# Software Engineering

# Project Scheduling and Tracking

- Why project scheduling
  - Interdependency
    - Relation among tasks
    - Output of a task may be input of another task
  - Assessing progress
- Root causes of late delivery of a software
  - Unrealistic deadline
    - Established by someone outside the software development group
    - Forced to the group
  - Changing customer requirements
    - Schedule not changed
  - Underestimating the effort, resources required
  - Unconsidered risks
  - Technical difficulties
    - Could not be foreseen in advance
  - Human difficulties
    - Could not be foreseen in advance
  - Miscommunication among project staff
    - Results in delay

# Project Scheduling and Tracking

- Root causes of late delivery of a software
  - Failure by project management
    - Project is falling behind schedule
    - Lack of action to correct the problem
- Basic principles of project scheduling
  - Compartmentalization
    - Project is compartmentalized into a number of manageable activities and tasks
    - Product and process are decomposed
  - Interdependency
    - Interdependency among each task must be determined
    - Sequential
    - Parallel
  - Time allocation
    - Allocating some number of work units
    - Assigning start date and completion date
  - Effort validation
  - Defined responsibilities
    - Assigning tasks to specific team members

# Project Scheduling and Tracking

- Basic principles of project scheduling
  - Defined outcomes
    - Work products
  - Defined milestones
- Degree of rigor
  - Casual
    - Process framework activities
    - Minimum task set
    - Minimized umbrella activities
    - Reduced documentation requirements
  - Structured
    - Process framework activities
    - Umbrella activities necessary to ensure high quality
    - Streamlined documentation
  - Strict
    - Full process
    - All umbrella activities
  - Quick reaction
    - Emergency situation
    - Only tasks essential to maintain good quality

# Project Scheduling and Tracking

- Defining a task network/activity network
  - Graphic representation of the task flow for a project
  - Depicts major software engineering tasks

