Time Planning and Control

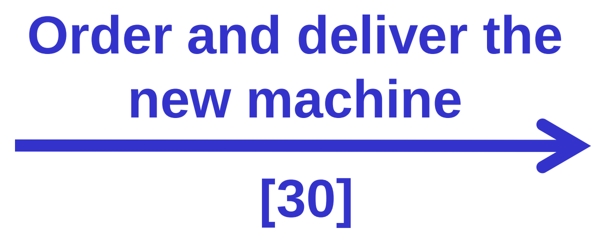
Activity on Arrow
(Arrow Diagramming Method)

Processes of Time Planning and Control

1. Visualize and define the **activities**.
2. Sequence the activities (**Job Logic**).
3. Estimate the **activity duration**.
4. **Schedule** the project or phase.
5. Allocate and balance **resources**.
6. Compare target, planned and actual dates and **update** as necessary.
7. **Control** the time schedule with respect to **changes**.

ARROW DIAGRAM

1) Each time-consuming activity (task) is portrayed by an **arrow**.



2) The tail and head of the arrow denote the start and finish of the activity whilst its duration is shown in brackets below.

3) The length of the arrow has no significance neither has its orientation.

ARROW DIAGRAM

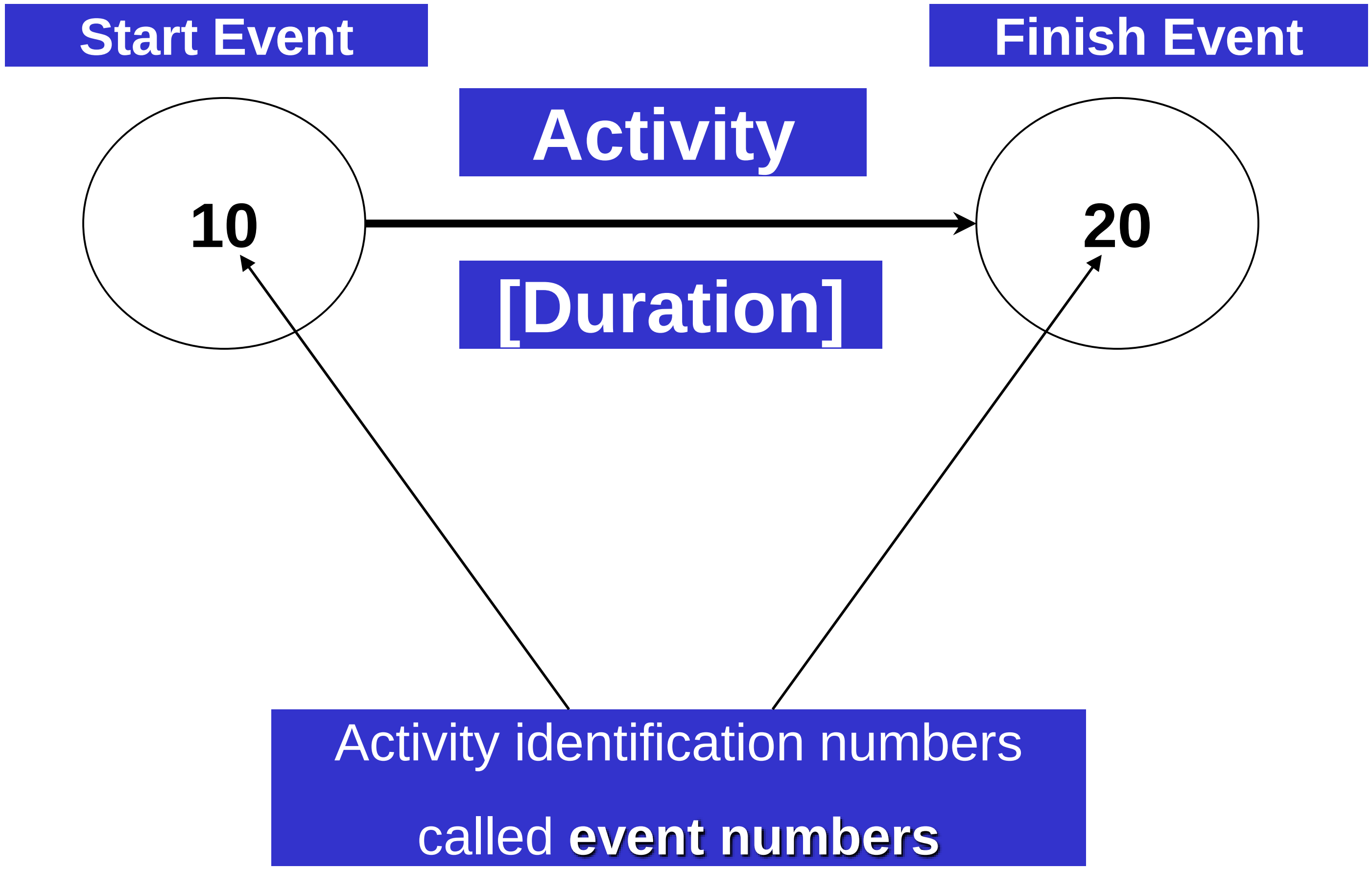
4) As means of further defining the point in time when an activity starts or finishes, start and finish events are added.

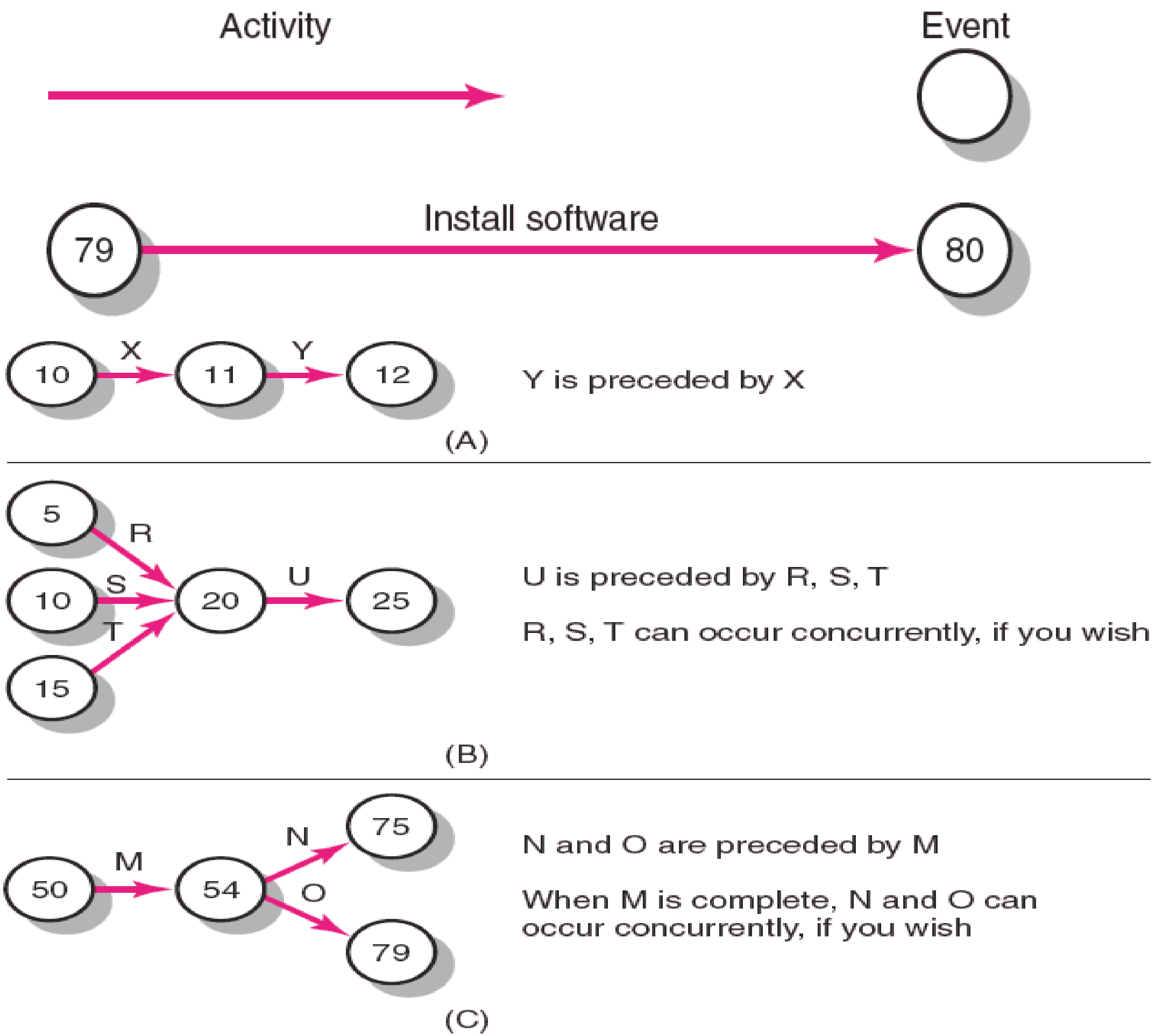
5) An **event** (= **node** = **connector**), unlike an activity, does not consume time or resources, it merely represents a **point in time** at which something or some things happen.

6) Numbers are given to the events to provide a unique identity to each activity.

7) The first event in a project schedule is the start of the project. The last event in a project schedule is the end of the project.

Activity Identification

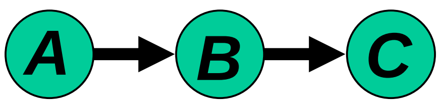



Activity
Event
Install software
79
80
10
X
11
Y
12
Y is preceded by X
(A)
5
R
10
S
T
15
20
U
25
U is preceded by R, S, T
R, S, T can occur concurrently, if you wish
(B)
50
M
54
N
O
75
79
N and O are preceded by M
When M is complete, N and O can occur concurrently, if you wish
(C)

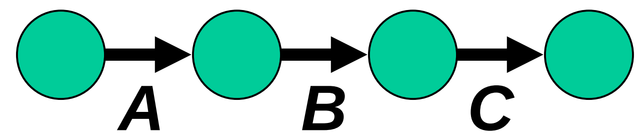
A Comparison of AON and AOA Network Conventions

Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)

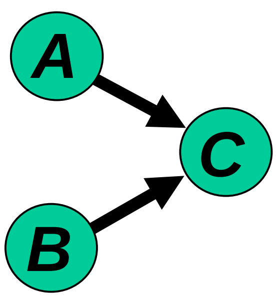
(a)



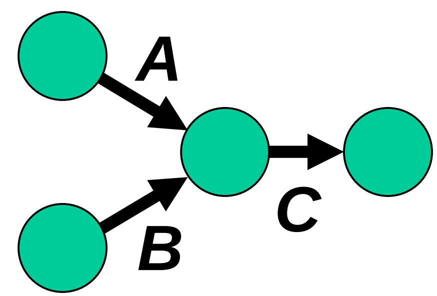
A comes before B, which comes before C



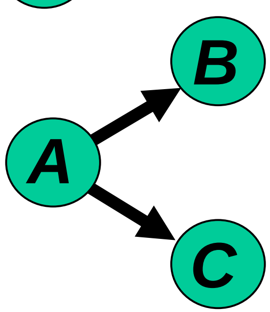
(b)



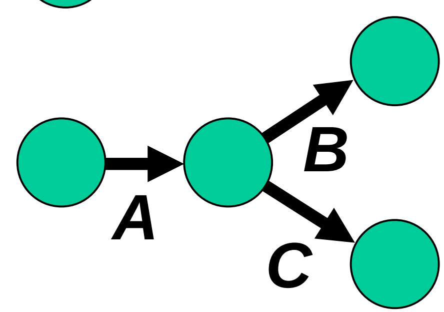
A and B must both be completed before C can start



(c)



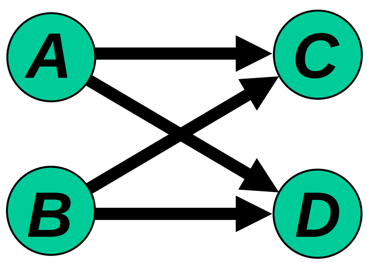
B and C cannot begin until A is completed



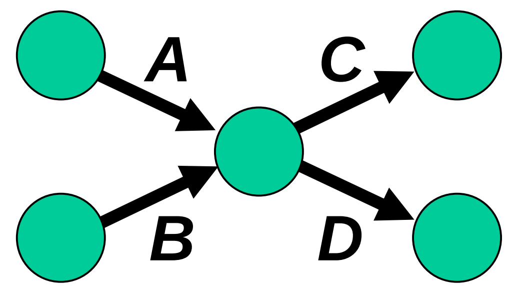
A Comparison of AON and AOA Network Conventions

	Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)

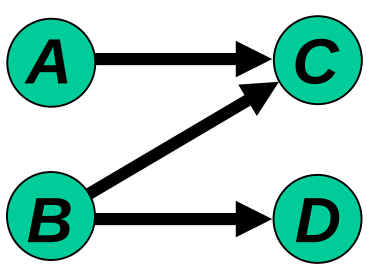
(d)



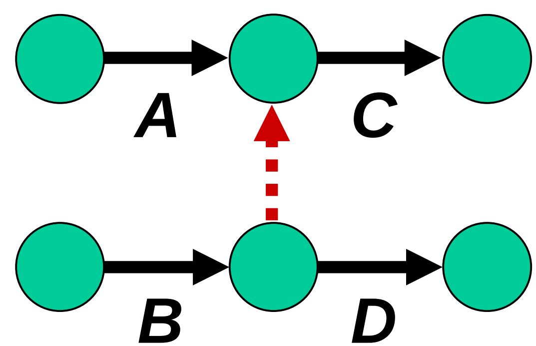
C and D cannot begin until A and B have both been completed



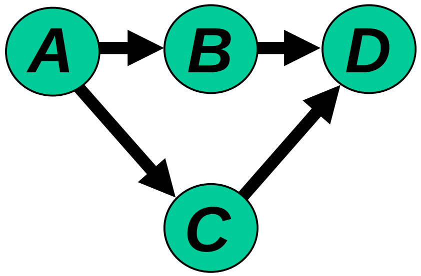
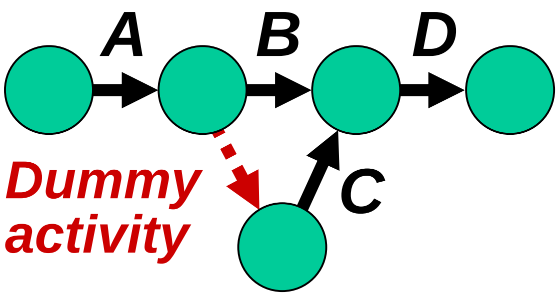
(e)



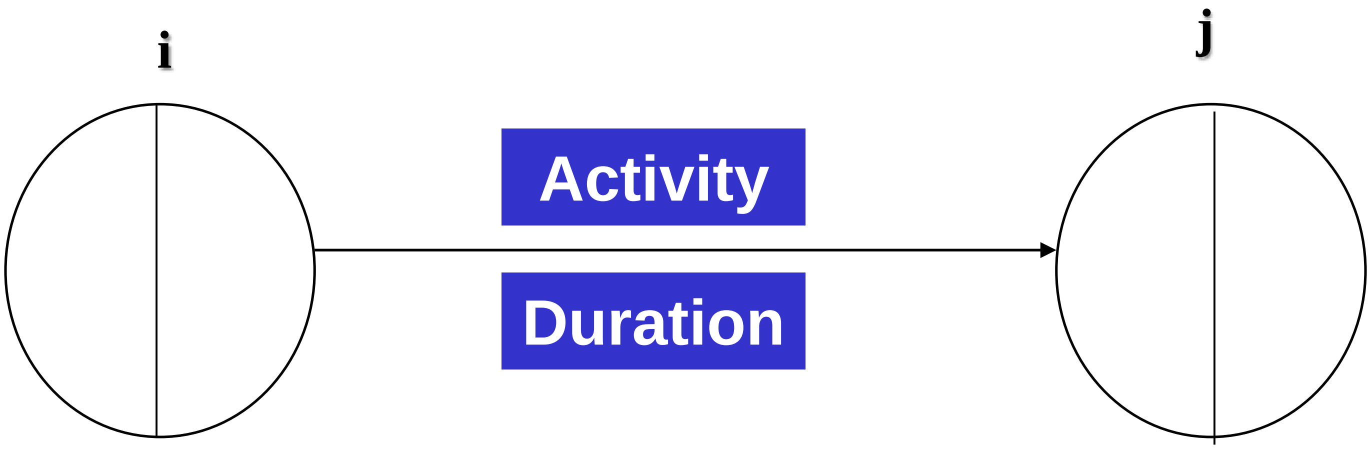
C cannot begin until both A and B are completed; D cannot begin until B is completed. A dummy activity is introduced in AOA



A Comparison of AON and AOA Network Conventions

Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)
(f) 	B and C cannot begin until A is completed. D cannot begin until both B and C are completed. A dummy activity is again introduced in AOA.	

i-j Numbers of Events



- The node at the tail of an arrow is the **i**-node.
- The node at the head of an arrow is the **j**-node

Rules of Making Arrow Diagram

1) The network (the graphical representation of a project plan) must have **definite points of beginning and finish**.

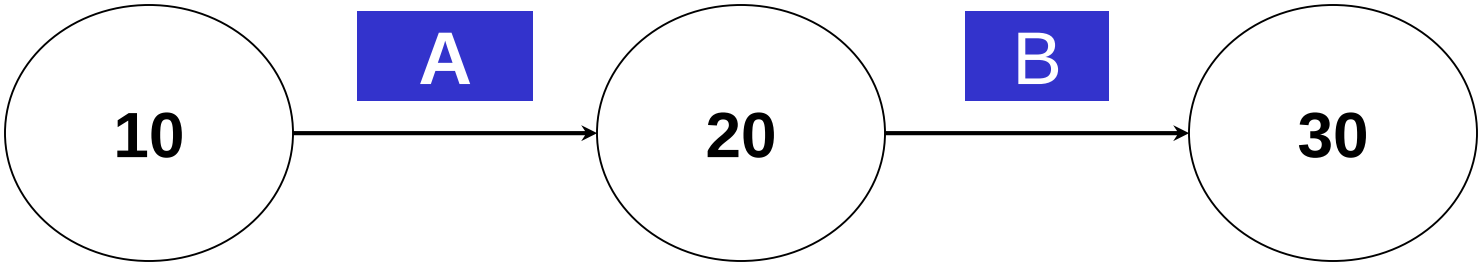
   (The accuracy and usefulness of a network is dependent mainly upon intimate knowledge of the project itself, and upon the general qualities of judgment and skill of the planning personnel.)

2) The arrows originate at the **right side** of a node and terminate at the **left side** of a node.

3) Any two events may be directly connected by **no** more than **one activity**.

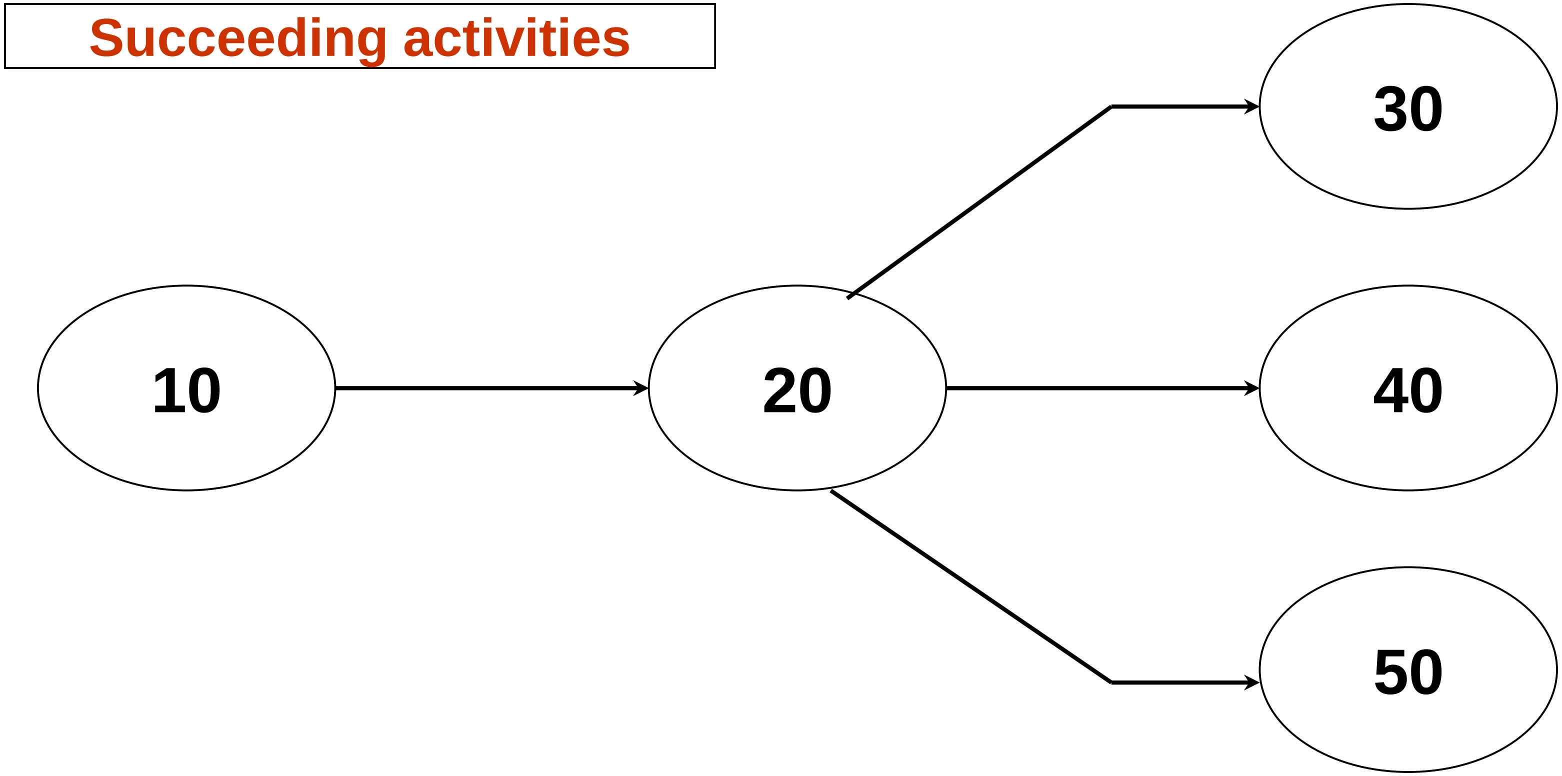
4) Use symbols to indicate crossovers to avoid misunderstanding.

Logical Relationships



- Node "20" is the j-node for activity "A" and it is also the i-node for activity "B" then activity "A" is a **predecessor** to activity "B".
- In other words activity "B" is a **successor** to activity "A".
- **Activity B depends on activity A.**

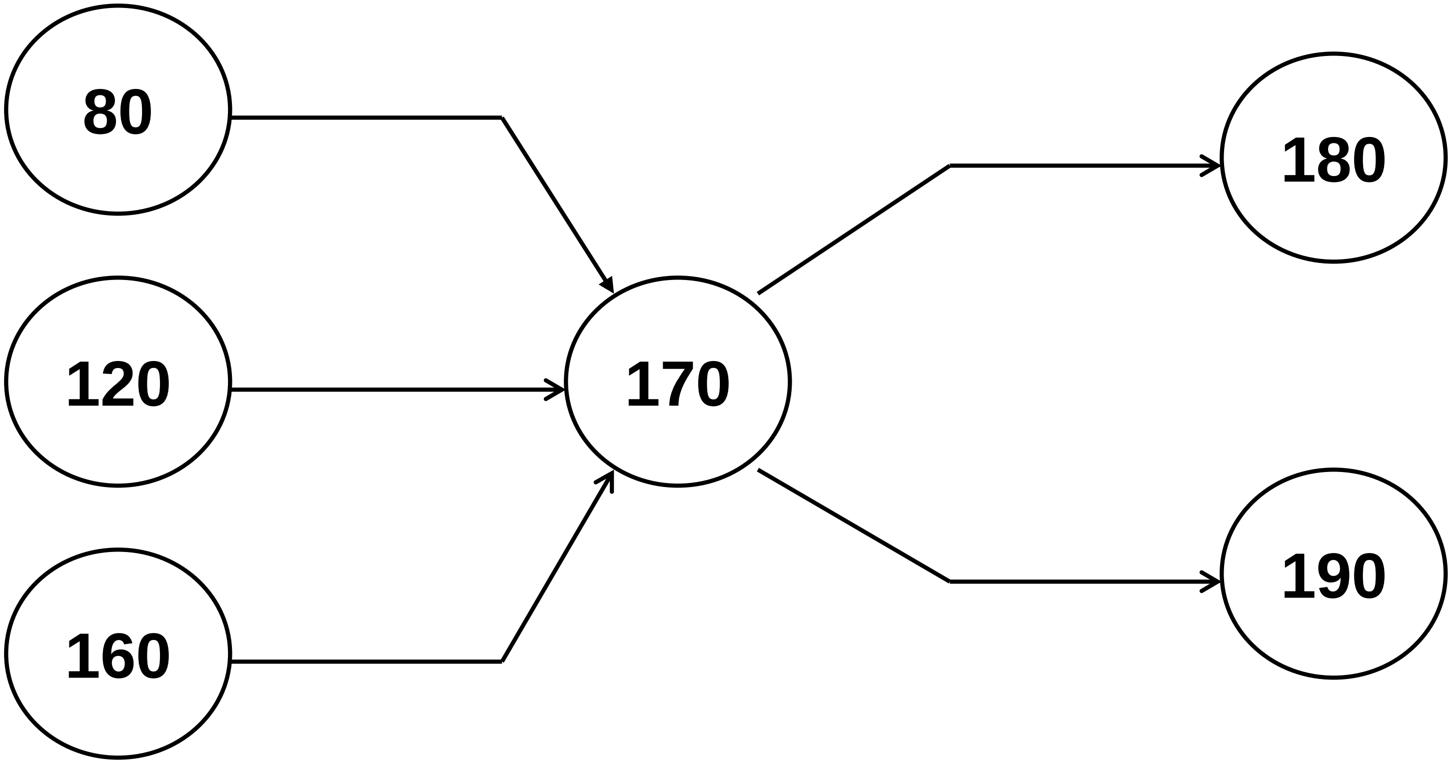
■ Logical Relationships



- Event numbers must not be duplicated in a network.
- j-node number greater than i-node number.

