on employment creation while moving families from the densely hills to the Terai .

The project is designed to :

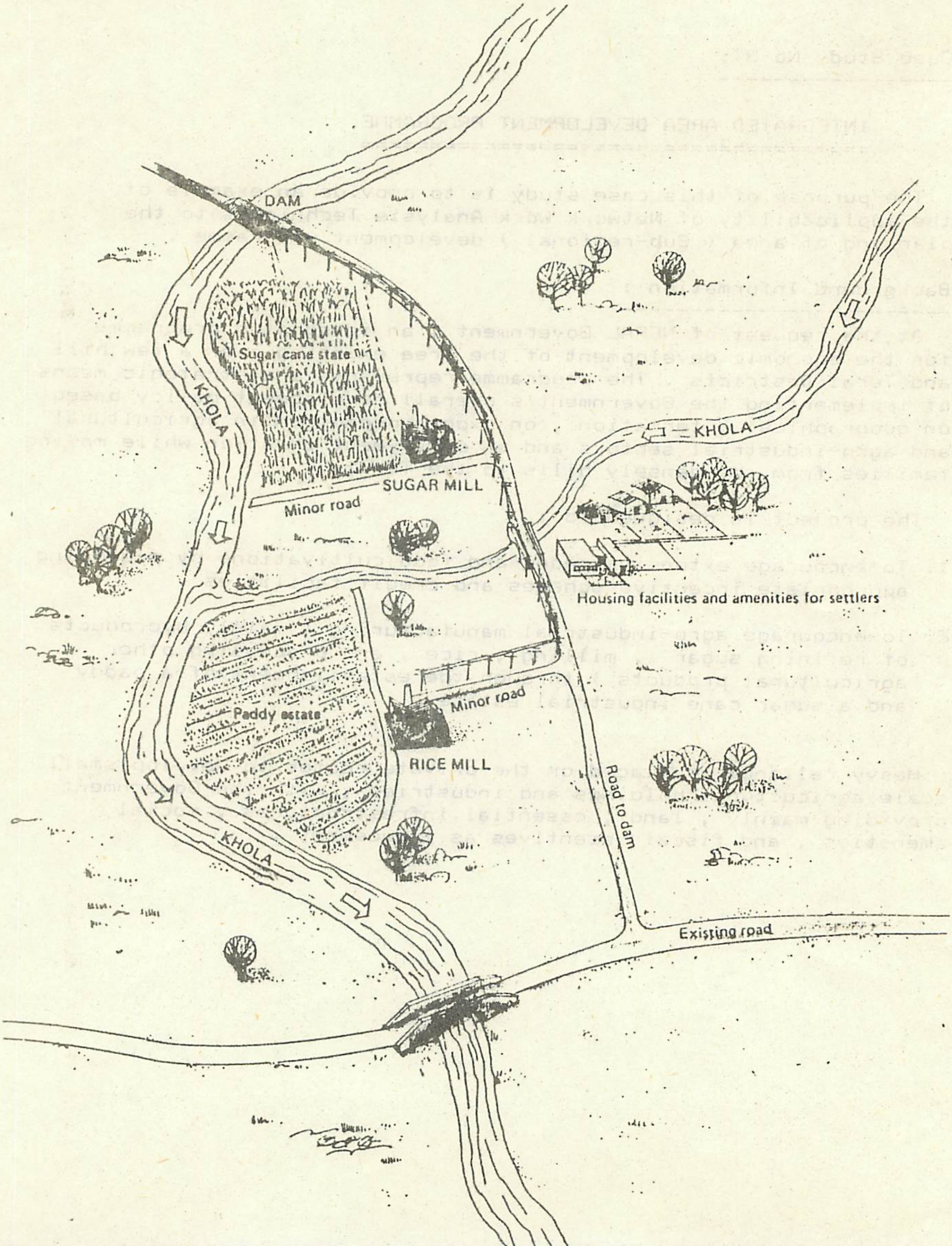
1. To encourage extensive paddy and food cultivations by providing appropriate incentive schemes and credit facilities .

2. To encourage agro-industrial manufacturing (mainly byproducts of refining sugar , milling , rice , and processing other agricultural products) through the establishment of a paddy and a sugar cane industrial estate .

Heavy reliance is placed on the private sector to develop small scale agricultural holdings and industries , with the Government providing mainly , land , essential infrastructures , social amenities , and fiscal incentives as inducement .