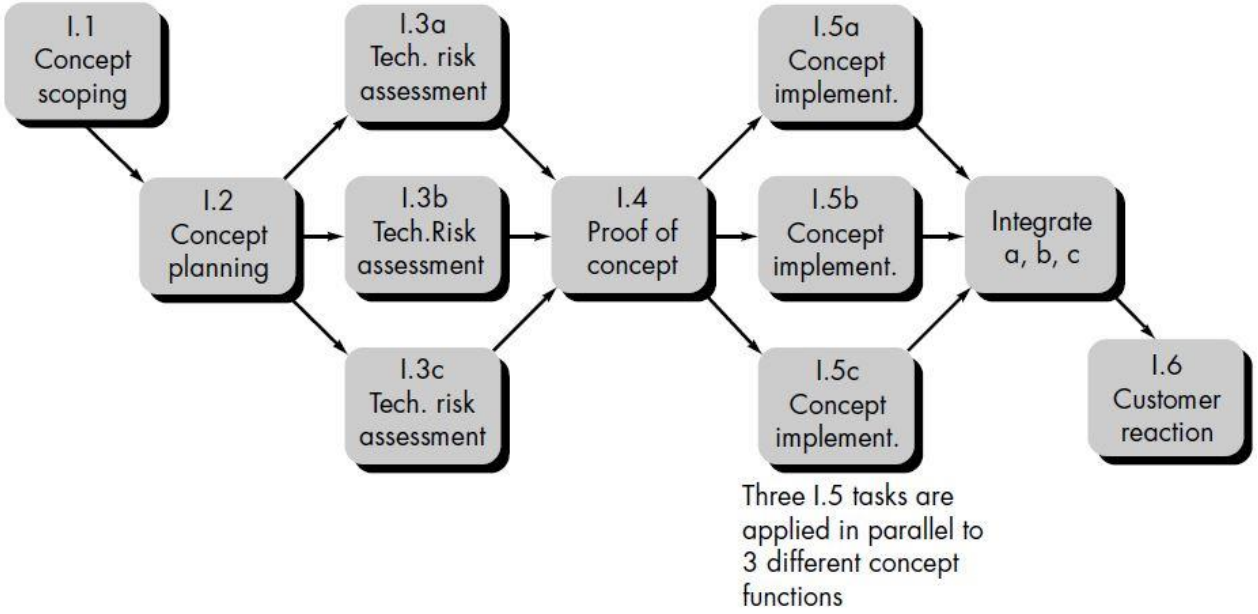


Figure 1: A task network for concept development

# Project Scheduling and Tracking

- Timeline chart/Gantt chart

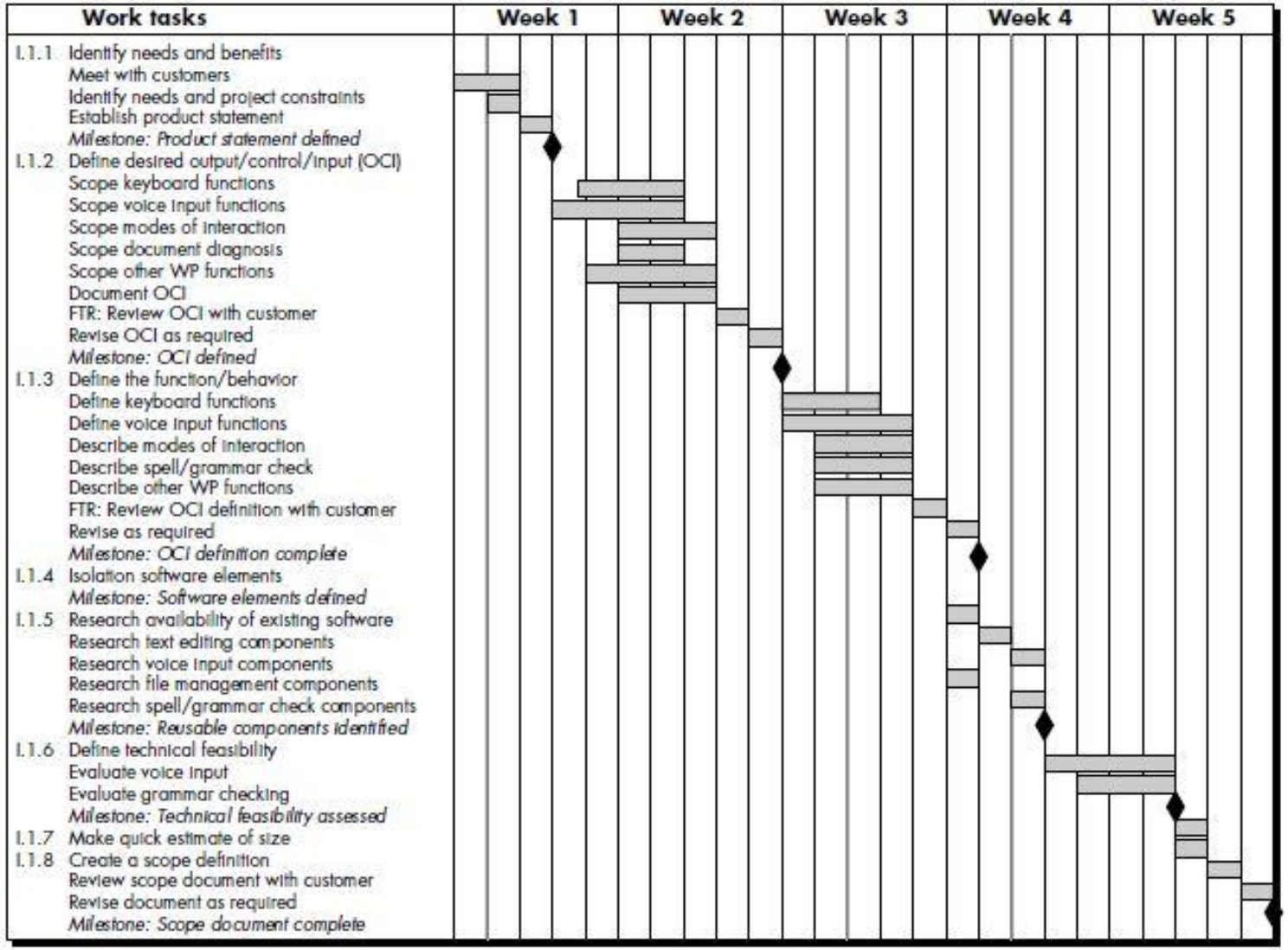


Figure 2: An example timeline chart

# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Unique Start (tail)
  - Unique End (head)

| Activity | Immediate Predecessor(s) | Duration (Months) |
|---|---|---|
| A | --- | 2 |
| B | --- | 5 |
| C | --- | 4 |
| D | B | 5 |
| E | A | 7 |
| F | A | 3 |
| G | B | 3 |
| H | C,D | 6 |
| I | C,D | 2 |
| J | E | 5 |
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https://www.youtube.com/watch?v=vUMGvpsb8dc&ab_channel=KauserWise