Logical Relationships

Concurrent activities



Rules of Making Arrow Diagram

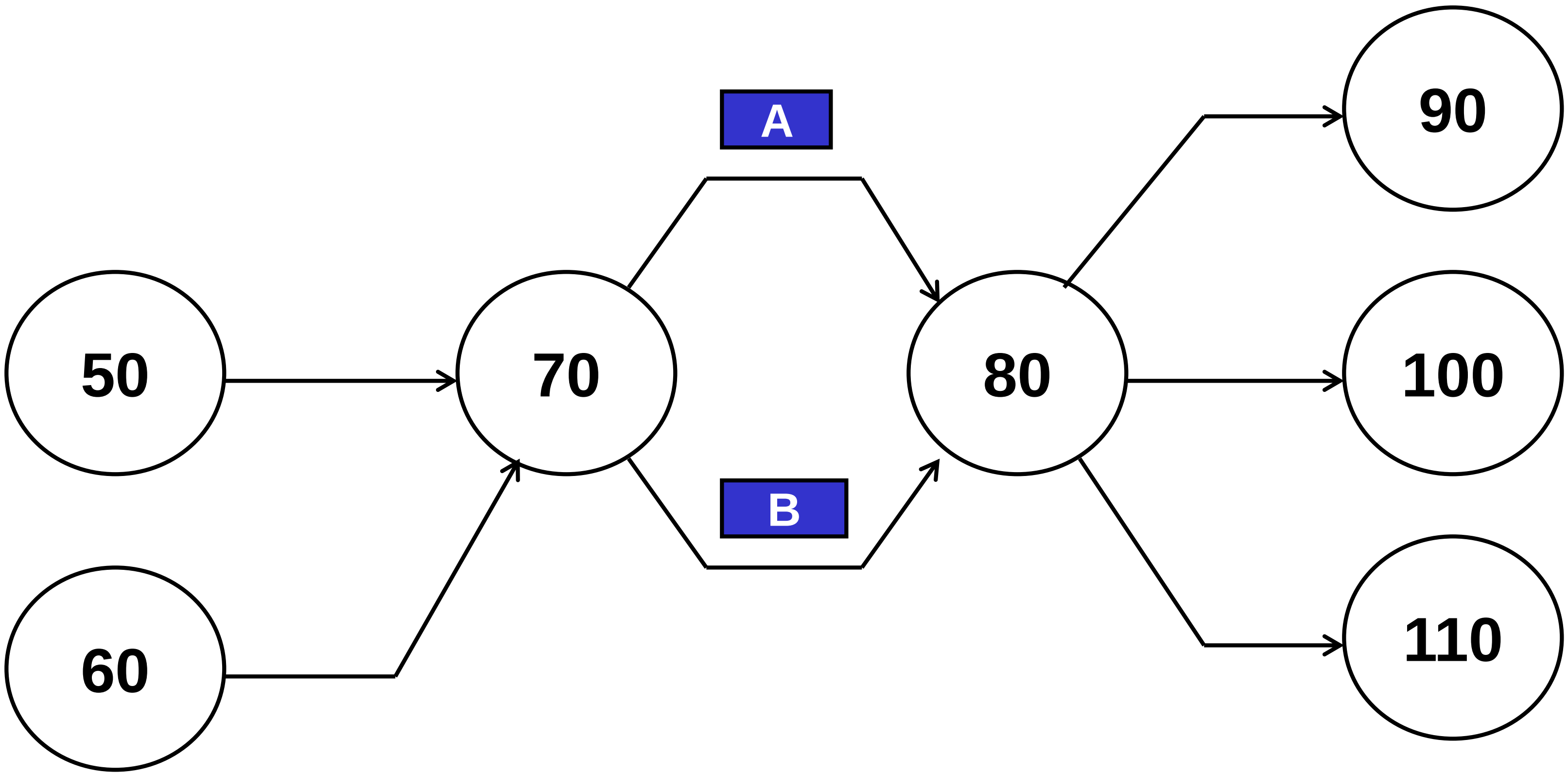
5) The network must be a logical representation of all the activities. Where necessary, "dummy activities" are used for:

- Unique numbering and
- Logical sequencing.

Dummy activity is an arrow that represents merely a dependency of one activity upon another. A dummy activity carries a ***zero*** time. It is also called **dependency arrow**.

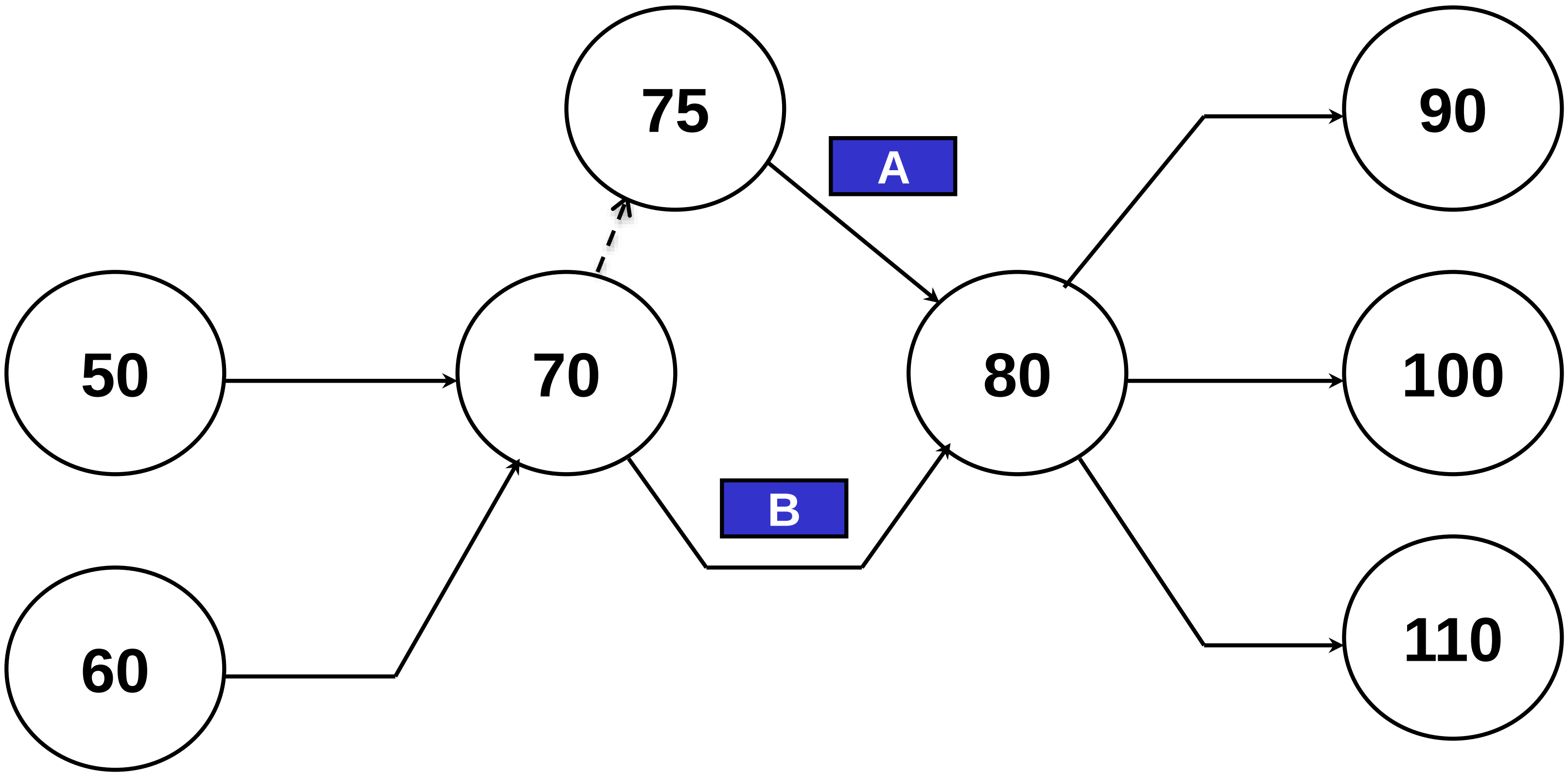
Dummy Activities

- The following network shows **incorrect activity numbering.**



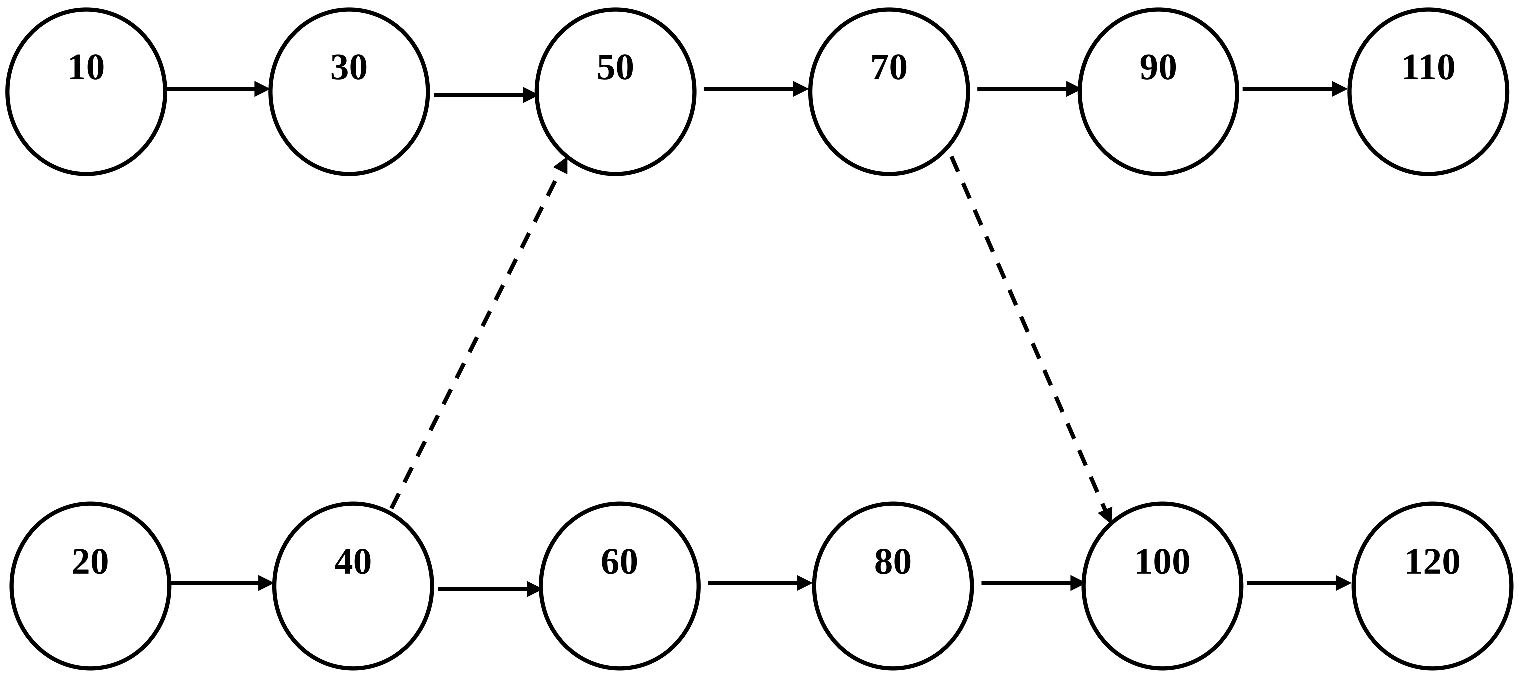
Dummy Activities

- For unique numbering, use dummies.



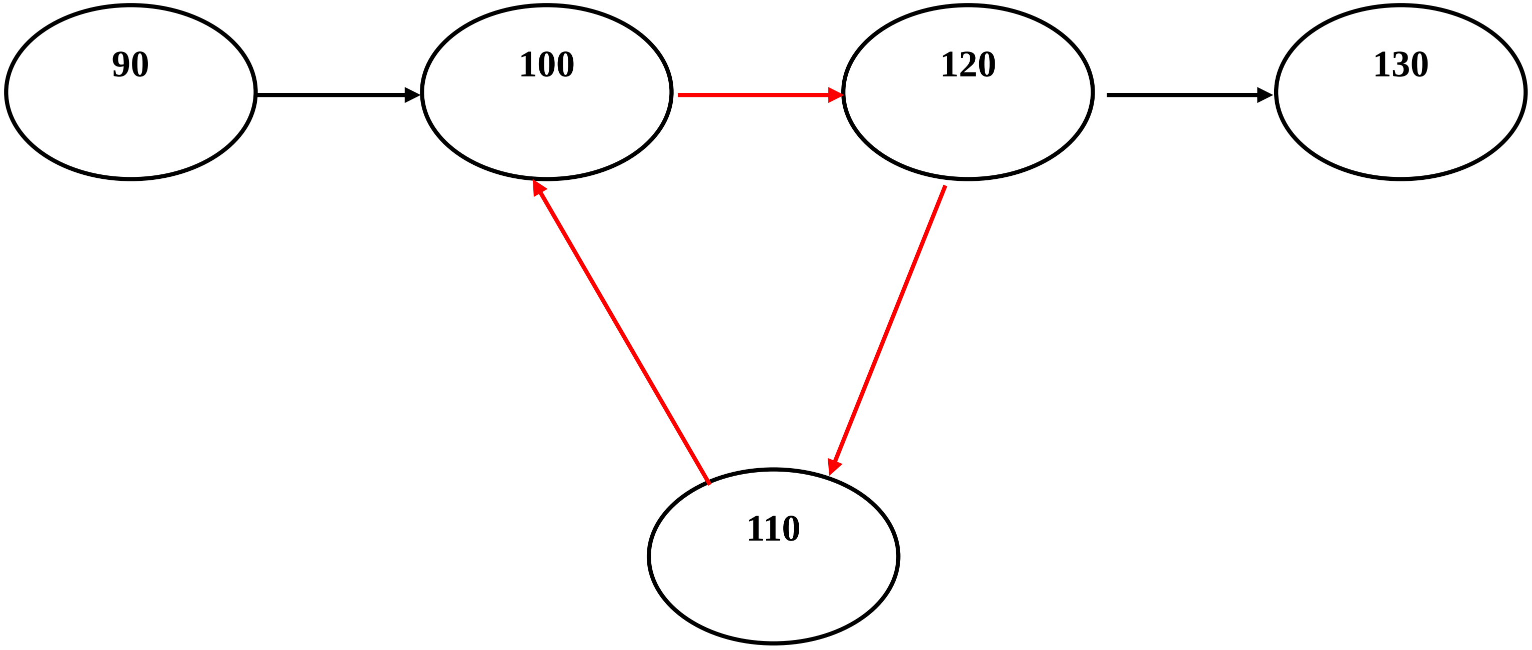
Dummy Activities

For representing logical relationships, you may need dummies.



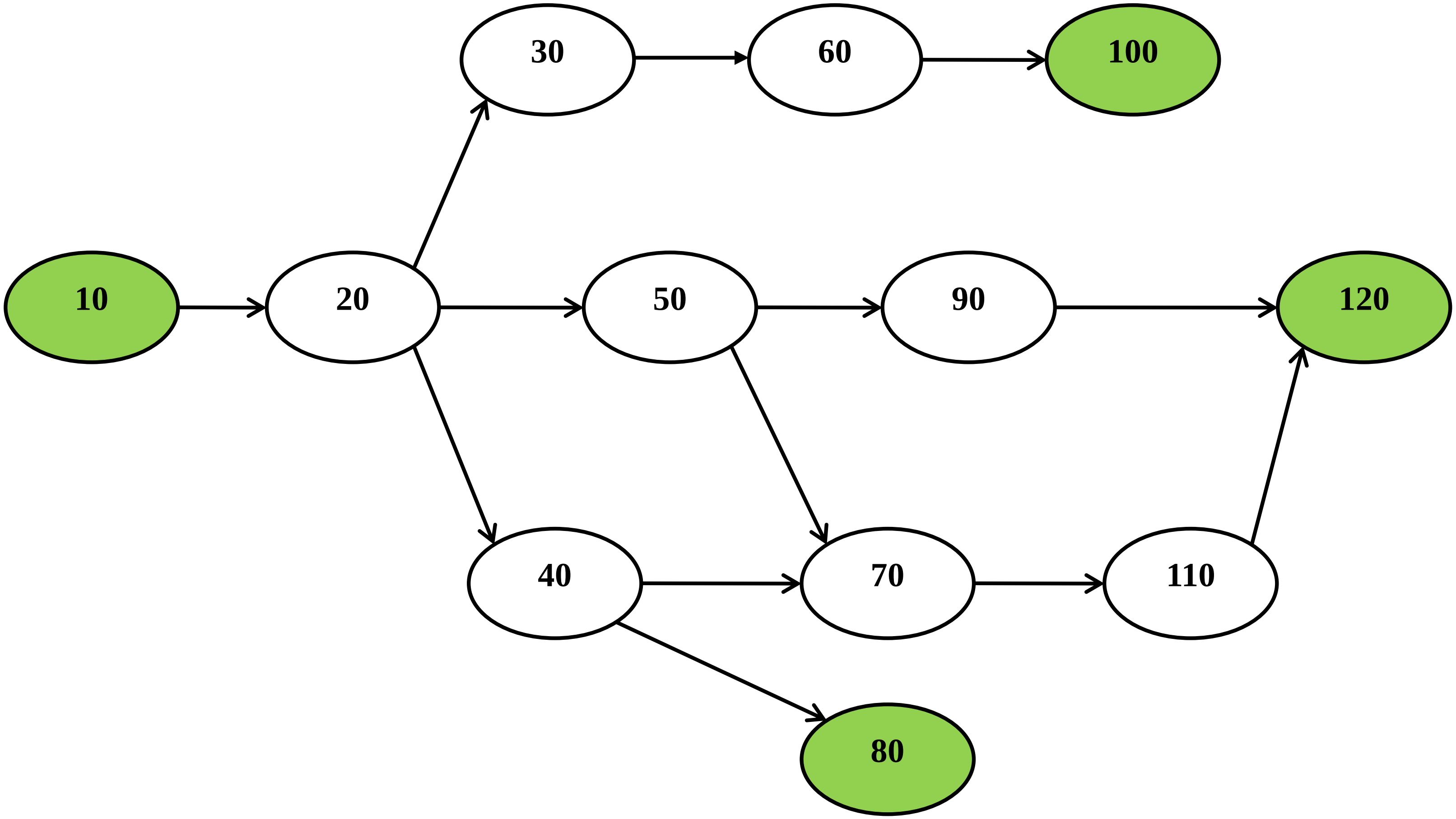
Rules of Making Arrow Diagram

There must be no "**looping**" in the network. The loop is an indication of **faulty logic**. The definition of one or more of the dependency relationships is not valid.



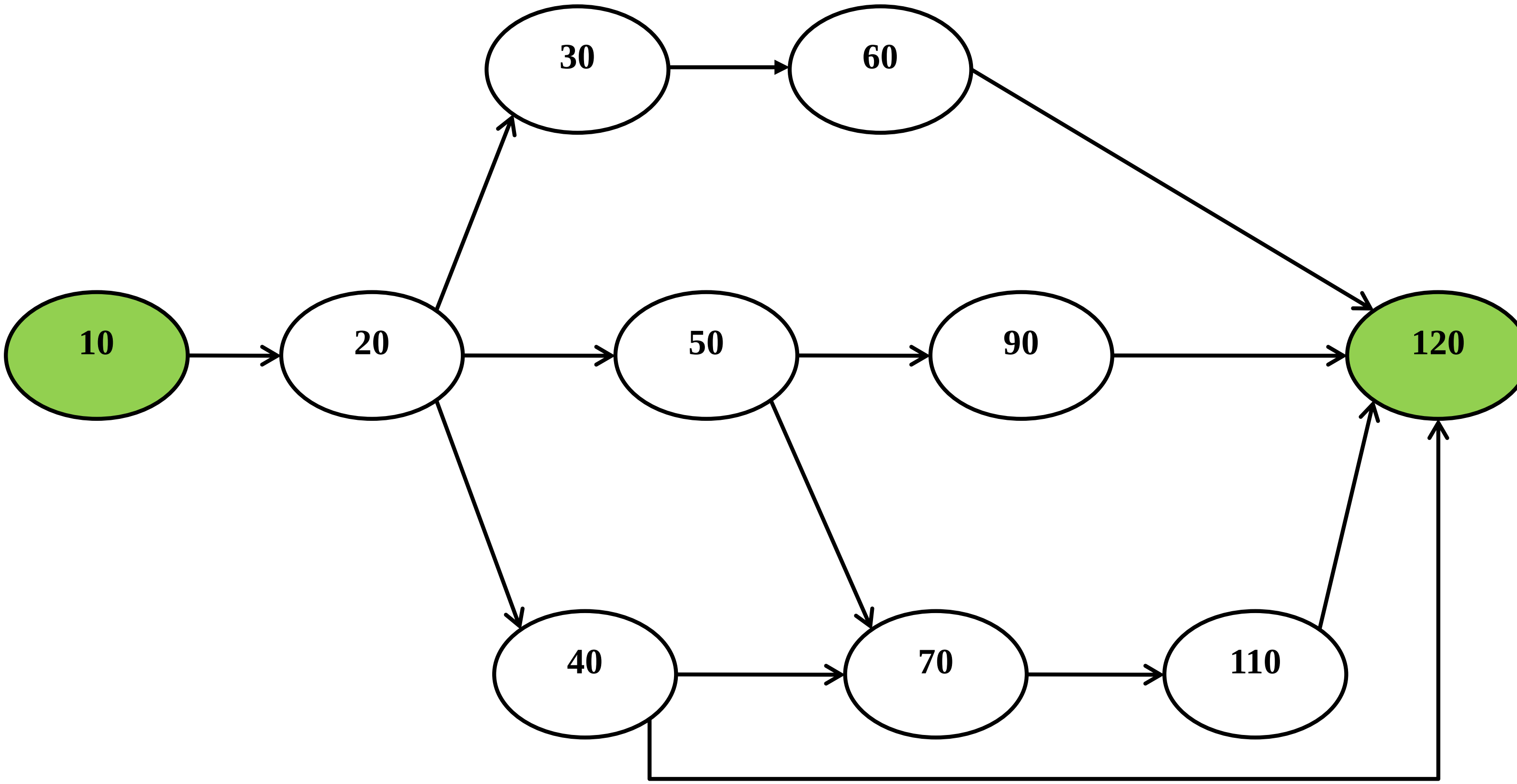
Rules of Making Arrow Diagram

The network must be continuous (without unconnected activities).



■ Rules of Making Arrow Diagram

Networks should have only one initial event and only one terminal event.

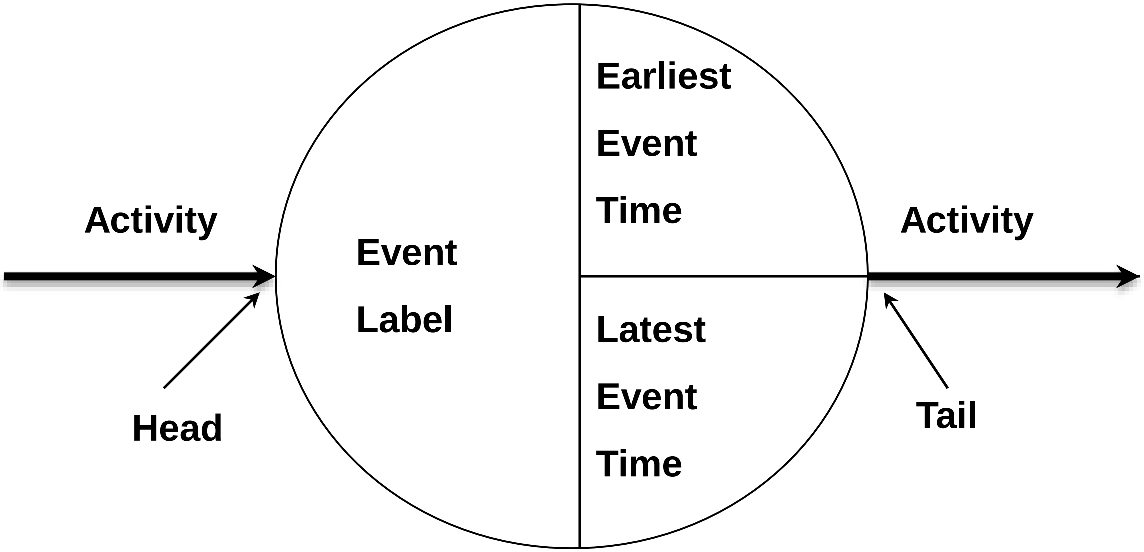


Rules of Making Arrow Diagram

6. Before an activity may begin, all activities preceding it must be completed (the logical relationship between activities is **finish to start**).

Network Analysis (Computation)

1. **Occurrence times of Events = Early and late timings of event occurrence = Early and late event times**



Standard layout for recording data

Early Event Time (EET = E = T_E)

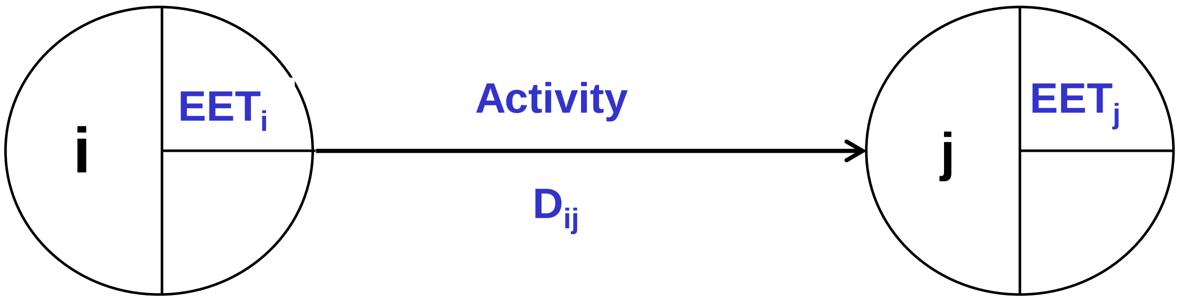
Early Event Time (Earliest occurrence time for event) is the earliest time at which an event can occur, considering the duration of precedent activities.

Forward Pass for Computing EET

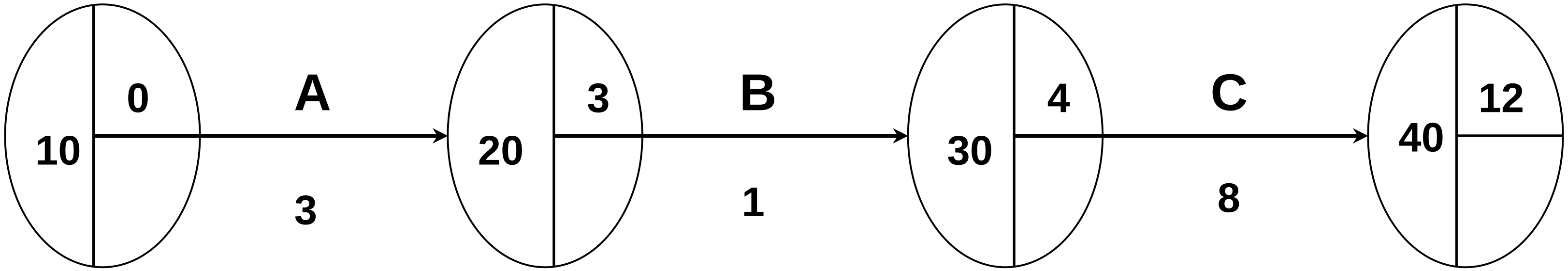
Each activity starts as soon as possible, i.e., as soon as all of its predecessor activities are completed.

