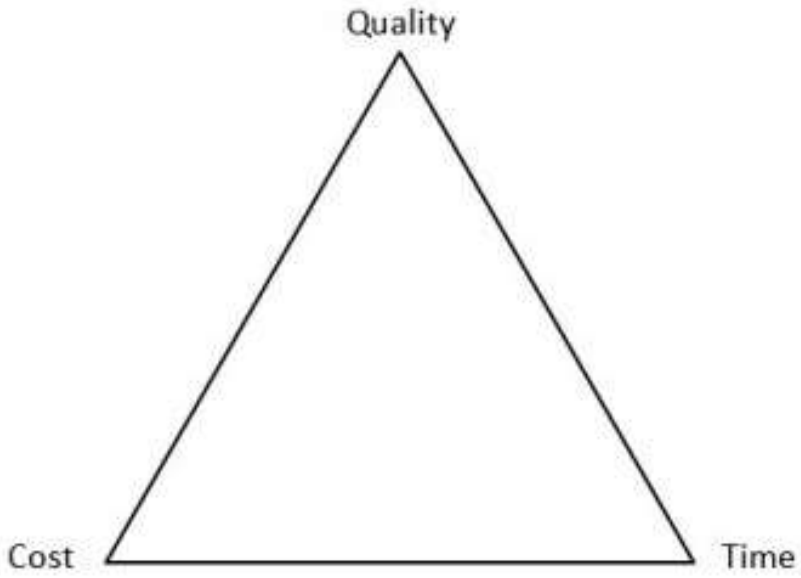
Construction Management

Recitation-1

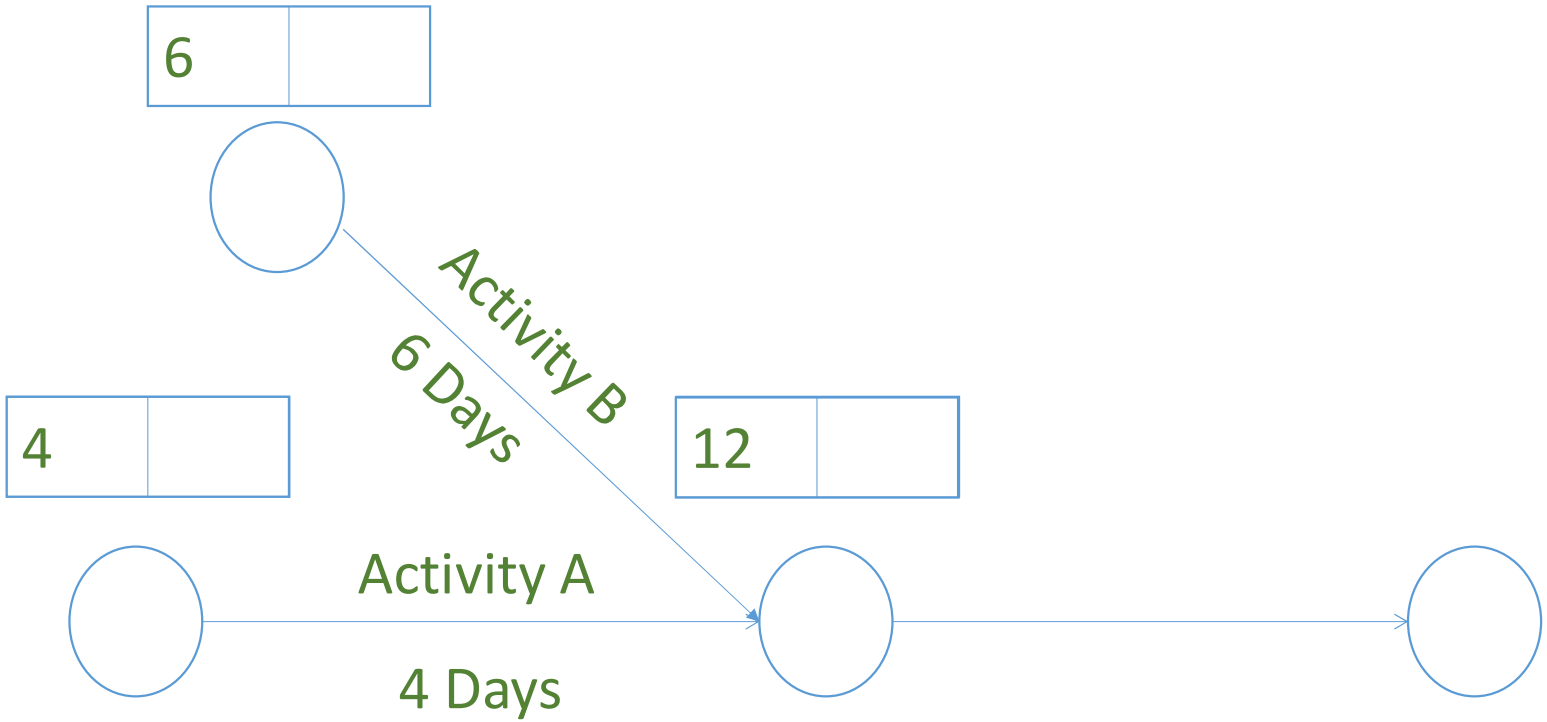
Project Management Triangle



CPM Calculations

- The aim is to find the critical path, total duration and which activities can be delayed.
- Forward pass: Early start and early finish of each activity are calculated. The calculations start from the first event to the last event.
- Backward pass: Late start and late finish of each activity are calculated. Forward pass calculations should be performed before perform backward pass. This pass starts from the last event to first event.

Arrow Diagram (Activity on arrow (AoA))



CPM Calculations

- The amount of time an activity may be delayed without delaying the completion date of project is called total float.
- Free float is the amount of time an activity may be delayed without delaying the early start time of the immediately following activity.

- TF= $LS_j - (ES_i + \text{duration})$
- FF = $ES_j - (ES_i + \text{duration})$
- Critical path: A series of interconnected activities through the network diagram, which cannot be delayed without increasing the duration of the project. The critical path determines the minimum time to complete the project (TF=0, FF=0).

Problem-solving Strategy

1- Draw the network

2- Write down the durations of each activity

3- Perform forward pass and backward pass

4- Calculate total and free floats of the activities

5- Draw critical path(s)

6- Crash the project if necessary

7- Calculate cost of the project by using following formula

Cost=Direct Cost + (Indirect Cost*Duration)+Crashing Cost (If necessary).

PROBLEM-1

- Draw the CPM diagram (A-O-A).
- Find critical path, normal duration, normal cost, total and free floats.

Activity		Normal Duration (Month)	Normal Cost (Million $)
1	2	3	14
1	3	2	10
1	5	5	10
2	4	4	25
2	5	5	29
3	5	2	25
3	6	4	35
4	5	6	29
4	8	3	14
4	7	2	10
5	6	5	10
5	7	4	25
6	7	5	29
6	9	2	25
6	10	-	-
8	9	6	29
8	10	10	14
7	8	4	35
7	9	2	10
9	10	5	10

TF=LF-(ES+Act. dur)

FF= EF-(ES+Act. dur)

TF=7-(3+4)=0

TF=3-(0+3)=0

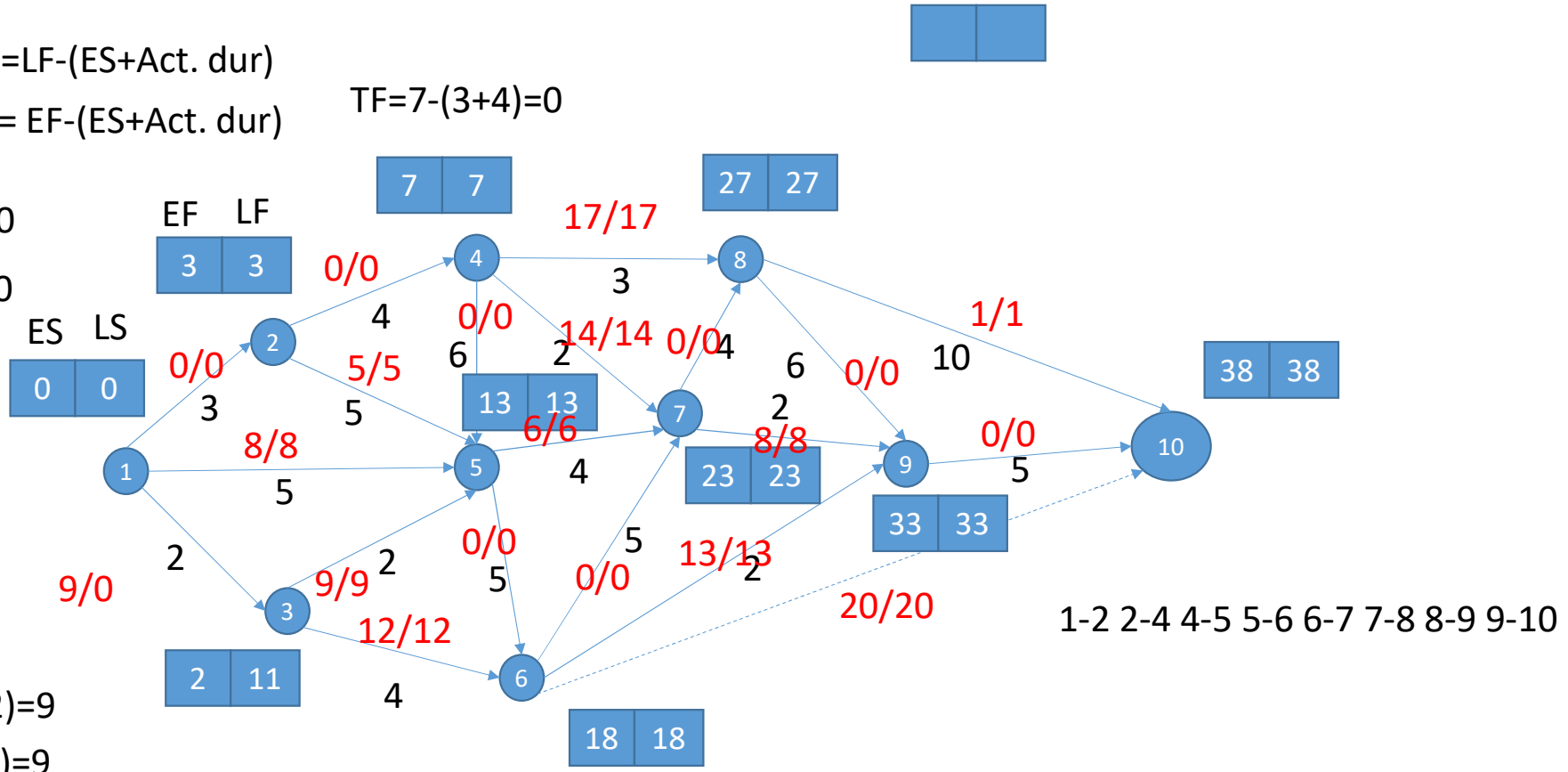
FF=3-(0+3)=0

TF=13-(2+2)=9

FF=13-(2+2)=9

TF=13-(3+5)=5

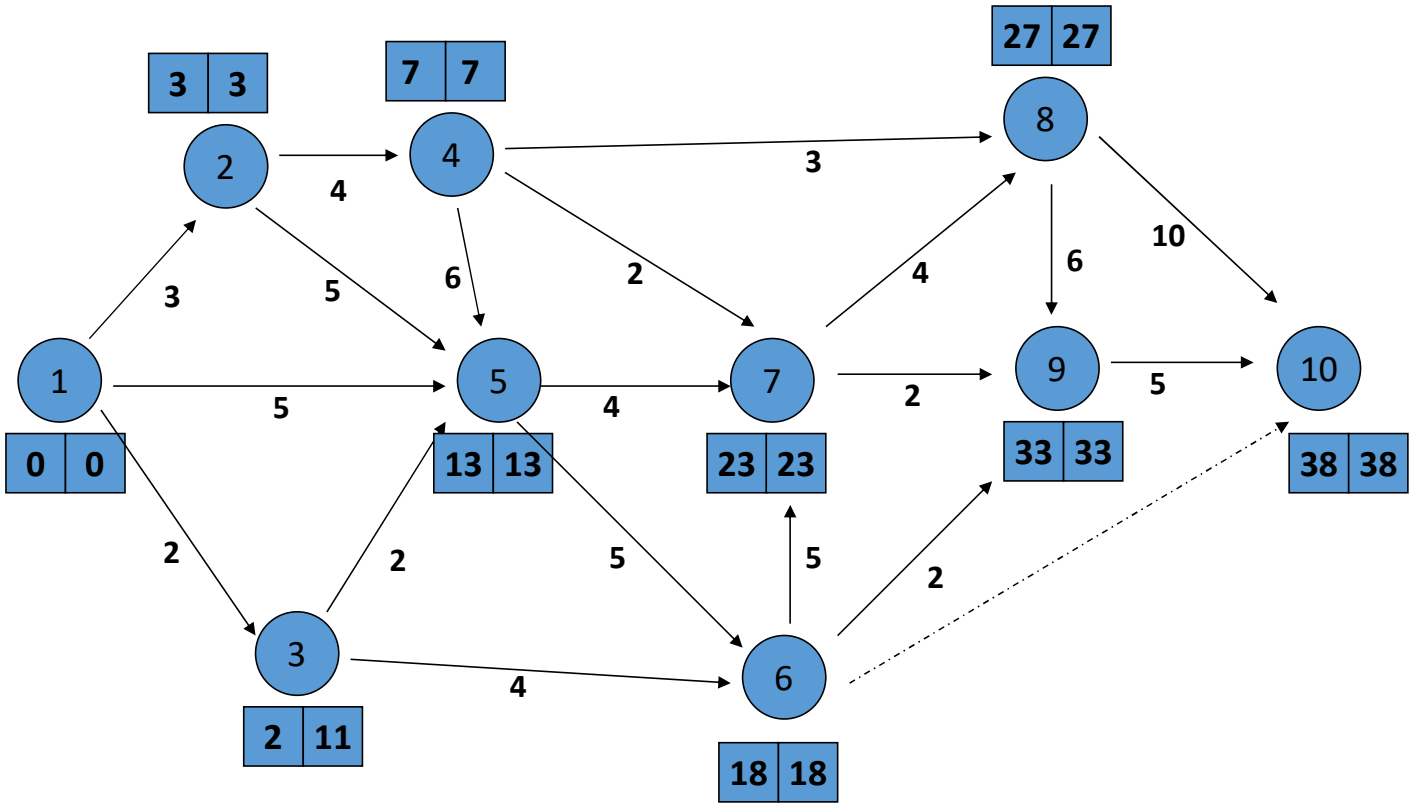
FF=13-(3+5)=5



Activity		Normal Duration (Month)	Normal Cost (Million $)
1	2	3	14
1	3	2	10
1	5	5	10
2	4	4	25
2	5	5	29
3	5	2	25
3	6	4	35
4	5	6	29
4	8	3	14
4	7	2	10
5	6	5	10
5	7	4	25
6	7	5	29
6	9	2	25
6	10	-	-
8	9	6	29
8	10	10	14
7	8	4	35
7	9	2	10
9	10	5	10