# Project Scheduling and Tracking

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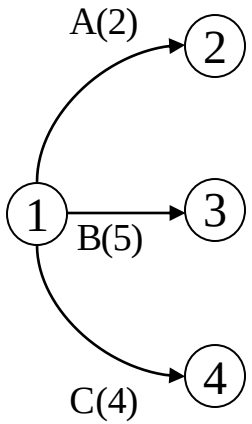


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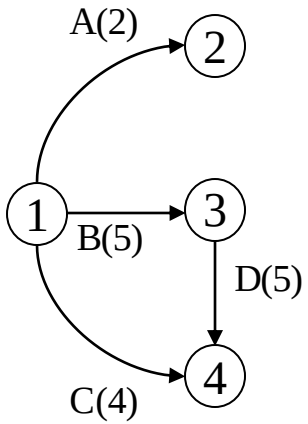


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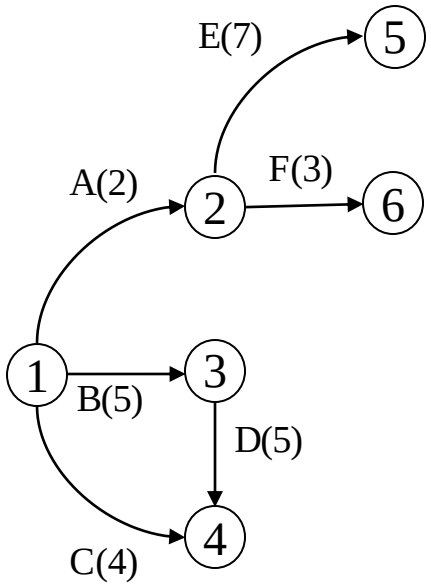


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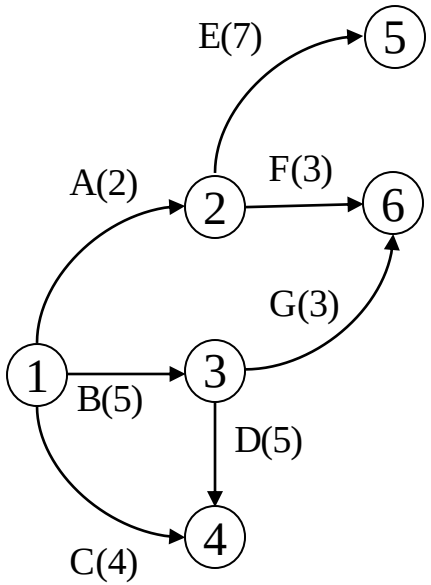


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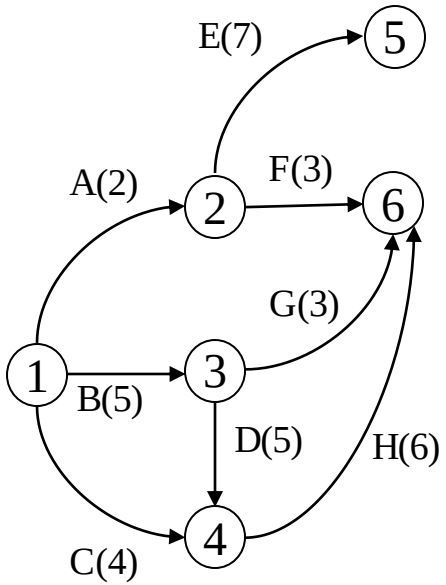