1. **Direction: Left to right, from the beginning to the end of the project**
2. **Set: EET of the initial node = 0**
3. **Add: $EET_j = EET_i + D_{ij}$**
4. **Take the maximum**

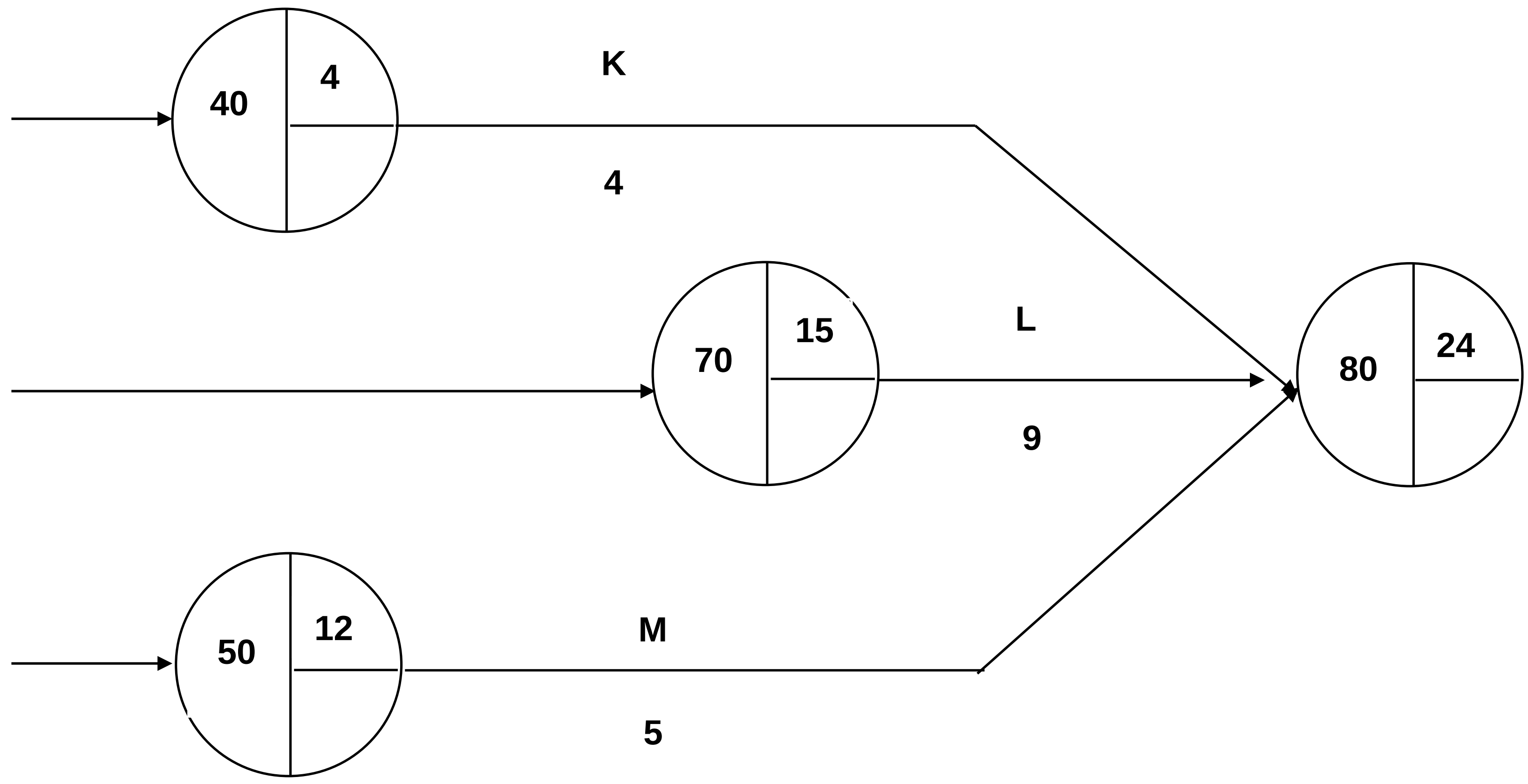
The estimated project duration = EET of the last node.



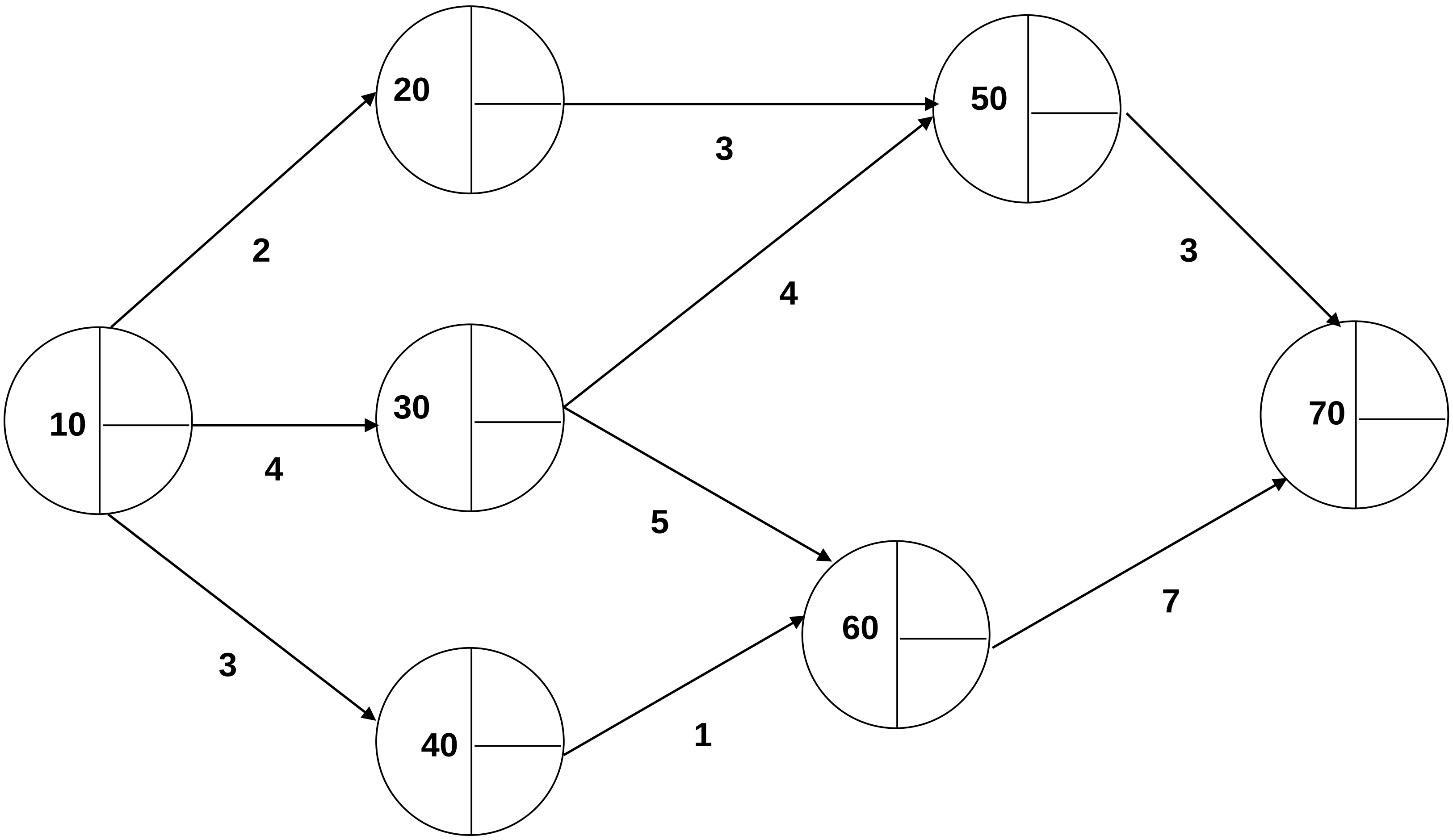
■ Early Event Times (EET = E = T_E)



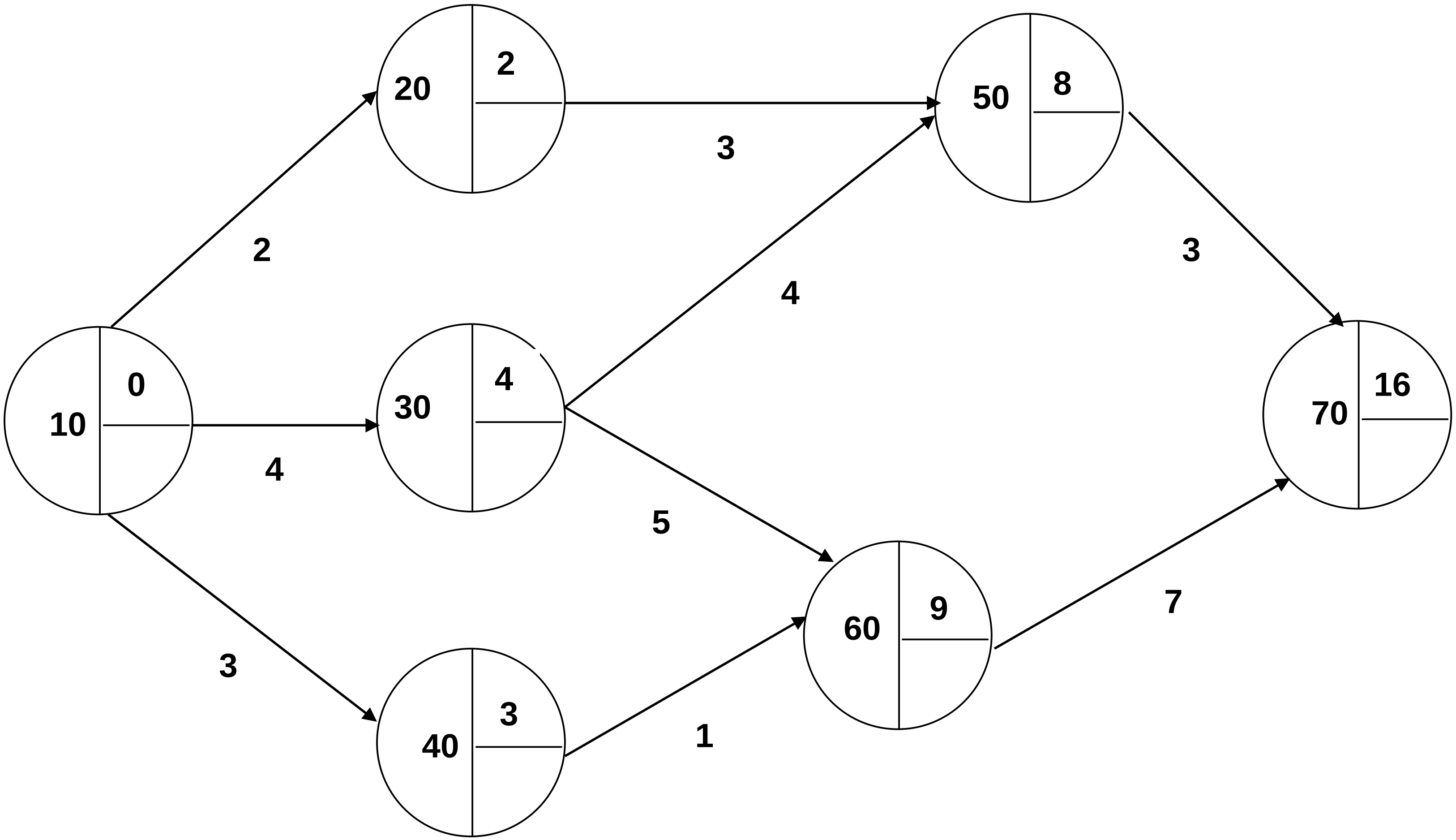
Early Event Times (T_E)



Early Event Times (T_E)



■ Early Event Times (T_E)

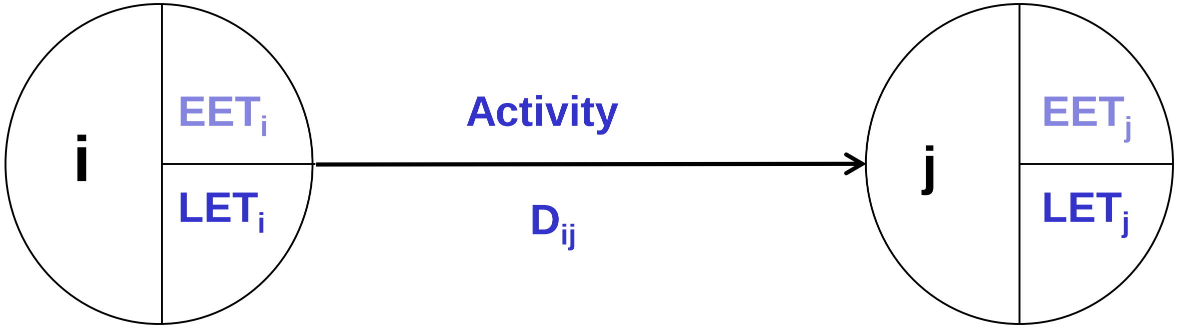


Late Event Time ($LET = L = T_L$)

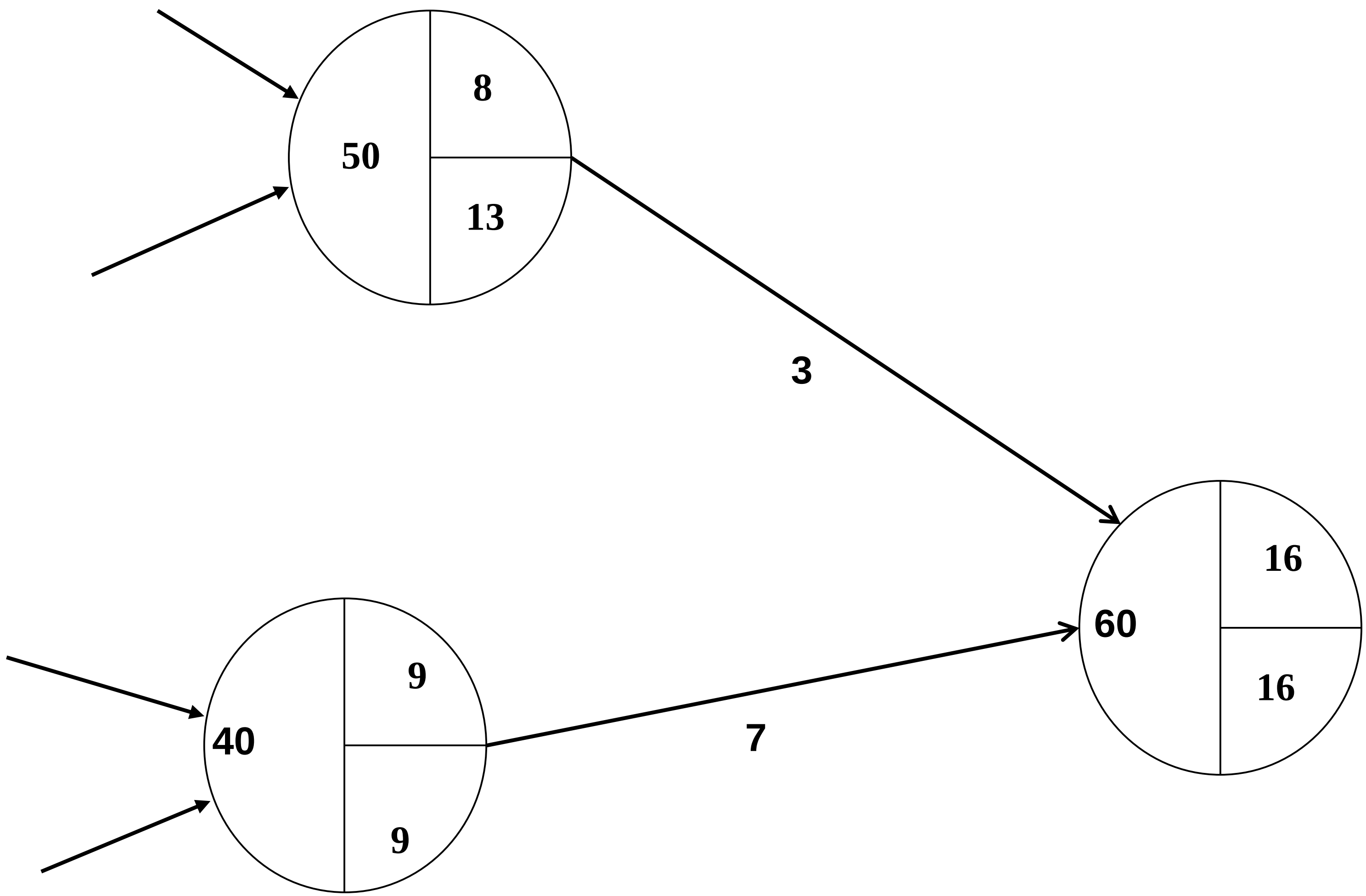
Late Event Time (Latest occurrence time of event) is the latest time at which an event can occur, if the project is to be completed on schedule.

Backward Pass for Computing LET

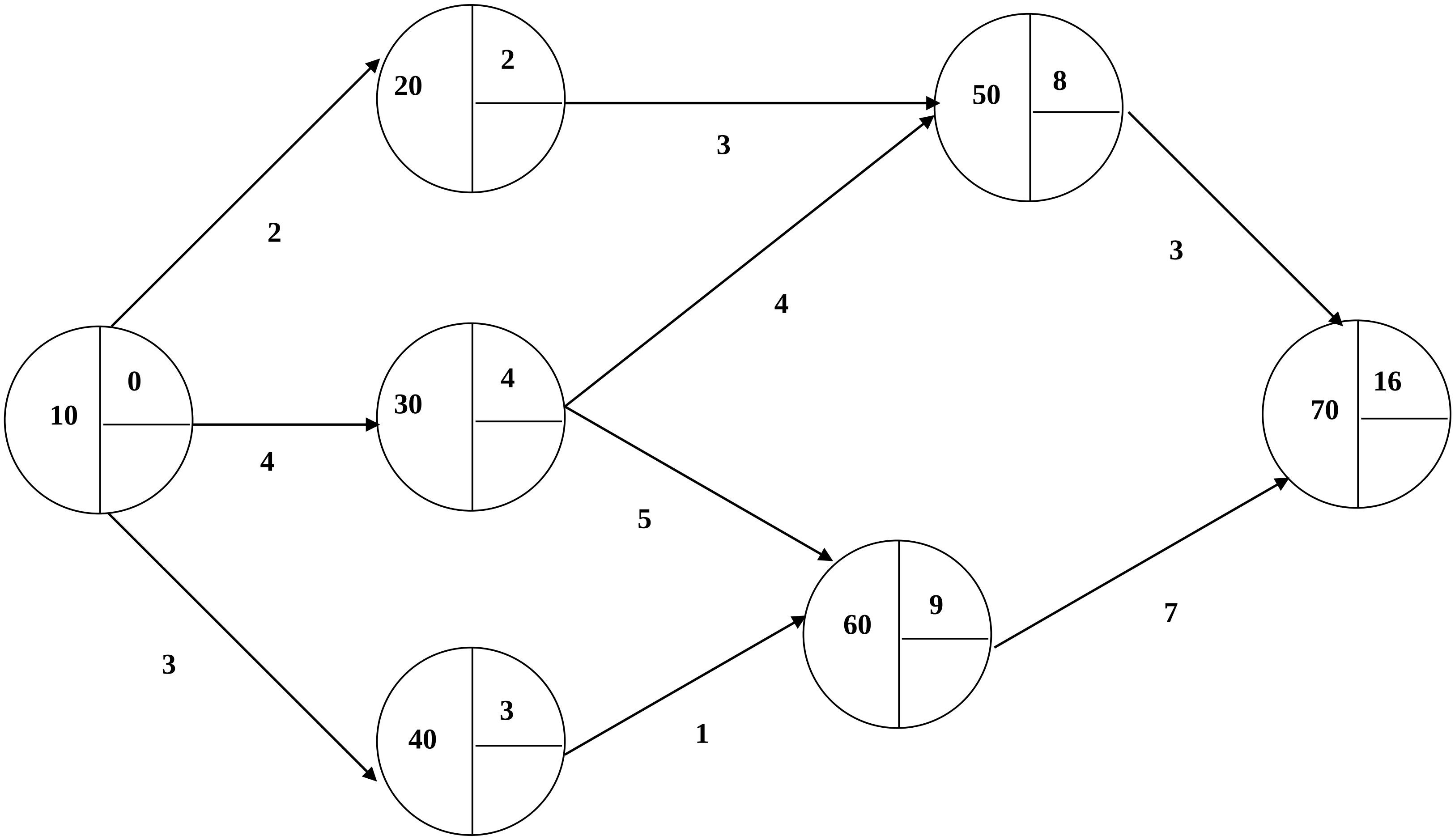
1. Direction: Right to left, from the end to the beginning of the project
2. Set: LET of the last (terminal) node = EET for it
3. Subtract: $LET_i = LET_j - D_{ij}$
4. Take the minimum



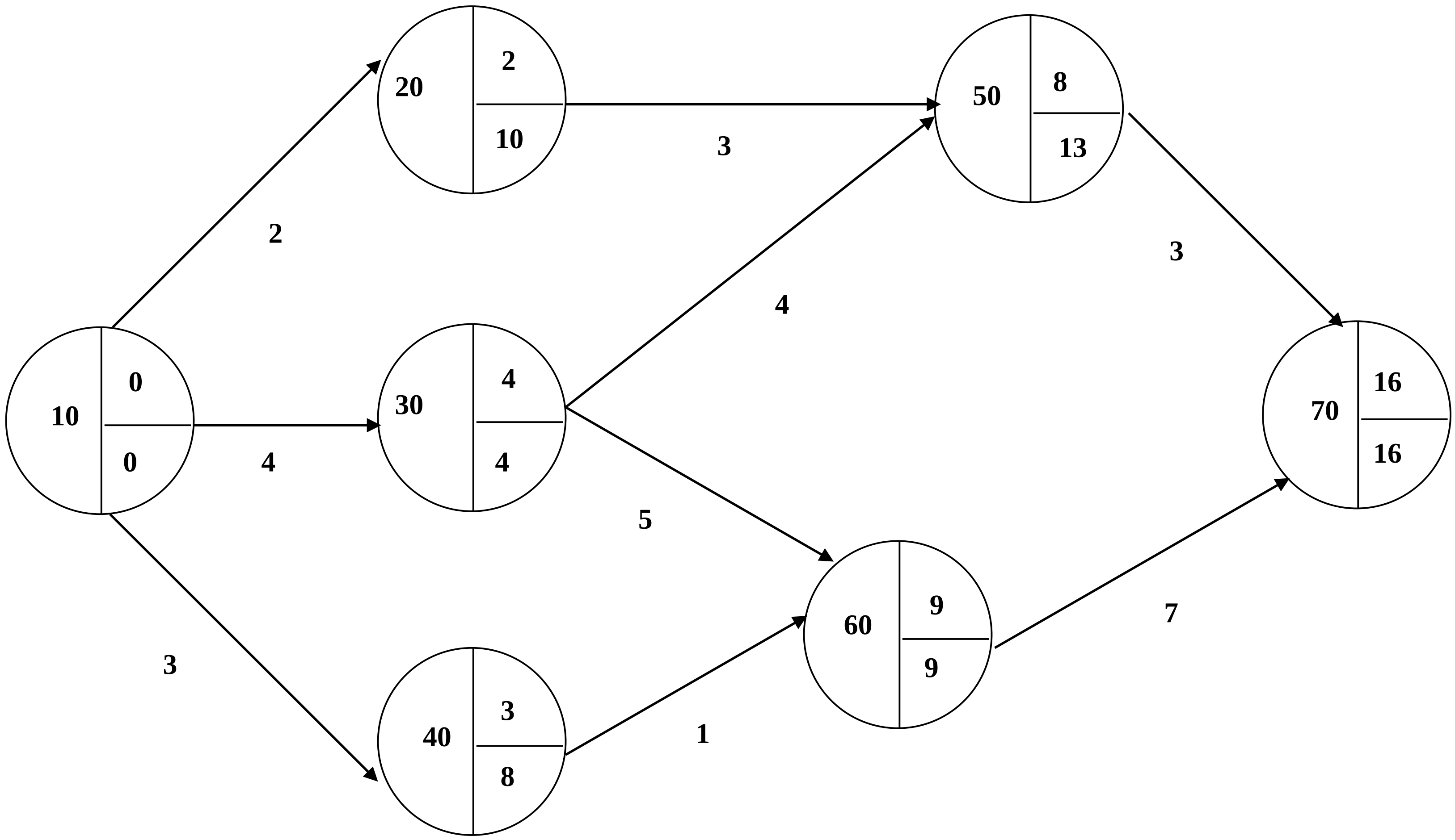
Late Event Times (T_L)



Late Event Times (T_L)



Late Event Times (T_L)



Network Analysis (Computation)

2. Activity Times (Schedule)

1. **Early Start (ES)**: The earliest time at which an activity can be started.

$$ES_{ij} = EET_i$$

2. **Early Finish (EF)**: The earliest time at which an activity can be completed.

$$EF_{ij} = ES_{ij} + D_{ij}$$

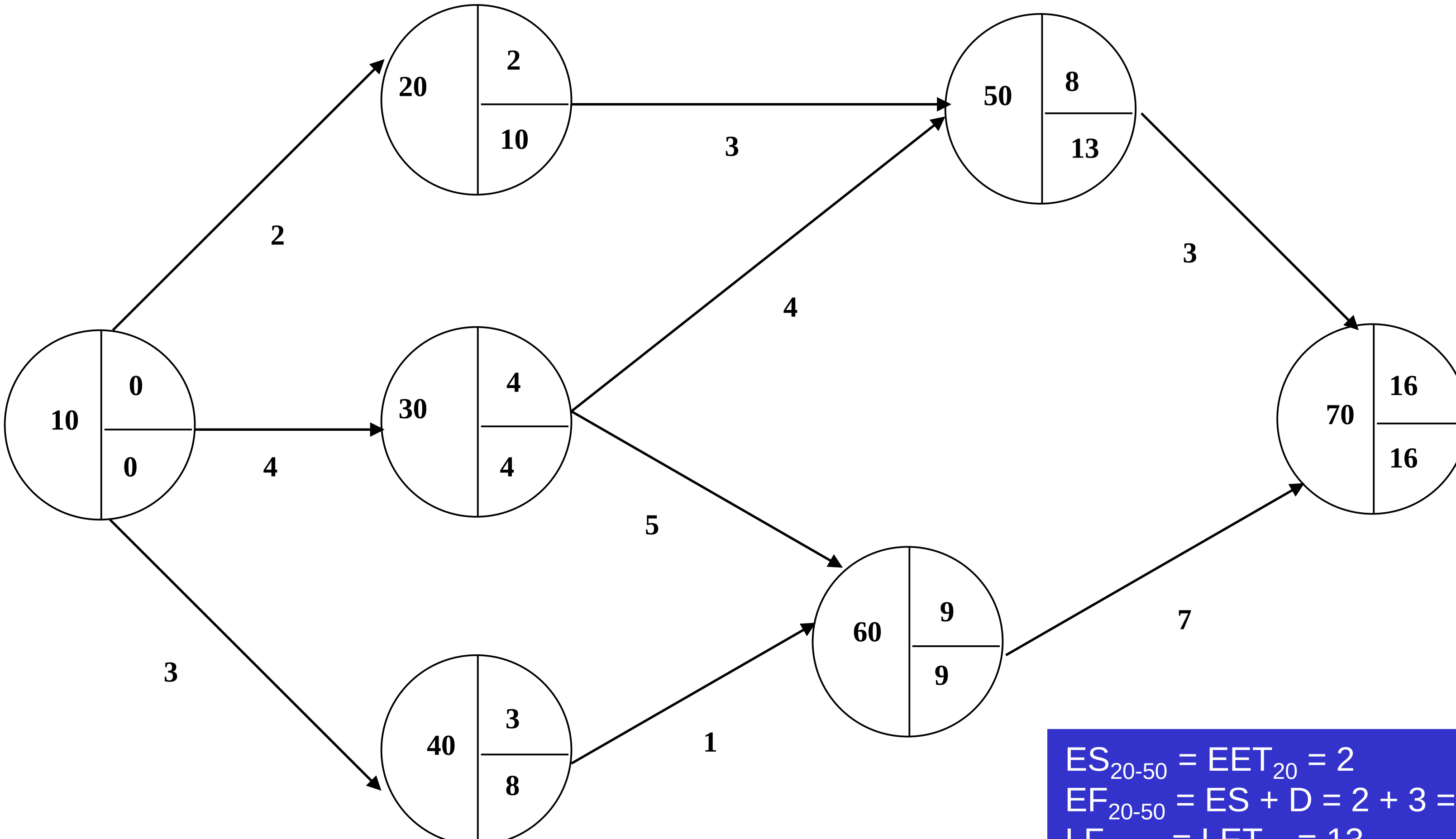
3. **Late Finish (LF)**: The latest time at which an activity can be completed without delaying project completion.

$$LF_{ij} = LET_j$$

4. **Late Start (LS)**: The latest time at which an activity can be started.

$$LS_{ij} = LF_{ij} - D_{ij}$$

■ Example: Activity Times



$ES_{20\text{-}50} = EET_{20} = 2$
$EF_{20\text{-}50} = ES + D = 2 + 3 = 5$
$LF_{20\text{-}50} = LET_{50} = 13$
$LS_{20\text{-}50} = LF – D = 13 – 3 = 10$

■ Network Analysis (Computation)

3. Activity Floats

1. Total Float (TF)

- **Total float or path float** is the amount of time that an activity's completion may be delayed ***without extending project completion time***.

