ARAB REPUBLIC OF EGYPT

THE INSTITUTE OF
NATIONAL PLANNING

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PERT / CPM

A Modified Version

By

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Abstract :

A few years ago, we carried out a large-scale project (Construction of Bridge) with the PERT / CPM Technique (we call it Activity-On-Arrow Approach).

Although in the course of applying this technique we managed to simplify the way of drawing the Project's Network (as a preliminary step for solving the problem) , it still requires further adjustments to be applicable in practice.

The present modified version (we call it Activity-On-Node Approach) being adjusted to resolve this problem since there is no need at all to draw the Project's Network. Moreover, the computers storage requirements do not exceed that of Activity-On-Arrow approach , but the number of activities described by the number of dummy (zero time) activities which introduced to enforce certain precedence ordering in drawing networks.

The integral part of this paper explains the Activity-On-Node Approach. The Activity-On-Arrow Approach with some remarks on its properties and disadvantages compared to the Activity-On-Node Approach is mentioned.

A PROJECT may be defined as a major work consists of many tasks or ACTIVITIES. The activities are interrelated through PRECEDENCE relationships so 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 terms immediate Predecessor and immediate Successor.

As we know , CPM (Critical Path Method) and 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 , and the development of new products or systems are typical applications of these techniques.

Applying the PERT / Time Technique , we usually 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 .

The precedence relationships between the project activities were specified by using the approach named :

<u>An Activity-On-Arrow representation. (or An Arrow Network) .</u>

The present modified approach is named :

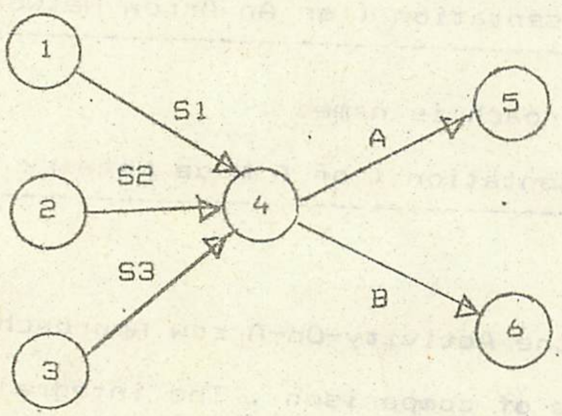
<u>An Activity-On-Node representation (or A Node Network) .</u>

In the present paper , the Activity-On-Arrow Approach is mentioned for the purposes of comparison . The integral part of this paper explains the Activity-On-Node approach .

1. 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 ,

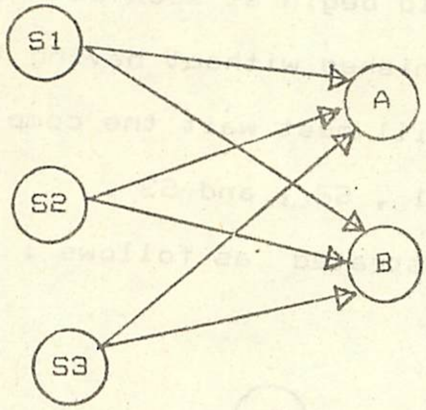
If activities A and B can both begin only after all of three activities S1 , S2 , and S3 are complete , the Activity-On-Arc (or the Arrow Network) can be represented as follows :



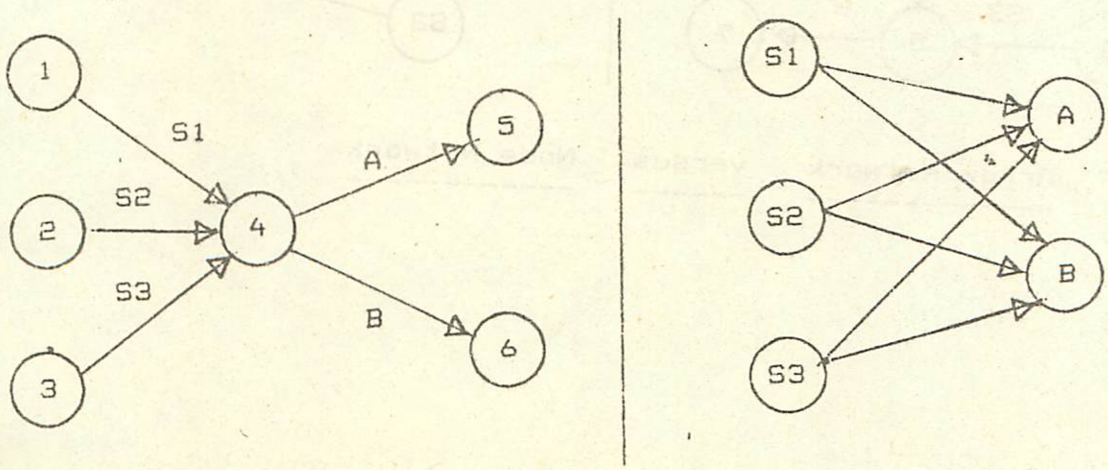
Node 4 represents the event that all of the activities S1 , S2 , and S3 have been completed ; and the activities A nd B can start .

2. The Activity-On-Node Approach :

Using this approach , we can represent activities by Nodes with arrows directed from each activity to each of its immediate successors . For example ,



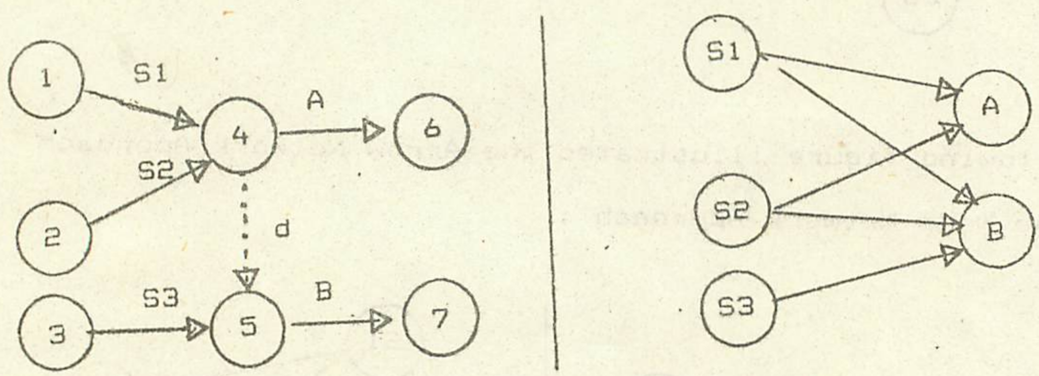
The following figure illustrates the Arrow Network Approach versus the Node Network Approach :



The Advantages of the Activity-On-Node Approach :

1 . The Node Networks are generally easier to construct because Arrow Networks sometimes require dummy (zero duration) activities be introduced to enforce certain precedence orderings . For example , if in the previous example , the activity A could begin as soon as both of activities S1 and S2 were finished without having to wait for S3 , while activity B still must wait the completion of all the three activities : S1 , S2 , and S3 .