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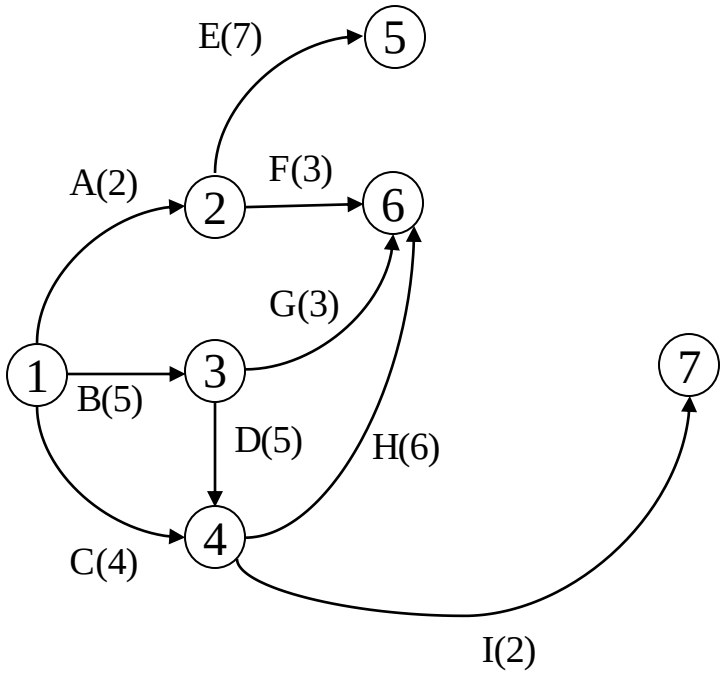


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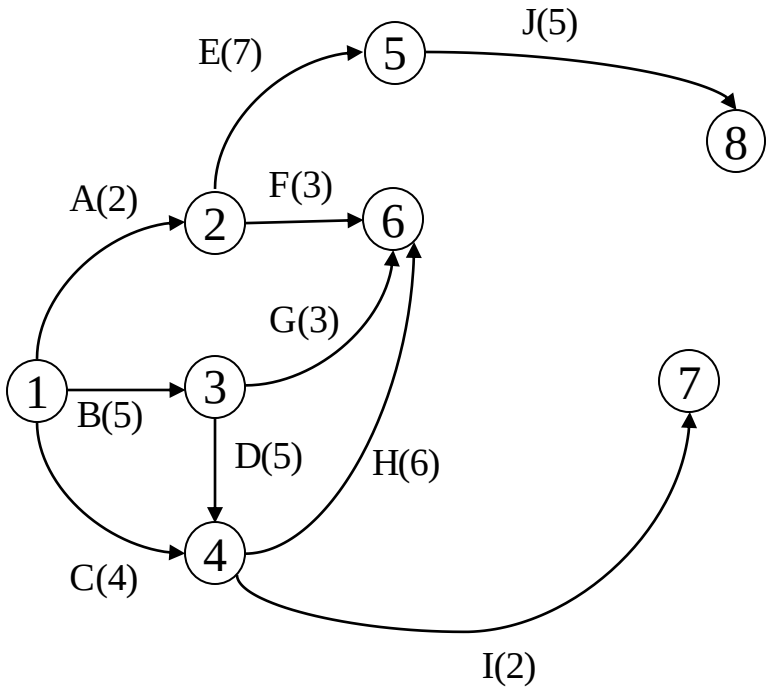