- **Total floa**t or path float is the amount of time that an activity's completion may be delayed ***without affecting the earliest start of any activity on the network critical path.***

Network Analysis (Computation)

3. Activity Floats

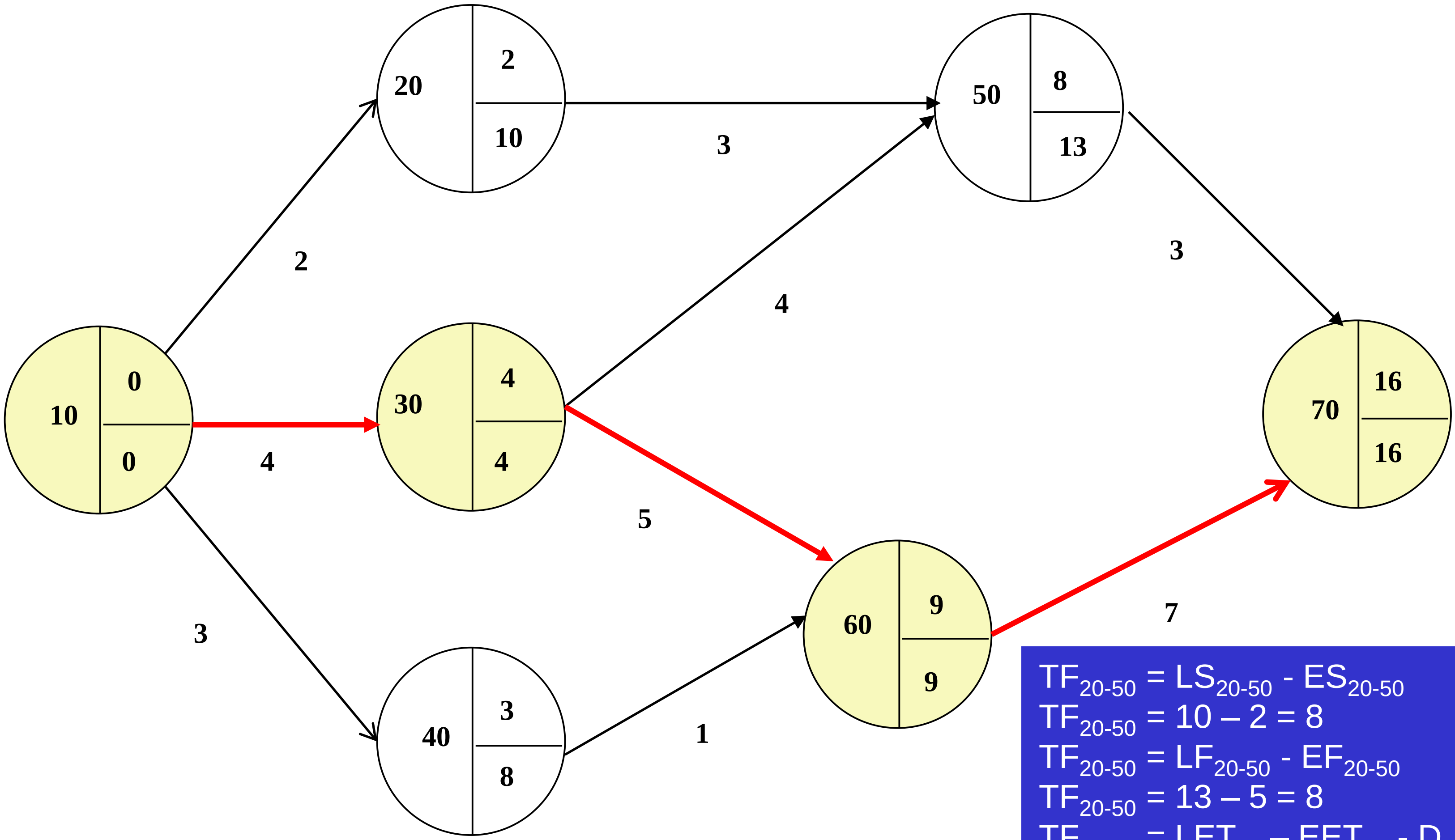
1. Total Float (TF)

- Total path float time for activity (i-j) is the total float associated with a path.
- For arbitrary activity (i–j), the total float can be written as:

Path Float =Total Float (TF_{ij})

$$= LS_{ij} - ES_{ij}$$
$$= LF_{ij} - EF_{ij}$$
$$= LET_j - EET_i - D_{ij}$$

Example: Total Float Times



$TF_{20\text{-}50} = LS_{20\text{-}50} - ES_{20\text{-}50}$

$TF_{20\text{-}50} = 10 - 2 = 8$

$TF_{20\text{-}50} = LF_{20\text{-}50} - EF_{20\text{-}50}$

$TF_{20\text{-}50} = 13 - 5 = 8$

$TF_{20\text{-}50} = LET_{50} - EET_{20} - D_{20\text{-}50}$

$TF_{20\text{-}50} = 13 - 2 - 3 = 8$

Network Analysis (Computation)

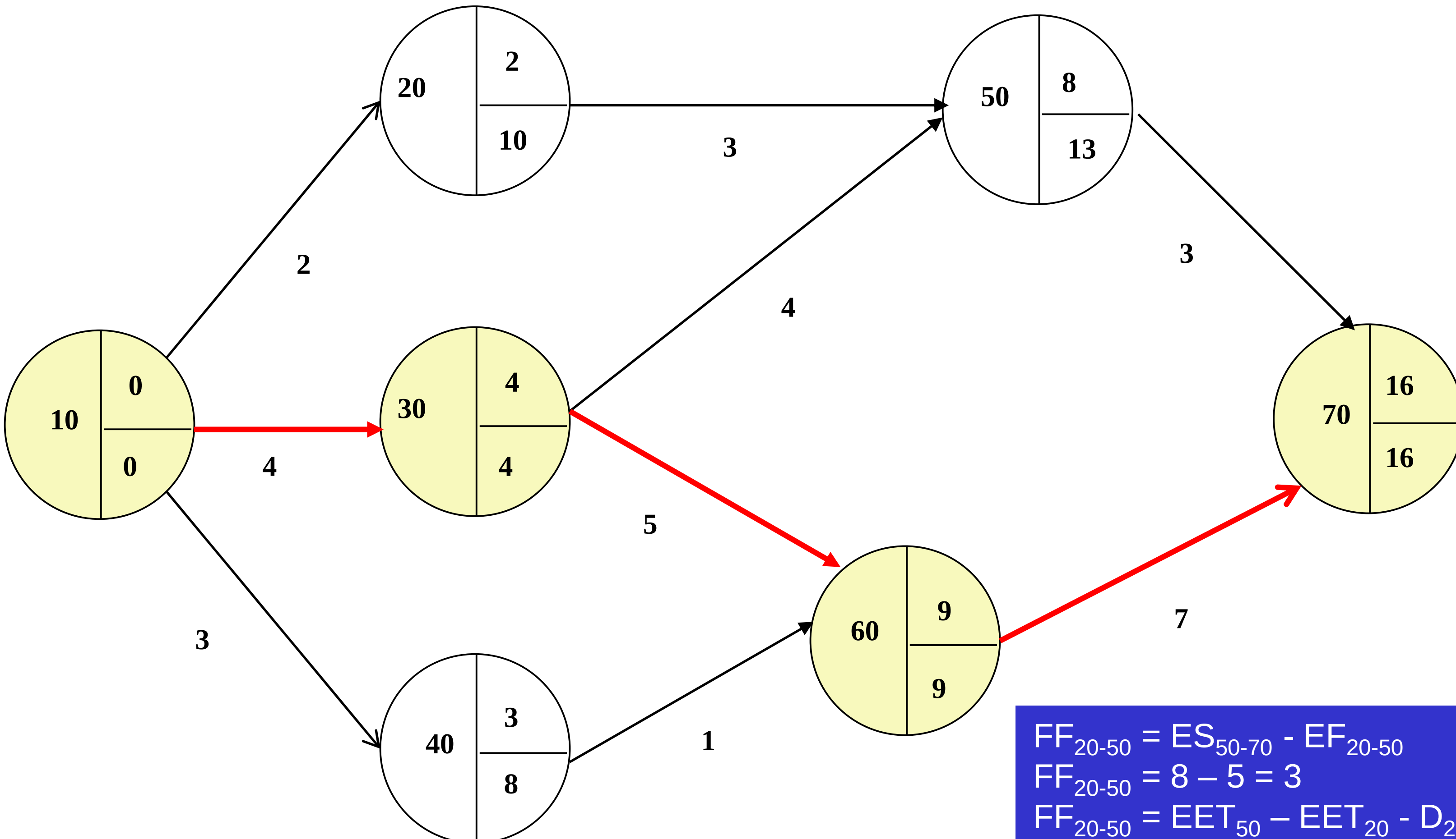
3. Activity Floats

2. Free Float (FF)

- Free float or activity float is the amount of time that an activity's completion time may be delayed ***without affecting the earliest start of succeeding activity***.
- Activity float is "owned" by an individual activity, whereas path or total float is shared by all activities along a slack path.
- ***Total float equals or exceeds free float (TF ≥ FF)***.
- For arbitrary activity (i–j), the free float can be written as:

$$\text{Activity Float} = \text{Free Float } (FF_{ij})$$
$$= ES_{jk} - EF_{ij}$$
$$= EET_j - EET_i - D_{ij}$$

Example: Free Float Times



$FF_{20\text{-}50} = ES_{50\text{-}70} - EF_{20\text{-}50}$
$FF_{20\text{-}50} = 8 – 5 = 3$
$FF_{20\text{-}50} = EET_{50} – EET_{20} - D_{20\text{-}50}$
$FF_{20\text{-}50} = 8 – 2 - 3 = 3$

■ Network Analysis (Computation)

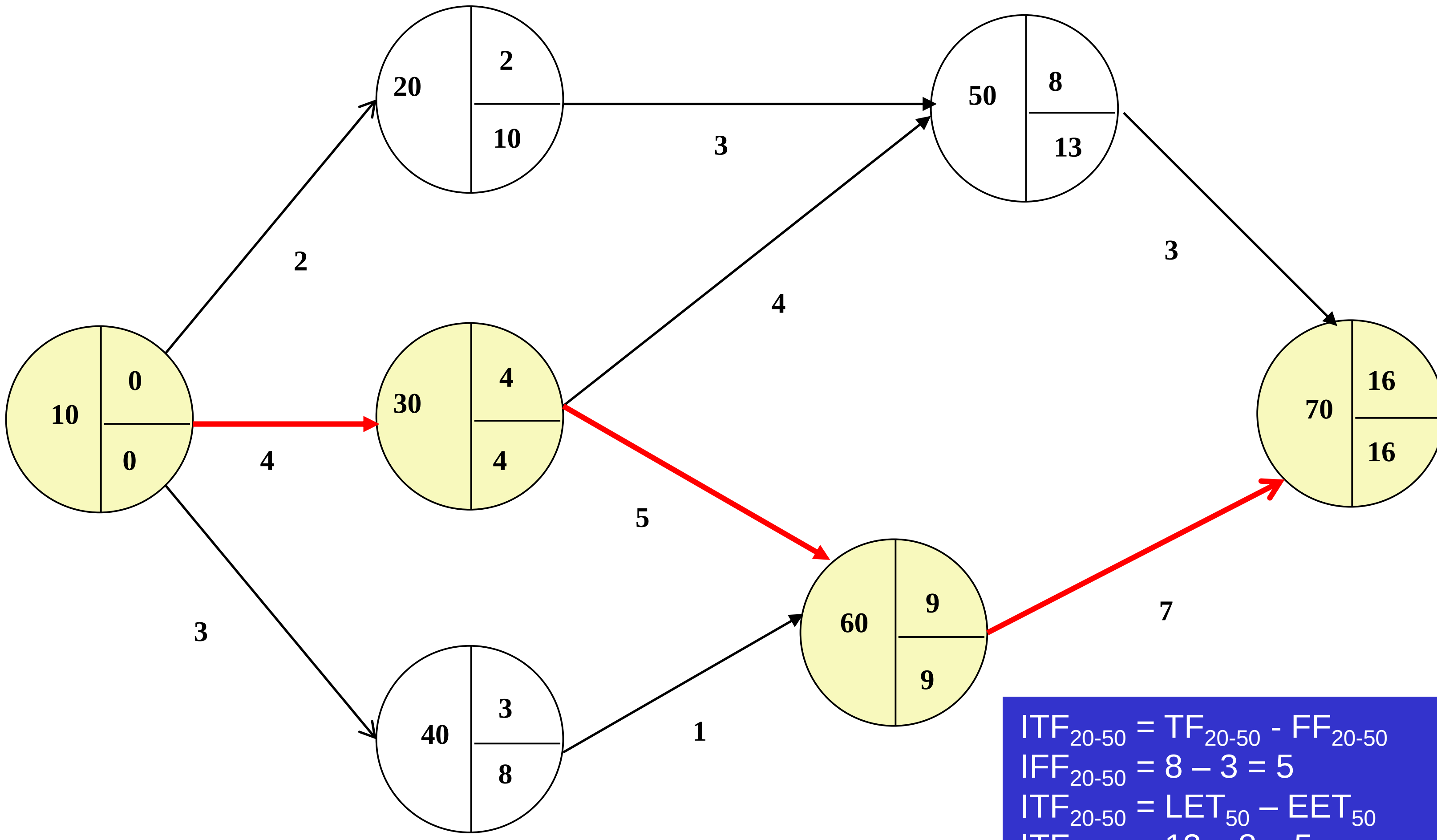
3. Activity Floats

3. Interfering Float (ITF)

- Interfering float is the difference between TF and FF.
- If ITF of an activity is used, the start of some succeeding activities will be delayed beyond its ES.
- In other words, if the activity uses its ITF, it “interferes” by this amount with the early times for the down path activity.
- For arbitrary activity (i–j), the Interfering float can be written as:

$$\textbf{Interfering Float } (ITF_{ij}) = TF_{ij} - FF_{ij} = LET_j - EET_j$$

Example: Interfering Float Times



$ITF_{20\text{-}50} = TF_{20\text{-}50} - FF_{20\text{-}50}$

$IFF_{20\text{-}50} = 8 - 3 = 5$

$ITF_{20\text{-}50} = LET_{50} - EET_{50}$

$ITF_{20\text{-}50} = 13 - 8 = 5$

Network Analysis (Computation)

3. Activity Floats

4. Independent Float (IDF)

- It is the amount of float which an activity will always possess no matter how early or late it or its predecessors and successors are.
- The activity has this float "independent" of any slippage of predecessors and any allowable start time of successors. **Assuming all predecessors end as late as possible and successors start as early as possible**.
- IDF is "owned" by one activity.
- In all cases, independent float is always less than or equal to free float (**IDF ≤ FF**).

Network Analysis (Computation)

3. Activity Floats

4. Independent Float (IDF)

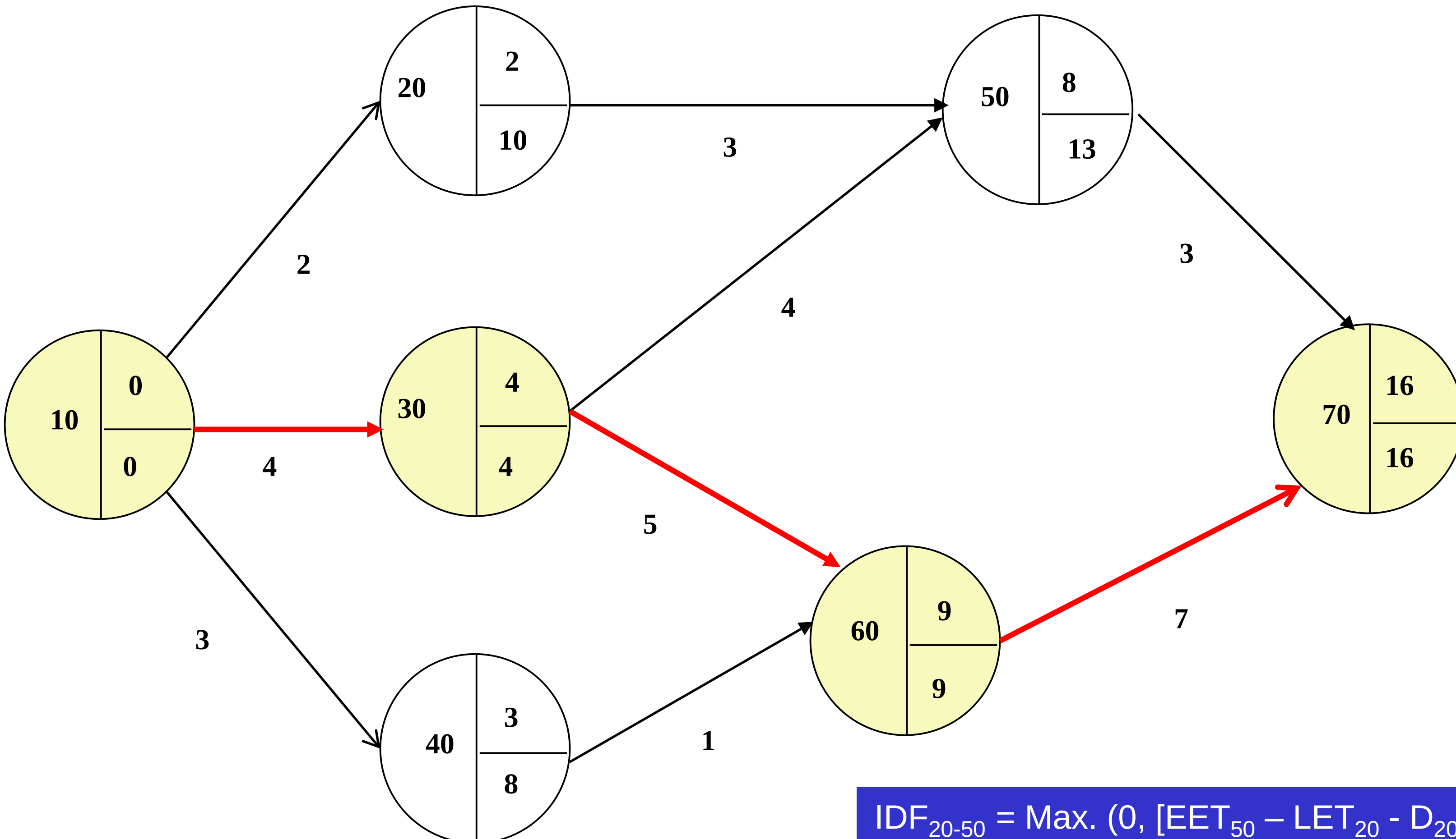
- For arbitrary activity (i–j), the Independent Float can be written as:

Independent Float (IDF_{ij})

$$= \text{Max}\,(0, EET_j - LET_i - D_{ij})$$

$$= \text{Max}\,(0, \text{Min}\,(ES_{jk}) - \text{Max}\,(LF_{hi}) - D_{ij})$$

Example: Independent Float Times



$IDF_{20\text{-}50}$ = Max. (0, [EET_{50} – LET_{20} - $D_{20\text{-}50}$])
$IDF_{20\text{-}50}$ = Max. (0, [8 – 10 – 3]) = 0

Network Analysis (Computation)

4. Critical Path

- Critical path is the path with the **least total float** = The **longest path through the network**.

5. Subcritical Paths

- Subcritical paths have varying degree of path float and hence depart from criticality by varying amounts.
- Subcritical paths can be found in the following way:
  1. Sort the activities in the network by their path float, placing those activities with a common path float in the same group.
  2. Order the activities within a group by early start time.
  3. Order the groups according to the magnitude of their path float, small values first.

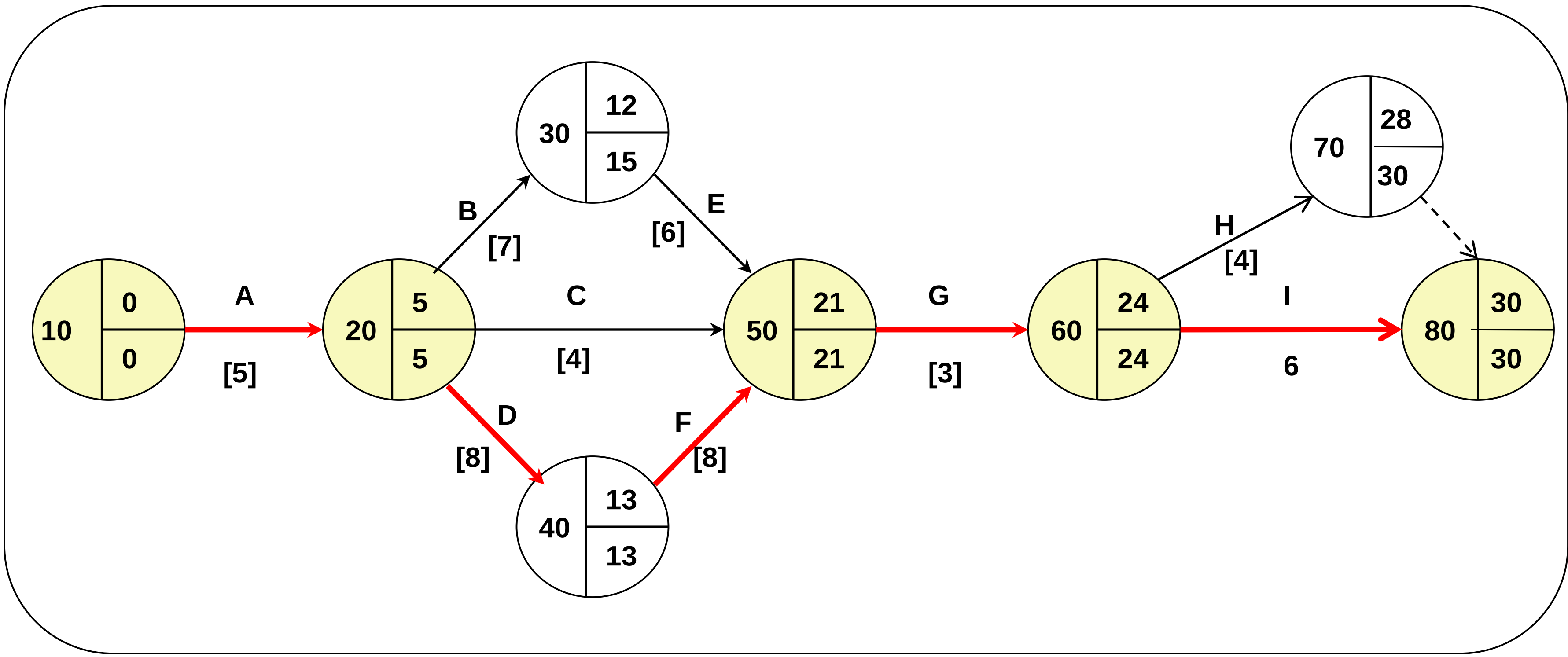
■ Example

Draw an arrow diagram to represent the following project. Calculate occurrence times of events, activity times, and activity floats. Also determine the critical path and the degree of criticality of other float paths.

Activity	Preceding Activity	Time (days)
A	None	5
B	A	7
C	A	4
D	A	8
E	B	6
F	D	8
G	E, C, F	3
H	G	4
I	G	6

■ Example

Activity on arrow network and occurrence times of events



Example

Activity times and activity floats

Activity	ES	EF	LF	LS	TF	FF	ITF	IDF
A	0	5	5	0	0	0	0	0
B	5	12	15	8	3	0	3	0
C	5	9	21	17	12	12	0	12
D	5	13	13	5	0	0	0	0
E	12	18	21	15	3	3	0	0
F	13	21	21	13	0	0	0	0
G	21	24	24	21	0	0	0	0
H	24	28	30	26	2	2	0	2
I	24	30	30	24	0	0	0	0

■ Example

Critical path and subcritical paths

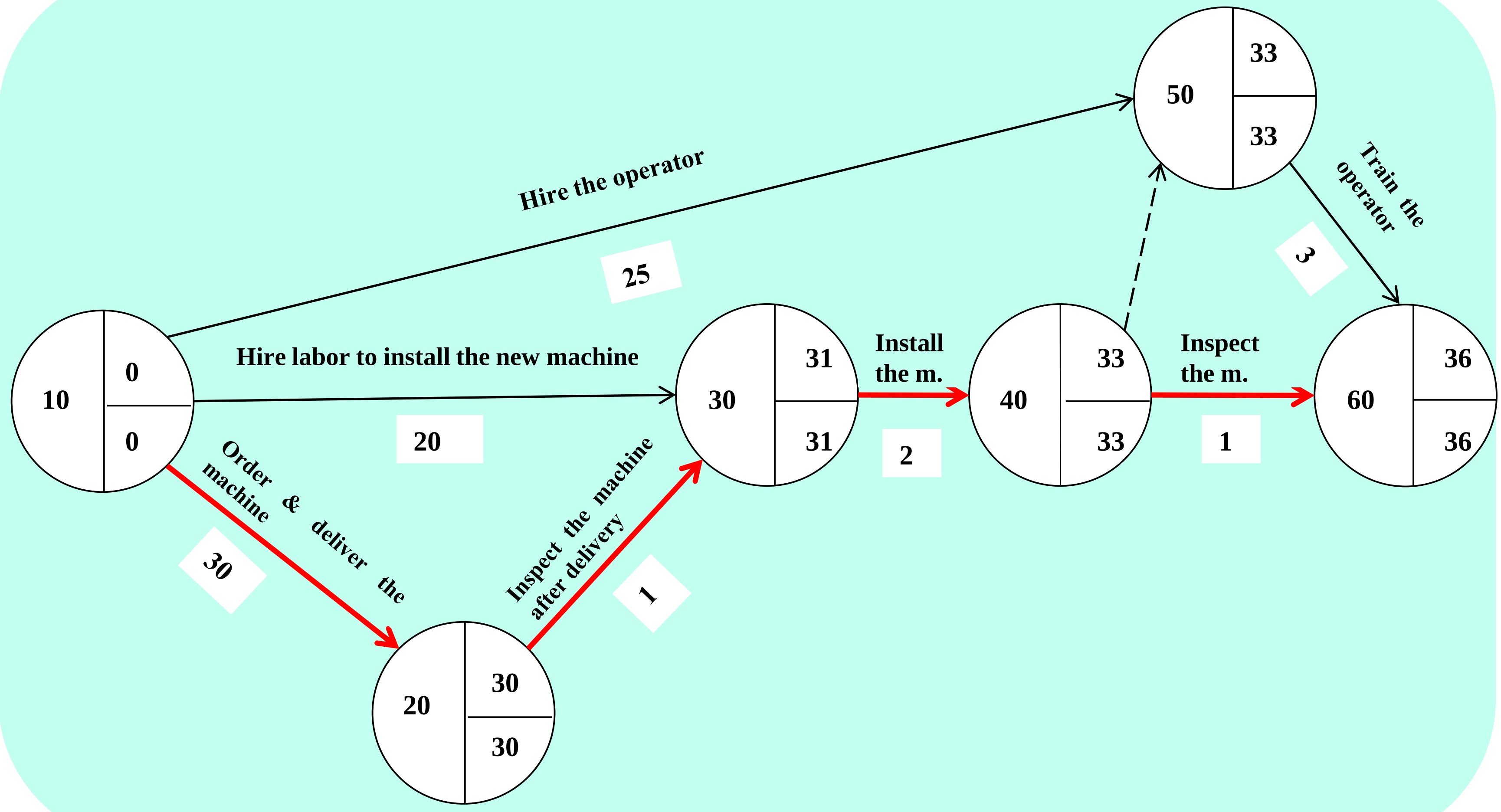
Activity	ES	EF	LF	LS	TF	Criticality
A	0	5	5	0	0	Critical Path
D	5	13	13	5	0	
F	13	21	21	13	0	
G	21	24	24	21	0	
I	24	30	30	24	0	
H	24	28	30	26	2	a "near critical" path
B	5	12	15	8	3	Third most critical path
E	12	18	21	15	3	
C	5	9	21	17	12	Path having most float