PROBLEM-1

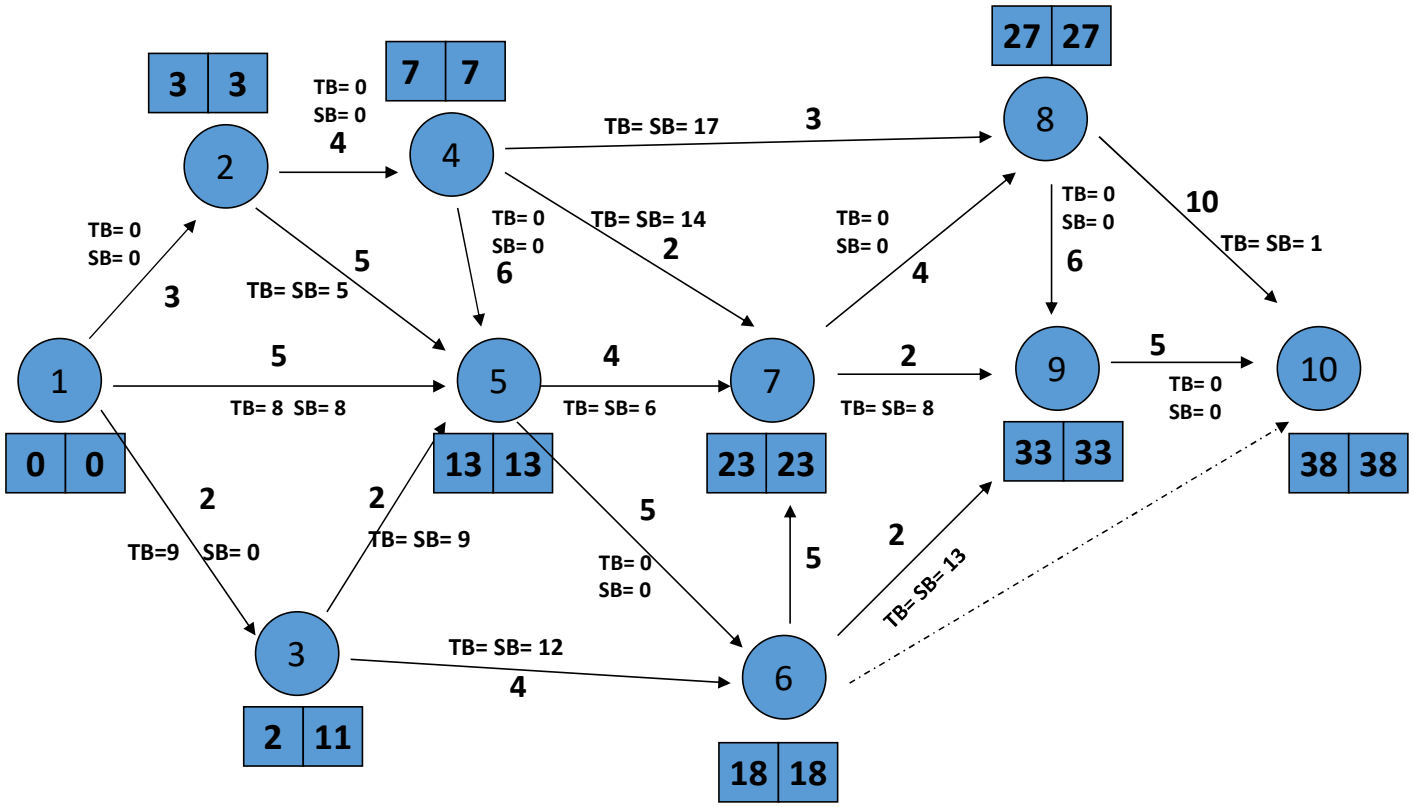
Activity		Normal Duration (Month)	Normal Cost (Million$)
1	2	3	14
1	3	2	10
1	5	5	10
2	4	4	25
2	5	5	29
3	5	2	25
3	6	4	35
4	5	6	29
4	8	3	14
4	7	2	10
5	6	5	10
5	7	4	25
6	7	5	29
6	9	2	25
6	10	-	-
8	9	6	29
8	10	10	14
7	8	4	35
7	9	2	10
9	10	5	10



Normal Duration: 38 ay

PROBLEM-1

Activity		Normal Duration (Month)	Normal Cost (Million$)
1	2	3	14
1	3	2	10
1	5	5	10
2	4	4	25
2	5	5	29
3	5	2	25
3	6	4	35
4	5	6	29
4	8	3	14
4	7	2	10
5	6	5	10
5	7	4	25
6	7	5	29
6	9	2	25
6	10	-	-
8	9	6	29
8	10	10	14
7	8	4	35
7	9	2	10
9	10	5	10



$TF = LS_j - (ES_i + duration)$

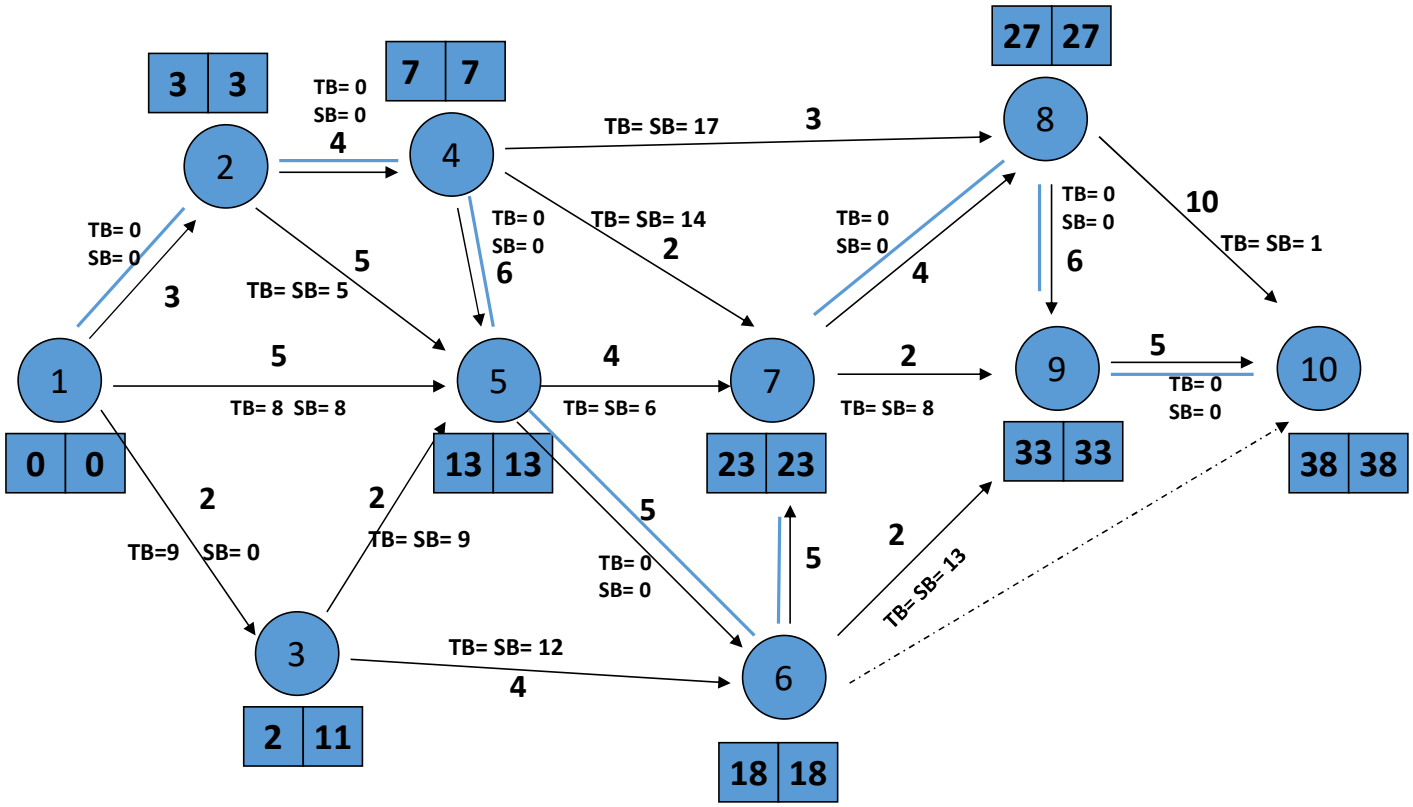
$FF = ES_j - (ES_i + duration)$

Critical Path: 1-2, 2-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10

Normal Duration: 38 Months

PROBLEM-1

Activity		Normal Duration (Month)	Normal Cost (Million $)
1	2	3	14
1	3	2	10
1	5	5	10
2	4	4	25
2	5	5	29
3	5	2	25
3	6	4	35
4	5	6	29
4	8	3	14
4	7	2	10
5	6	5	10
5	7	4	25
6	7	5	29
6	9	2	25
6	10	-	-
8	9	6	29
8	10	10	14
7	8	4	35
7	9	2	10
9	10	5	10



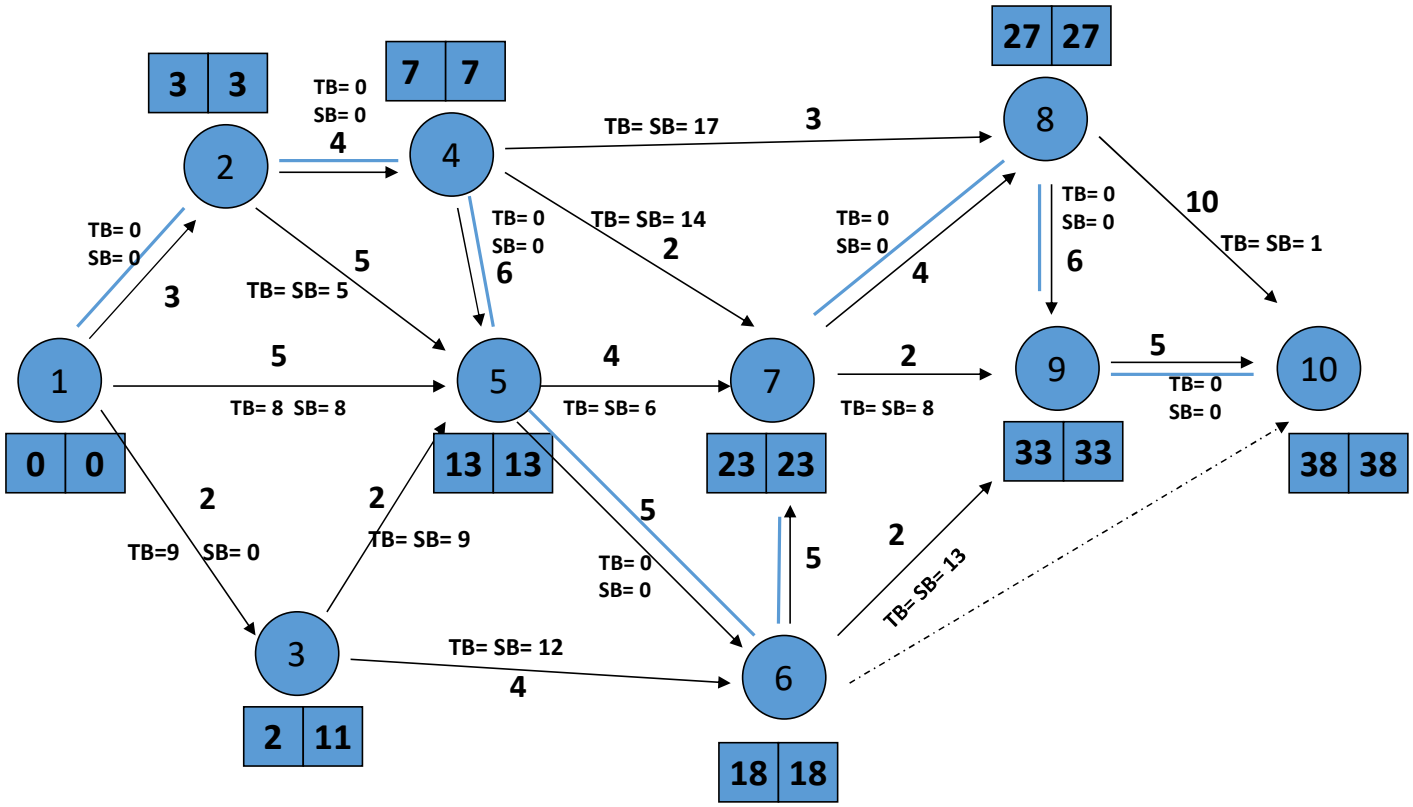
All activities whose TF and FF are equal to zero are critical activity.