INTEGRATED AREA DEVELOPMENT PROGRAMME

Diagram



The various essential projects composing the programme have been grouped into the following main sub-programme :

1. Infrastructure ,

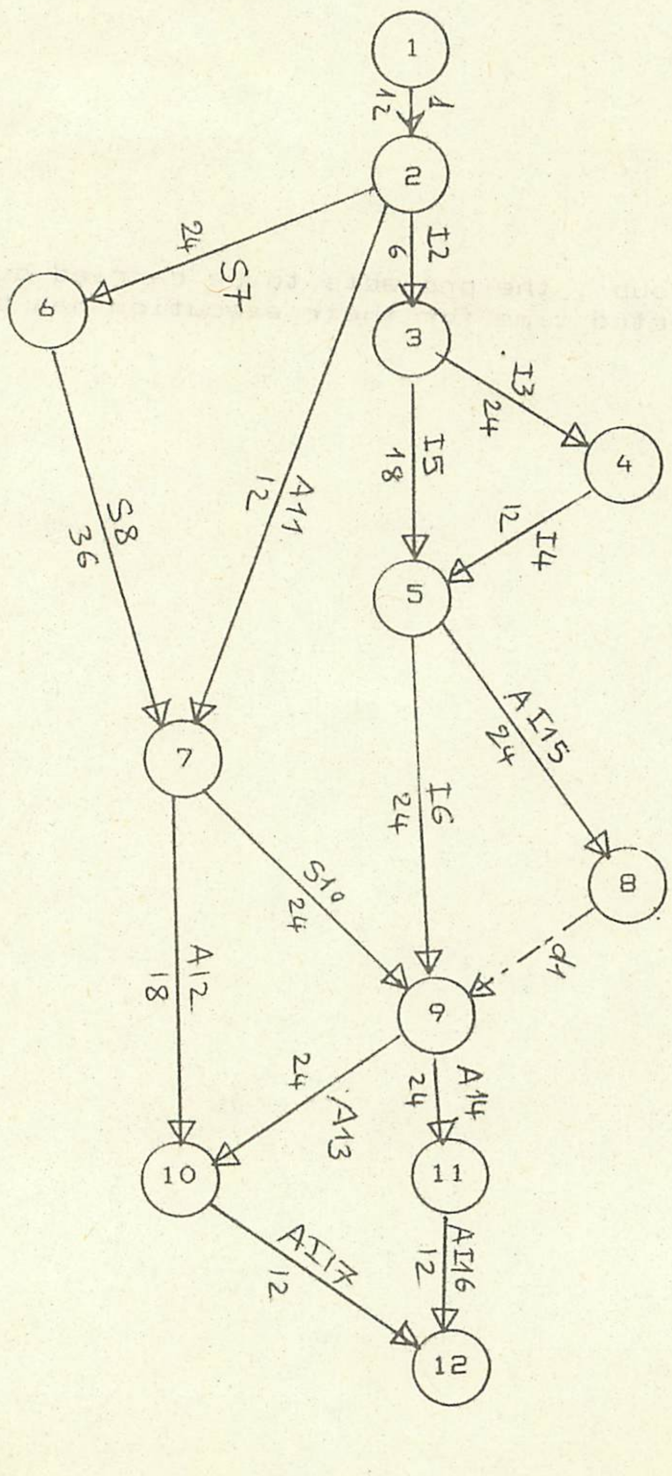
2. Settlement ,

3. Agriculture , and

4. Agro-industry .

For each of the above group , the projects to be carried out have been listed and the expected time for their execution has been estimated .

Integrated Area Development Programmes -- Network :



List Of Project Activities For Computer purposes :

S.No	Act.Nodes i	j	Time	Code	MP	Predecessors *
1	1	2	12	1		--
2	2	3	6	I2		1
3	2	6	24	S7		1
4	2	7	12	A11		1
5	3	4	24	I3		I2
6	3	5	18	I5		I2
7	4	5	12	I4		I3
8	5	7	24	S9		I4 , I5
9	5	8	24	AI15		I4 , I5
10	5	9	24	I6		I4 , I5
11	6	7	36	S8		S7
12	7	9	24	S10		S8,S9,A11
13	7	10	18	A12		S8,S9,A11
14	8	9	0	d1		I4 , I5
15	9	10	24	A13		I6,S10,AI15
16	9	11	24	A14		I6,S10,AI15
17	10	12	12	AI17		A13,A14
18	11	12	12	AI16		A14

a: AINTGADP.DAT

* we need only the first 4 columns for the purposes of computer input data .