The two Networks can be illustrated as follows :



Arrow Network versus Node Network

We notice that :

The Arrow Network now has a dummy activity u' while the Node Network became simpler .

2. If the Activity-On-Node approach is to be used , <u>there is no need to draw a Network representation of the project before using the ALGORITHM</u> . You must simply list all the immediate Predecessors of each activity ; While with the Activity-On-Arc approach , You must draw the appropriate network and number all the nodes as a preliminary step because You will be conveying the precedence information to the ALGORITHM by entering the STARTing and ENDing nodes for each activity .

The solution ALGORITHM in both versions :

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 ,
- The critical activities ,
- The slack times , and
- The minimum duration of the project as a whole .

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 calculations 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 .

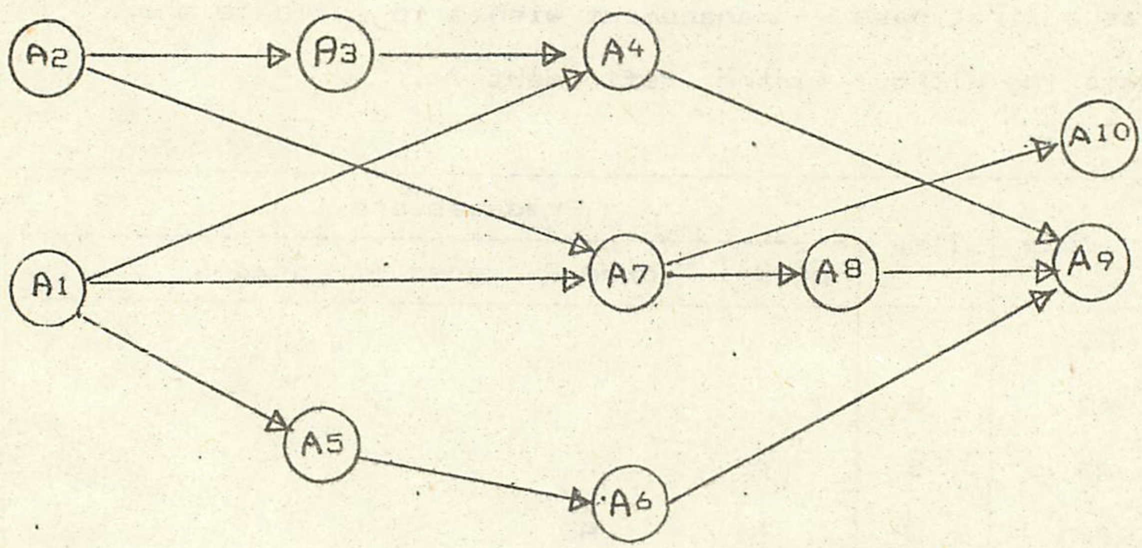
Sample Problems :

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) .

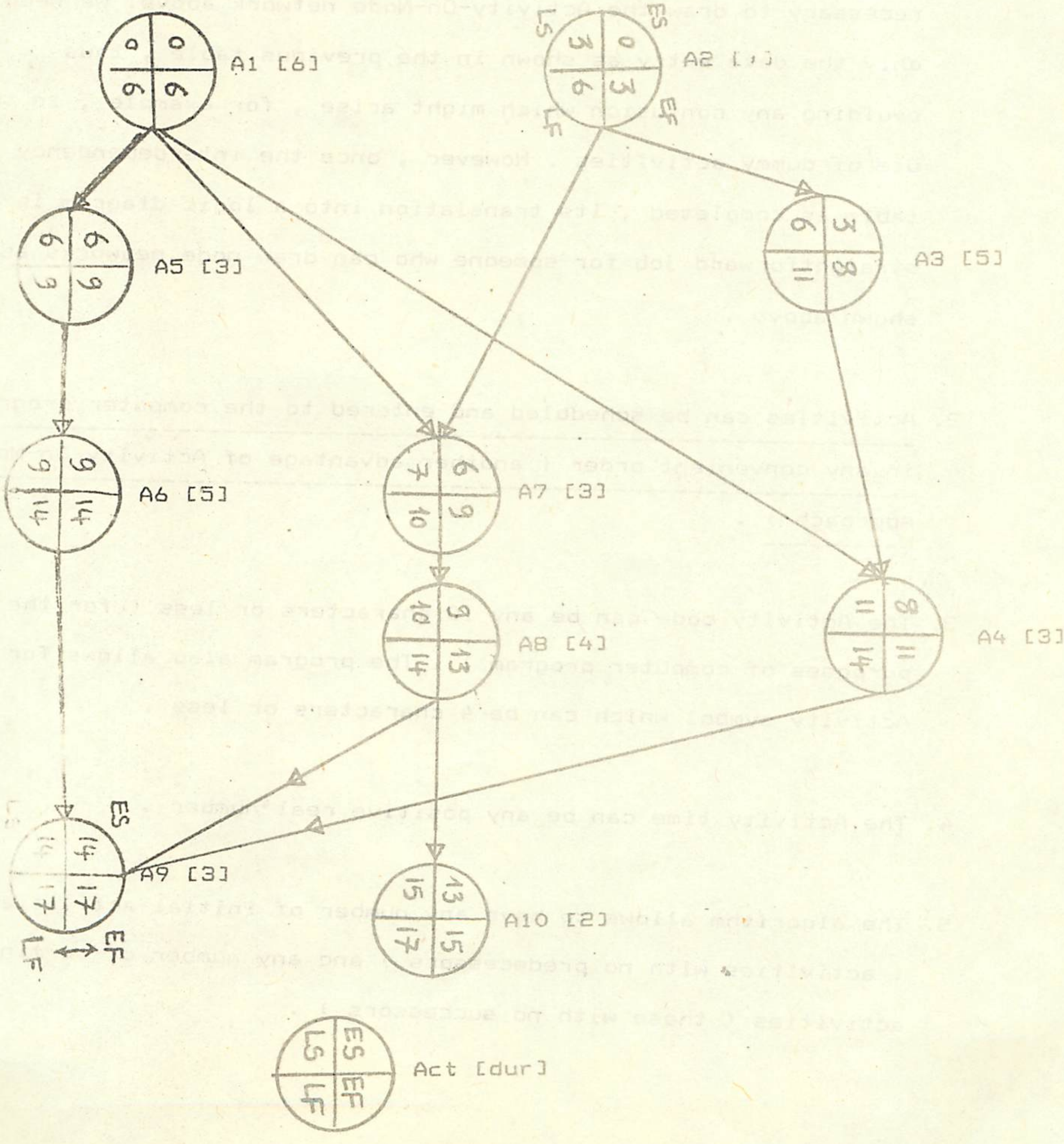
Act. code	Time	Predecessors				
		pred 1	pred 2	pred 3	pred 4	. . .
A1	6					
A2	3					
A3	5	A2				
A4	3	A1	A3			
A5	3	A1				
A6	5	A5				
A7	3	A1	A2			
A8	4	A7				
A9	3	A4	A6	A8		
A10	2	A7				

a: Prob01N.DAT

The Activity-On-Node Network :



The Problem Activity-On-Node Network and Solution Algorithm :



WE notice that :

1. This modified approach allows the logical relationships to be specified without becoming involved in how these relationships are to represented in the logic diagram ; i.e., it is not really necessary to draw the Activity-On-Node network above. We need only the data entry as shown in the previous table , thus avoiding any confusion which might arise , for example , in the use of dummy activities . However , once the interdependency table is completed , its translation into a logic diagram is a straightforward job for someone who can draw node networks as shown above .