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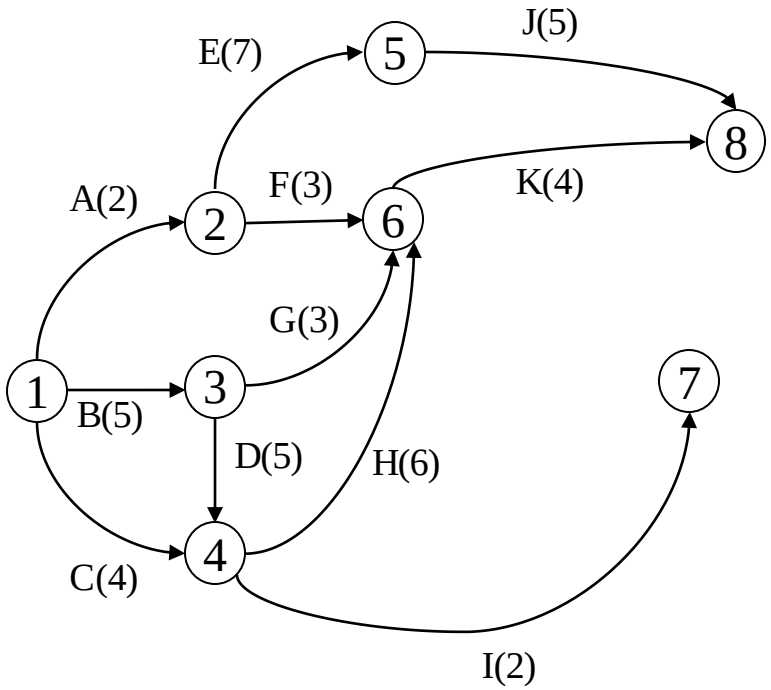


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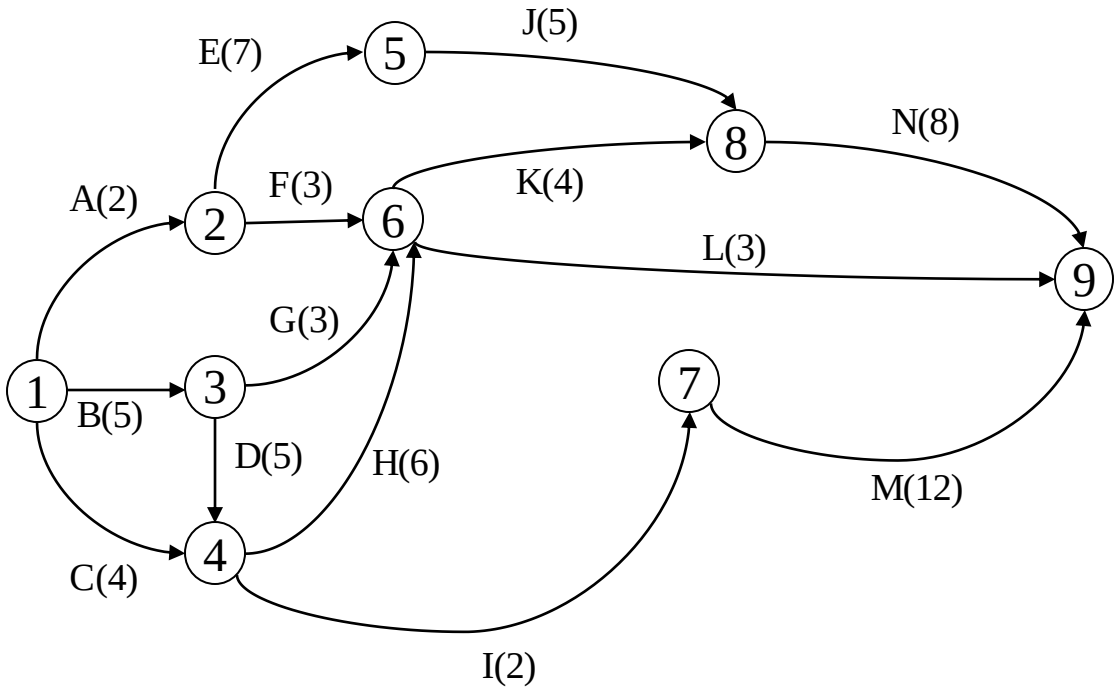