Critical Path: 1-2, 2-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10

Normal Duration: 38 Months

PROBLEM-1

Activity		Normal Duration (Month)	Normal Cost (Million $)
1	2	3	14
1	3	2	10
1	5	5	10
2	4	4	25
2	5	5	29
3	5	2	25
3	6	4	35
4	5	6	29
4	8	3	14
4	7	2	10
5	6	5	10
5	7	4	25
6	7	5	29
6	9	2	25
6	10	-	-
8	9	6	29
8	10	10	14
7	8	4	35
7	9	2	10
9	10	5	10



Critical Path: 1-2, 2-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10

Normal Duration: 38 Months

Normal Cost: 388 million $

PROBLEM-2

Tunnel tender was held in the Black Sea region in winter because the roads were closed for 3 months due to snow. The tunnel will connect the two cities and shorten the road by an hour. Since the length of the tunnel is 8,5 km and the duration of the project is 2 years. 9 construction companies will take part in the construction of the tunnel. Yıldız Construction company will be responsible for the 1.2 km section of the tunnel. The activities and their relationship with each other are given below.

- The indirect cost for the project is 80.000 TL / month.
- Draw the network for this job and make the necessary calculations, find the critical path and show on the network.
- How much does it cost to complete this project as soon as possible?
- Calculate the total project cost as a result of each crashing step ?
- Find the optimum duration of the project ?

Activity	Normal Duration (Months)
Geotechnical Investigation	2
Construction of Shoring	8
Tunnel Boring	8
Shotcrete	4
Isolation works	5
Material Supply	2
Formwork and Steel Works	7
Concrete Works	5
Asphalt pavement, installation of traffic signs	4

Relationship between the activities;

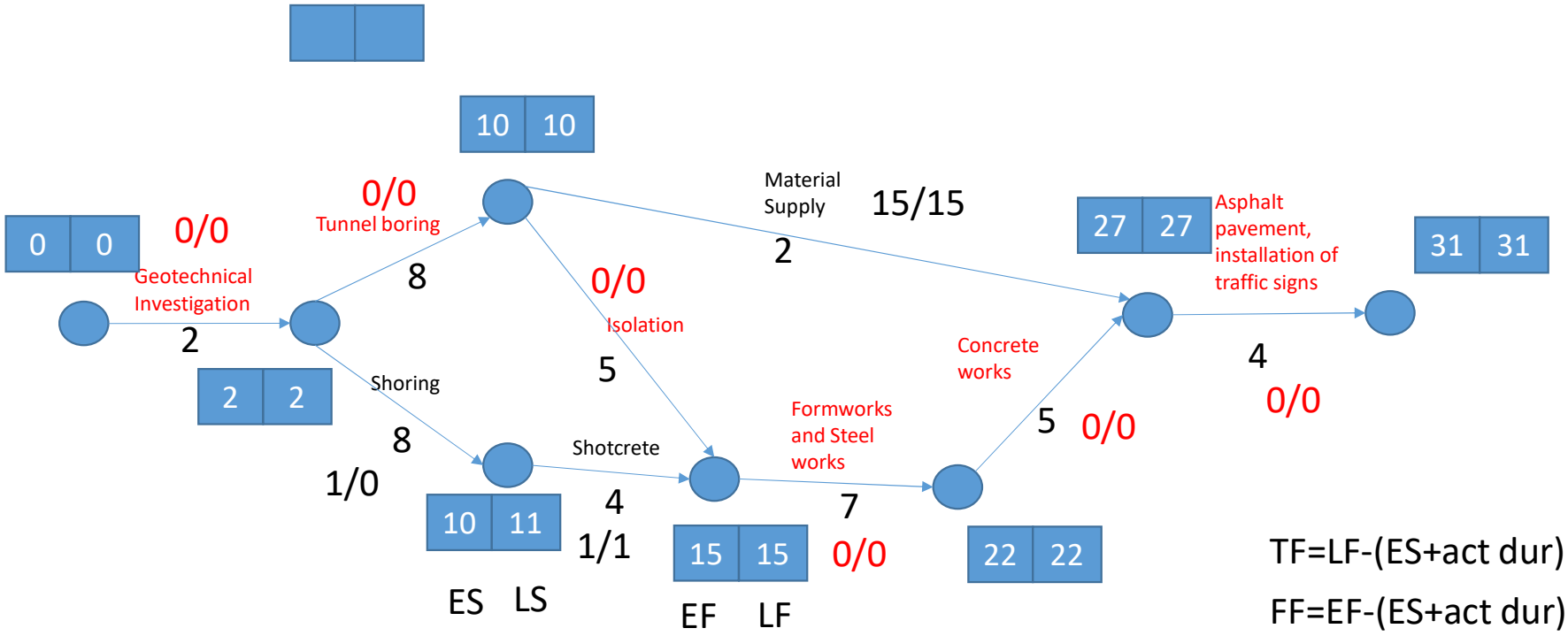
1. “Tunnel boring” and “Shoring” are going to start after “Geotechnical Investigation” is completed
2. “Shotcrete” starts after “Shoring” is completed.

3. “Isolation” and “Material Supply“ are going to start after “Tunnel Boring” is completed.

4. “Formworks and Steel works” is completed upon the completion of “Isolation” and “Shotcrete”.

5. “Concrete works” is completed after the “Formwork and Steel work”

6. “Asphalt pavement, installation of traffic signs” will start after “Concrete works” and “Material Supply” are competed.



Relat.	Activity	Normal Duration (Month)	Crashing Duration (Month)
1 – 2	Geotechnical Investigation	2 ay	1 ay
2 – 3	Construction of Shoring	8 ay	
2 – 4	Tunnel Boring	8 ay	
3 – 5	Shotcrete	4 ay	
4 – 5	Isolation works	5 ay	4 ay
4 – 7	Material Supply	2 ay	
5 – 6	Formwork and Steel Works	7 ay	5 ay
6 – 7	Concrete Works	5 ay	3 ay
7 – 8	Asphalt pavement, installation of traffic signs	4 ay	3 ay

Cost=7.150.000+31*80.000=9630.000

Relationship between the activities;

1. "Tunnel boring" and "Shoring" are going to start after "Geotechnical Investigation" is completed
2. "Shotcrete" starts after "Shoring" is completed.

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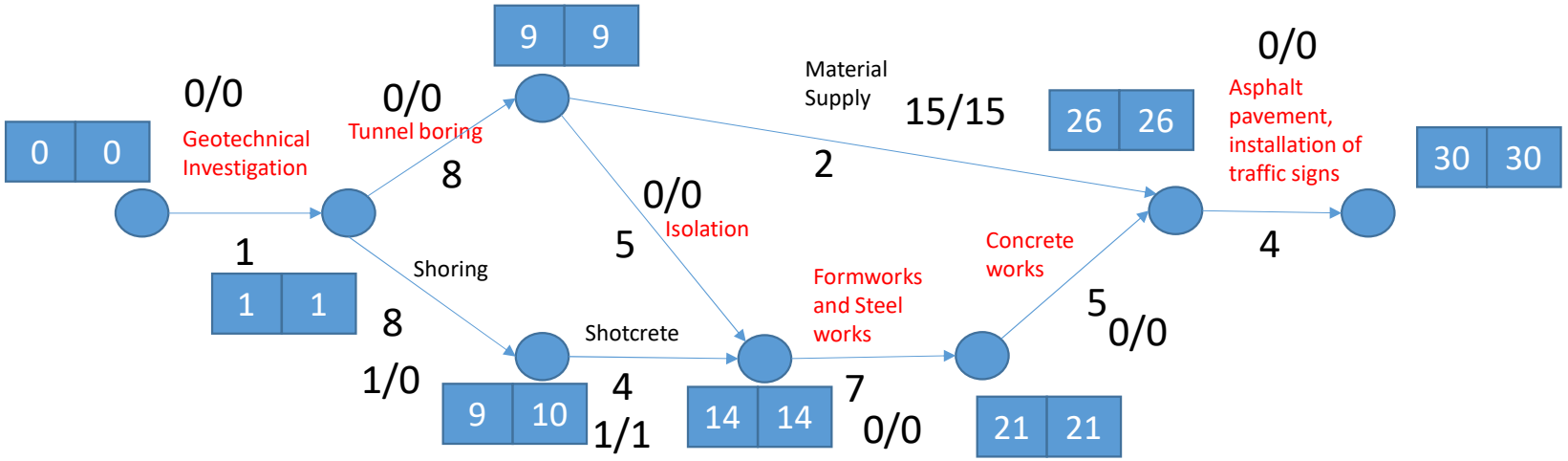
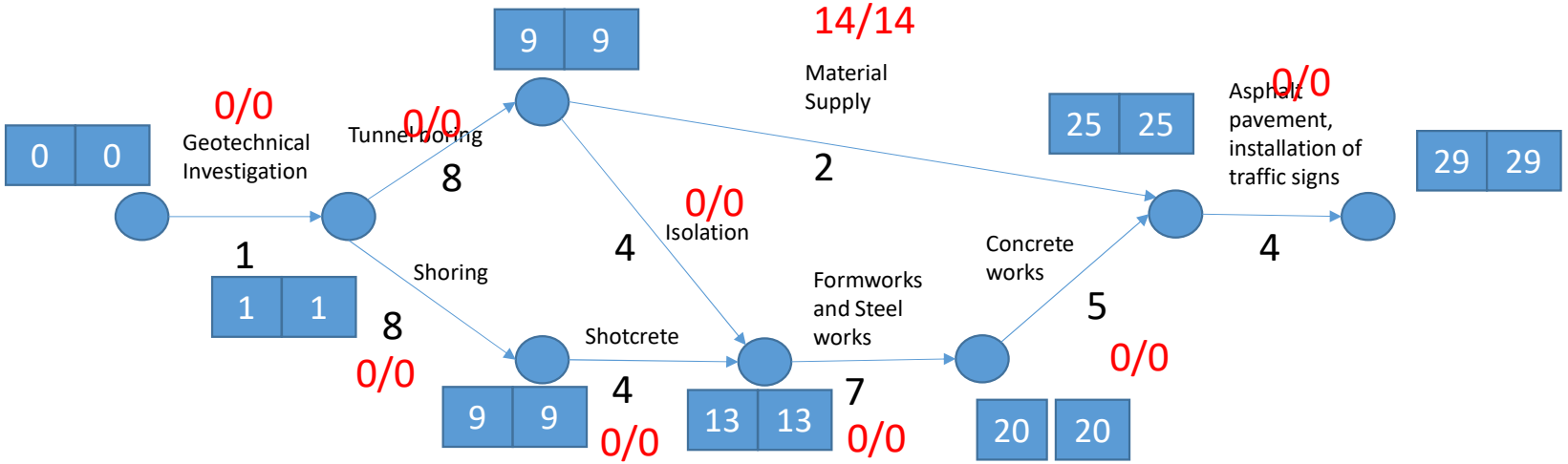


Relat.	Activity	Normal Duration (Month)	Crashing Duration (Month)	Cost (TL)	Unit Crashing Cost ($/Month)
1 – 2	Geotechnical Investigation	2 ay	1 ay	150.000	50.000
2 – 3	Construction of Shoring	8 ay		800.000	
2 – 4	Tunnel Boring	8 ay		1.300.000	
3 – 5	Shotcrete	4 ay		350.000	
4 – 5	Isolation works	5 ay	4 ay	400.000	75.000
4 – 7	Material Supply	2 ay		1.350.000	
5 – 6	Formwork and Steel Works	7 ay	5 ay	1.850.000	325.000
6 – 7	Concrete Works	5 ay	3 ay	650.000	225.000
7 – 8	Asphalt pavement, installation of traffic signs	4 ay	3 ay	300.000	150.000
				7.150.000	