2. Activities can be scheduled and entered to the computer program in any convenient order (another advantage of Activity-On-Node Approach) .

3. The Activity code can be any 10 characters or less (for the purposes of computer program) . The program also allows for Activity symbol which can be 4 characters or less .

4. The Activity time can be any positive real number .

5. The algorithm allows to have any number of initial activities (activities with no predecessors) and any number of terminal activities (those with no successors) .

DETAILED PROBLEM DATA LISTING FOR
Sample Problem 1 :

ROW LABEL	SYMBOL	MEAN TIME	PRED 1	PRED 2	PRED 3
ACT 1	A01	6.			
ACT 2	A02	3.			
ACT 3	A03	5.	A02		
ACT 4	A04	3.	A01	A03	
ACT 5	A05	3.	A01		
ACT 6	A06	5.	A05		
ACT 7	A07	3.	A01	A02	
ACT 8	A08	4.	A07		
ACT 9	A09	3.	A04	A06	A08
ACT 10	A10	2.	A07		

Sample Problem 1 :
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	3.00	8.00	6.00	11.00	3.00	
ACT 4	A04	8.00	11.00	11.00	14.00	3.00	
ACT 5	A05	6.00	9.00	6.00	9.00	0.00	C
ACT 6	A06	9.00	14.00	9.00	14.00	0.00	C
ACT 7	A07	6.00	9.00	7.00	10.00	1.00	
ACT 8	A08	9.00	13.00	10.00	14.00	1.00	
ACT 9	A09	14.00	17.00	14.00	17.00	0.00	C
ACT 10	A10	9.00	11.00	15.00	17.00	6.00	

Earliest project completion time = 17.00000

```
Sample Problem 1 : : Bar chart                                           17.00
Act.    0
-------+------+------+------+------+------+------+------+------+------+------+-
                                                                               |
A01     |CCCCCCCCCCCCCCCCCCCCCCCCCC                                            |
A05     |                         CCCCCCCCCCCCC                                |
A06     |                                     CCCCCCCCCCCCCCCCCCCCCCC          |
A09     |                                                            CCCCCCCCCCCC
A07     |                         xxxxxxxxxxxxx....                            |
A08     |                                     xxxxxxxxxxxxxxxxxxx....          |
A02     |xxxxxxxxxxxxx.............                                            |
A03     |            xxxxxxxxxxxxxxxxxxxxxx............                        |
A04     |                                  xxxxxxxxxxxxx.............          |
A10     |                                      xxxxxxxxx.........................
-------------------------------------------------------------------------------
```

Simple Restrictions when using the computer program :

1. It is necessary to avoid the impossible precedence requirements . For example , it is impossible to specify that Act A precedes Act B ; Act B precedes Act C , and Act C precedes Act A .

2. It is impossible to use the same Activity symbol for more than one activity .

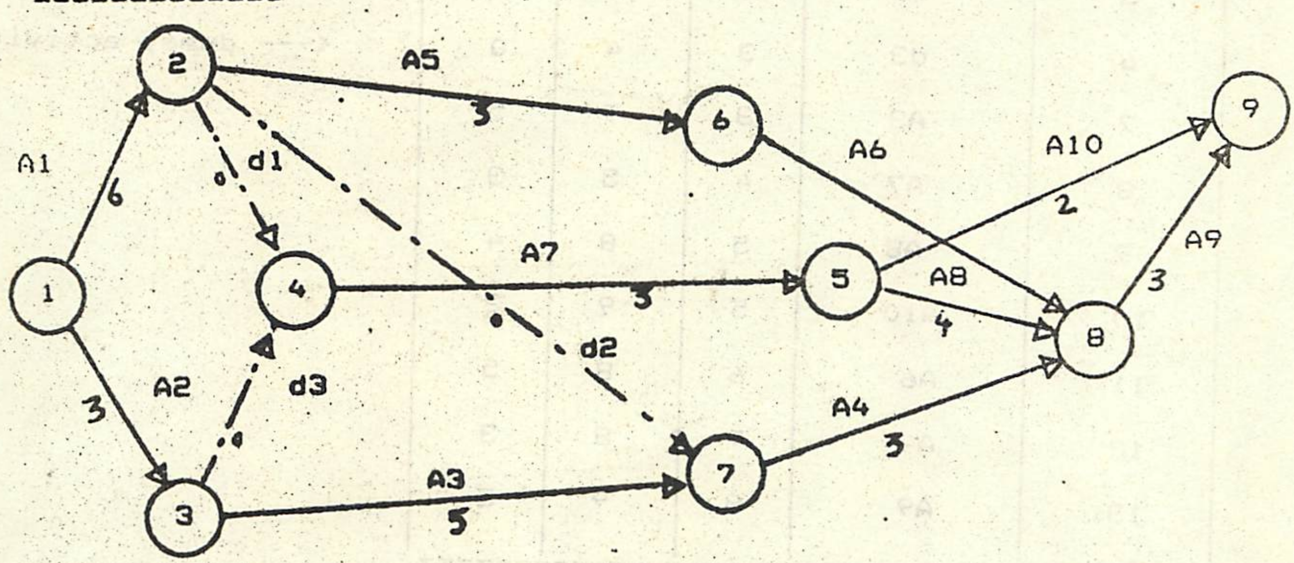
3. The Predecessor Activity symbol must correspond to one code of the activity symbols used .

The Activity-On-Arrow Approach :

The Activity-On-Arrow Approach will be used here for only the purposes of illustration . This requires that an Arrow Network to be prepared as a first step .