DETAILED PROBLEM DATA LISTING FOR
Integrated Area Development Programme

ROW LABEL		SYMBOL	MEAN TIME	START NODE	END NODE
ACT	1	1	12.	1	2
ACT	2	I2	6.	2	3
ACT	3	S7	24.	2	6
ACT	4	A11	12.	2	7
ACT	5	I3	24.	3	4
ACT	6	I5	18.	3	5
ACT	7	I4	12.	4	5
ACT	8	S9	24.	5	7
ACT	9	AI15	24.	5	8
ACT	10	I6	24.	5	9
ACT	11	S8	36.	6	7
ACT	12	S10	24.	7	9
ACT	13	A12	18.	7	10
ACT	14	d1	0.	8	9
ACT	15	A13	24.	9	10
ACT	16	A14	24.	9	11
ACT	17	AI17	12.	10	12
ACT	18	AI16	12.	11	12

Integrated Area Development Programme
ACTIVITY LIST REPORT

Activity Name	Symb	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	
ACT 1	1	0.00	12.00	0.00	12.00	0.00	c
ACT 2	I2	12.00	18.00	12.00	18.00	0.00	c
ACT 3	S7	12.00	36.00	18.00	42.00	6.00	
ACT 4	A11	12.00	24.00	66.00	78.00	54.00	
ACT 5	I3	18.00	42.00	18.00	42.00	0.00	c
ACT 6	I5	18.00	36.00	36.00	54.00	18.00	
ACT 7	I4	42.00	54.00	42.00	54.00	0.00	c
ACT 8	S9	54.00	78.00	54.00	78.00	0.00	c
ACT 9	AI15	54.00	78.00	78.00	102.00	24.00	
ACT 10	I6	54.00	78.00	78.00	102.00	24.00	
ACT 11	S8	36.00	72.00	42.00	78.00	6.00	
ACT 12	S10	78.00	102.00	78.00	102.00	0.00	c
ACT 13	A12	78.00	96.00	108.00	126.00	30.00	
ACT 14	d1	78.00	78.00	102.00	102.00	24.00	
ACT 15	A13	102.00	126.00	102.00	126.00	0.00	c
ACT 16	A14	102.00	126.00	102.00	126.00	0.00	c
ACT 17	AI17	126.00	138.00	126.00	138.00	0.00	c
ACT 18	AI16	126.00	138.00	126.00	138.00	0.00	c