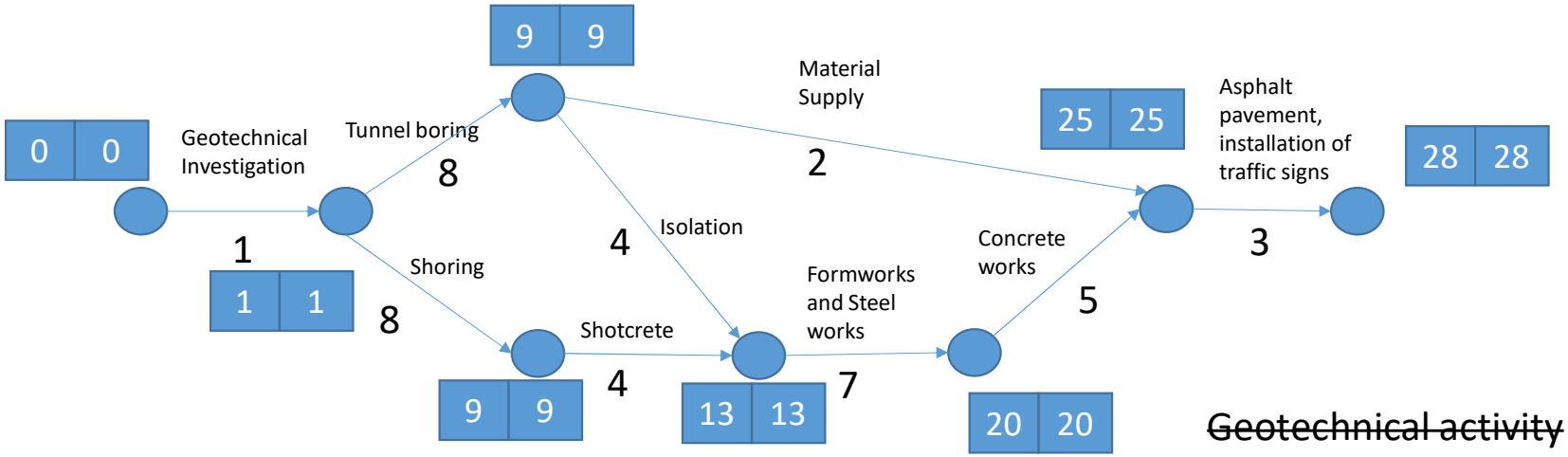
1st Cost=7.150.000+30*80.000+50.000=9.600.000



Relat.	Activity	Normal Duration (Month)	Crashing Duration (Month)	Cost (TL)	Unit Crashing Cost ($/Month)
1 – 2	Geotechnical Investigation	2 ay	1 ay	150.000	50.000
2 – 3	Construction of Shoring	8 ay		800.000	
2 – 4	Tunnel Boring	8 ay		1.300.000	
3 – 5	Shotcrete	4 ay		350.000	
4 – 5	Isolation works	5 ay	4 ay	400.000	75.000
4 – 7	Material Supply	2 ay		1.350.000	
5 – 6	Formwork and Steel Works	7 ay	5 ay	1.850.000	325.000
6 – 7	Concrete Works	5 ay	3 ay	650.000	225.000
7 – 8	Asphalt pavement, installation of traffic signs	4 ay	3 ay	300.000	150.000
				7.150.000	

~~Geotechnical activity~~
~~Tunnel boring+Shoring~~
~~Tunnel boring+shotcrete~~
~~Isolation+shoring~~
~~Isolation+shotcrete~~
Formworks=325.000
Concrete Works=225.000
Asphalt=150.000

2nd
Cost=7.150.000+29*80.000+50.000+75.000=9.595.000

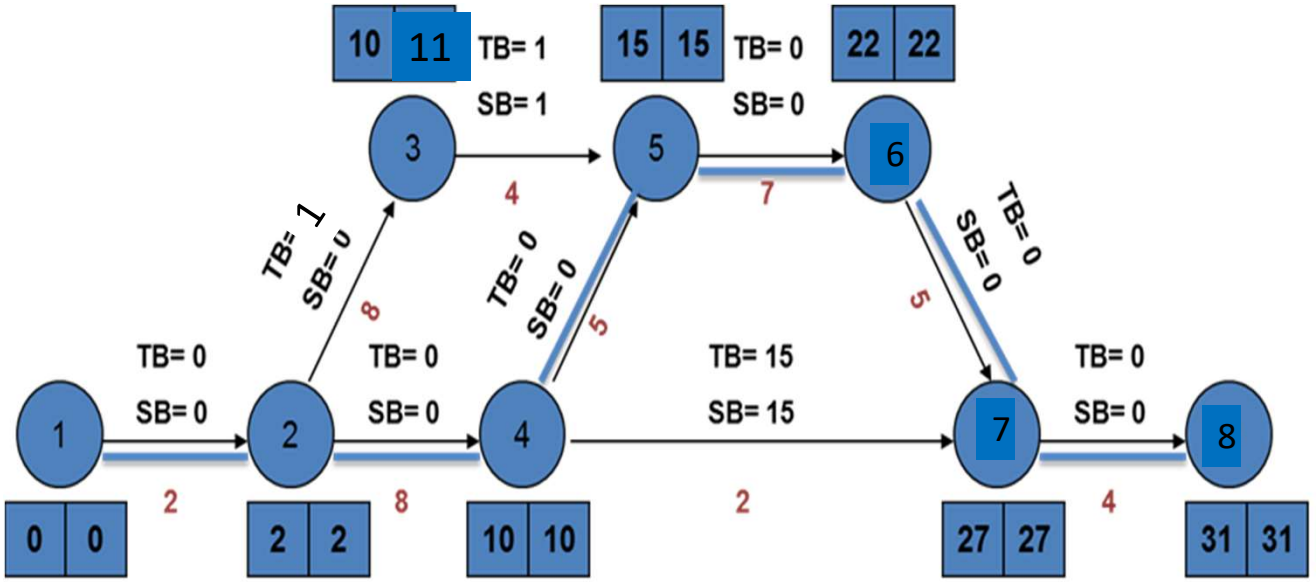


Relat.	Activity	Normal Duration (Month)	Crashing Duration (Month)	Cost (TL)	Unit Crashing Cost ($/Month)
1 – 2	Geotechnical Investigation	2 ay	1 ay	150.000	50.000
2 – 3	Construction of Shoring	8 ay		800.000	
2 – 4	Tunnel Boring	8 ay		1.300.000	
3 – 5	Shotcrete	4 ay		350.000	
4 – 5	Isolation works	5 ay	4 ay	400.000	75.000
4 – 7	Material Supply	2 ay		1.350.000	
5 – 6	Formwork and Steel Works	7 ay	5 ay	1.850.000	325.000
6 – 7	Concrete Works	5 ay	3 ay	650.000	225.000
7 – 8	Asphalt pavement, installation of traffic signs	4 ay	3 ay	300.000	150.000
				7.150.000	

~~Geotechnical activity~~
~~Tunnel boring+Shoring~~
~~Tunnel boring+shotcrete~~
~~Isolation+shoring~~
~~Isolation+shotcrete~~
Formworks=325.000
Concrete Works=225.000
~~Asphalt=150.000~~

3rd
Cost=7.150.000+28*80.000+50.000+75.000+150.000=9.665.000

Relat.	Activity	Normal Duration (Month)	Crashing Duration (Month)	Cost (TL)	Unit Crashing Cost ($/Month)
1 – 2	Geotechnical Investigation	2 ay	1 ay	150.000	50.000
2 – 3	Construction of Shoring	8 ay		800.000	
2 – 4	Tunnel Boring	8 ay		1.300.000	
3 – 5	Shotcrete	4 ay		350.000	
4 – 5	Isolation works	5 ay	4 ay	400.000	75.000
4 – 7	Material Supply	2 ay		1.350.000	
5 – 6	Formwork and Steel Works	7 ay	5 ay	1.850.000	325.000
6 – 7	Concrete Works	5 ay	3 ay	650.000	225.000
7 – 8	Asphalt pavement, installation of traffic signs	4 ay	3 ay	300.000	150.000
				7.150.000	



TB = GK – (EA + SÜRE)

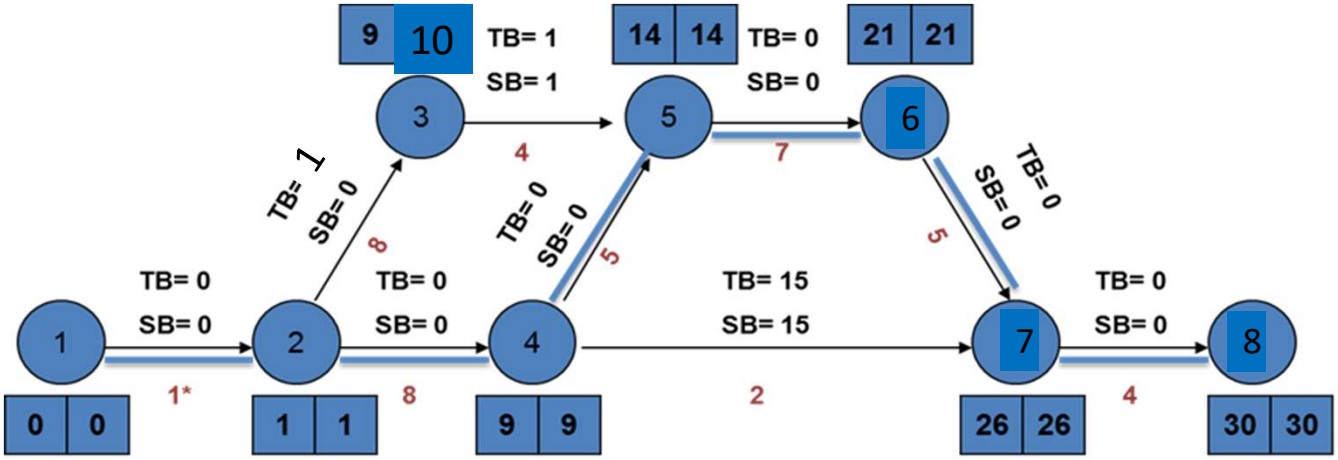
SB = EK – (EA + SÜRE)

Critical Path: 1-2, 2-4, 4-5, 5-6, 6-7, 7-8

Total Cost= Direct Cost+Indirect Cost

Total Project Cost: 7.150.000 + (31 x 80.000) = 9.630.000

1. HIZLANDIRMA : 1 – 2 / 2 months ⟶ 1 month / Cost = 50.000 TL



TB = GK – (EA + SÜRE)

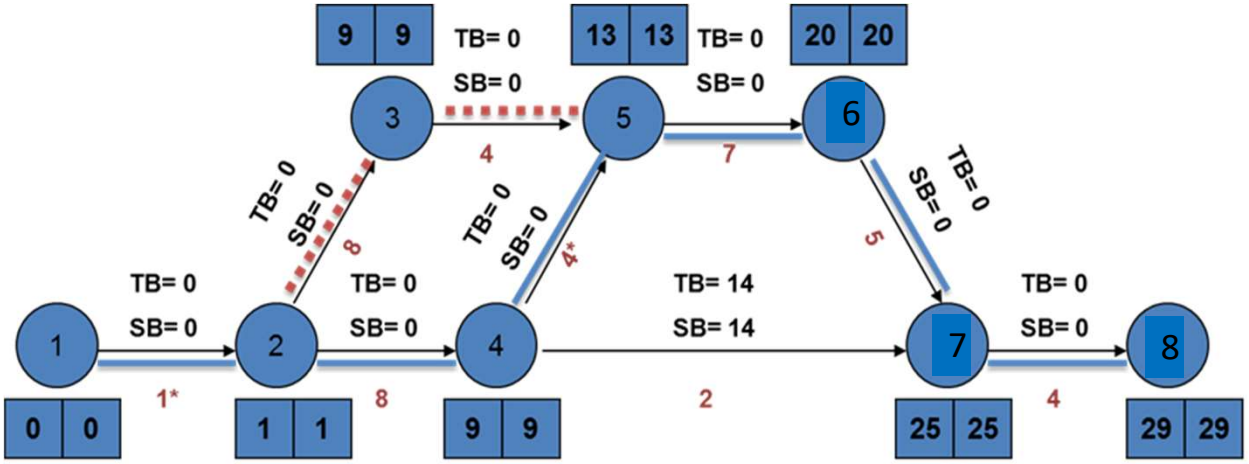
SB = EK – (EA + SÜRE)

Critical Path : 1-2, 2-4, 4-5, 5-6, 6-7, 7-8

Total cost of the project after first crashing

7.150.000 + (30 x 80.000) +50.000= 9.600.000 TL

2. HIZLANDIRMA : İş 4 – 5 / 5 months ⟶ 4 months / Cost = 75.000 TL



TB = GK – (EA + SÜRE)

SB = EK – (EA + SÜRE)

1+2
2-3+2-4
2-3+4-5
3-5+2-4
3-5+4-5
5-6=325.000
6-7=225.000
7-8=150.000

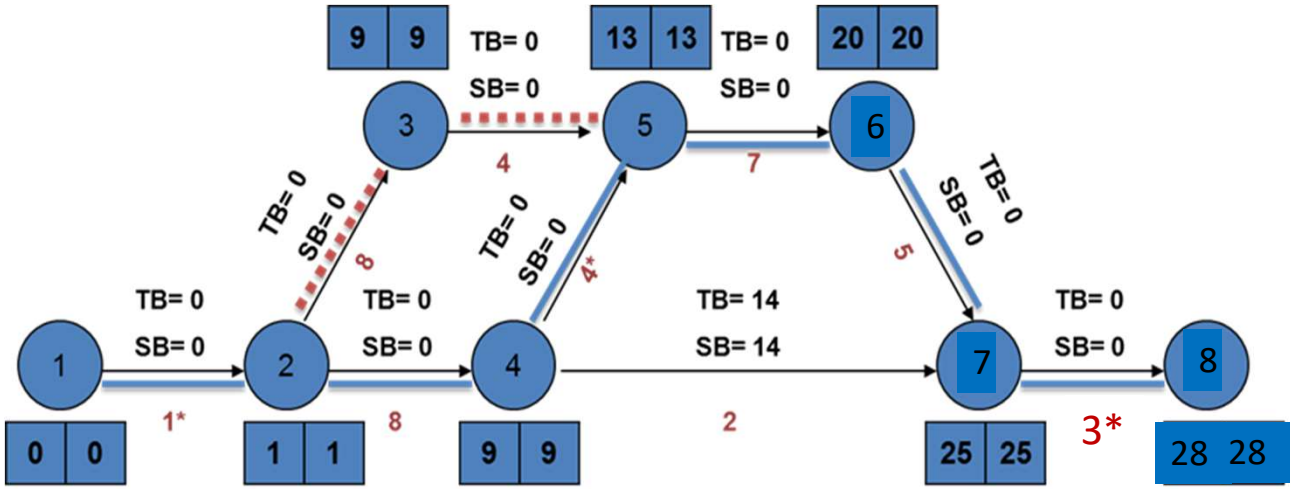
Critical Path-1: 1-2, 2-4, 4-5, 5-6, 6-7, 7-8