The following figure represents the Arrow Network corresponding to the Node Network described above . (there are two alternatives for drawing the Arrow Network)

Alternate 1 :



The Corresponding Activity-On-Arc Table :

Act.No.	Act. Code	Act. Nodes i	Act. Nodes j	Time	
1	A1	1	2	6	
2	A2	1	3	3	
3	d1	2	4	0	<--- dummy activity
4	A5	2	6	3	
5	d2	2	7	0	<--- dummy activity
6	d3	3	4	0	<--- dummy activity
7	A3	3	7	5	
8	A7	4	5	3	
9	A8	5	8	4	
10	A10	5	9	2	
11	A6	6	8	5	
12	A4	7	8	3	
13	A9	8	9	3	

a: Prob01A.DAT

DETAILED PROBLEM DATA LISTING FOR
Sample Problem 1 :

ROW LABEL	SYMBOL	MEAN TIME	START NODE	END NODE
ACT 1	A01	6.	1	2
ACT 2	A02	3.	1	3
ACT 3	d1	0.	2	4
ACT 4	A05	3.	2	6
ACT 5	d2	0.	[illegible]	7
ACT 6	d3	0.	3	4
ACT 7	A03	5.	3	7
ACT 8	A07	3.	4	5
ACT 9	A08	4.	5	8
ACT 10	A10	2.	5	9
ACT 11	A06	5.	6	8
ACT 12	A04	3.	7	8
ACT 13	A09	3.	8	9

Sample Problem 1 :
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	d1	6.00	6.00	7.00	7.00	1.00	
ACT 4	A05	6.00	9.00	6.00	9.00	0.00	c
ACT 5	d2	6.00	6.00	11.00	11.00	5.00	
ACT 6	d3	3.00	3.00	7.00	7.00	4.00	
ACT 7	A03	3.00	8.00	6.00	11.00	3.00	
ACT 8	A07	6.00	9.00	7.00	10.00	1.00	
ACT 9	A08	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	A06	9.00	14.00	9.00	14.00	0.00	c
ACT 12	A04	8.00	11.00	11.00	14.00	3.00	
ACT 13	A09	14.00	17.00	14.00	17.00	0.00	c

liest project completion time = 17.00000

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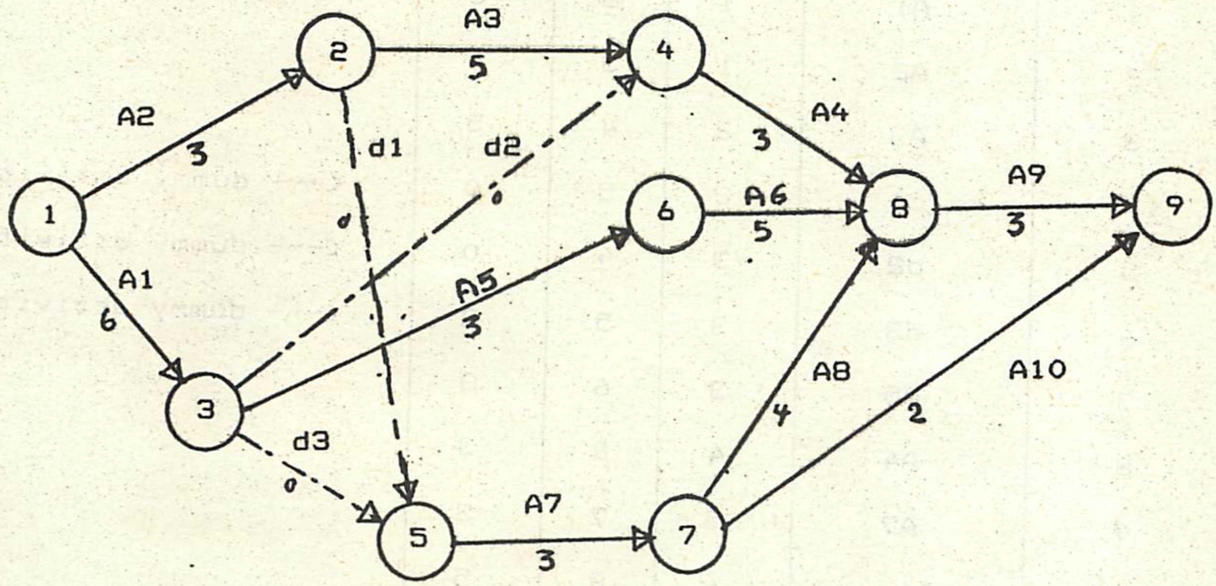
```
mple Problem 1 : : Bar chart
 t.   0                                                                    17.00
  --+-------+-------+-------+-------+-------+-------+-------+-------+-------+-
    |CCCCCCCCCCCCCCCCCCCCCCCCCCC                                              |
    |                          CCCCCCCCCCCCC                                  |
    |                                      CCCCCCCCCCCCCCCCCCCCCCC            |
    |                                                             CCCCCCCCCCCC
    |                          x....                                          |
 .7 |                          xxxxxxxxxxxxx....                              |
  8 |                                      xxxxxxxxxxxxxxxxxx....             |
 .2 |xxxxxxxxxxxxx.............                                               |
 .3 |            xxxxxxxxxxxxxxxxxxxxxxx............                          |
    |                                  xxxxxxxxxxxxx.............             |
    |            x..................                                          |
    |                          x.....................                         |
    |                                      xxxxxxxxx........................
 -----------------------------------------------------------------------------
```

Alternate 2 :



The corresponding Activity-On-Arrow Table :

Act.No.	Act. Code	Act. Nodes i	Act. Nodes j	Time	Note
1	A1	1	2	3	
2	A2	1	3	6	
3	A3	2	4	5	
4	d1	2	5	0	<--- dummy activity
5	d2	3	4	0	<--- dummy activity
6	d3	3	5	0	<--- dummy activity
7	A5	3	6	3	
8	A4	4	8	3	
9	A7	5	7	3	
10	A6	6	8	5	
11	A8	7	8	4	
12	A10	7	9	2	
13	A9	8	9	3	

a: Prob01A2.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 .

DETAILED PROBLEM DATA LISTING FOR
Sample Problem 1 : Alt 2

ROW LABEL	SYMBOL	MEAN TIME	START NODE	END NODE
ACT 1	A01	3.	1	2
ACT 2	A02	6.	1	3
ACT 3	A03	5.	2	4
ACT 4	d1	0.	2	5
ACT 5	d2	0.	3	4
ACT 6	d3	0.	3	5
ACT 7	A05	3.	3	6
ACT 8	A04	3.	4	8
ACT 9	A07	3.	5	7
ACT 10	A06	5.	6	8
ACT 11	A08	4.	7	8
ACT 12	A10	2.	7	9
ACT 13	A09	3.	8	9