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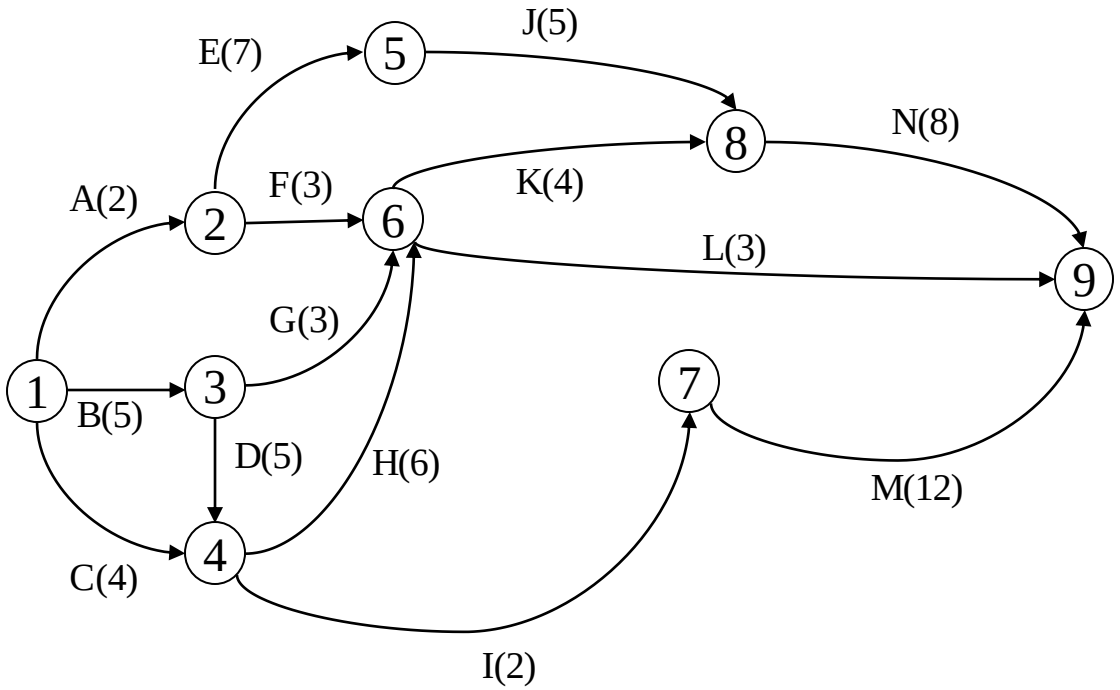


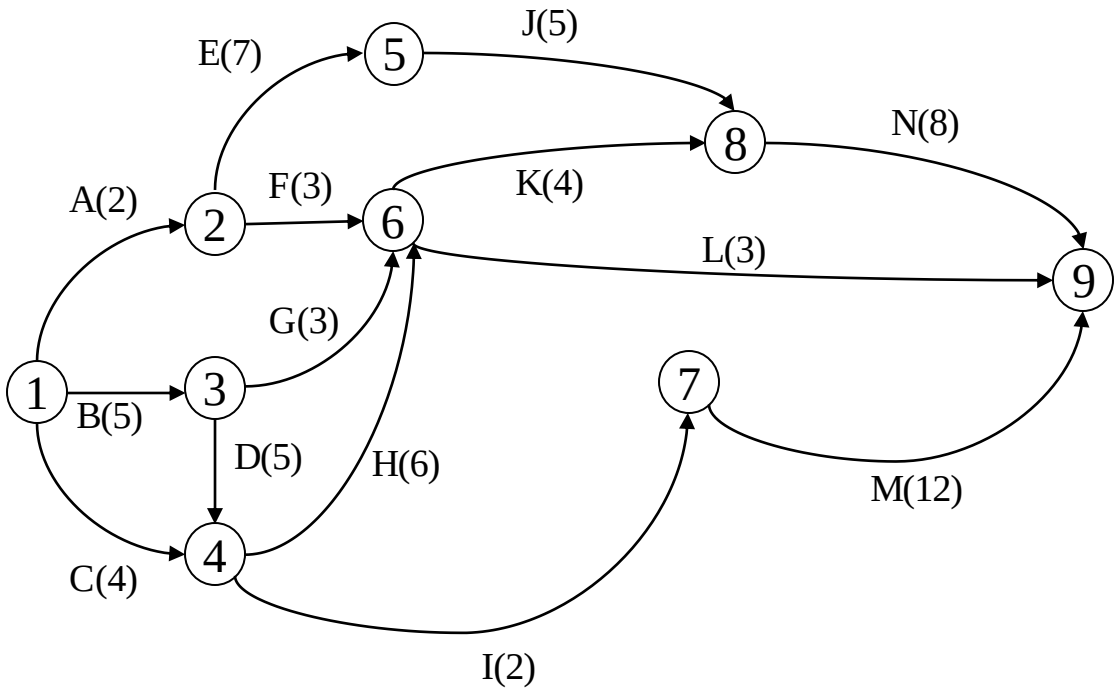

Figure 3: CPM Network

https://www.youtube.com/watch?v=vUMGvpsb8dc&ab_channel=KauserWise

# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Critical Path
    - Longest distance between start and end
    - Earliest Start time (ES) [forward pass]
      - $ES_j = Max_i(ES_i + D_{ij})$
    - Latest Completion time (LC) [backward pass]
      - $LC_i = Min_j(LC_j - D_{ij})$