■ Case Study

Installation of a new machine and training the operator

Activity Code	Activity Description	Depends on	Level	Duration (day)
100	Inspect the machine after installation	300	4	1
200	Hire the operator	None	1	25
300	Install the new machine	500, 400	3	2
400	Inspect and store the machine after delivery	700	2	1
500	Hire labor to install the new machine	None	1	20
600	Train the operator	200, 300	4	3
700	Order and deliver the new machine	None	1	30

■ Case Study: Installation of a New Machine and Training the Operator



■ Case Study: Installation of a New Machine and Training the Operator

- Activity times and activity floats

Activity	i-j number	ES	EF	LS	LF	TF	FF	ITF	IDF
Hire the operator	10-50	0	25	8	33	8	8	0	8
Hire labor to install the machine	10-30	0	20	11	31	11	11	0	11
Order and deliver the machine	10-20	0	30	0	30	0	0	0	0
Inspect the m. after delivery	20-30	30	31	30	31	0	0	0	0
Install the machine	30-40	31	33	31	33	0	0	0	0
Inspect the machine	40-60	33	34	35	36	2	2	0	2
Train the operator	50-60	33	36	33	36	0	0	0	0

- Critical path: 10-20, 20-30, 30-40, 50-60.
- Near critical path: 40-60
- Third most critical path: 10-50
- Path having most float: 10-30

Time Estimates

- Deterministic
  - Time estimates that are fairly certain
- Probabilistic
  - Estimates of times that allow for variation

Computing Algorithm

- Network activities
  - ES: earliest start
  - EF: earliest finish
  - LS: latest start
  - LF: latest finish
- Used to determine
  - Expected project duration
  - Slack time
  - Critical path

Determining the Project Schedule

Perform a Critical Path Analysis

Earliest start (ES) = earliest time at which an activity can start, assuming all predecessors have been completed

Earliest finish (EF) = earliest time at which an activity can be finished

Latest start (LS) = latest time at which an activity can start so as to not delay the completion time of the entire project

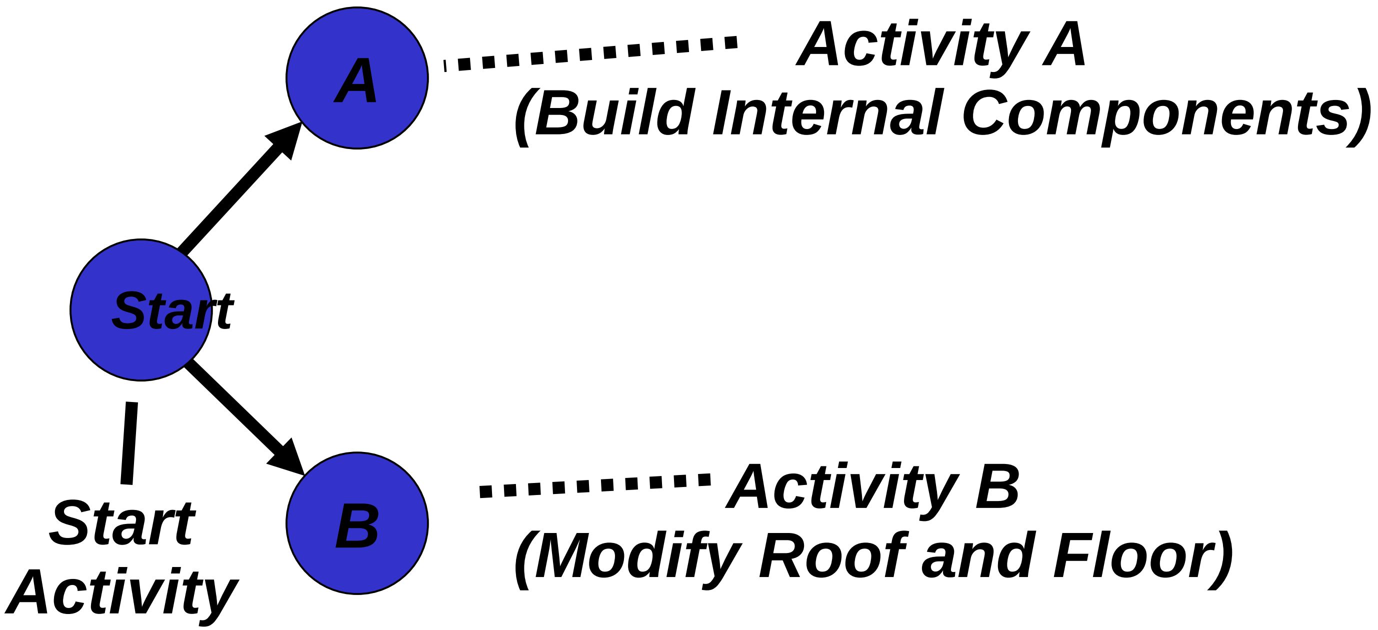
Latest finish (LF) = latest time by which an activity has to be finished so as to not delay the completion time of the entire project

AON Example

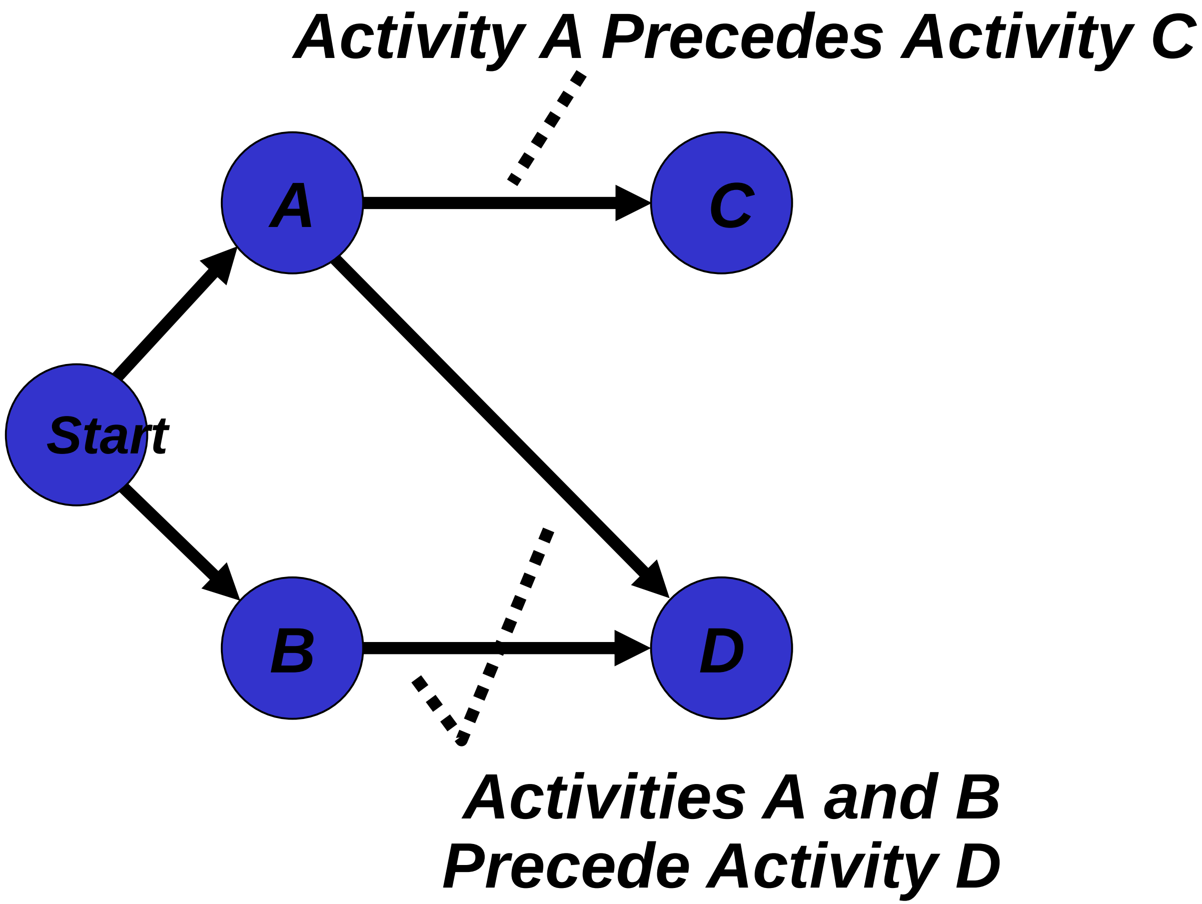
Milwaukee Paper Manufacturing's Activities and Predecessors

Activity	Description	Immediate Predecessors
A	Build internal components	—
B	Modify roof and floor	—
C	Construct collection stack	A
D	Pour concrete and install frame	A, B
E	Build high-temperature burner	C
F	Install pollution control system	C
G	Install air pollution device	D, E
H	Inspect and test	F, G

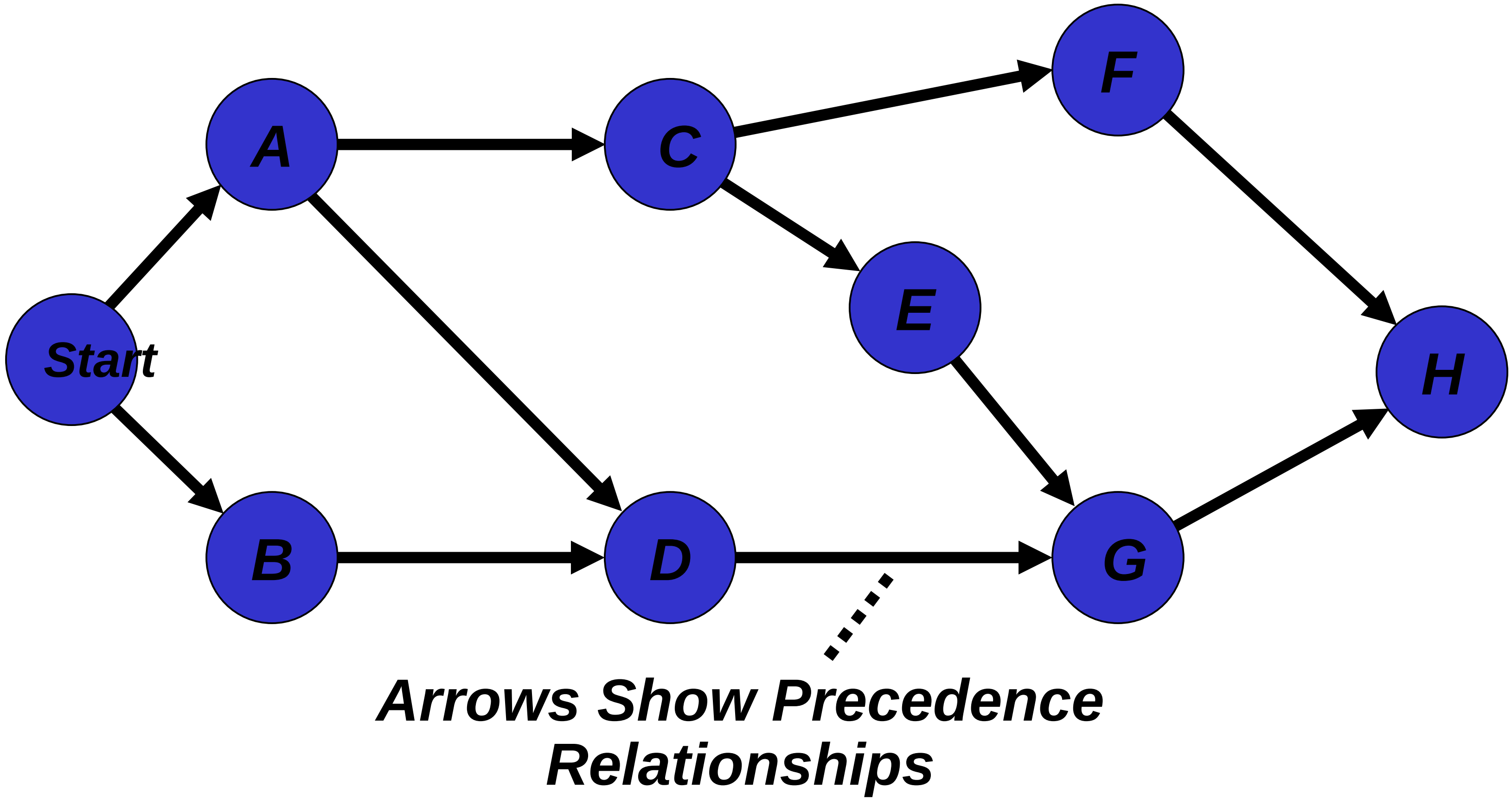
- AON Network for Milwaukee Paper



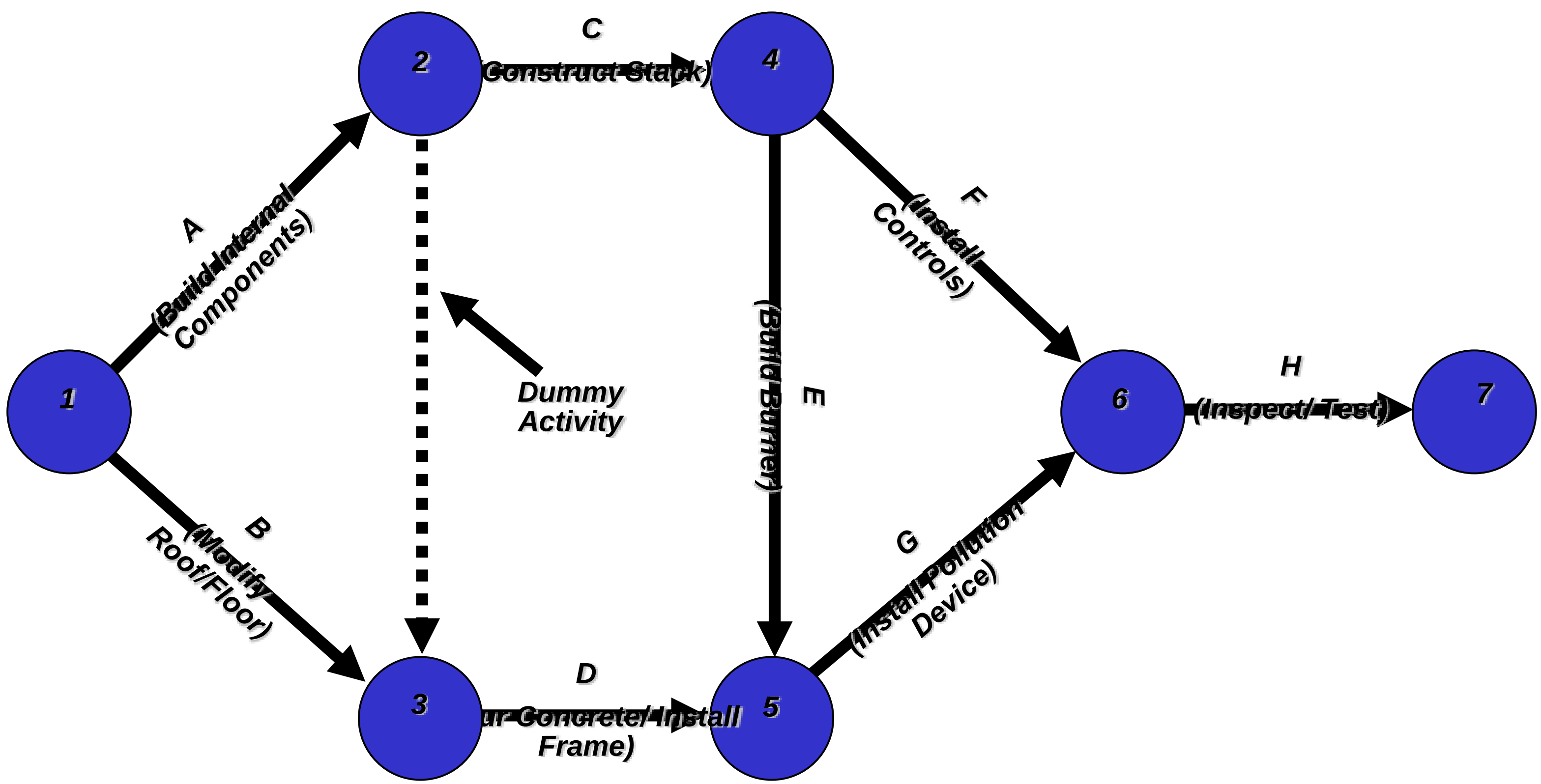
- **AON Network for Milwaukee Paper**



- **AON Network for Milwaukee Paper**



AOA Network for Milwaukee Paper



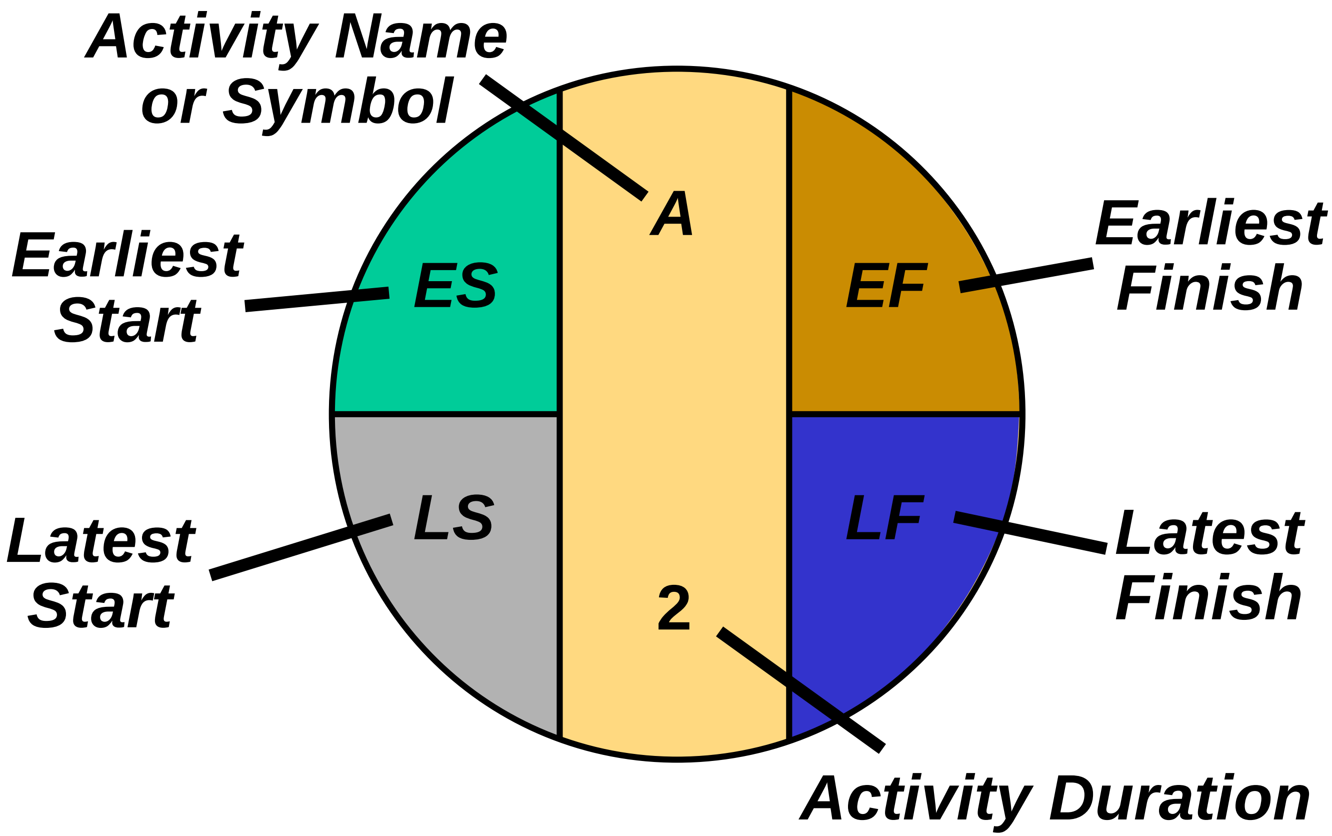
Determining the Project Schedule

Perform a Critical Path Analysis

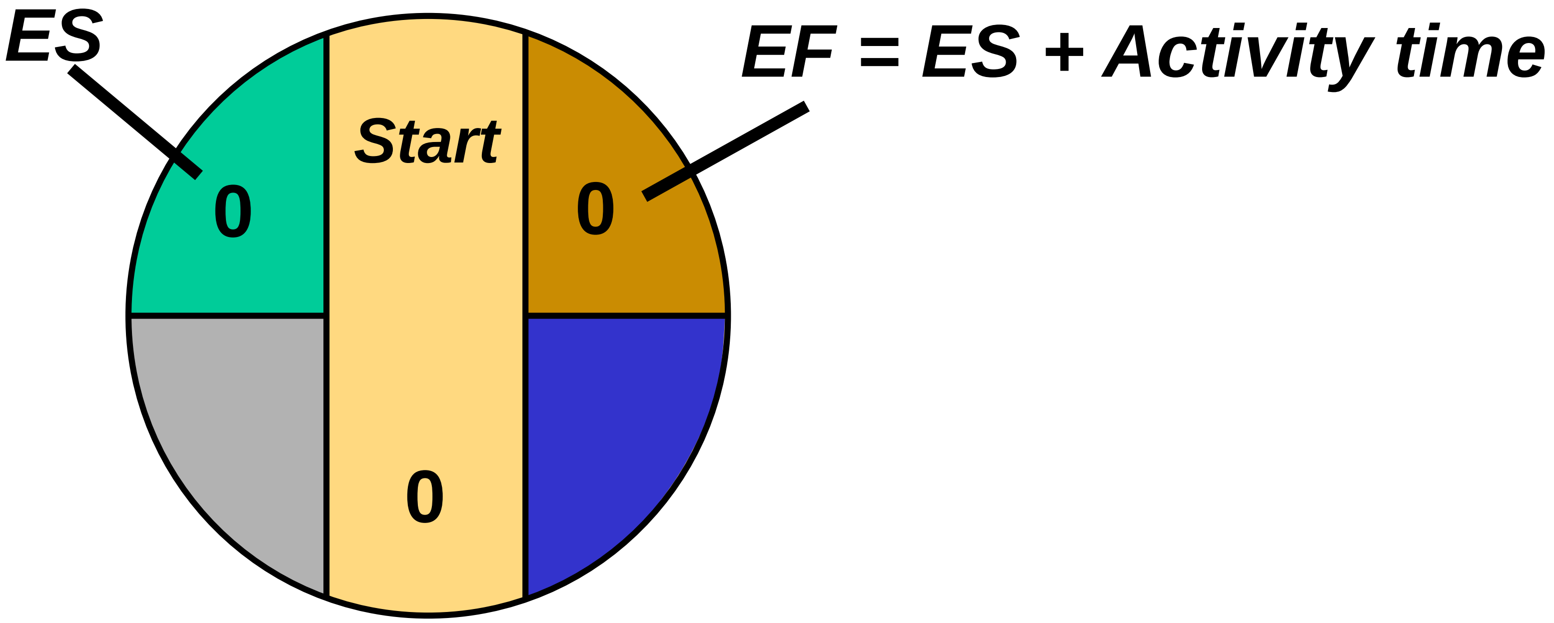
Activity	*Description*	*Time (weeks)*
A	*Build internal components*	2
B	*Modify roof and floor*	3
C	*Construct collection stack*	2
D	*Pour concrete and install frame*	4
E	*Build high-temperature burner*	4
F	*Install pollution control system*	3
G	*Install air pollution device*	5
H	*Inspect and test*	2
	Total Time (weeks)	25