Sample Problem 1 : Alt 2
ACTIVITY LIST REPORT

Activity Name	Symb	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	
ACT 1	A01	0.00	3.00	3.00	6.00	3.00	
ACT 2	A02	0.00	6.00	0.00	6.00	0.00	c
ACT 3	A03	3.00	8.00	6.00	11.00	3.00	
ACT 4	d1	3.00	3.00	7.00	7.00	4.00	
ACT 5	d2	6.00	6.00	11.00	11.00	5.00	
ACT 6	d3	6.00	6.00	7.00	7.00	1.00	
ACT 7	A05	6.00	9.00	6.00	9.00	0.00	c
ACT 8	A04	8.00	11.00	11.00	14.00	3.00	
ACT 9	A07	6.00	9.00	7.00	10.00	1.00	
ACT 10	A06	9.00	14.00	9.00	14.00	0.00	c
ACT 11	A08	9.00	13.00	10.00	14.00	1.00	
ACT 12	A10	9.00	11.00	15.00	17.00	6.00	
ACT 13	A09	14.00	17.00	14.00	17.00	0.00	c

Earliest project completion time = 17.00000

```
Sample Problem 1 : Alt 2 : Bar chart
Act.      0                                                                                              17.00
----------+---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+--

A02       |CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC                                                               |
A05       |                                    CCCCCCCCCCCCCCCCC                                              |
A06       |                                                     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCC                |
A09       |                                                                                   CCCCCCCCCCCCCCCCC
A07       |                                    xxxxxxxxxxxxxxxxxx....                                         |
d3        |                                    x....                                                          |
A08       |                                                     xxxxxxxxxxxxxxxxxxxxxxxxxx....                |
A01       |xxxxxxxxxxxxxxxxxxx.................                                                               |
A03       |                 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.................                                  |
A04       |                                               xxxxxxxxxxxxxxxxxx..................                |
di        |                 x.........................                                                        |
d2        |                                    x............................                                  |
A10       |                                                     xxxxxxxxxxxx...................................
    -------------------------------------------------------------------------------------------------------------
```

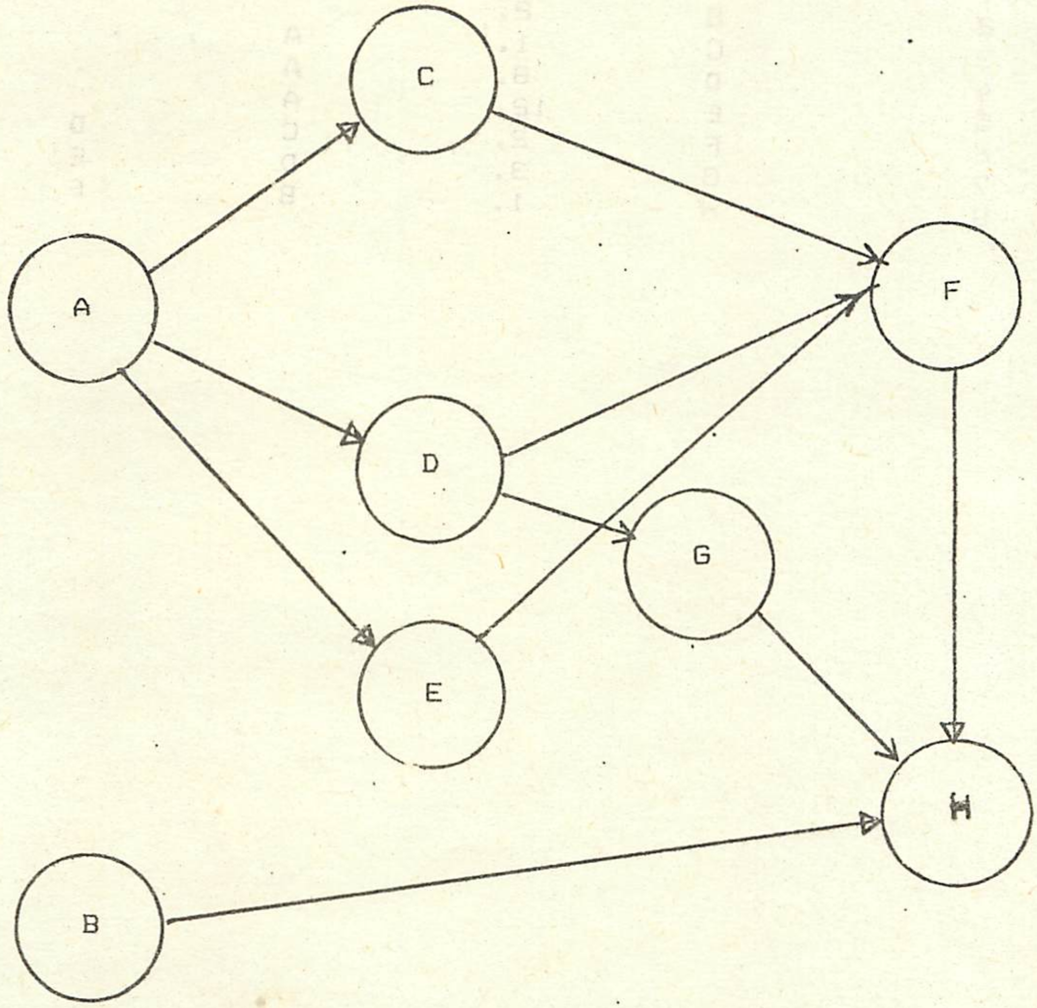
Sample Problems :

2. Suppose you have been asked to supervise the preparation of a project appraisal. Your objective is a completed draft report. The activities which (you have decided) must be undertaken are given in the following table :

Act.No.	Act.Code	Act.Description	time	Predecessor
1	A	Collect project data	4	----
2	B	Evaluate non-quantitive economic data	2	----
3	C	Determine shad.prices	1	A
4	D	Determine technical feasibility	8	A
5	E	Conduct market study	12	A
6	F	Prepare econ. analys.	2	C , D , E
7	G	Prepare final analys.	3	D , E
8	H	Draft report	1	B , F , G

a: Prob02N.DAT

The Activity-On-Node Network :



DETAILED PROBLEM DATA LISTING FOR
Sample Problem 2

ROW LABEL	SYMBOL	MEAN TIME	PRED 1	PRED 2	PRED 3
ACT 1	A	4.			
ACT 2	B	2.			
ACT 3	C	1.	A		
ACT 4	D	8.	A		
ACT 5	E	12.	A		
ACT 6	F	2.	C	D	E
ACT 7	G	3.	D	E	
ACT 8	H	1.	B	F	G

Sample Problem 2
ACTIVITY LIST REPORT

Activity Name	Symb	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	
ACT 1	A	0.00	4.00	0.00	4.00	0.00	c
ACT 2	B	0.00	2.00	17.00	19.00	17.00	
ACT 3	C	4.00	5.00	16.00	17.00	12.00	
ACT 4	D	4.00	12.00	8.00	16.00	4.00	
ACT 5	E	4.00	16.00	4.00	16.00	0.00	c
ACT 6	F	16.00	18.00	17.00	19.00	1.00	
ACT 7	G	16.00	19.00	16.00	19.00	0.00	c
ACT 8	H	19.00	20.00	19.00	20.00	0.00	c