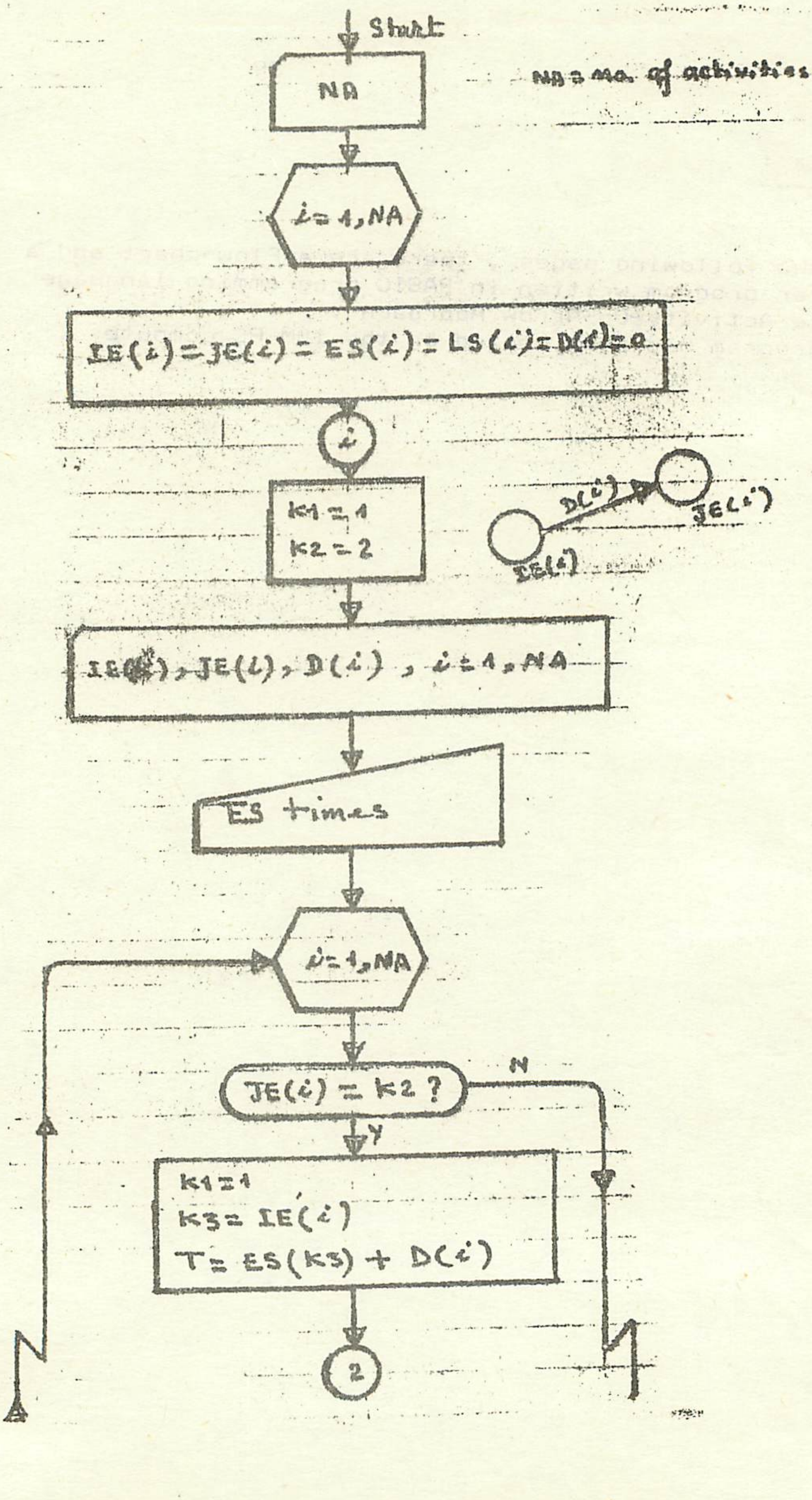
Earliest project completion time = 138.00000