| LC |
|---|
| ES |

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# Project Scheduling and Tracking

- CPM (Critical Path Method)
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    - › Longest distance between start and end
    - › Earliest Start time (ES) [forward pass]
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|---|
| ES |

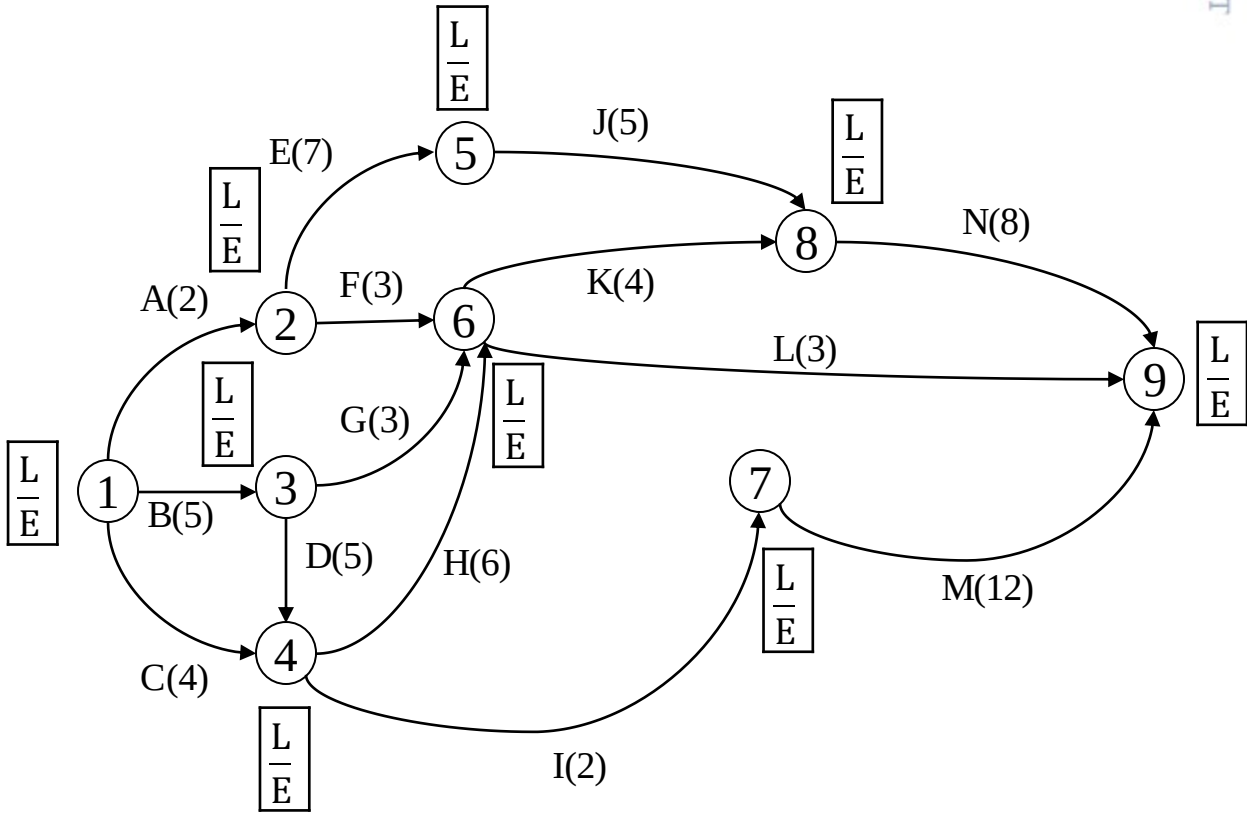



Figure 3: CPM Network

# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Critical Path
    - ES for Node 1: 0
    - ES for Node 2