Earliest project completion time = 20.00000

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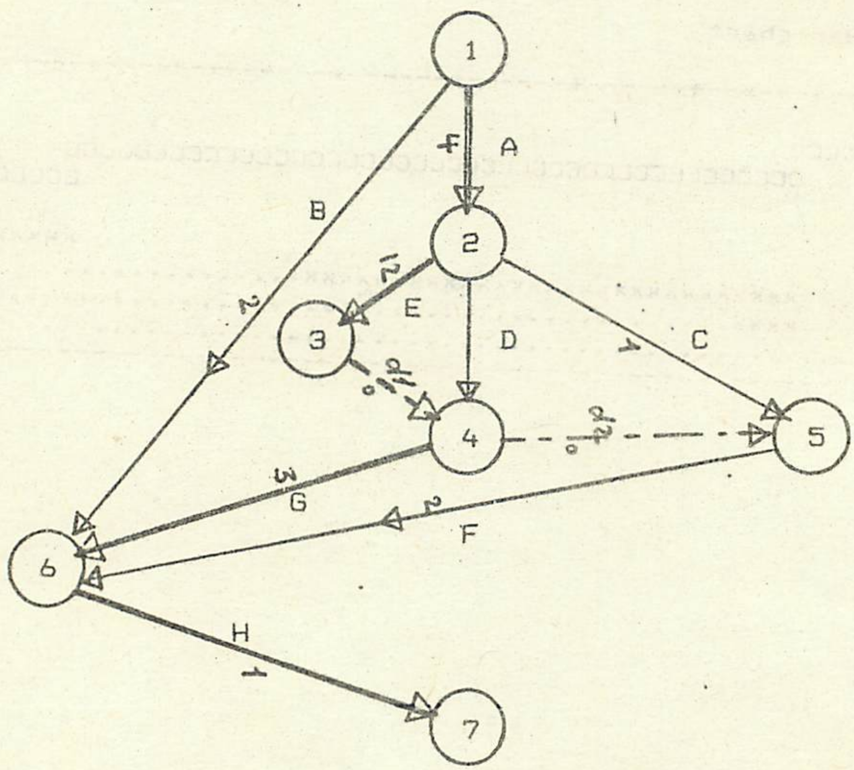
```
Sample Problem 2 : Bar chart                                                20.00
Act.   0
--------+-------+-------+-------+-------+-------+-------+-------+-------+-------+--
                                                                                 |
A       |CCCCCCCCCCCCCCCCC                                                       |
E       |                CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC CCCCCCCCCCCC |
G       |                                                                     CCCC
H       |                                                              XXXXXXXX...   |
F       |                                                                         |
D       |                XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX................       |
C       |                XXXX...................................................  |
B       |XXXXXXXX.....................................................................
------------------------------------------------------------------------------------
```

The Activity-On-Arrow Network :



The Corresponding Activity-On-Arrow Table :

Act.No.	Act.Code	Act.Nodes i	Act.Nodes j	Time
1	A	1	2	4
2	B	1	6	2
3	E	2	3	12
4	D	2	4	8
5	C	2	5	1
6	d1	3	4	0
7	d2	4	5	0
8	G	4	6	3
9	F	5	6	2
10	H	6	7	1

a: Prob02A.DAT

DETAILED PROBLEM DATA LISTING FOR
Sample Problem 2 :

ROW LABEL	SYMBOL	MEAN TIME	START NODE	END NODE
ACT 1	A	4.	1	2
ACT 2	B	2.	1	6
ACT 3	E	12.	2	3
ACT 4	D	8.	2	4
ACT 5	C	1.	2	5
ACT 6	d1	0.	3	4
ACT 7	d2	0.	4	5
ACT 8	G	3.	4	6
ACT 9	F	2.	5	6
ACT 10	H	1.	6	7

Sample Problem 2 :
ACTIVITY LIST REPORT

Activity Name	Symb	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	
ACT 1	A	0.00	4.00	0.00	4.00	0.00	c
ACT 2	B	0.00	2.00	17.00	19.00	17.00	
ACT 3	E	4.00	16.00	4.00	16.00	0.00	c
ACT 4	D	4.00	12.00	8.00	16.00	4.00	
ACT 5	C	4.00	5.00	16.00	17.00	12.00	
ACT 6	d1	16.00	16.00	16.00	16.00	0.00	c
ACT 7	d2	16.00	16.00	17.00	17.00	1.00	
ACT 8	G	16.00	19.00	16.00	19.00	0.00	c
ACT 9	F	16.00	18.00	17.00	19.00	1.00	
ACT 10	H	19.00	20.00	19.00	20.00	0.00	c