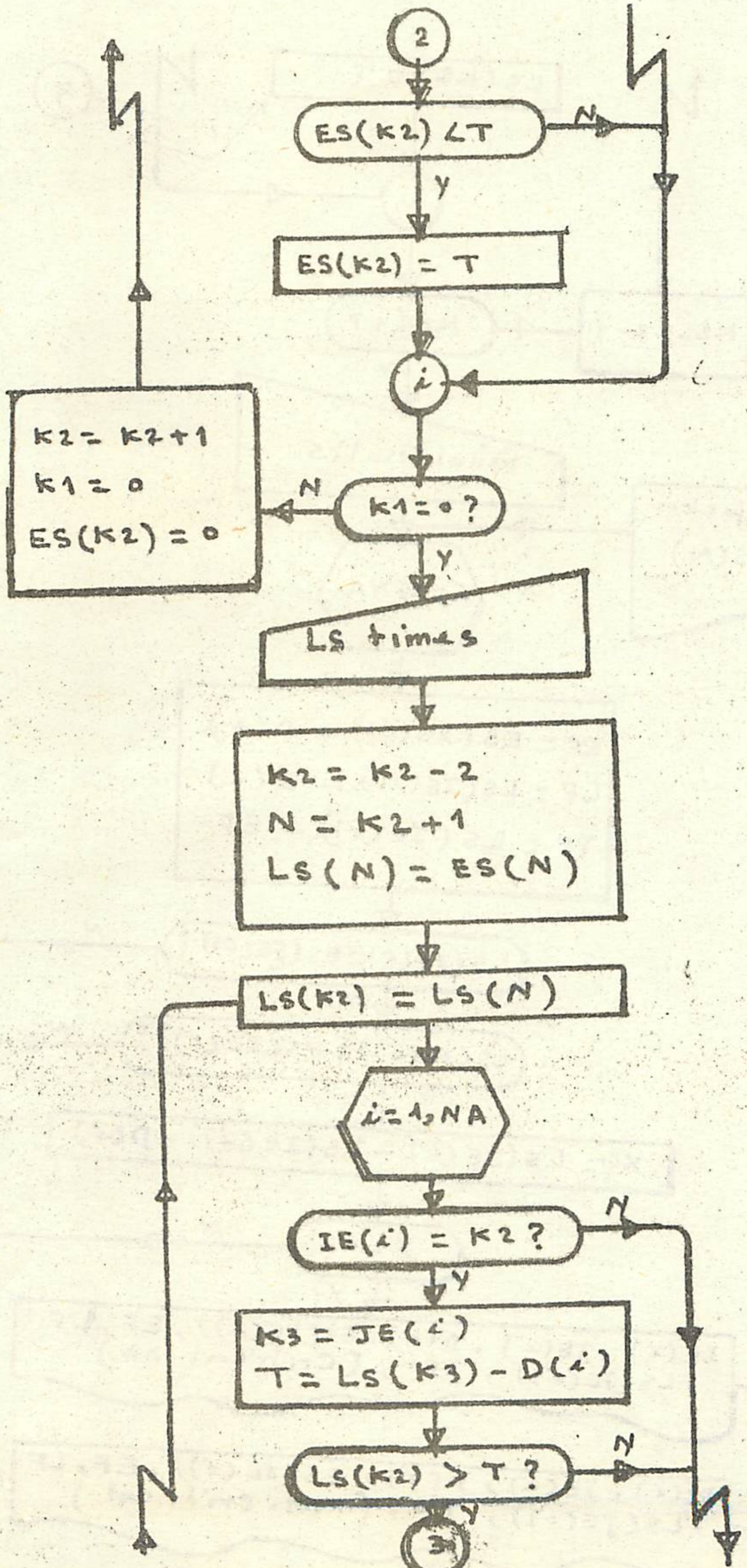
```
Integrated Area Development Programme : Bar chart                       138.0
Act.   0
-------+------+------+------+------+------+------+------+------+------+------+

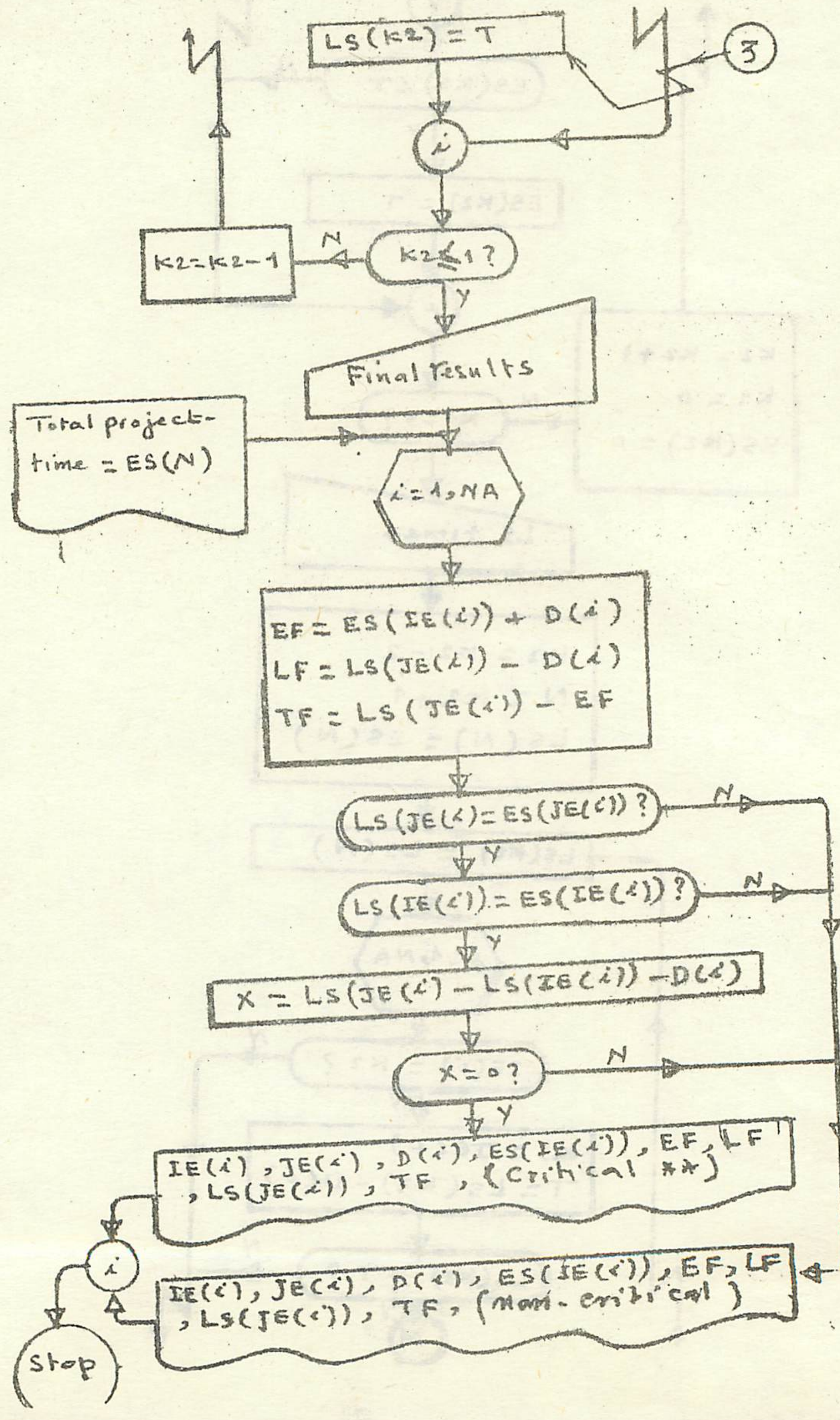
1      |CCCCCCC
I2     |      CCCC
I3     |         CCCCCCCCCCCCC
I4     |                     CCCCCCC
S9     |                           CCCCCCCCCCCCCC
S10    |                                        CCCCCCCCCCCCC
A13    |                                                     CCCCCCCCCCCCC   |
A14    |                                                     CCCCCCCCCCCCC   |
AI16   |                                                                 CCCCCC
AI17   |                                                                 CCCCCC
S7     |      xxxxxxxxxxxxx...                                               |
S8     |                  xxxxxxxxxxxxxxxxxxxx...                            |
I5     |         xxxxxxxxxx.........                                         |
I6     |                            xxxxxxxxxxxxxx............               |
AI15   |                            xxxxxxxxxxxxxx............               |
d1     |                                         x........                   |
A12    |                                         xxxxxxxxxx...............   |
A11    |      xxxxxxx............................                            |
-----------------------------------------------------------------------------
```