Determining the Project Schedule

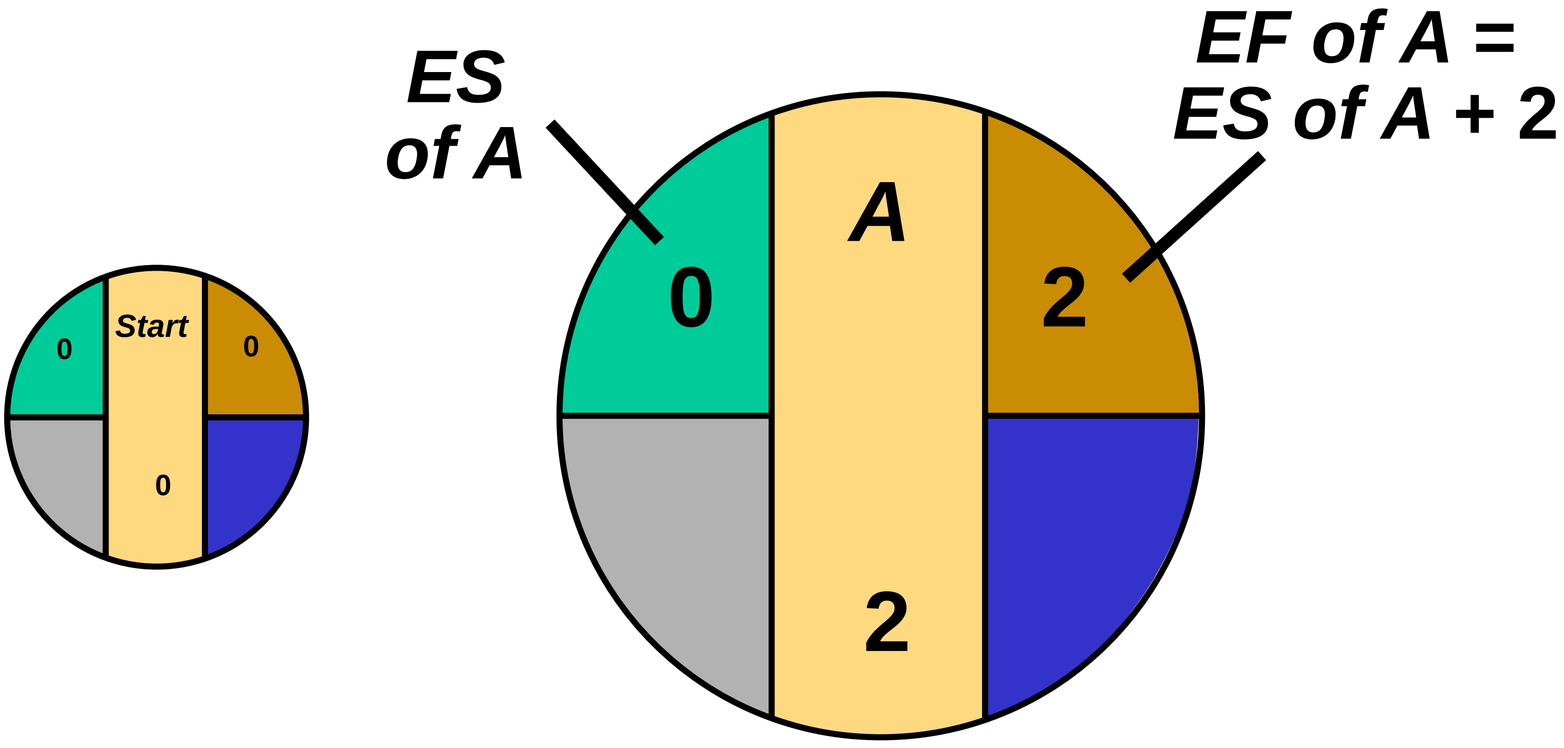
Perform a Critical Path Analysis



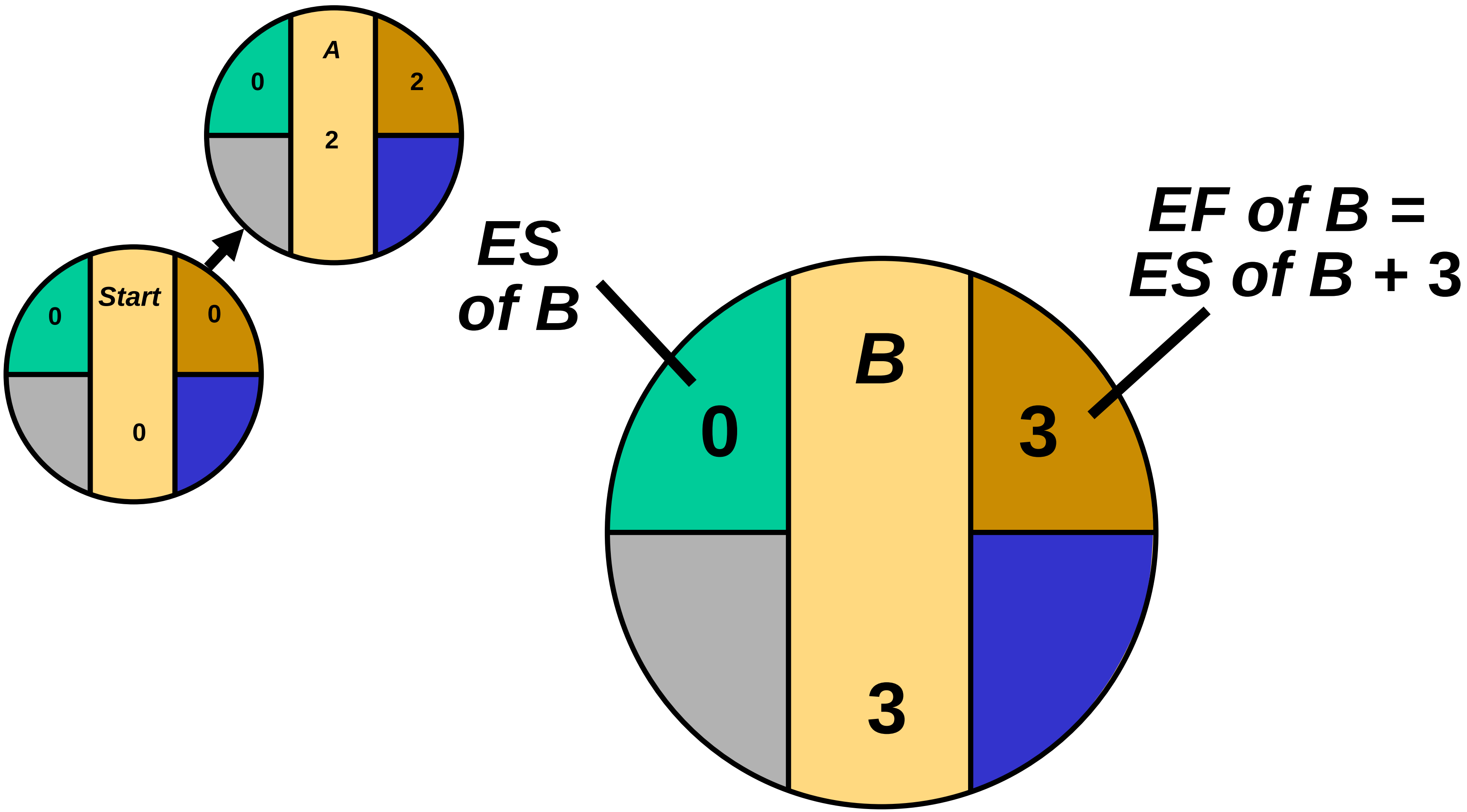
- ES/EF Network for Milwaukee Paper (Forward pass)



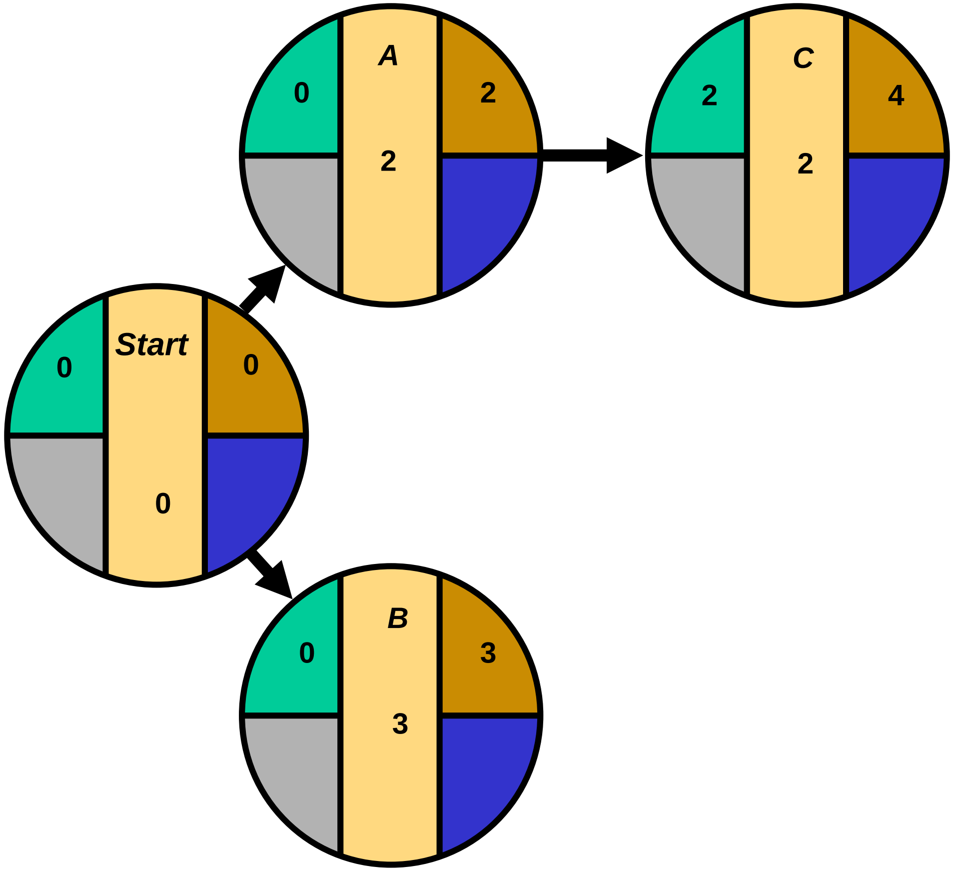
- **ES/EF Network for Milwaukee Paper**



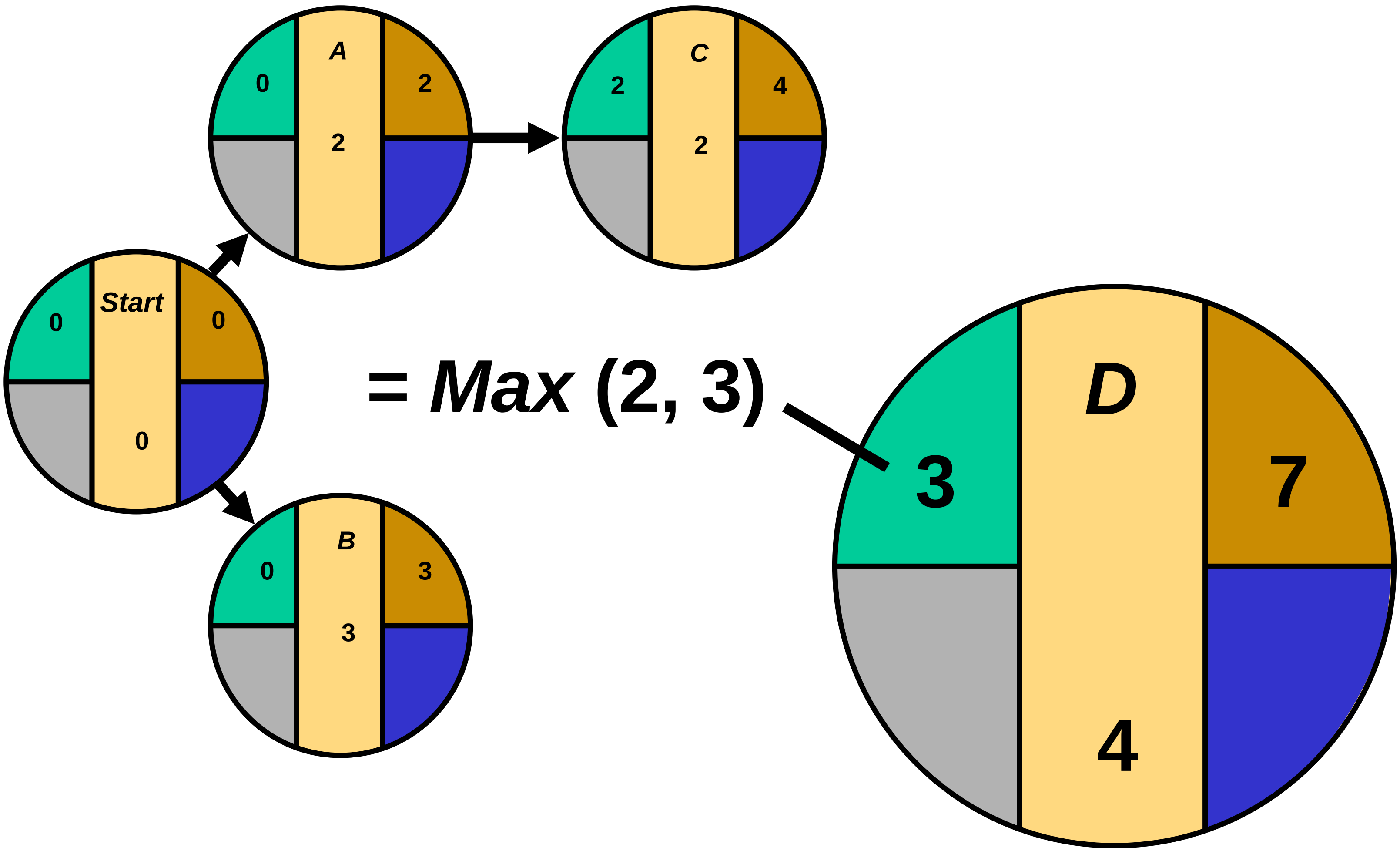
ES/EF Network for Milwaukee Paper



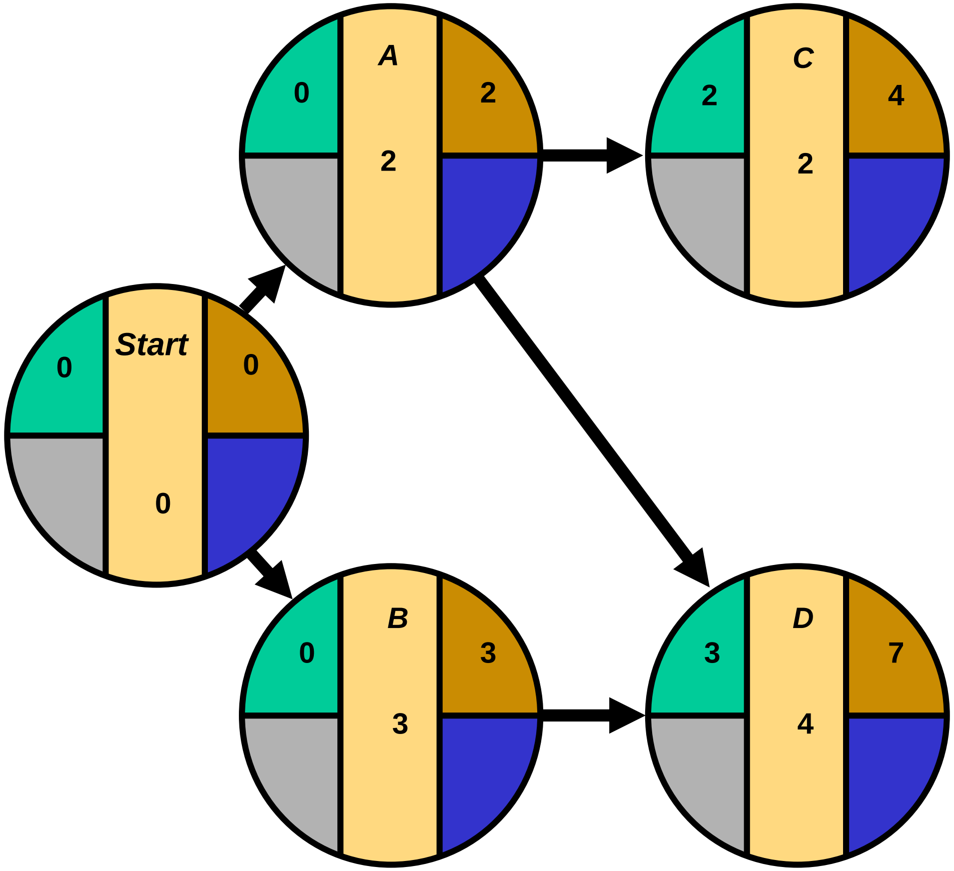
ES/EF Network for Milwaukee Paper



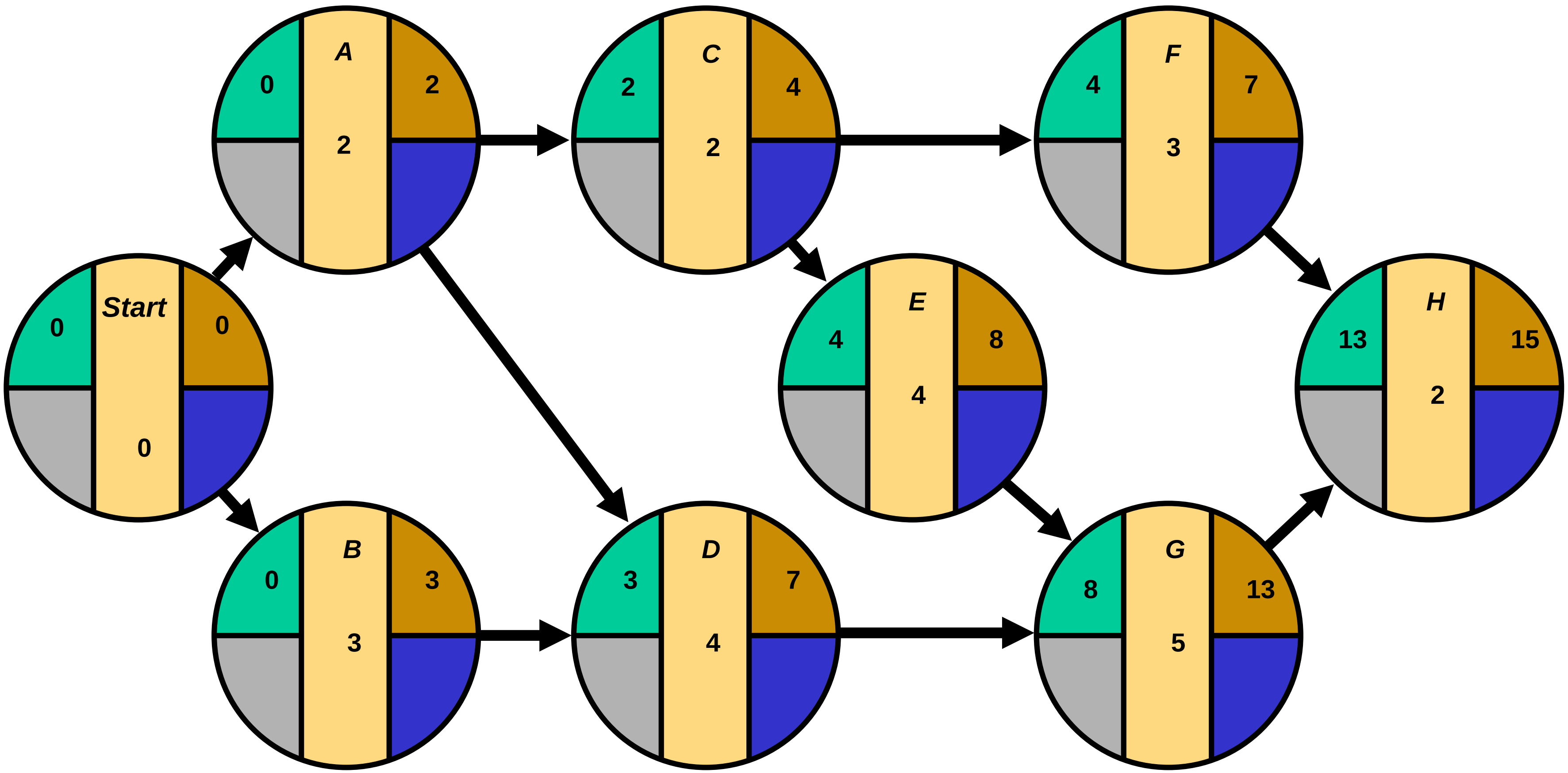
- **ES/EF Network for Milwaukee Paper**



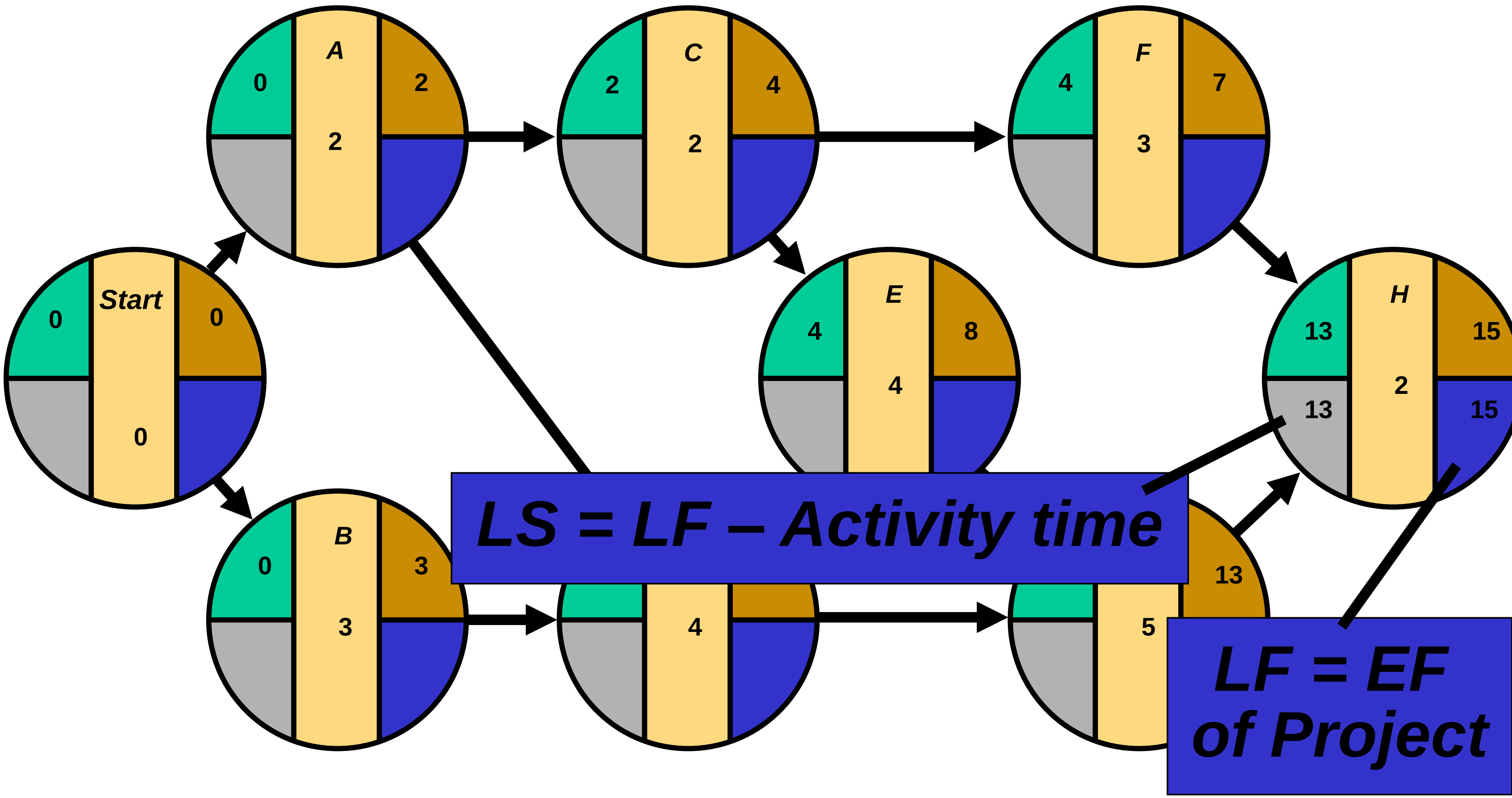
ES/EF Network for Milwaukee Paper



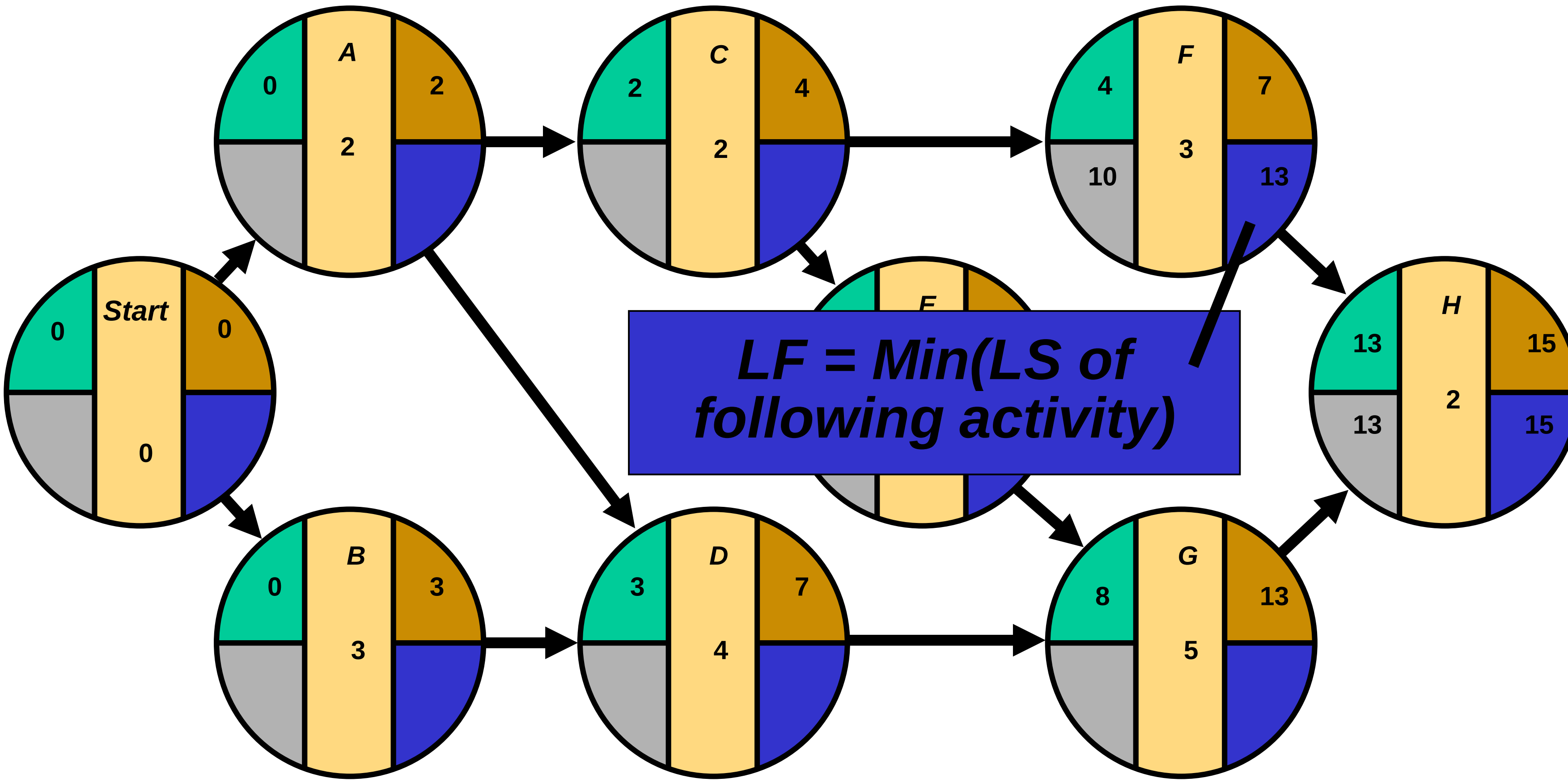
■ ES/EF Network for Milwaukee Paper



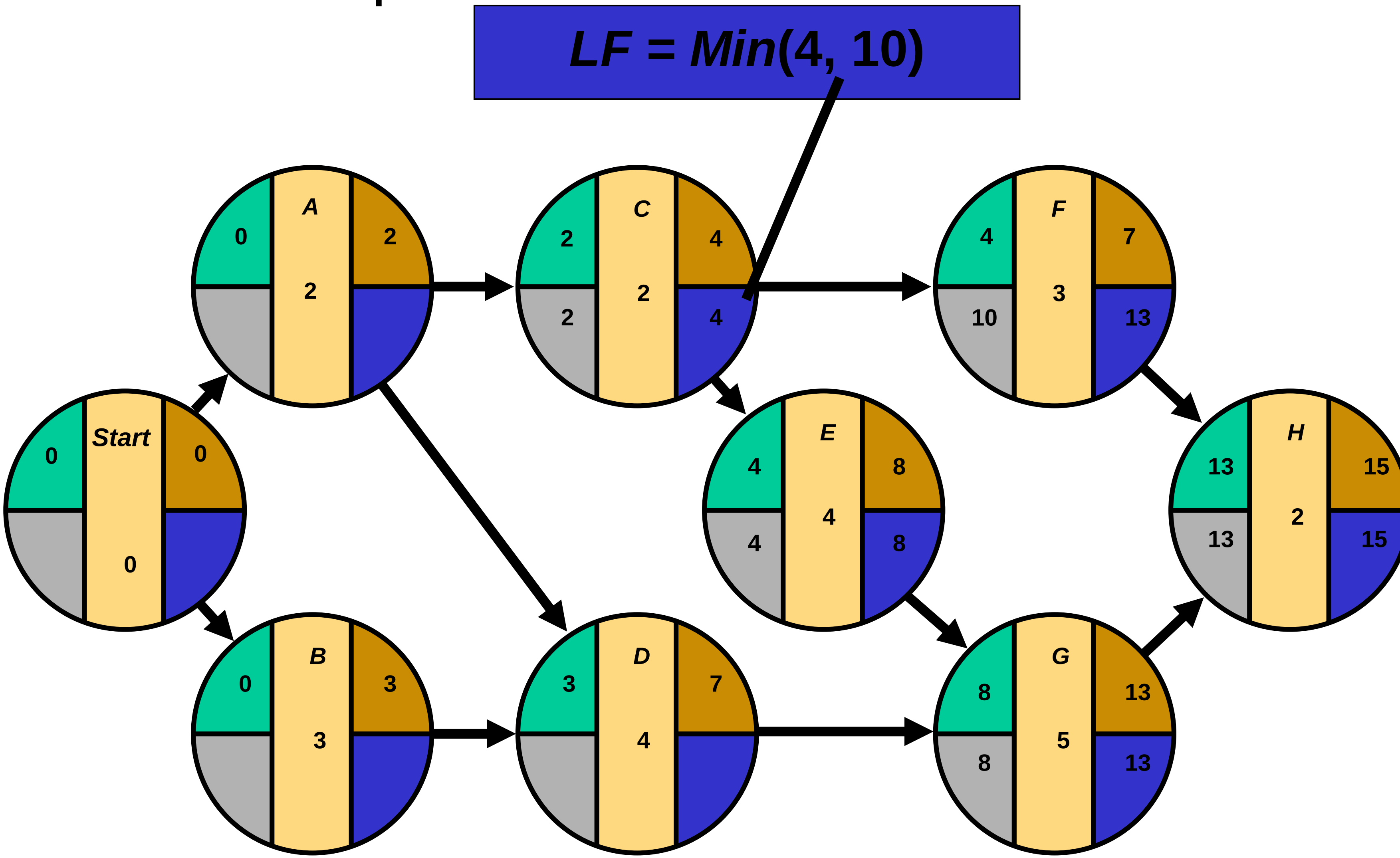
- **LS/LF Times for Milwaukee Paper (Backward pass)**