Earliest project completion time = 20.00000

```
Sample Problem 2 : : Bar chart                                                                  20.00
Act.    0
--------+-------+-------+-------+-------+-------+-------+-------+--  ---+-------+-------+--
                                                                                        |
A       |CCCCCCCCCCCCCCCC                                                               |
E       |                CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC                 |
d1      |                                                              C                |
G       |                                                              CCCCCCCCCCCC     |
H       |                                                                          CCCC
d2      |                                                              x...             |
F       |                                                              xxxxxxxxx...     |
D       |                xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx...............                |
C       |                xxxx...................................                        |
B       |xxxxxxxxx..................................................................    |
-----------------------------------------------------------------------------------------
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APPENDIX

The following represents CASE-STUDIES solved in Memo. No. 877 (for the same author) by the Activity-On-Arrow Approach.

Here, we are solving the same CASE-STUDIES by the Activity-On-Node Approach.

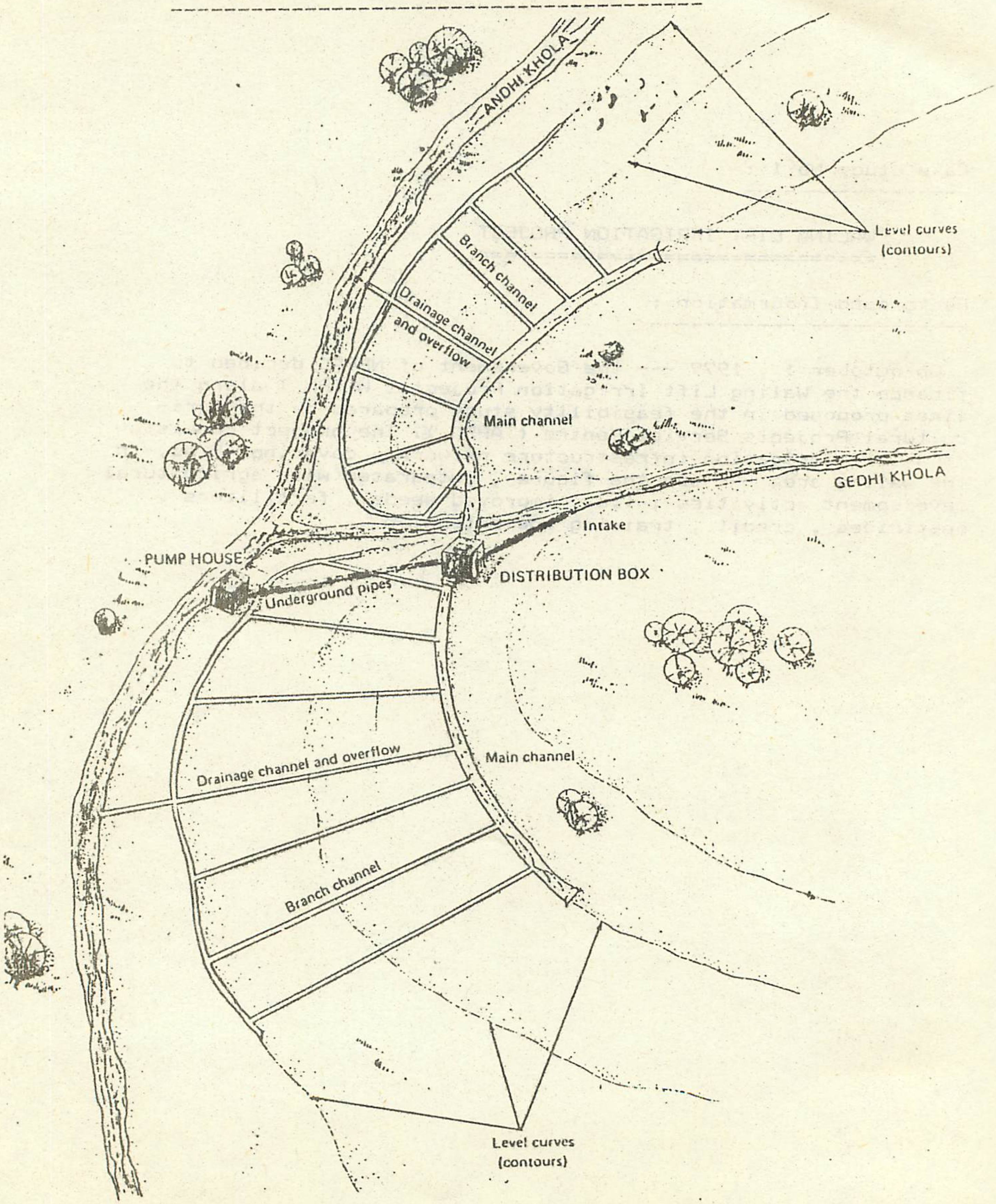
Case study No 1 :

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

DETAILED PROBLEM DATA LISTING FOR
Waling Lift Irrigation Project

ROW LABEL	SYMBOL	MEAN TIME	PRED 1	PRED 2	PRED 3
ACT 1	A01	3.			
ACT 2	A02	4.	A01		
ACT 3	A03	6.			
ACT 4	A04	6.			
ACT 5	A05	3.			
ACT 6	A06	3.	A02	A03	A04
ACT 7	A07	8.	A06		
ACT 8	A08	1.	A07		
ACT 9	A09	1.	A07		
ACT 10	A10	1.	A07		
ACT 11	A11	26.	A08		
ACT 12	A12	8.	A09		
ACT 13	A13	2.	A10		
ACT 14	B01	3.	A06		
ACT 15	B02	4.	A07	B01	
ACT 16	B03	4.	B02		
ACT 17	B04	1.	B03		
ACT 18	B05	2.	B04		
ACT 19	B06	6.	B01	A07	
ACT 20	B07	3.	B05	B06	
ACT 21	B08	2.	B05	B06	
ACT 22	C01	15.	B07		
ACT 23	C02	3.	C01	A11	
ACT 24	C03	2.	B08		
ACT 25	C04	3.	C03	A13	
ACT 26	C05	1.	C02	C04	
ACT 27	C06	2.	A12		
ACT 28	C07	16.	A12		
ACT 29	C08	4.	A12		
ACT 30	C09	1.	C05	C06	C07

Waling Lift Irrigation Project
ACTIVITY LIST REPORT

Activity Name	Symb	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack	
ACT 1	A01	0.00	3.00	0.00	3.00	0.00	C
ACT 2	A02	3.00	7.00	3.00	7.00	0.00	C
ACT 3	A03	0.00	6.00	1.00	7.00	1.00	
ACT 4	A04	0.00	6.00	1.00	7.00	1.00	
ACT 5	A05	0.00	3.00	4.00	7.00	4.00	
ACT 6	A06	7.00	10.00	7.00	10.00	0.00	C
ACT 7	A07	10.00	18.00	10.00	18.00	0.00	C
ACT 8	A08	18.00	19.00	20.00	21.00	2.00	
ACT 9	A09	18.00	19.00	26.00	27.00	8.00	
ACT 10	A10	18.00	19.00	44.00	45.00	26.00	
ACT 11	A11	19.00	45.00	21.00	47.00	2.00	
ACT 12	A12	19.00	27.00	27.00	35.00	8.00	
ACT 13	A13	19.00	21.00	45.00	47.00	26.00	
ACT 14	B01	10.00	13.00	15.00	18.00	5.00	
ACT 15	B02	18.00	22.00	18.00	22.00	0.00	C
ACT 16	B03	22.00	26.00	22.00	26.00	0.00	C
ACT 17	B04	26.00	27.00	26.00	27.00	0.00	C
ACT 18	B05	27.00	29.00	27.00	29.00	0.00	C
ACT 19	B06	18.00	24.00	23.00	29.00	5.00	
ACT 20	B07	29.00	32.00	29.00	32.00	0.00	C
ACT 21	B08	29.00	31.00	43.00	45.00	14.00	
ACT 22	C01	32.00	47.00	32.00	47.00	0.00	C
ACT 23	C02	47.00	50.00	47.00	50.00	0.00	C
ACT 24	C03	31.00	33.00	45.00	47.00	14.00	
ACT 25	C04	33.00	36.00	47.00	50.00	14.00	
ACT 26	C05	50.00	51.00	50.00	51.00	0.00	C
ACT 27	C06	27.00	29.00	49.00	51.00	22.00	
ACT 28	C07	27.00	43.00	35.00	51.00	8.00	
ACT 29	C08	27.00	31.00	47.00	51.00	20.00	
ACT 30	C09	51.00	52.00	51.00	52.00	0.00	C

Earliest project completion time = 52.00000

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Waling Lift Irrigation Project : Bar chart                                          52.00
Act.   0
-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+--

A01     |CCCCC                                                                       |
A02     |    CCCCCC                                                                  |
A06     |         CCCCC                                                              |
A07     |             CCCCCCCCCCCC                                                   |
B02     |                         CCCCCCC                                            |
B03     |                               CCCCCC                                       |
B04     |                                     CC                                     |
B05     |                                      CCCC                                  |