Appendix :

In the following pages , there are a Flow-chart and a computer program written in BASIC programming language for the Activity-On-Arrow Approach .
This program has been tested on the IBM PC computer .


Start
NA
NA = no. of activities
i = 1, NA
IE(i) = JE(i) = ES(i) = LS(i) = D(i) = 0
i
K1 = 1
K2 = 2
D(i)
JE(i)
IE(i)
IE(i), JE(i), D(i), i = 1, NA
ES times
i = 1, NA
JE(i) = K2 ?
N
Y
K1 = 1
K3 = IE(i)
T = ES(K3) + D(i)
2


2
ES(K2) < T
N
Y
ES(K2) = T
i
K2 = K2+1
K1 = 0
ES(K2) = 0
N
K1 = 0 ?
Y
LS times
K2 = K2 - 2
N = K2+1
LS(N) = ES(N)
LS(K2) = LS(N)
i = 1, NA
IE(i) = K2 ?
N
Y
K3 = JE(i)
T = LS(K3) - D(i)
LS(K2) > T ?
N
Y
3


LS(K2) = T
3
i
K2 ≤ 1 ?
N
Y
K2 = K2 - 1
Final results
Total project-time = ES(N)
i = 1, NA
EF = ES(IE(i)) + D(i)
LF = LS(JE(i)) - D(i)
TF = LS(JE(i)) - EF
LS(JE(i) = ES(JE(i)) ?
LS(IE(i)) = ES(IE(i)) ?
X = LS(JE(i) - LS(IE(i)) - D(i)
X = 0 ?
IE(i), JE(i), D(i), ES(IE(i)), EF, LF, LS(JE(i)), TF, (Critical **)
IE(i), JE(i), D(i), ES(IE(i)), EF, LF, LS(JE(i)), TF, (non-critical)
Stop