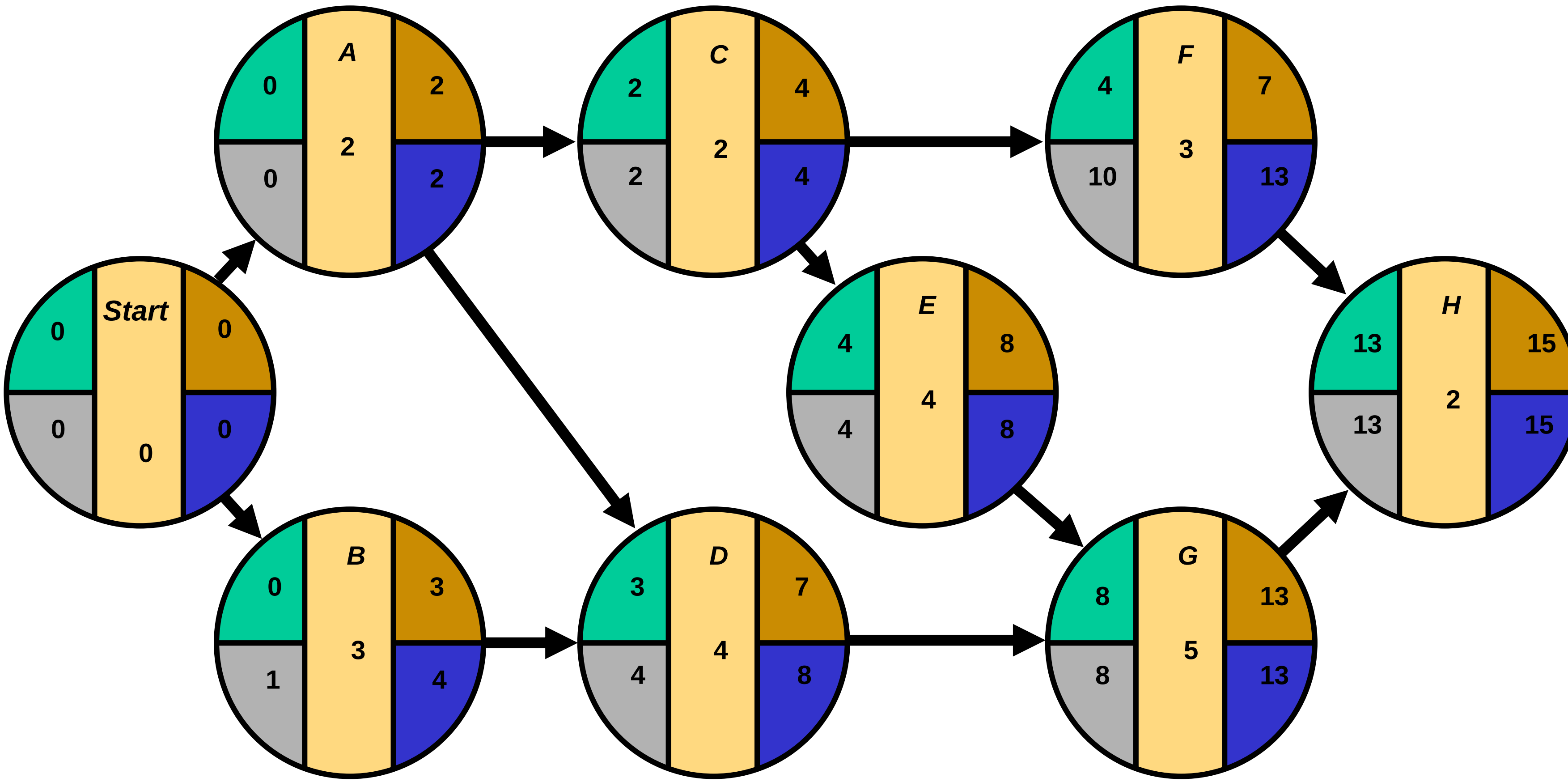
- **LS/LF Times for Milwaukee Paper**



- **LS/LF Times for Milwaukee Paper**



- **LS/LF Times for Milwaukee Paper**



Computing Slack Time

After computing the ES, EF, LS, and LF times for all activities, compute the slack or free time for each activity

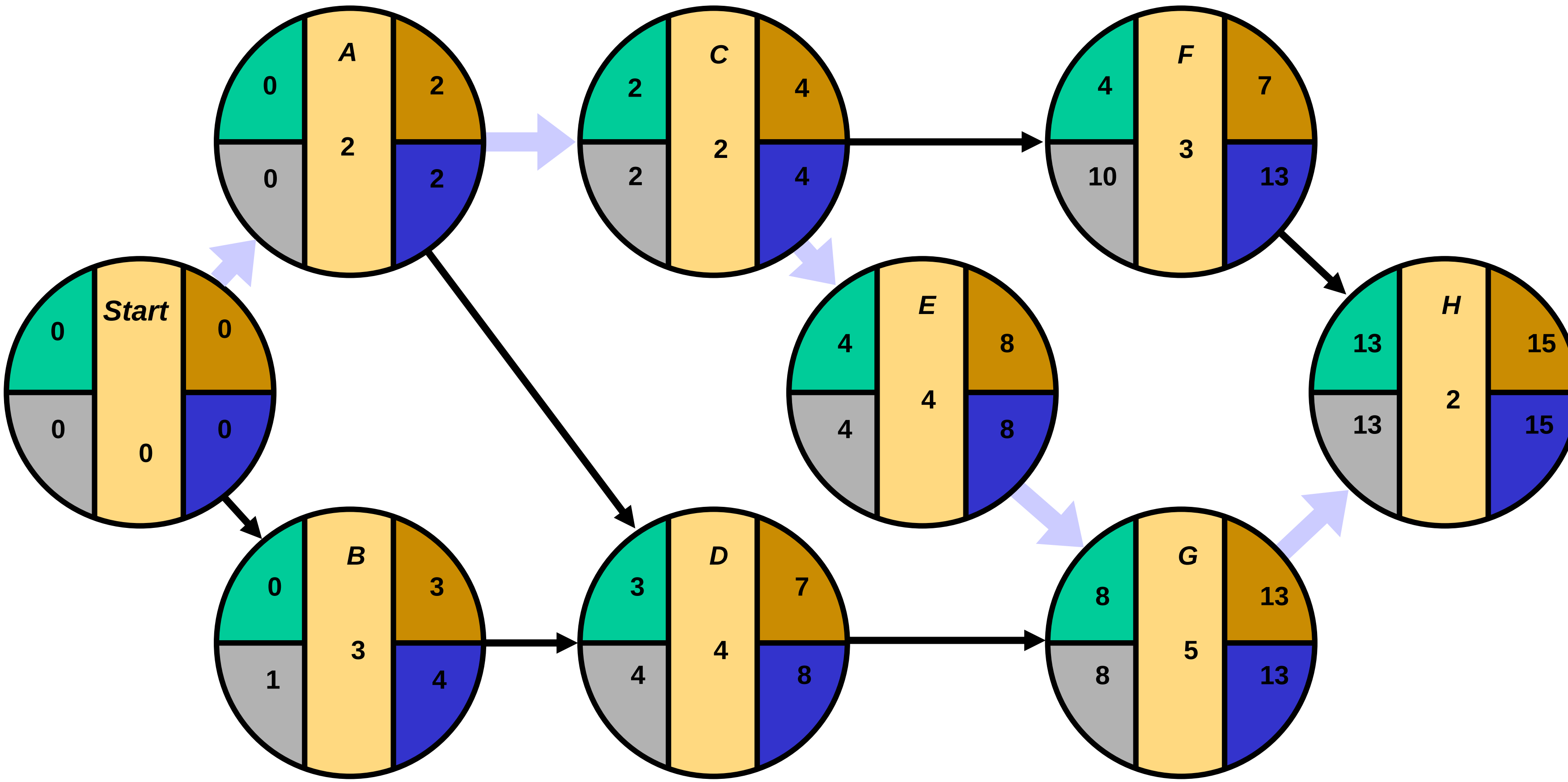
- ☑ *Slack is the length of time an activity can be delayed without delaying the entire project*

Slack = LS – ES   or   Slack = LF – EF

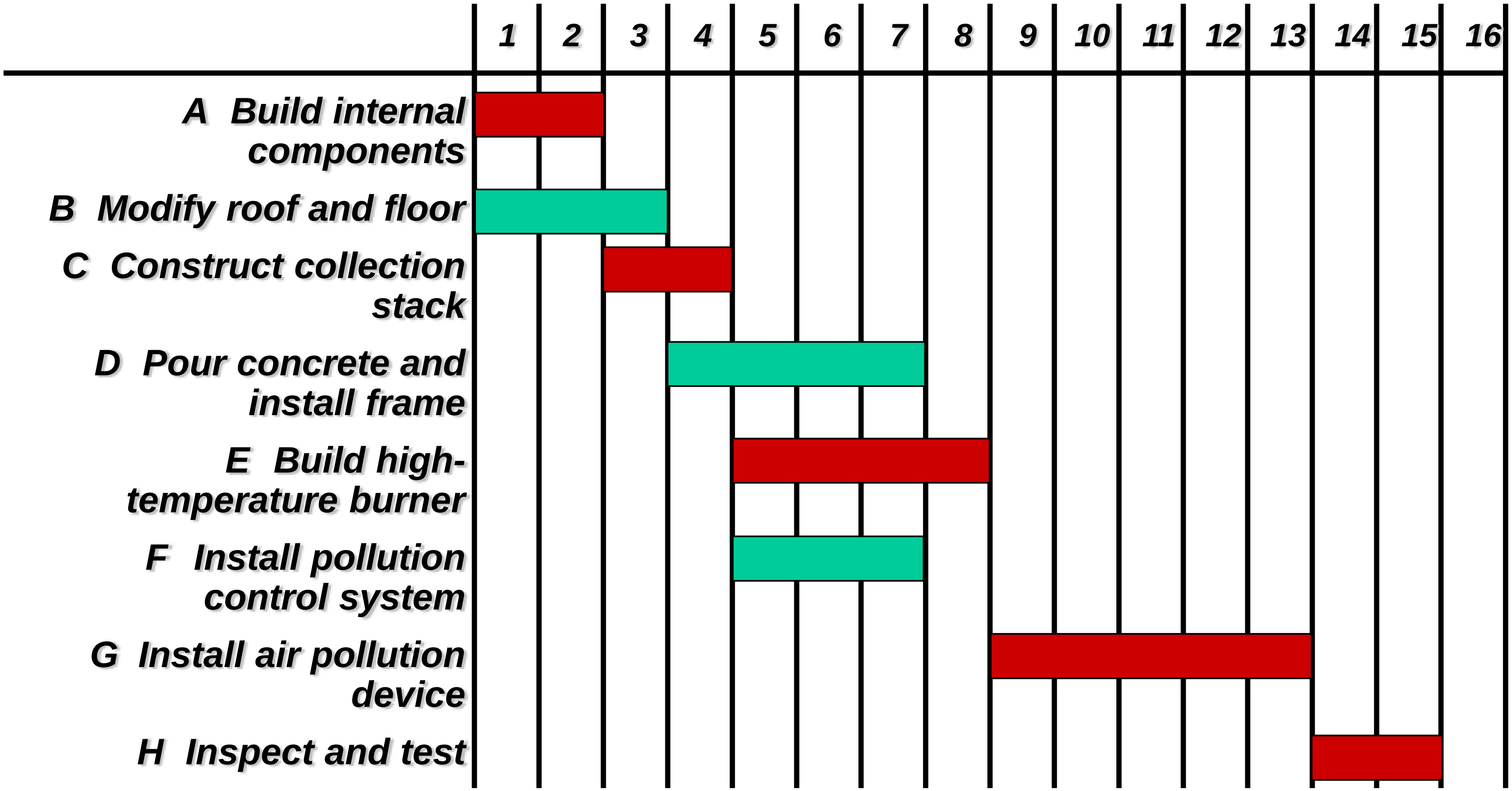
Computing Slack Time

Activity	*Earliest Start ES*	*Earliest Finish EF*	*Latest Start LS*	*Latest Finish LF*	*Slack LS – ES*	*On Critical Path*
A	0	2	0	2	0	*Yes*
B	0	3	1	4	1	*No*
C	2	4	2	4	0	*Yes*
D	3	7	4	8	1	*No*
E	4	8	4	8	0	*Yes*
F	4	7	10	13	6	*No*
G	8	13	8	13	0	*Yes*
H	13	15	13	15	0	*Yes*

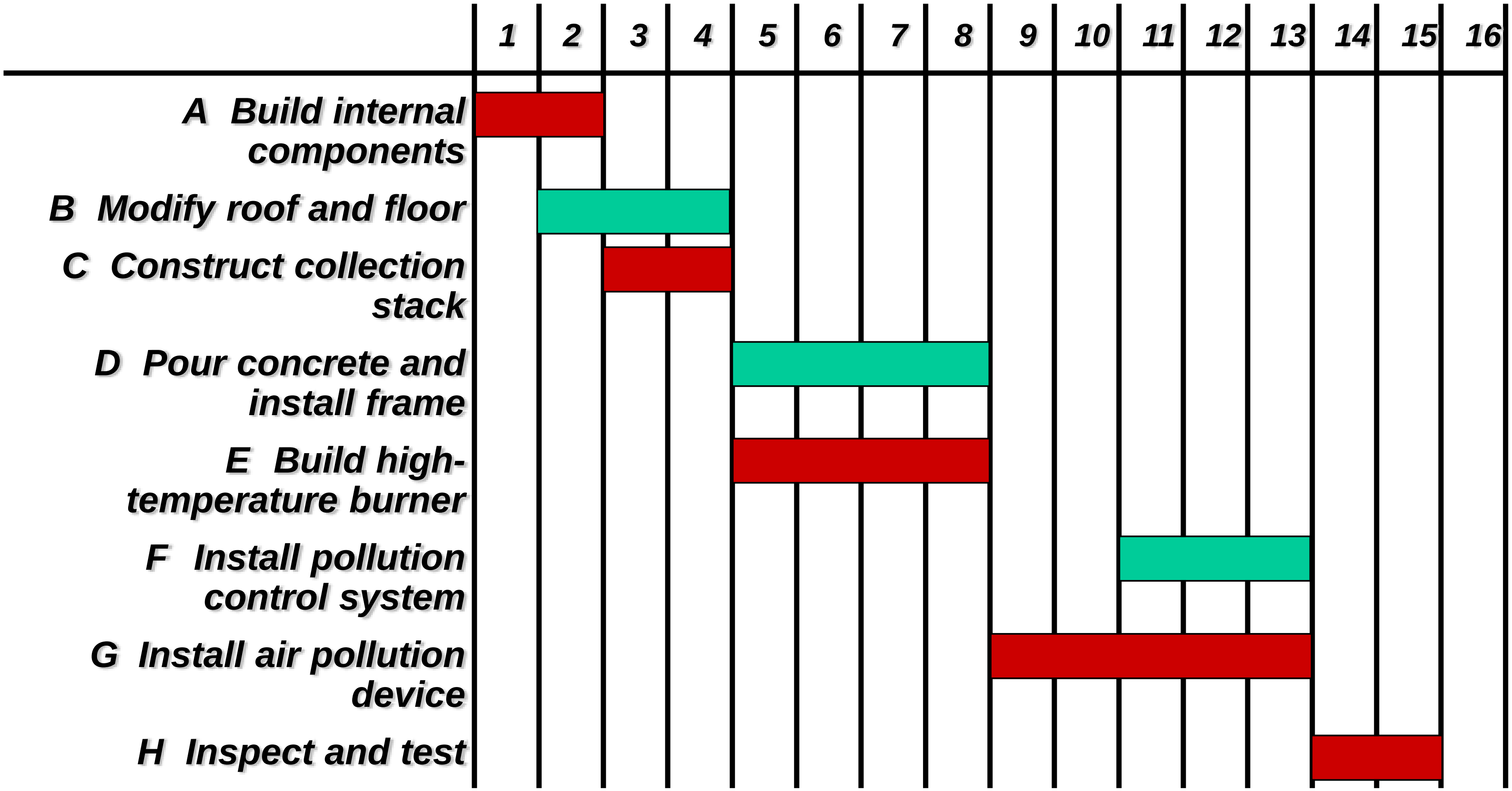
Critical Path for Milwaukee Paper



ES – EF Gantt Chart for Milwaukee Paper



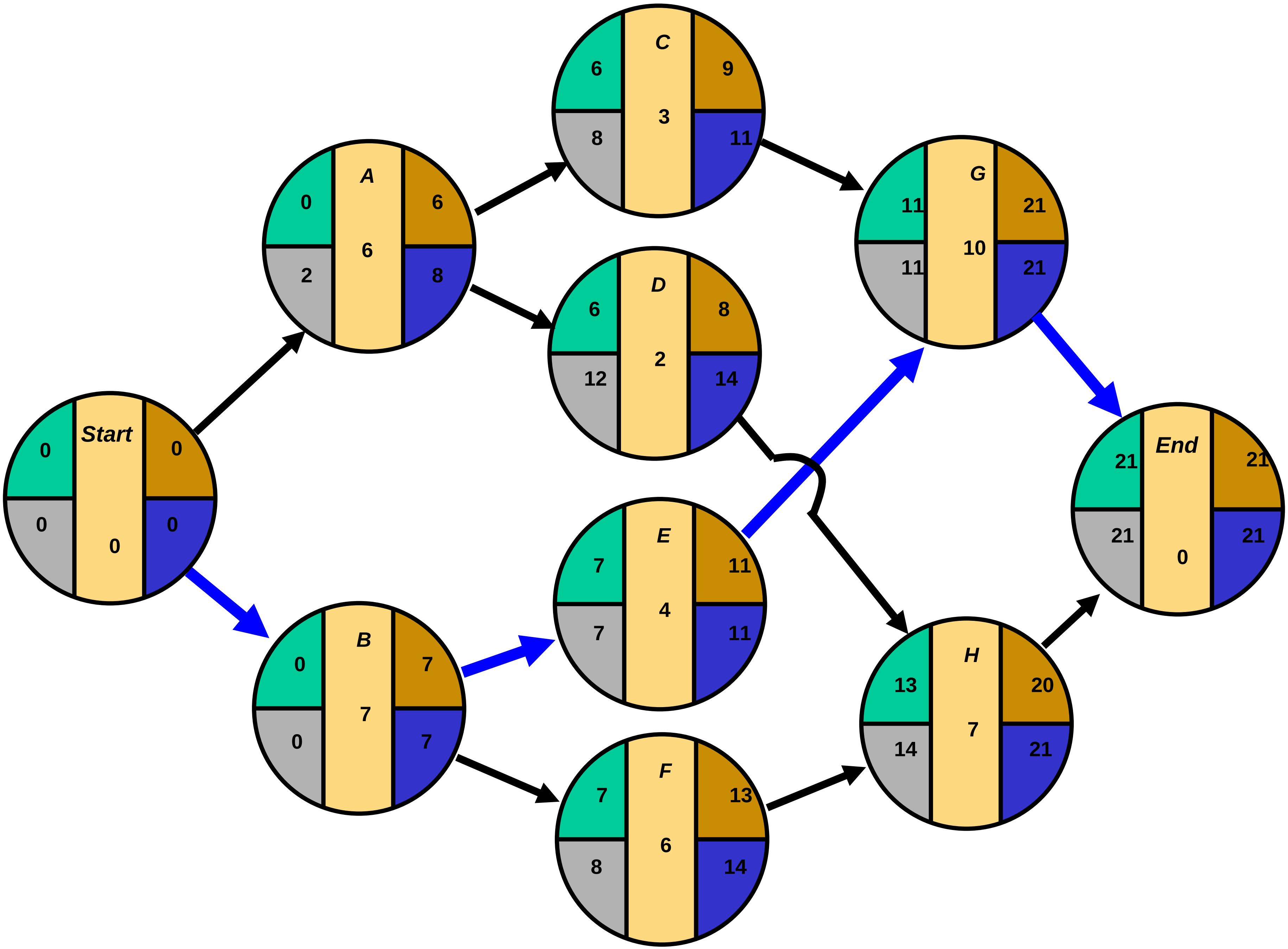
LS – LF Gantt Chart for Milwaukee Paper



Critical Path Example

Perform a Critical Path Analysis

Activity	Immediate Predecessors	Time (weeks)
A	-	6
B	-	7
C	A	3
D	A	2
E	B	4
F	B	6
G	C, E	10
H	D, F	7



Start
0
0
0
0
0
A
0
6
6
2
8
B
0
7
7
0
7
C
6
9
3
8
11
D
6
8
2
12
14
E
7
11
4
7
11
F
7
13
6
8
14
G
11
21
10
11
21
H
13
20
7
14
21
End
21
21
0
21
21

- **Computing Slack Time**

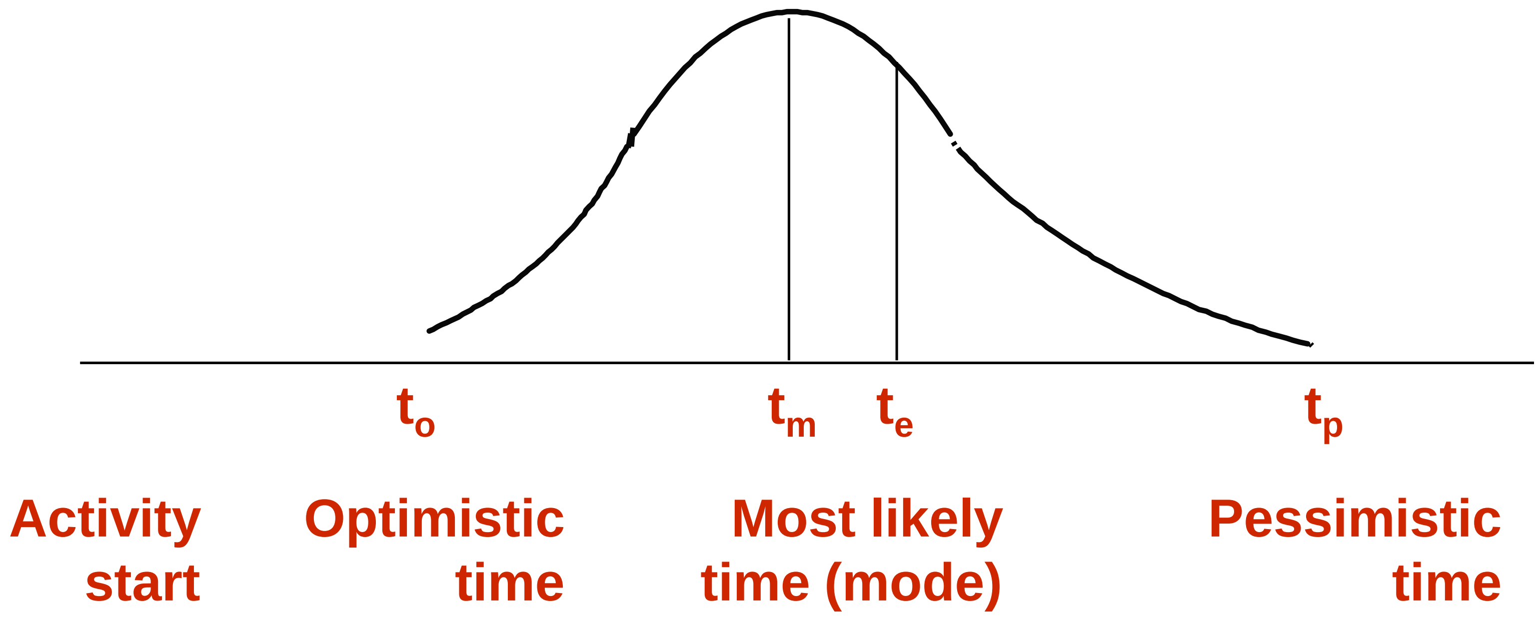
Activity	*Earliest Start ES*	*Earliest Finish EF*	*Latest Start LS*	*Latest Finish LF*	*Slack LS – ES*	*On Critical Path*
A	0	6	2	8	2	*No*
B	0	7	0	7	0	*Yes*
C	6	9	8	11	2	*No*
D	6	8	12	14	6	*No*
E	7	11	7	11	0	*Yes*
F	7	13	8	14	1	*No*
G	11	21	11	21	0	*Yes*
H	13	20	14	21	1	*No*

Probabilistic Time Estimates

- Optimistic time
    - Time required under optimal conditions
- Pessimistic time
    - Time required under worst conditions
- Most likely time
    - Most probable length of time that will be required

- **Probabilistic Estimates**

Beta Distribution



Expected Time

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

t_e = expected time

t_o = optimistic time

t_m = most likely time

t_p = pessimistic time

Variance

$$\sigma^2 = \frac{(t_p - t_o)^2}{36}$$

σ^2 = variance

t_o = optimistic time

t_p = pessimistic time

Computing Variance

Activity	*Optimistic* *a*	*Most Likely* *m*	*Pessimistic* *b*	*Time* $t = (a + 4m + b)/6$	*Expected Variance* $[(b - a)/6]^2$
A	1	2	3	2	.11
B	2	3	4	3	.11
C	1	2	3	2	.11
D	2	4	6	4	.44
E	1	4	7	4	1.00
F	1	2	9	3	1.78
G	3	4	11	5	1.78
H	1	2	3	2	.11