B07     |                                         CCCCC                              |
C01     |                                             CCCCCCCCCCCCCCCCCCCCCCC        |
C02     |                                                                    CCCCC   |
C05     |                                                                        CCC
C09     |                                                                          C
A04     |xxxxxxxxx.                                                                  |
A03     |xxxxxxxxx.                                                                  |
A08     |                         xxx..                                              |
A11     |                           xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx..        |
A05     |xxxxx.....                                                                  |
B01     |              xxxxx......                                                   |
B06     |                         xxxxxxxxx.......                                   |
A09     |                         xxx.........                                       |
A12     |                           xxxxxxxxxxx..........                            |
C07     |                                     xxxxxxxxxxxxxxxxxxxxxxxxx.............
B08     |                                        xxxx............                    |
C03     |                                           xxx..........                    |
C04     |                                             xxxxx......................... 
C08     |                                     xxxxxxx................................
C06     |                                       xxxx.......................          |
A10     |                         xxx................................                |
A13     |                           xxx...................................           |
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Case Study No 2 :

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 .

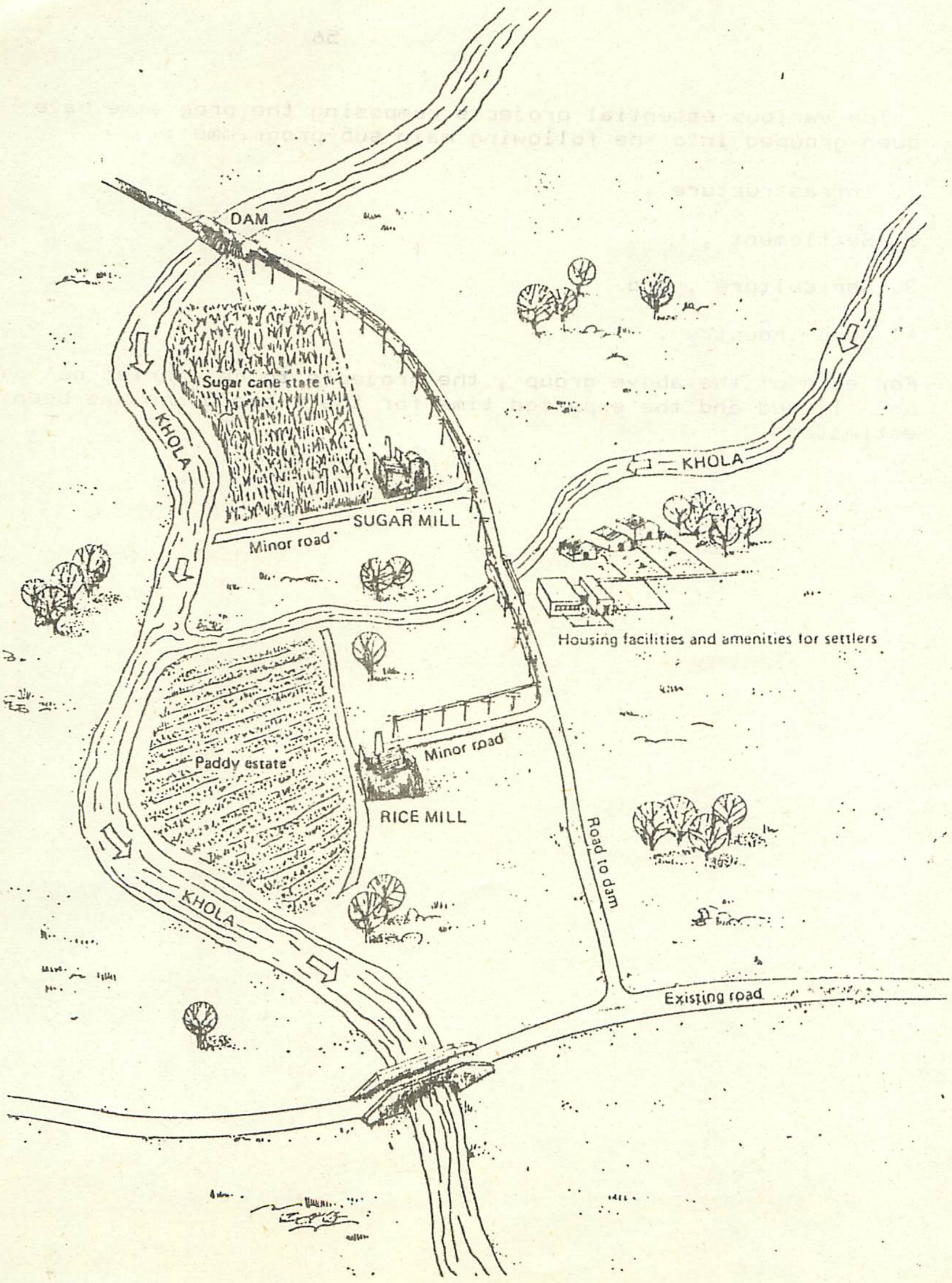
The project is designed :

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



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 .

DETAILED PROBLEM DATA LISTING FOR
Integrated Area Development Programme --- Node Approach

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

Integrated Area Development Programme --- Node Approach

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	A115	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	A13	102.00	126.00	102.00	126.00	0.00	c
ACT 15	A14	102.00	126.00	102.00	126.00	0.00	c
ACT 16	A117	126.00	138.00	126.00	138.00	0.00	c
ACT 17	A116	126.00	138.00	126.00	138.00	0.00	c

Earliest project completion time = 138.00000

Integrated Area Development Programme --- Node Approach : Bar chart

```
Act.    0                                                                                      138.00
--------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+---
                                                                                              |
1       |CCCCCCC                                                                              |
I2      |      CCCC                                                                           |
I3      |         CCCCCCCCCCCCC                                                               |
I4      |                     CCCCCCC                                                         |
S9      |                           CCCCCCCCCCCCCC                                            |
S10     |                                         CCCCCCCCCCCCC                               |
A14     |                                                     CCCCCCCCCCCCC                   |
A13     |                                                     CCCCCCCCCCCCC                   |
AI16    |                                                                 CCCCCC
AI17    |                                                                 CCCCCC
S7      |      xxxxxxxxxxxxx...                                                               |
S8      |                  xxxxxxxxxxxxxxxxxxx....                                            |
I5      |         xxxxxxxxxx.........                                                         |
I6      |                           xxxxxxxxxxxxx............                                 |
AI15    |                           xxxxxxxxxxxxx.....................                        |
AI2     |                                         xxxxxxxxxx...........                       |
AI1     |      xxxxxxx.........................                                               |
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