Critical Path-2: 1-2, 2-3, 3-5, 5-6, 6-7, 7-8

Total cost of the project after second crashing

7.150.000 + (29 x 80.000) +50.000 + 75.000 = 9.595.000 TL

. HIZLANDIRMA : İş 7 – 8 / 4 months ⟶ 3 months / Cost = 150.000 TL



TB = GK – (EA + SÜRE)

SB = EK – (EA + SÜRE)

Critical Path-1: 1-2, 2-4, 4-5, 5-6, 6-7, 7-8

Critical Path-2: 1-2, 2-3, 3-5, 5-6, 6-7, 7-8

Total cost of the project after third crashing

7.150.000 + (28 x 80.000) +50.000 + 75.000 + 150.000 = 9.665.000 TL

Assessments Related to Cost

- **Crashing Costs:**

➢ **Cost of first crashing**: **50.000 TL**

➢ **Cost of second crashing** : **75.000 TL**

➢ **Cost of third crashing** **150.000 TL**

Total cost of crashing: **275 .000 TL**

- **Total direct cost of the project:**

7.150.000 TL (indirect costs are excluded).

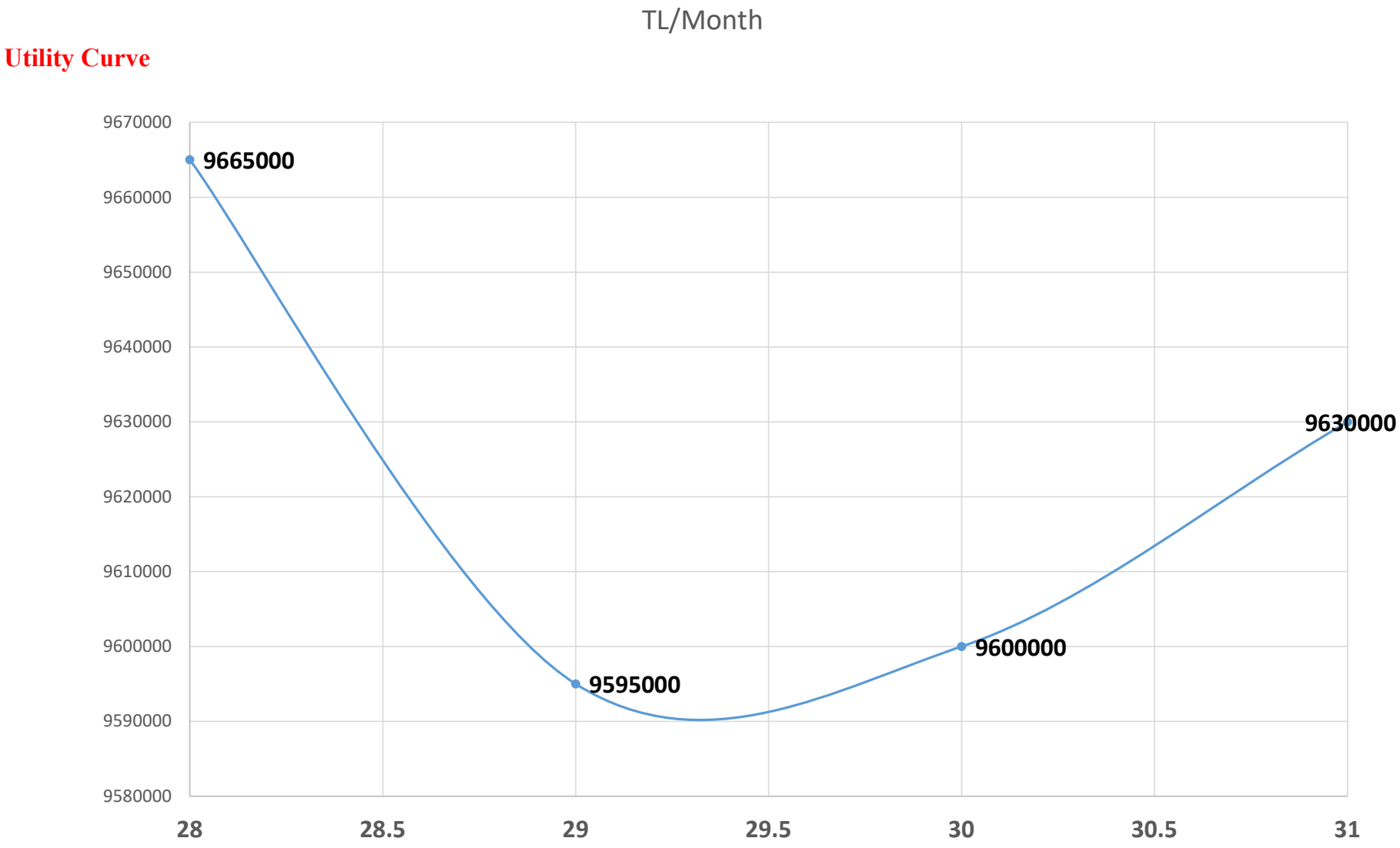
- **If indirect costs are 80.000 TL/months :**

1. Cost of first crashing : $7.150.000 + (30 \times 80.000) + 50.000 = 9.600.000$ TL

2. Cost of second crashing : $7.150.000 + (29 \times 80.000) + 50.000 + 75.000 = 9.595.000$ TL

3. Cost of third crashing : $7.150.000 + (28 \times 80.000) + 50.000 + 75.000 + 150.000 = 9.665.000$ TL

As figure given below shows, the optimum duration of the project is 29 months. Beyond this, each crashing will increase the cost of the project

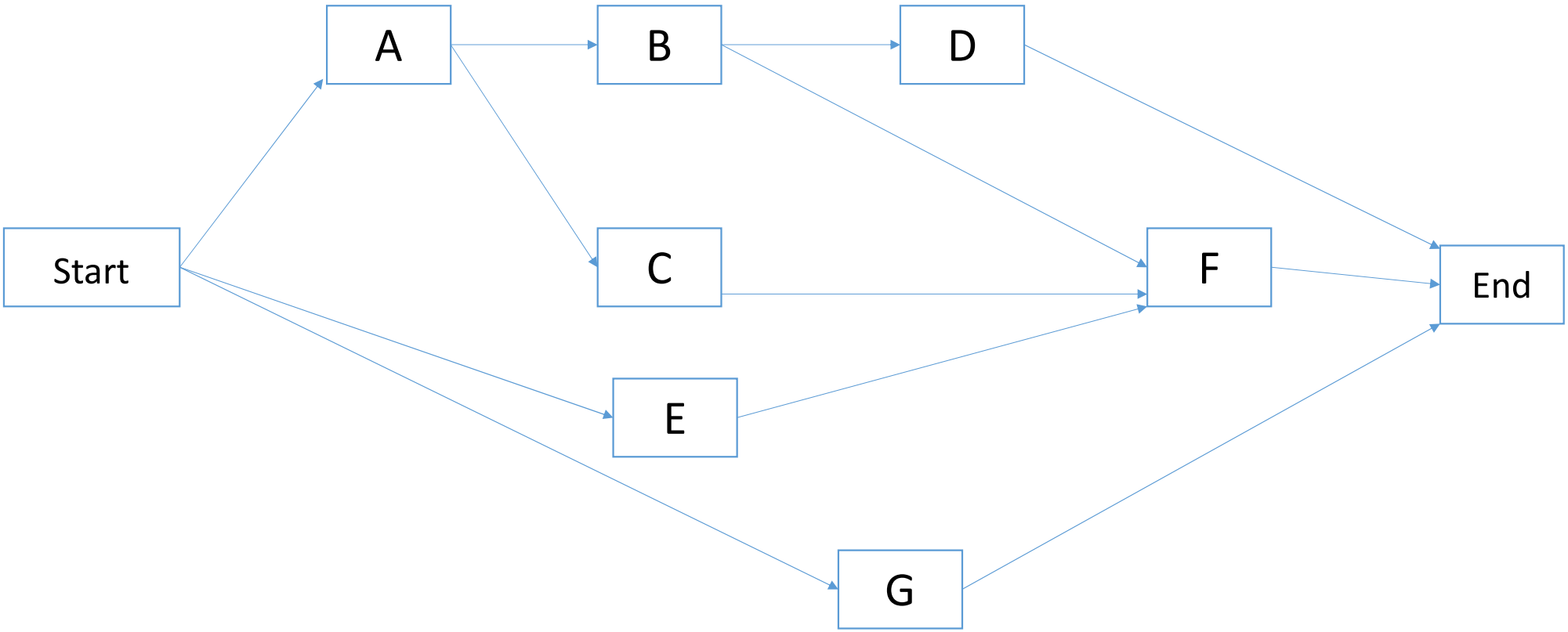


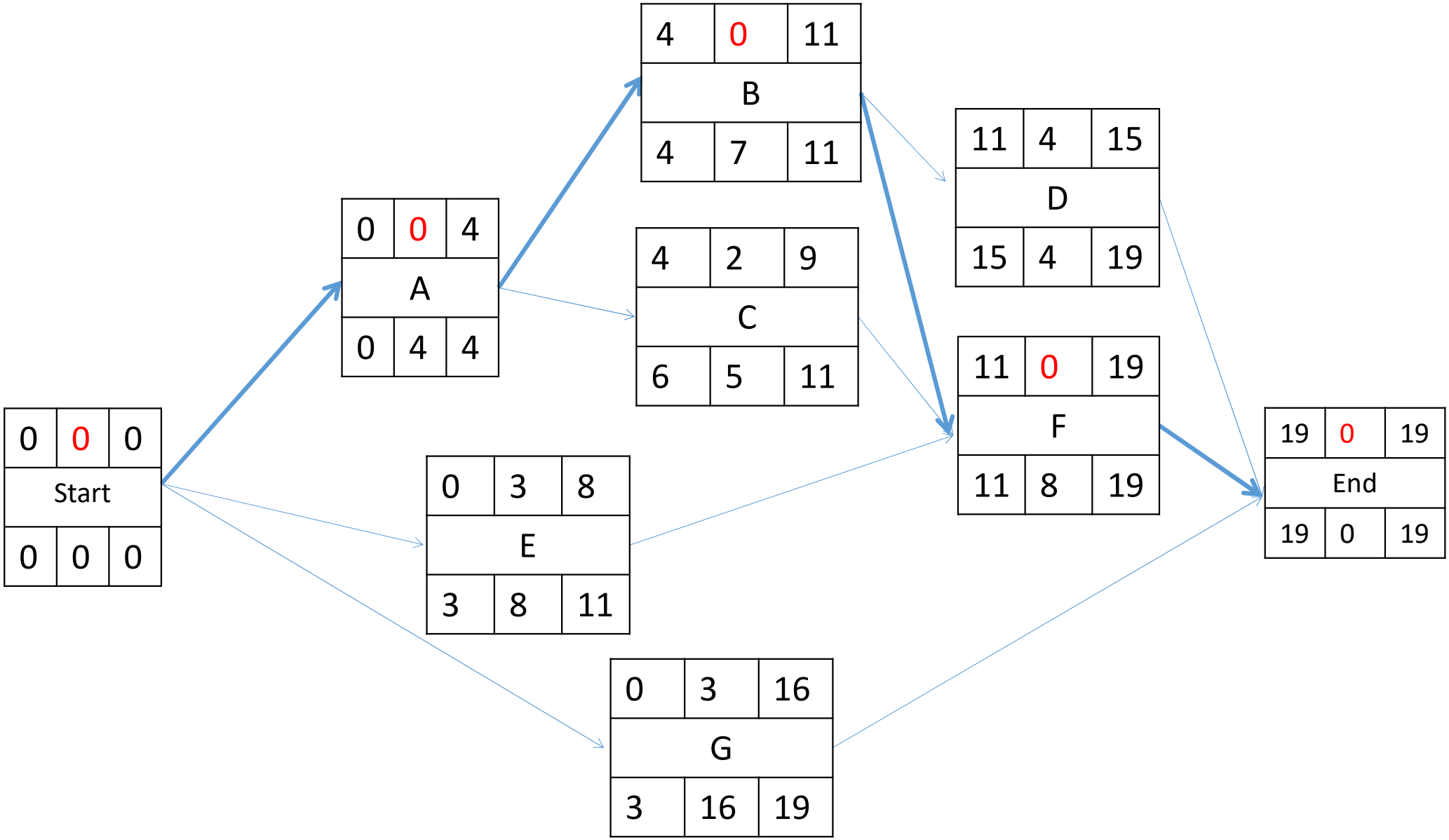
PROBLEM-3

Draw the A-O-N network using the activities given below.
Calculate the normal duration, total floats.