The computer program (output on screen only) :

```
10 REM ........
20 REM ........PERT/TIME program..............
30 REM       Dr. Abdalla El-daoushy
40 REM
50 WIDTH "lpt1:",132
60 DEFINT I-N
70 OPTION BASE 1
80 DIM SYMBOL$(150) , IA(150) , JA(150) , DUR(150) , ES(150) , LS(150)
90 CLS
100 INPUT "No. of activities = "; NA
110 PRINT
150 REM ...............
160 FOR I=1 TO NA
170 IA(I)=0
180 JA(I)=0
190 ES(I)=0
200 LS(I)=0
210 DUR(I)=0
220 NEXT I
230 K1=1
240 K2=2
250 PRINT "Enter Symbol(3 chs) ,i , j , &  t  of every act in the project "
260 PRINT "------------------------------------------------------------------- "
270 FOR I=1 TO NA
280 PRINT USING "### ";I;
290 INPUT  SYMBOL$(I),IA(I),JA(I),DUR(I)
300 NEXT I
310 CLS
311 GOSUB 2040
312 PRINT
313 INPUT "Press Any Key And ENTER To Continue " ; SPCACE$
314 CLS
330 PRINT "The output Results :"
340 PRINT "--------------------"
350 PRINT "--------------------------------------------------------------------------
360 PRINT " S.no.  i    j    dur.    EStime  EFtime  LStime  LFtime  T.F.
370 PRINT "--------------------------------------------------------------------------
380 REM   calculations of ES times
390 FOR I=1 TO NA
400 IF JA(I) <> K2 THEN 460
410 K1=1
420 K3=IA(I)
430 T=ES(K3)+DUR(I)
440 IF ES(K2) >= T THEN 460
450 ES(K2)=T
460 NEXT I
```

```
470 REM     ..................................
480 IF K1 = 0 THEN 540
490 K2=K2+1
500 K1=0
510 ES(K2)=0
520 GOTO 390
530 REM   calculations of LS times
540 K2=K2-2
550 N1=K2+1
560 LS(N1)=ES(N1)
570 LS(K2)=LS(N1)
580 FOR I=1 TO NA
590 IF IA(I) <> K2 THEN 640
600 K3=JA(I)
610 T=LS(K3)-DUR(I)
620 IF LS(K2) <= T THEN 640
630 LS(K2)=T
640 NEXT I
650 REM     ............................
660 IF K2 <= 1 THEN 700
670 K2=K2-1
680 GOTO 570
690 REM   final results
700 FOR I=1 TO NA
710 I1=IA(I)
720 J1=JA(I)
730 EF=ES(I1)+DUR(I)
740 LF=LS(J1)-DUR(I)
750 F=LS(J1)-EF
760 IF LS(J1) <> ES(J1) THEN 900
770 IF LS(I1) <> ES(I1) THEN 900
780 X=LS(J1)-LS(I1)-DUR(I)
790 IF X <> 0 THEN 900
800 REM     ............................
810 REM
820 REM
830 F1$="###   ###  ###   ###.#   ###.#   ###.#   ###.#   ###.#   ###.#
850 PRINT USING F1$;I;IA(I);JA(I);DUR(I);ES(I1);EF;LF;LS(J1);F
860 GOTO 930
870 REM
880 REM
890 REM
900 F2$="###   ###  ###   ###.#   ###.#   ###.#   ###.#  ###.#   ###.#"
910 PRINT USING F2$;I;IA(I);JA(I);DUR(I);ES(I1);EF;LF;LS(J1);F
920 REM
930 NEXT I
```

```
940 REM
950 REM
970 PRINT "--------------------------------------------------------------------------------------------"
980 PRINT " total project time =  "; ES(N1)
990 PRINT "--------------------------------------------------------------------------------------------
1010 PRINT "  *  means Critical Activity . . .
1020 GOTO 2150
2040 X$ = "           &###           &        ###.        ###         ### "
2050 PRINT "                     DETAILED PROBLEM DATA LISTING FOR "
2060 PRINT "                       " ; PROBNAME$   ' max. 32 characters..
2070 PRINT "          ROW LABEL      SYMBOL  MEAN TIME START NODE     END NODE "
2080 PRINT
2090 '
2100 FOR I = 1 TO NA
2110 ACT$ = "ACT"
2120 PRINT USING X$; ACT$ ; I ; SYMBOL$( I ) ; DUR( I ) ; IA( I ) ; JA( I )
2130 NEXT I
2140 RETURN
2150 END
```