Probability of Project Completion

Project variance is computed by summing the variances of critical activities

$$\sigma_p^2 = \textit{Project variance}$$

$$= \sum(\textit{variances of activities on critical path})$$

Project variance is computed by summing the variances of critical activities

Project variance

$$\sigma_p^2 = .11 + .11 + 1.00 + 1.78 + .11 = 3.11$$

Project standard deviation

$$\sigma_p = \sqrt{\text{Project variance}}$$

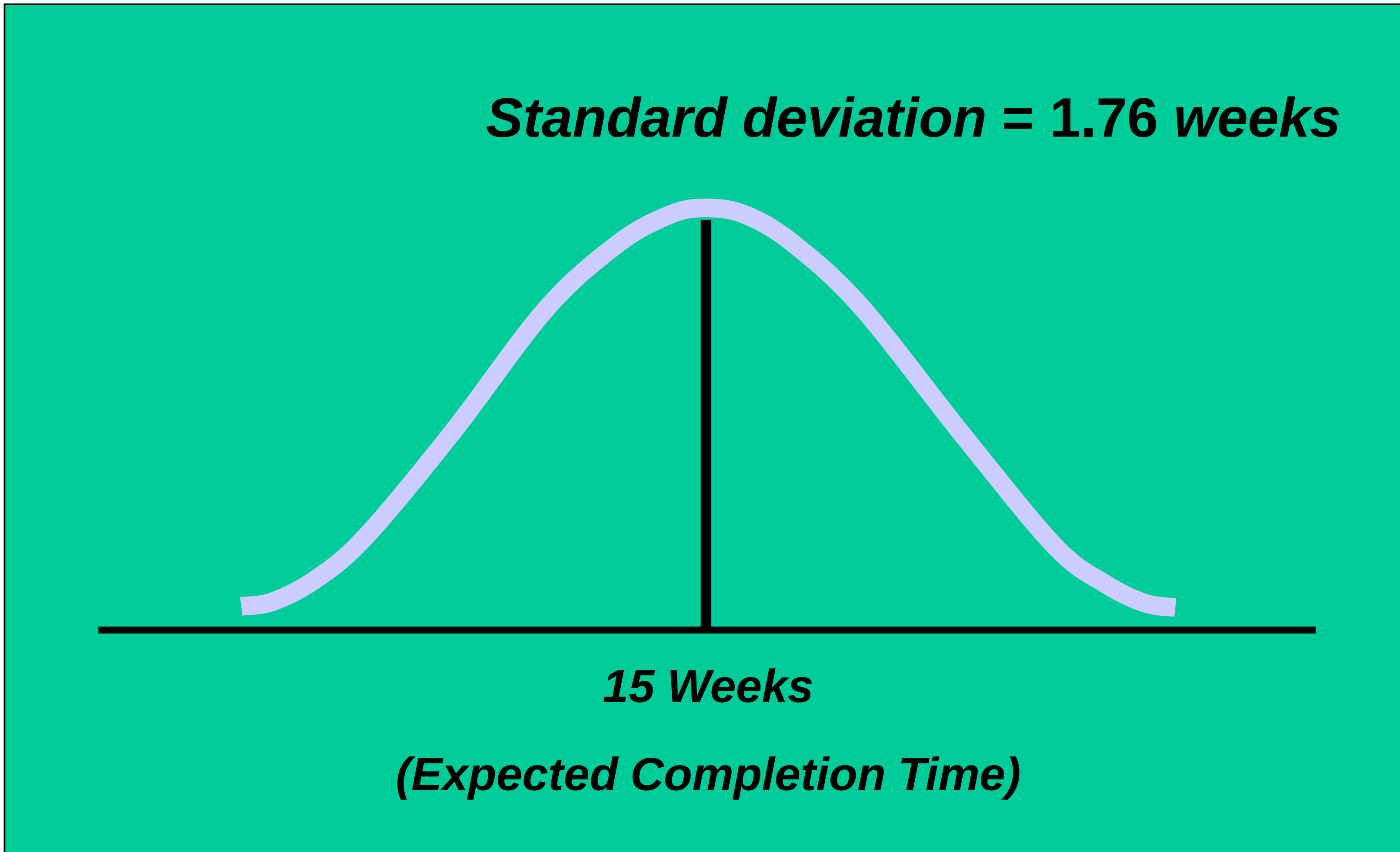
$$= \sqrt{3.11} = 1.76 \text{ weeks}$$

Probability of Project Completion

PERT makes two more assumptions:

- ☑ ***Total project completion times follow a normal probability distribution***
- ☑ ***Activity times are statistically independent***

■ Probability of Project Completion



Probability of Project Completion

What is the probability this project can be completed on or before the **16** *week deadline?*

$$Z = \left(\begin{matrix} \text{due} \\ \text{date} \end{matrix} - \begin{matrix} \text{expected date} \\ \text{of completion} \end{matrix} \right) / \sigma_p$$

$$= (16 \text{ wks} - 15 \text{ wks})/1.76$$

$$= 0.57$$

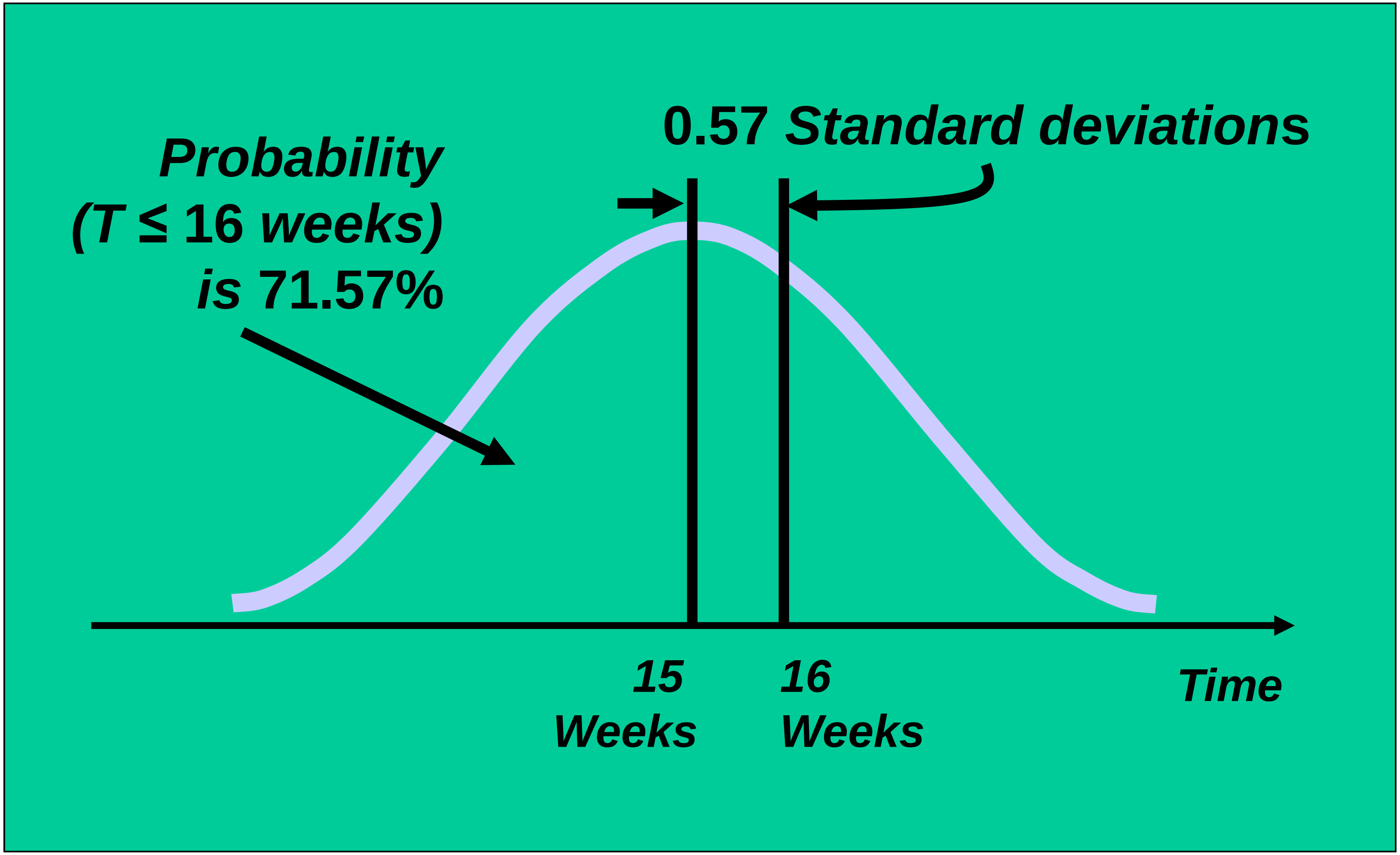
Where Z is the number of standard deviations the due date lies from the mean

Probability of Project Completion

	.00	.01	.07	.08
.1	.50000	.50399	.52790	.53188
.2	.53983	.54380	.56749	.57142
.5	.69146	.69497	$\boxed{.71566}$	.71904
.6	.72575	.72907	.74857	.75175

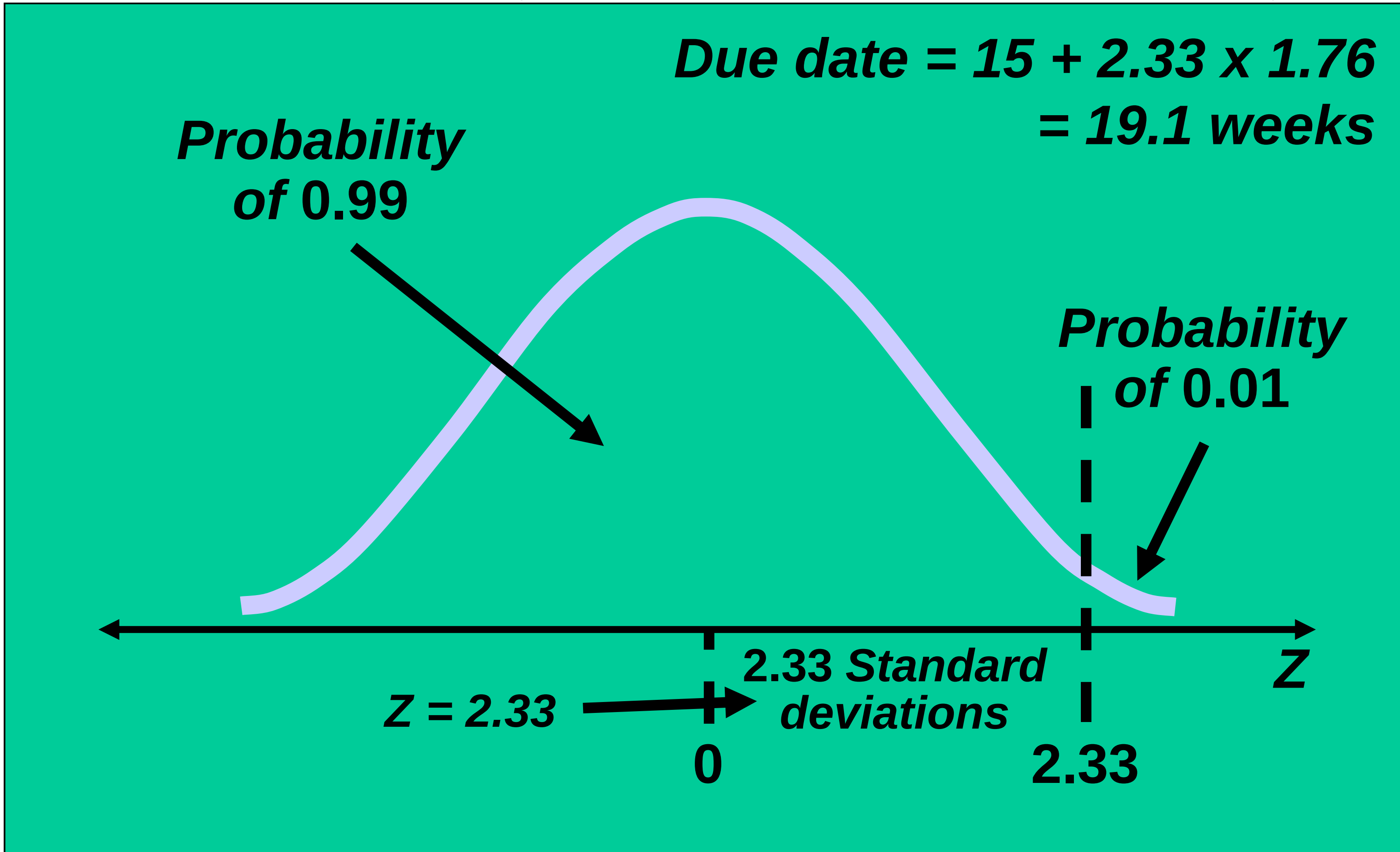
Where Z is the number of standard deviations the due date lies from the mean

Probability of Project Completion



Determining Project Completion Time

$$Z = \left(\text{due date} - \text{expected date of completion} \;/\sigma_p \right)$$



PERT Example

Activity	*Optimistic* *a*	*Most Likely* *m*	*Pessimistic* *b*	*Immediate Predecessors*
A	3	6	8	-
B	2	4	4	-
C	1	2	3	-
D	6	7	8	*C*
E	2	4	6	*B,D*
F	6	10	14	*A,E*
G	1	2	4	*A,E*
H	3	6	9	*F*
I	10	11	12	*G*
J	14	16	20	*C*
K	2	8	10	*H,I*

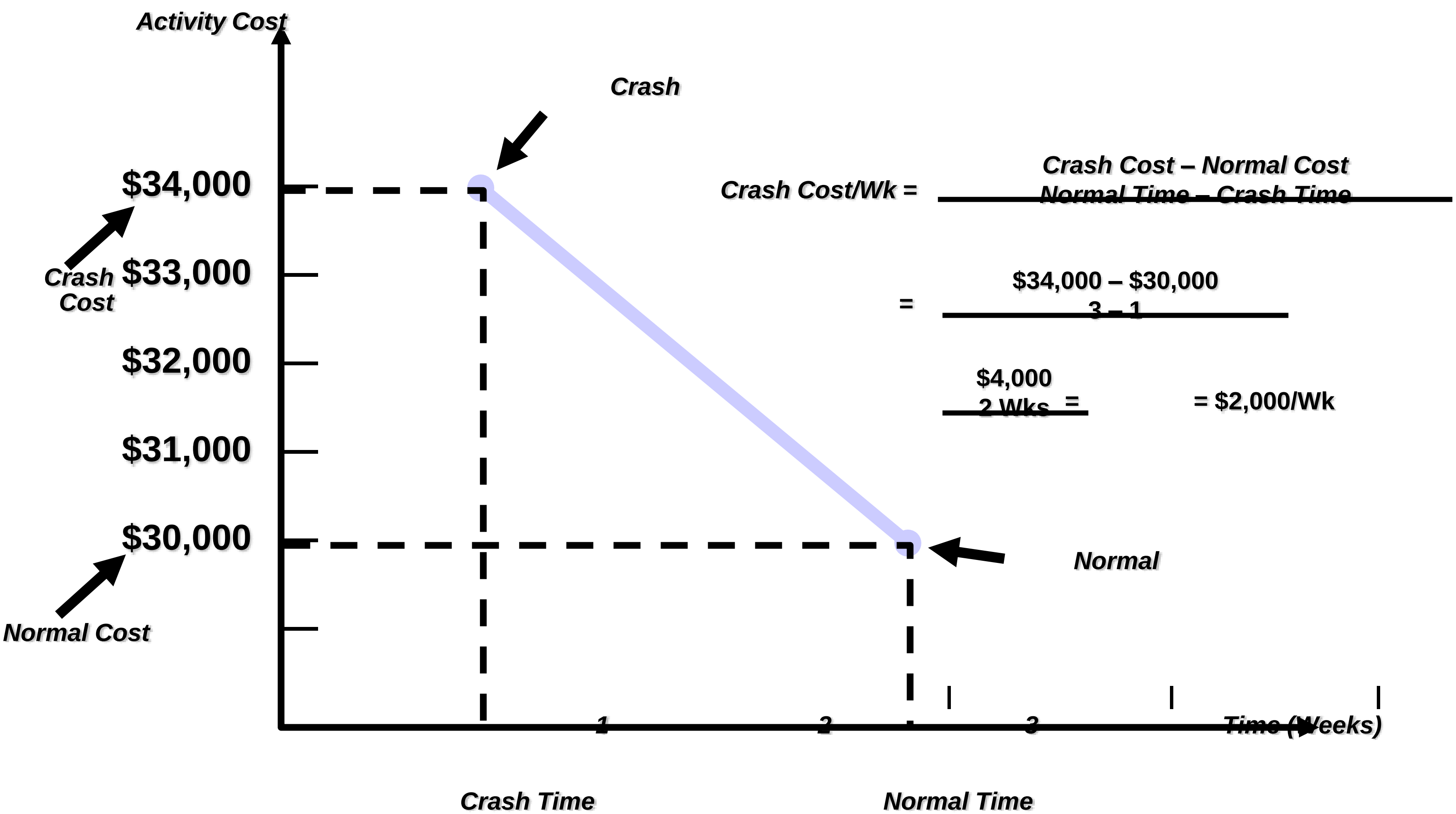
Time-cost Trade-offs: Crashing

- Crash – shortening activity duration
- Procedure for crashing
  - Crash the project one period at a time
  - Only an activity on the critical path
  - Crash the least expensive activity
  - Multiple critical paths: find the sum of crashing the least expensive activity on each critical path

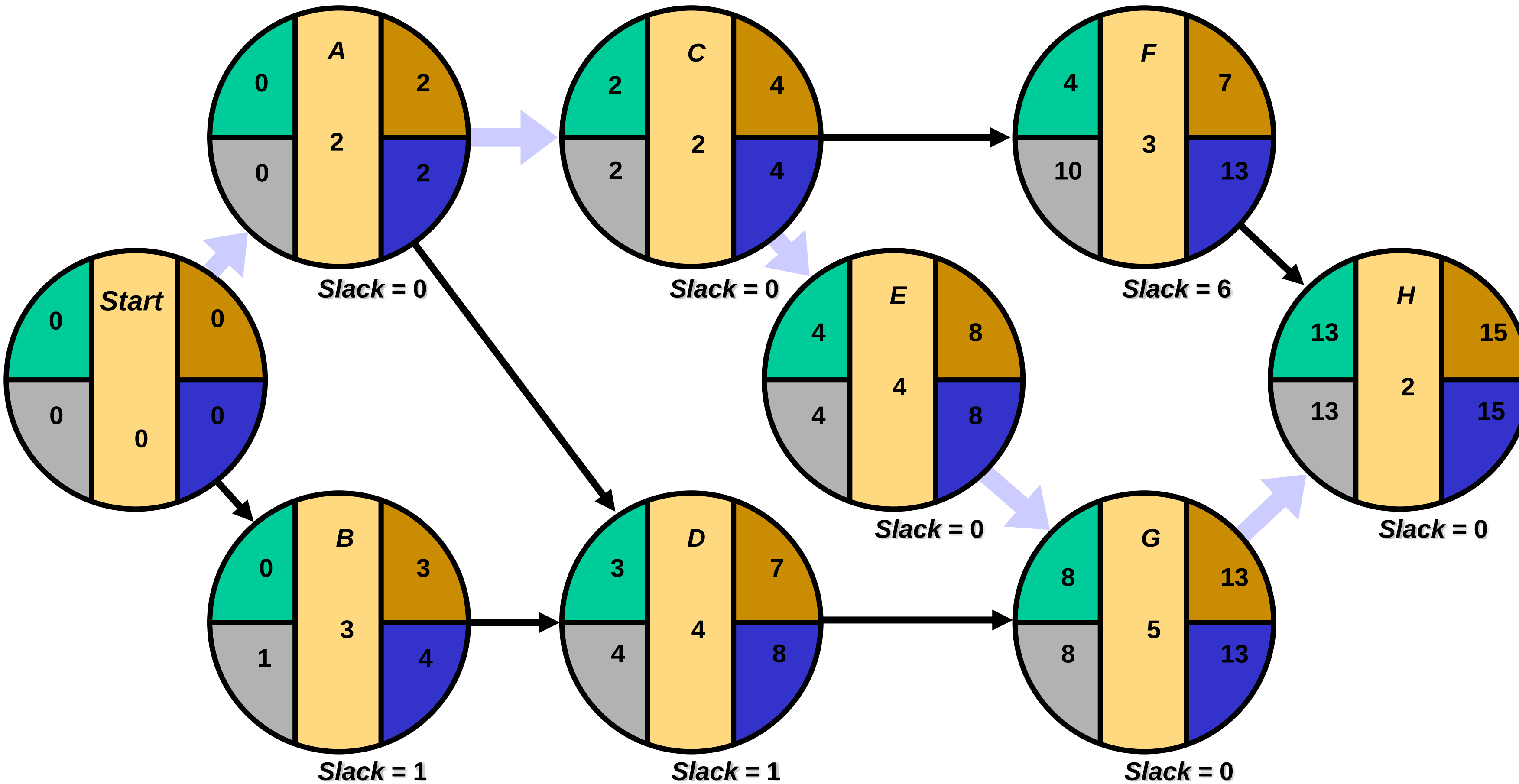
Crashing The Project

Activity	Time (Wks) Normal	Time (Wks) Crash	Cost ($) Normal	Cost ($) Crash	Crash Cost Per Wk ($)	Critical Path?
A	2	1	22,000	22,750	750	*Yes*
B	3	1	30,000	34,000	2,000	*No*
C	2	1	26,000	27,000	1,000	*Yes*
D	4	2	48,000	49,000	1,000	*No*
E	4	2	56,000	58,000	1,000	*Yes*
F	3	2	30,000	30,500	500	*No*
G	5	2	80,000	84,500	1,500	*Yes*
H	2	1	16,000	19,000	3,000	*Yes*
			308,000			

Crash and Normal Times and Costs for Activity B

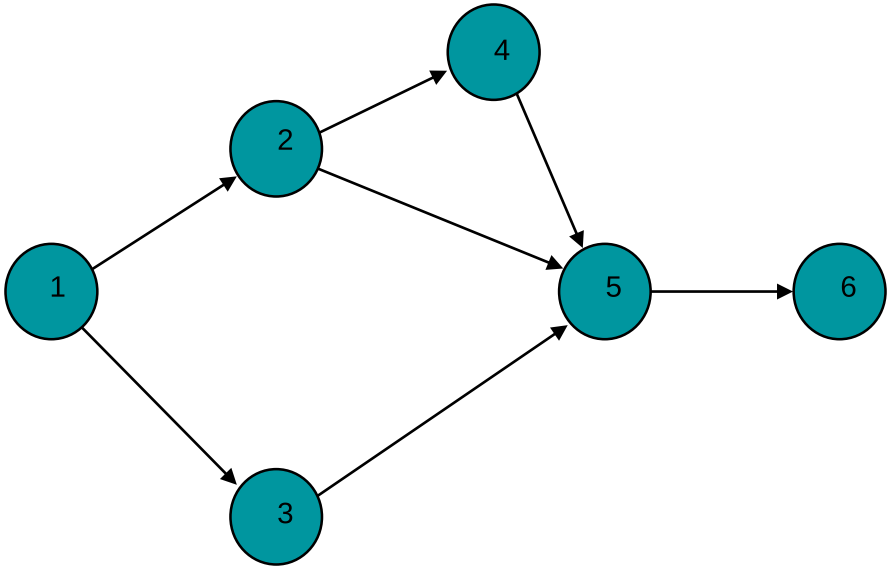


Critical Path And Slack Times For Milwaukee Paper



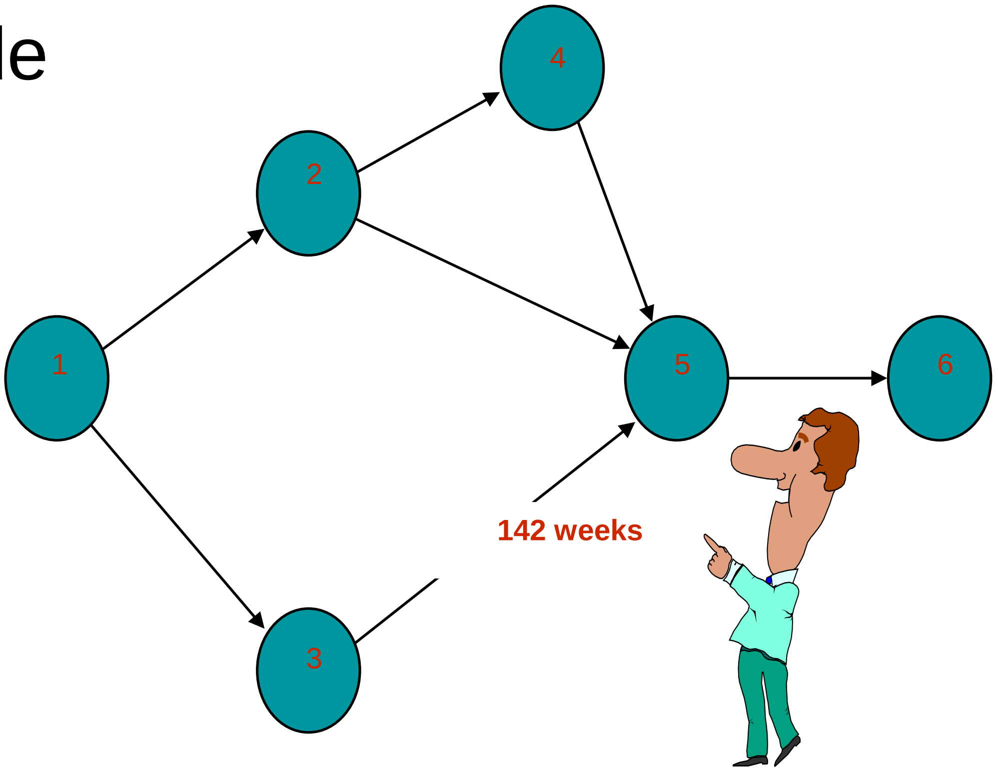
Advantages of PERT

- Forces managers to organize
- Provides graphic display of activities
- Identifies
  - Critical activities
  - Slack activities



Limitations of PERT

- Important activities may be omitted
- Precedence relationships may not be correct
- Estimates may include a fudge factor
- May focus solely on critical path



Goldratt’s Critical Chain

- Goldratt’s insight on project management
  - Time estimates are often pessimistic
  - Activities finished ahead of schedule often go unreported
  - With multiple projects, resources needed for one project may be in use on another

Project Activity Variance

Activity	Optimistic	Most Likely	Pessimistic	Variance
A	2	4	6	0.44
B	3	7	10	1.36
C	2	3	5	0.25
D	4	7	9	0.69
E	12	16	20	1.78
F	2	5	8	1.00
G	2	2	2	0.00
H	2	3	4	0.11
I	2	3	5	0.25
J	2	4	6	0.44
K	2	2	2	0.00

Variances of Each Path through the Network

Path Number	Activities on Path	Path Variance (weeks)
1	A,B,D,E,G,H,J,k	4.82
2	A,B,D,E,G,I,J,K	4.96
3	A,C,F,G,H,J,K	2.24
4	A,C,F,G,I,J,K	2.38

Calculating the Probability of Completing the Project in Less Than a Specified Time

- **When you know:**
  - The expected completion time
  - Its variance
- **You can calculate the probability of completing the project in “X” weeks with the following formula:**

$$\mathbf{z} = \frac{\text{specified time} - \text{path expected finish time}}{\text{path standard deviation}} = \left(\frac{D_T - EF_P}{\sqrt{\sigma_P^{\,2}}} \right)$$

Where D_T **= the specified project completion time**

EF_P **= the expected completion time of the path**

$\sigma_P^{\,2} = \text{variance of path}$

Example: Calculating the probability of finishing the project in 48 weeks

- Use the z values in Appendix B to determine probabilities
- E.G. for path 1

$$z = \left(\frac{48 \text{ weeks} - 44.66 \text{ weeks}}{\sqrt{4.82}} \right) = 1.52$$

Path Number	Activities on Path	Path Variance (weeks)	z-value	Probability of Completion
1	A,B,D,E,G,H,J,k	4.82	1.5216	0.9357
2	A,B,D,E,G,I,J,K	4.96	1.4215	0.9222
3	A,C,F,G,H,J,K	2.24	16.5898	1.000
4	A,C,F,G,I,J,K	2.38	15.9847	1.000

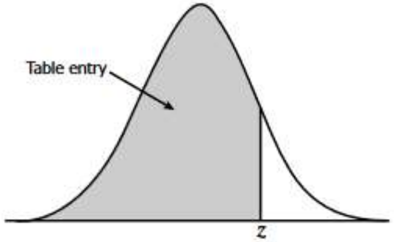


Table entry for z is the area under the standard normal curve to the left of z.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

Project Management Software

- Computer aided design (CAD)
- Groupware (Lotus Notes)
- CA Super Project
- Harvard Total Manager
- MS Project
- Sure Track Project Manager
- Time Line

Project Risk Management

- Risk: occurrence of events that have undesirable consequences
  - Delays
  - Increased costs
  - Inability to meet specifications
  - Project termination

Risk Management

- Identify potential risks
- Analyze and assess risks
- Work to minimize occurrence of risk
- Establish contingency plans

Summary

- Projects are a unique set of activities
- Projects go through life cycles
- PERT and CPM are two common techniques
- Network diagrams
- Project management software available