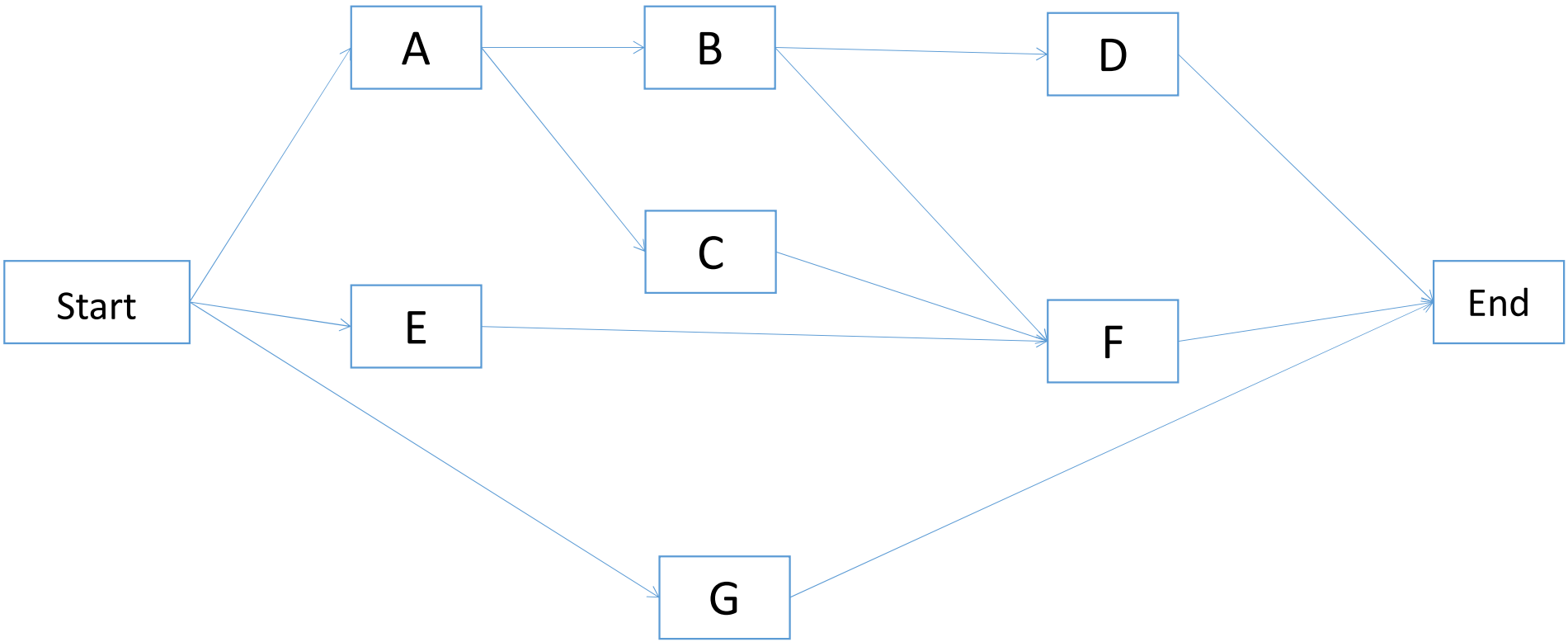
Activity	Duration (Day)	Dependency
A	4	-
B	7	A
C	5	A
D	4	B
E	8	-
F	8	B,C,E
G	16	-

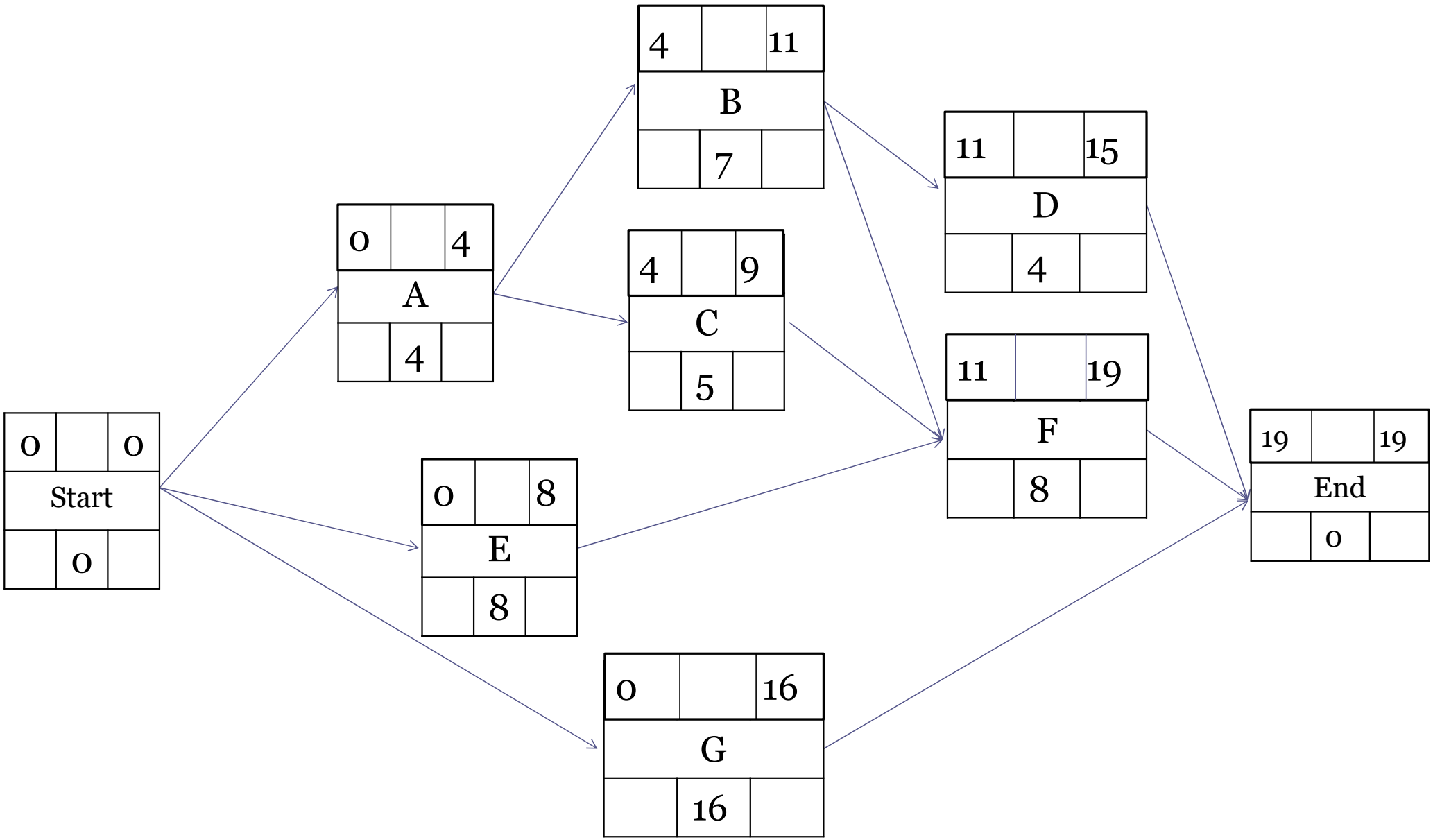
Activity	Duration (Day)	Dependency
A	4	-
B	7	A
C	5	A
D	4	B
E	8	-
F	8	B,C,E
G	16	-

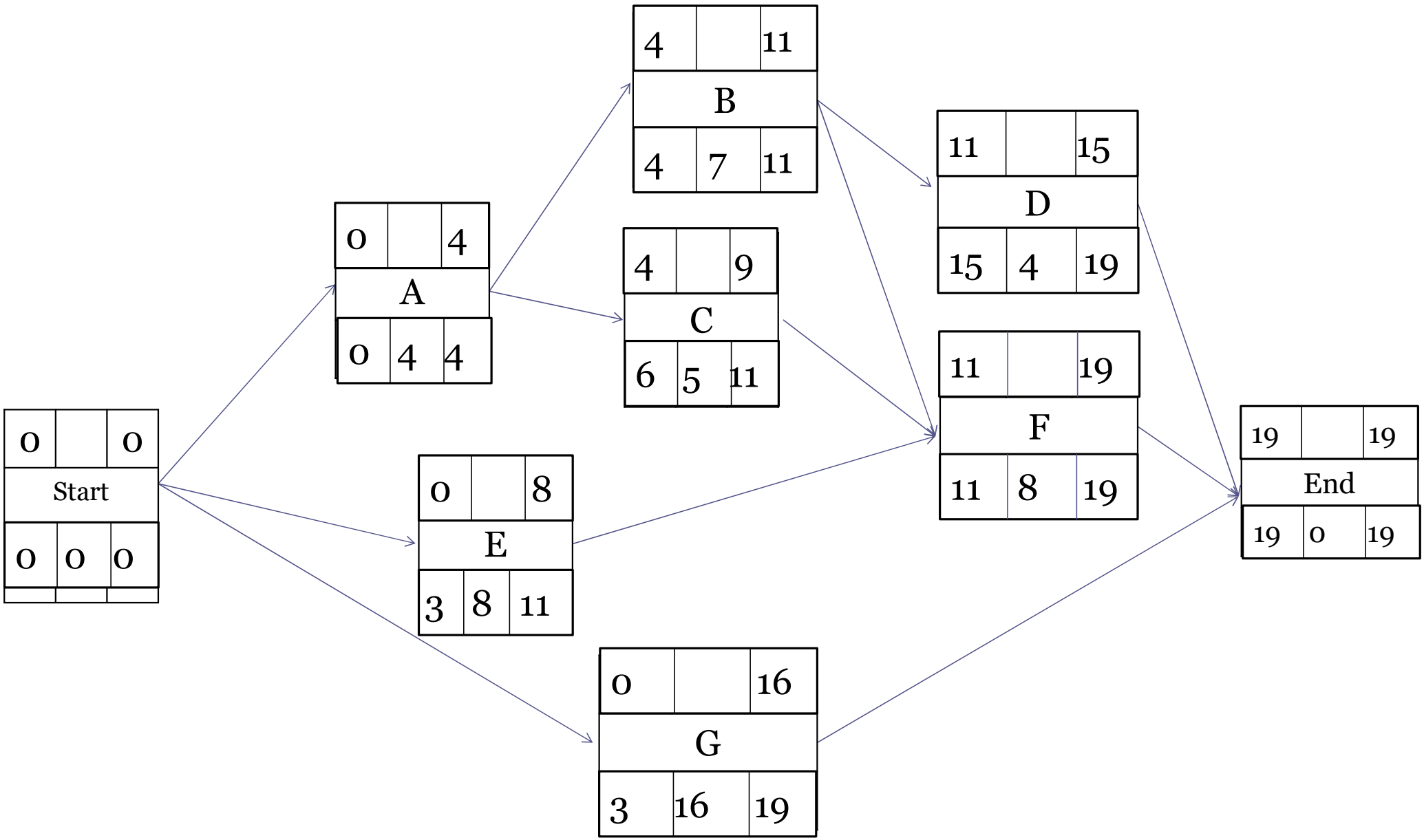


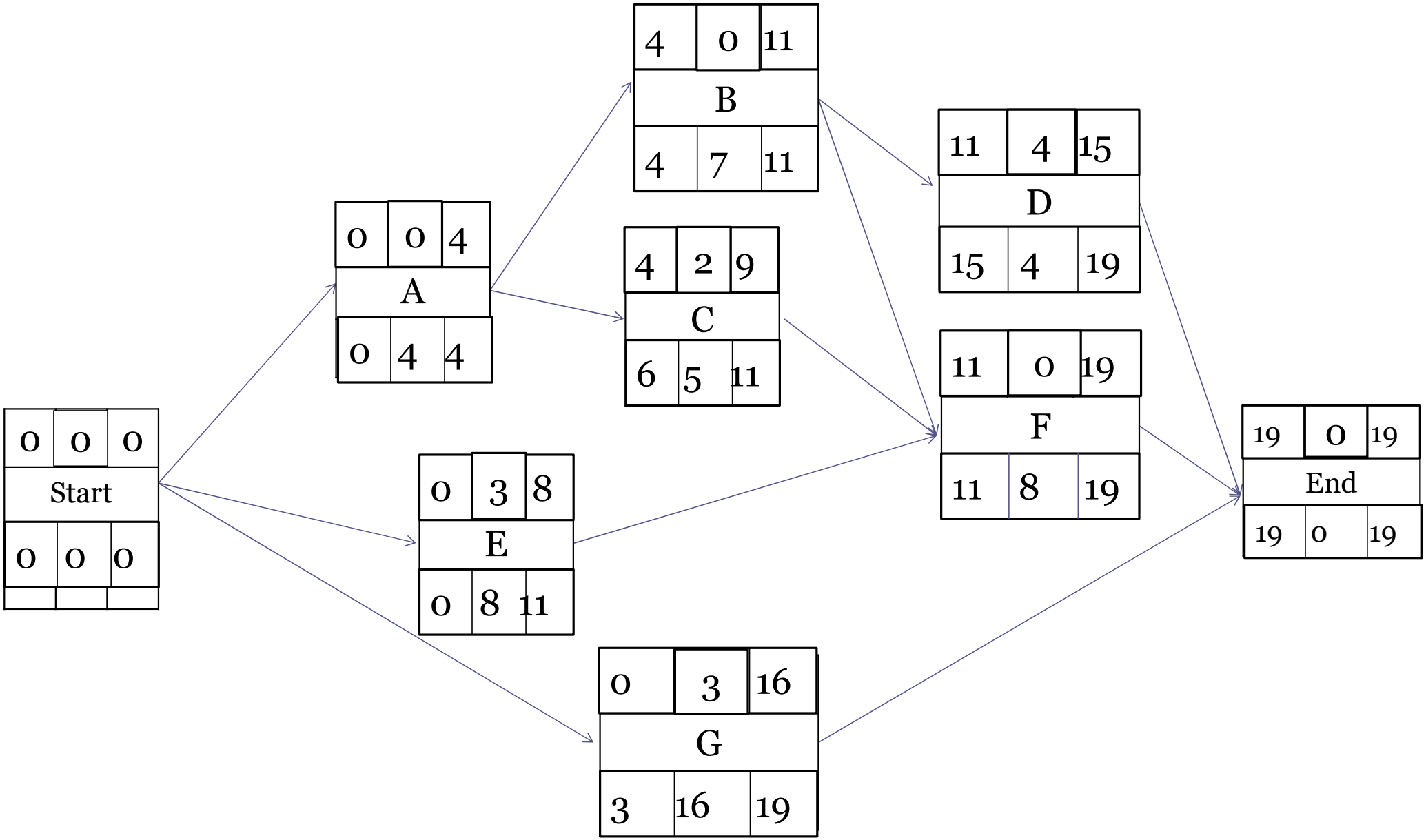

0 0 0
Start
0 0 0
0 0 4
A
0 4 4
4 0 11
B
4 7 11
4 2 9
C
6 5 11
0 3 8
E
3 8 11
0 3 16
G
3 16 19
11 4 15
D
15 4 19
11 0 19
F
11 8 19
19 0 19
End
19 0 19