The Computer Program (Output on Printer Only) :

```
10 REM ........
20 REM ........PERT/TIME program..............
30 REM        Dr. Abdalla El-daoushy
40 REM
50 WIDTH "lpt1:",132
60 DEFINT I-N
70 OPTION BASE 1
80 DIM SYMBOL$(150) , IA(150) , JA(150) , DUR(150) , ES(150) , LS(150)
90 CLS
100 INPUT "No. of activities = "; NA
110 PRINT
150 REM ................
160 FOR I=1 TO NA
170 IA(I)=0
180 JA(I)=0
190 ES(I)=0
200 LS(I)=0
210 DUR(I)=0
220 NEXT I
230 K1=1
240 K2=2
250 PRINT "Enter Symbol(3 chs) ,i , j , & t  of every act in the project "
260 PRINT "------------------------------------------------------------------------------------ "
270 FOR I=1 TO NA
280 PRINT USING "### ";I;
290 INPUT  SYMBOL$(I),IA(I),JA(I),DUR(I)
300 NEXT I
310 CLS
311 GOSUB 2040
312 PRINT
313 INPUT "Press Any Key And ENTER To Continue " ; SPCACE$
314 CLS
330 LPRINT "The output Results :"
340 LPRINT "----------------------"
350 LPRINT "-------------------------------------------------------------------------------------------
360 LPRINT " S.no.  i    j    dur.    EStime  EFtime  LStime  LFtime  T.F.
370 LPRINT "-------------------------------------------------------------------------------------------
380 REM   calculations of ES times
390 FOR I=1 TO NA
400 IF JA(I) <> K2 THEN 460
410 K1=1
420 K3=IA(I)
430 T=ES(K3)+DUR(I)
440 IF ES(K2) >= T THEN 460
450 ES(K2)=T
460 NEXT I
```

```
470 REM    ..................................
480 IF K1 = 0 THEN 540
490 K2=K2+1
500 K1=0
510 ES(K2)=0
520 GOTO 390
530 REM   calculations of LS times
540 K2=K2-2
550 N1=K2+1
560 LS(N1)=ES(N1)
570 LS(K2)=LS(N1)
580 FOR I=1 TO NA
590 IF IA(I) <> K2 THEN 640
600 K3=JA(I)
610 T=LS(K3)-DUR(I)
620 IF LS(K2) <=T THEN 640
630 LS(K2)=T
640 NEXT I
650 REM   .............................
660 IF K2 <= 1 THEN 700
670 K2=K2-1
680 GOTO 570
690 REM   final results
700 FOR I=1 TO NA
710 I1=IA(I)
720 J1=JA(I)
730 EF=ES(I1)+DUR(I)
740 LF=LS(J1)-DUR(I)
750 F=LS(J1)-EF
760 IF LS(J1) <> ES(J1) THEN 900
770 IF LS(I1) <> ES(I1) THEN 900
780 X=LS(J1)-LS(I1)-DUR(I)
790 IF X <> 0 THEN 900
800 REM  ............................
810 REM
820 REM
830 F1$="###   ###  ###   ###.#   ###.#   ###.#   ###.#   ###.#   ###.#
850 LPRINT USING F1$;I;IA(I);JA(I);DUR(I);ES(I1);EF;LF;LS(J1);F
860 GOTO 930
870 REM
880 REM
890 REM
900 F2$="###   ###  ###   ###.#   ###.#   ###.#   ###.#   ###.#   ###.#"
910 LPRINT USING F2$;I;IA(I);JA(I);DUR(I);ES(I1);EF;LF;LS(J1);F
920 REM
930 NEXT I
```

```
940 REM
950 REM
970 LPRINT "--------------------------------------------------------------------------------------------------------------
980 LPRINT " total project time =  "; ES(N1)
990 LPRINT "--------------------------------------------------------------------------------------------------------------
1010 LPRINT "  *  means Critical Activity . . .
1020 GOTO 2150
2040 X$ = "            &###            &           ###.          ###         ### "
2050 LPRINT "                        DETAILED PROBLEM DATA LISTING FOR "
2060 LPRINT "                           " ; PROBNAME$    ' max. 32 characters..
2070 LPRINT "           ROW LABEL      SYMBOL  MEAN TIME START NODE    END NODE
2080 LPRINT
2090 '
2100 FOR I = 1 TO NA
2110 ACT$ = "ACT"
2120 LPRINT USING X$; ACT$ ; I ; SYMBOL$( I ) ; DUR( I ) ; IA( I ) ; JA( I )
2130 NEXT I
2140 RETURN
2150 END
```

References :

1. Abdalla A. El-daoushy ,

Memo. No. 793 , Institute of National Planning , Cairo (INP)
Network Analysis Using PERT and/or CPM Techniques , 1983

2. Maurizio Garzia ,

Project Planning and Monitoring Using Network Analysis Techniques , 1982
Development Policy & Training Services (ESPT)

3. James Evans , David Anderson , Dennis Sweeny , Thomas Williams

Applied Production and Operations Management , 1984
West Publishing Company , Stpaul , New York , Los Angeles , San Francisco

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