Activity	Duration (Day)	Dependency
A	4	-
B	7	A
C	5	A
D	4	B
E	8	-
F	8	B,C,E
G	16	-



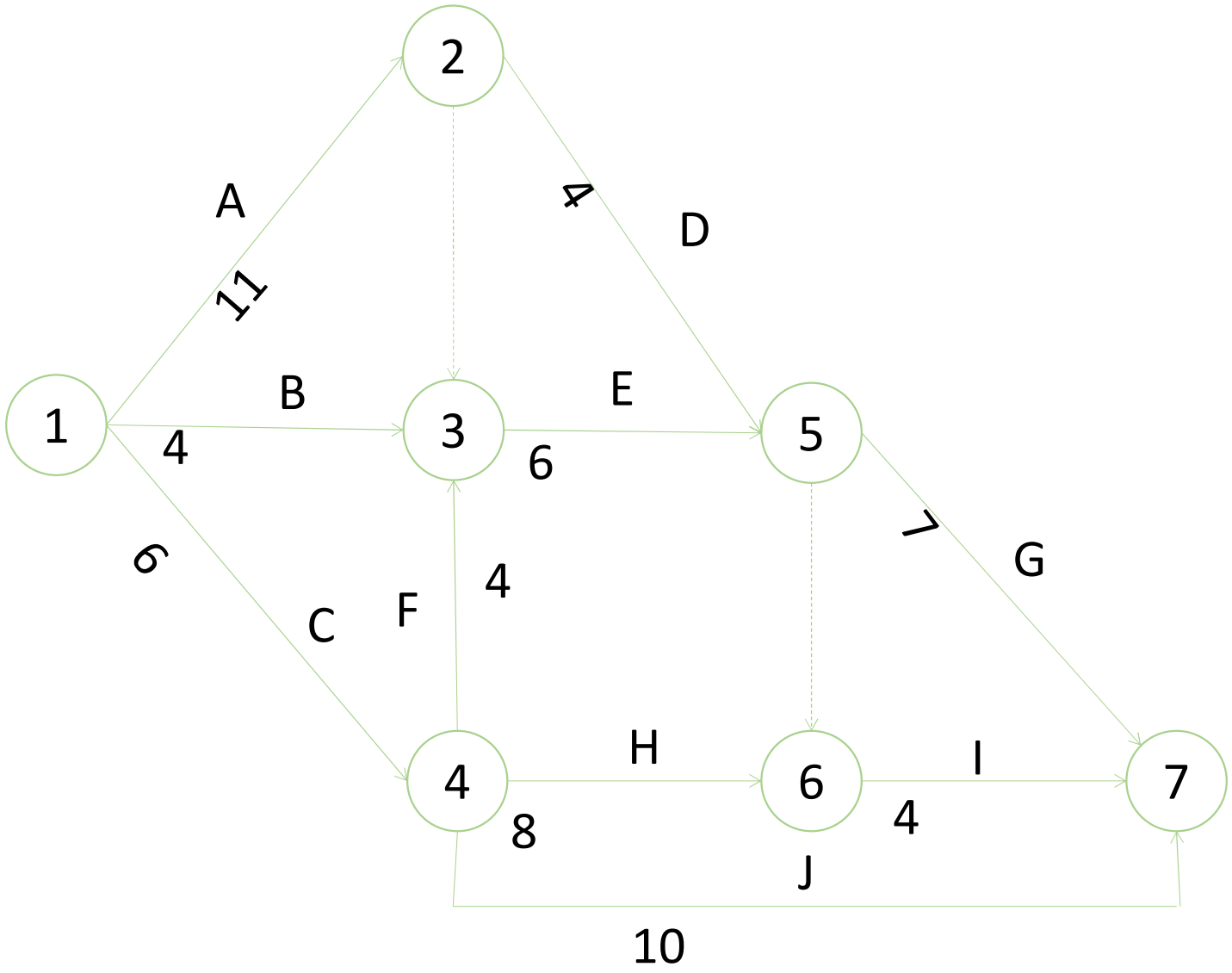

0
0
Start
0
4
A
4
4
11
B
7
4
9
C
5
11
15
D
4
0
8
E
8
0
16
G
16
11
19
F
8
19
19
End
0

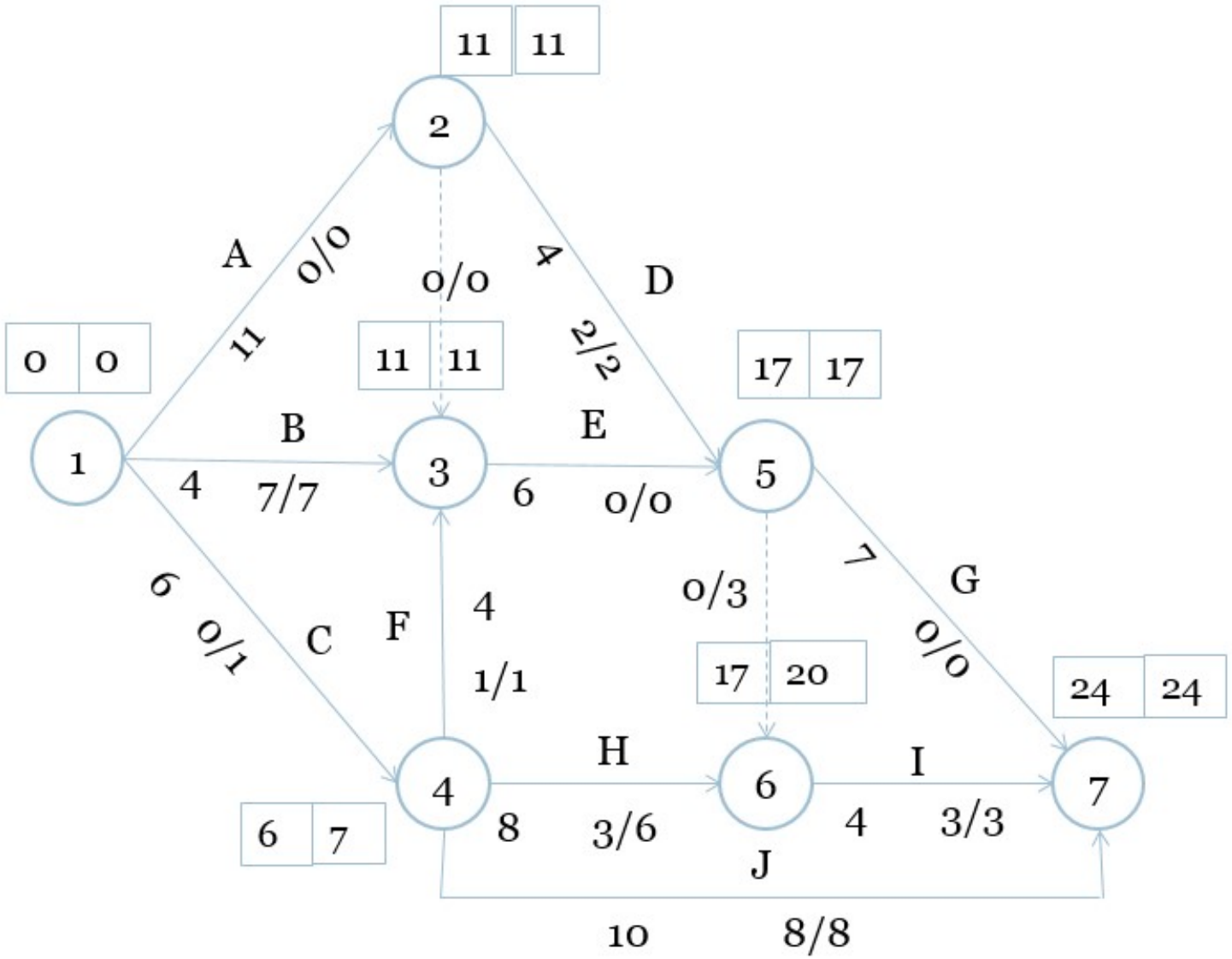

0 0
Start
0 0 0
0 4
A
0 4 4
4 11
B
4 7 11
4 9
C
6 5 11
0 8
E
3 8 11
0 16
G
3 16 19
11 15
D
15 4 19
11 19
F
11 8 19
19 19
End
19 0 19

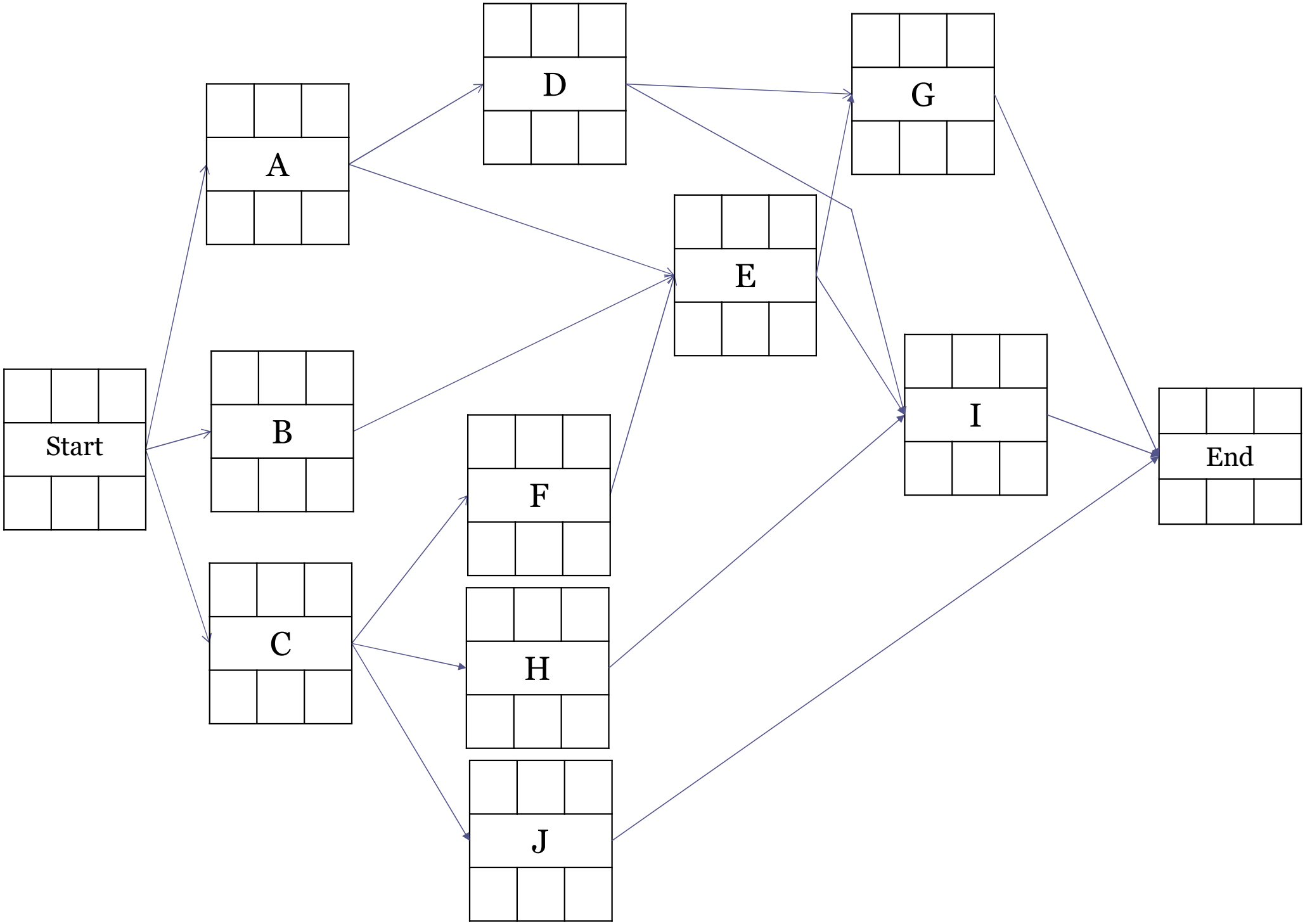

0 0 0
Start
0 0 0
0 0 4
A
0 4 4
4 0 11
B
4 7 11
4 2 9
C
6 5 11
0 3 8
E
0 8 11
0 3 16
G
3 16 19
11 4 15
D
15 4 19
11 0 19
F
11 8 19
19 0 19
End
19 0 19

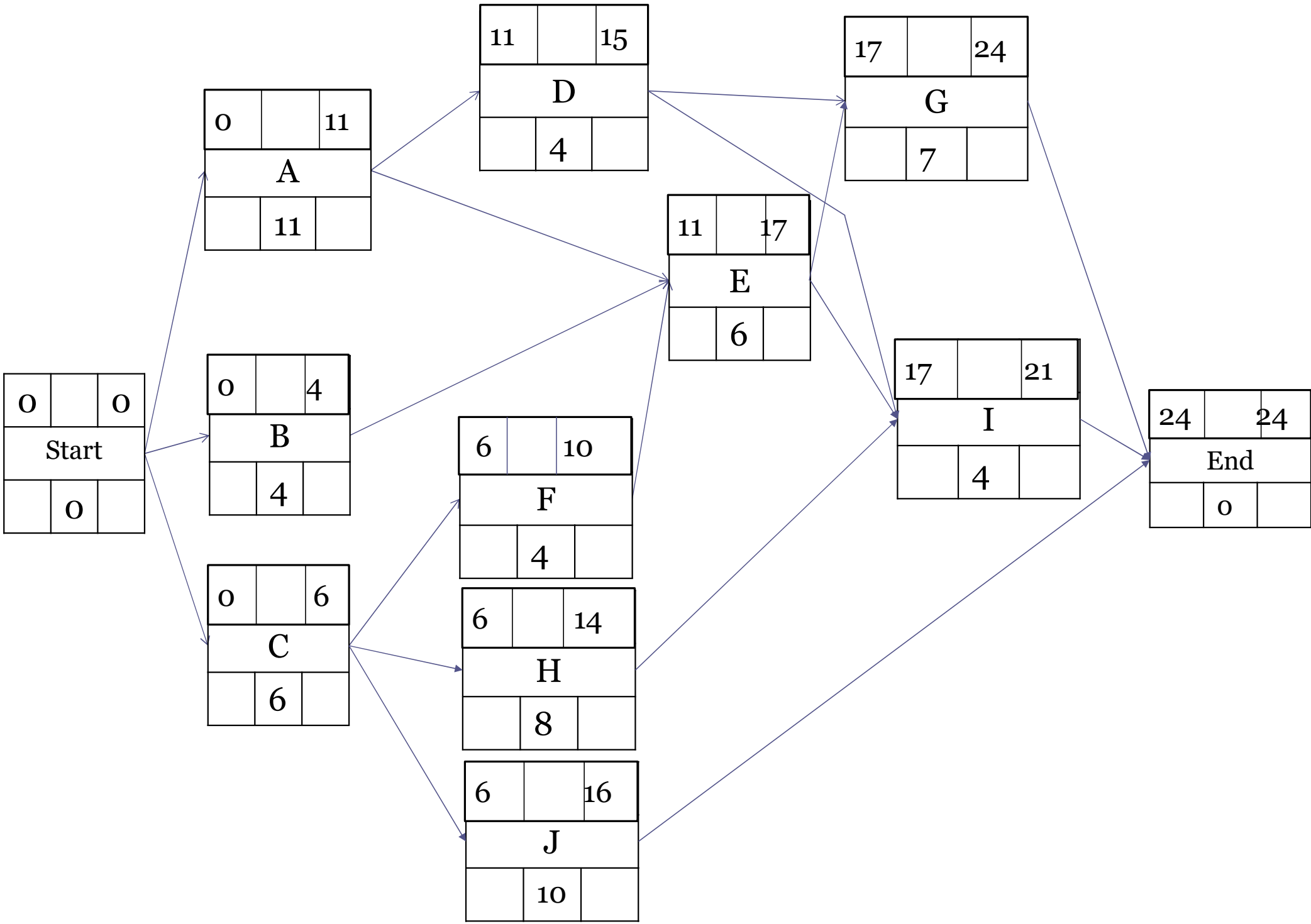
PROBLEM-4

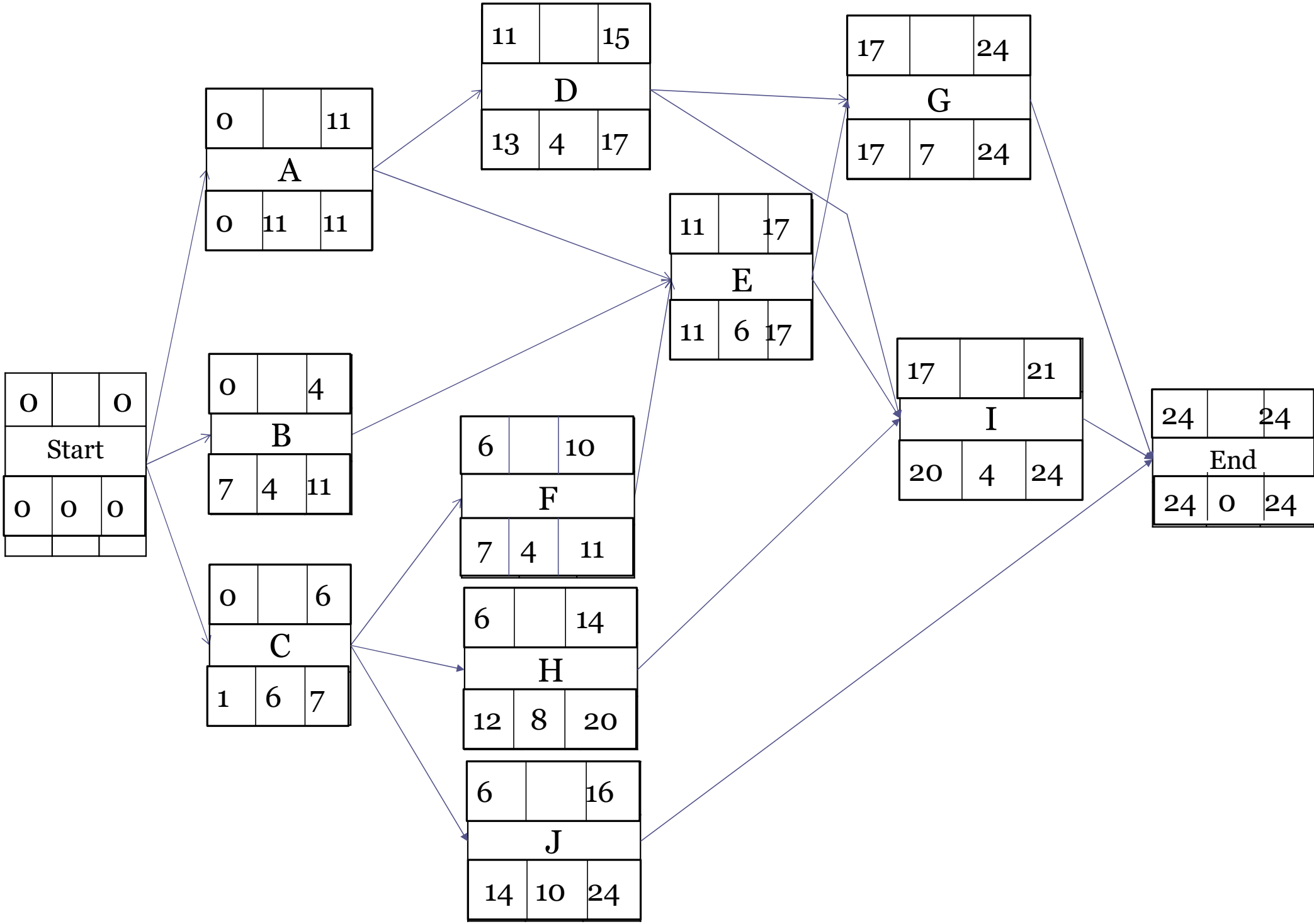
Please re-draw the A-o-A network given below as A-o-N network.
Find the critical path, normal duration, total floats.

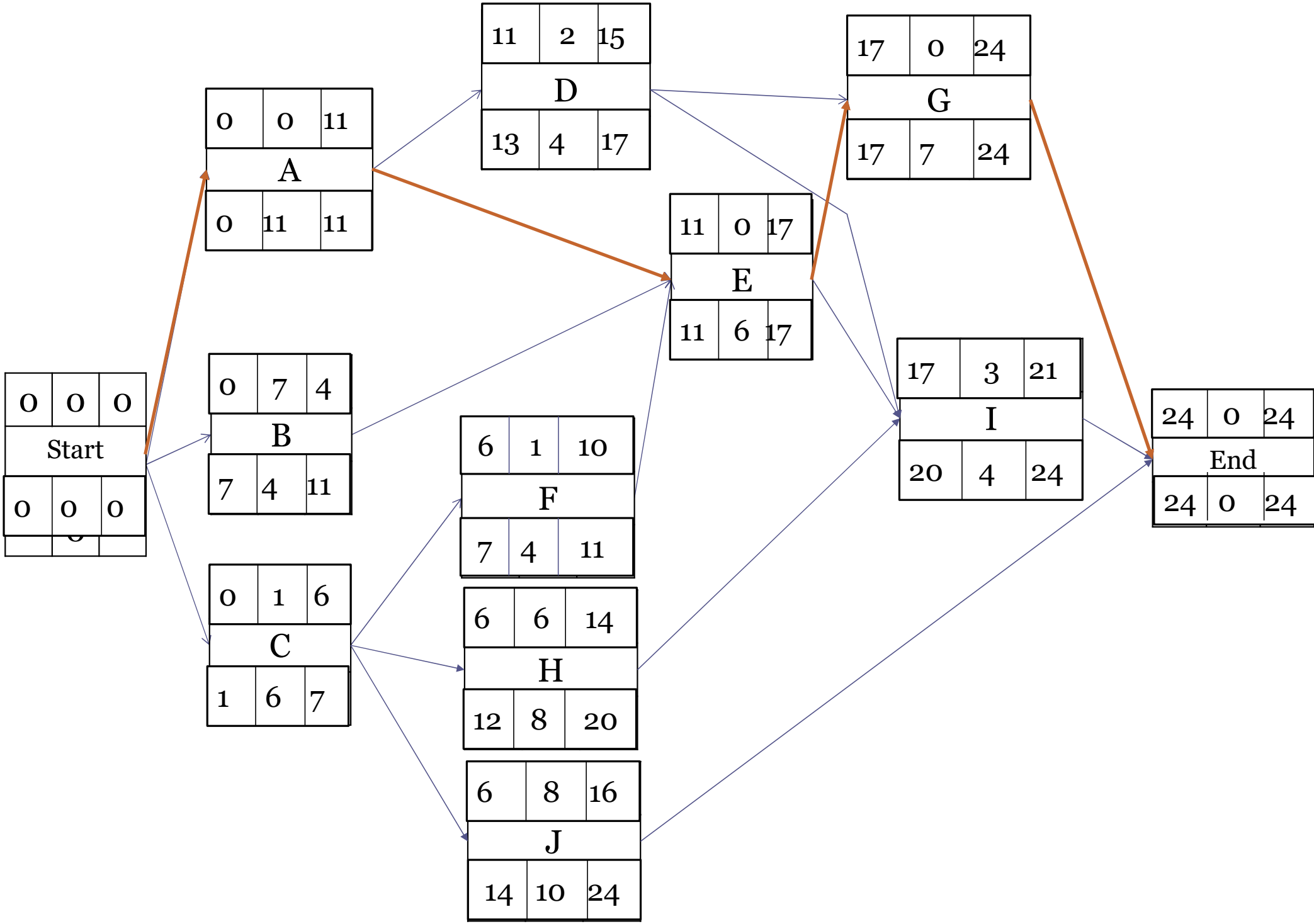



11 11
2
A
11
0/0
0/0
4
D
2/2
0 0
11 11
17 17
1
B
4
7/7
3
E
6
0/0
5
6
0/1
C
F
4
1/1
0/3
7
G
0/0
17 20
24 24
4
H
8
3/6
6
I
4
3/3
7
6 7
J
10
8/8


Start
A
B
C
D
E
F
H
J
G
I
End


0 0
Start
0
0 11
A
11
0 4
B
4
0 6
C
6
11 15
D
4
6 10
F
4
6 14
H
8
6 16
J
10
11 17
E
6
17 24
G
7
17 21
I
4
24 24
End
0


0 0
Start
0 0 0
0 11
A
0 11 11
11 15
D
13 4 17
17 24
G
17 7 24
11 17
E
11 6 17
0 4
B
7 4 11
6 10
F
7 4 11
0 6
C
1 6 7
6 14
H
12 8 20
6 16
J
14 10 24
17 21
I
20 4 24
24 24
End
24 0 24


0 0 0
Start
0 0 0
0 0 11
A
0 11 11
0 7 4
B
7 4 11
0 1 6
C
1 6 7
11 2 15
D
13 4 17
6 1 10
F
7 4 11
6 6 14
H
12 8 20
6 8 16
J
14 10 24
11 0 17
E
11 6 17
17 0 24
G
17 7 24
17 3 21
I
20 4 24
24 0 24
End
24 0 24