      $ES = Max(0 + 2) = 2$
    - ES for Node 3

      $ES = Max(0 + 5) = 5$
    - ES for Node 4

      $ES = Max(0 + 4{,}5 + 5) = 10$
    - ES for Node 5

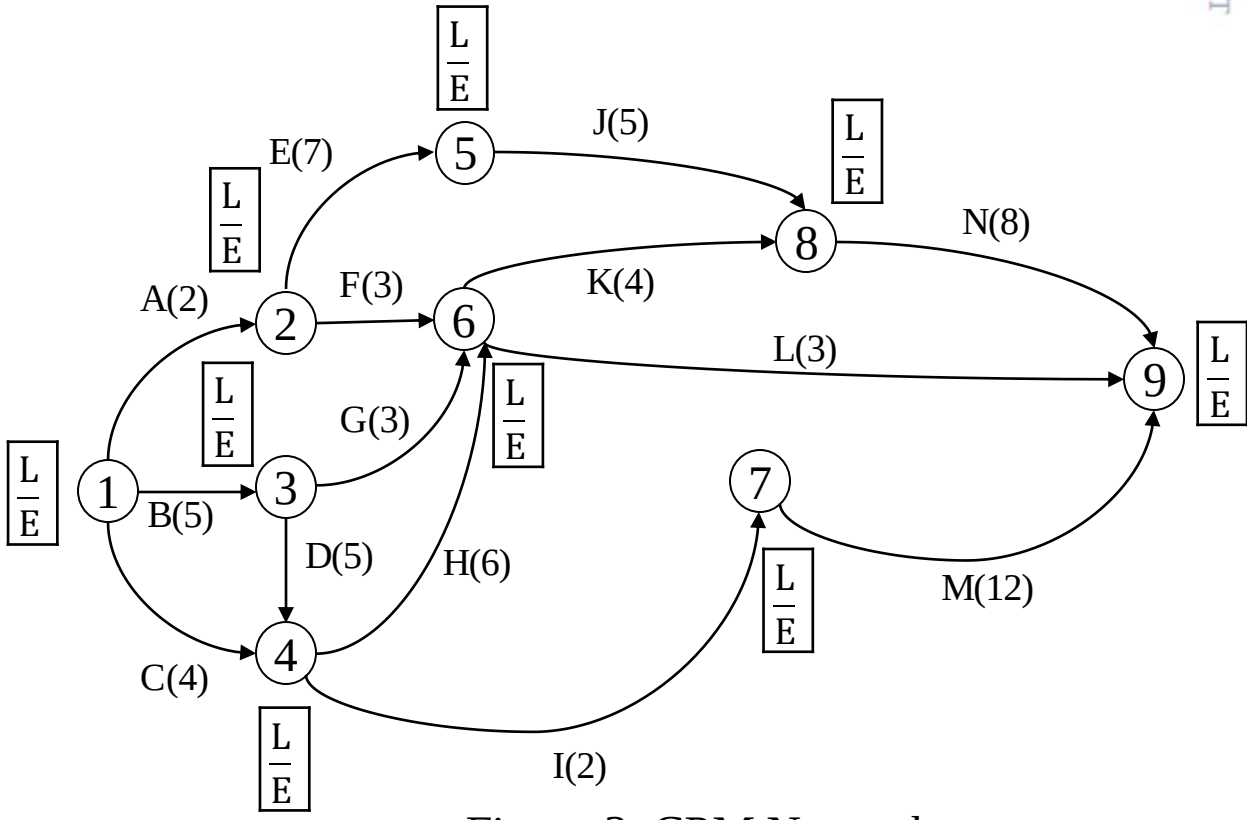
      $ES = 9$
    - ES for Node 6

      $ES = Max(3 + 2{,}3 + 5{,}6 + 10) = 16$
    - ES for Node 7

      $ES = 12$
    - ES for Node 8

      $ES = Max(5 + 9{,}4 + 16) = 20$
    - ES for Node 9

      $ES = Max(8 + 20{,}3 + 16{,}12 + 12) = 28$

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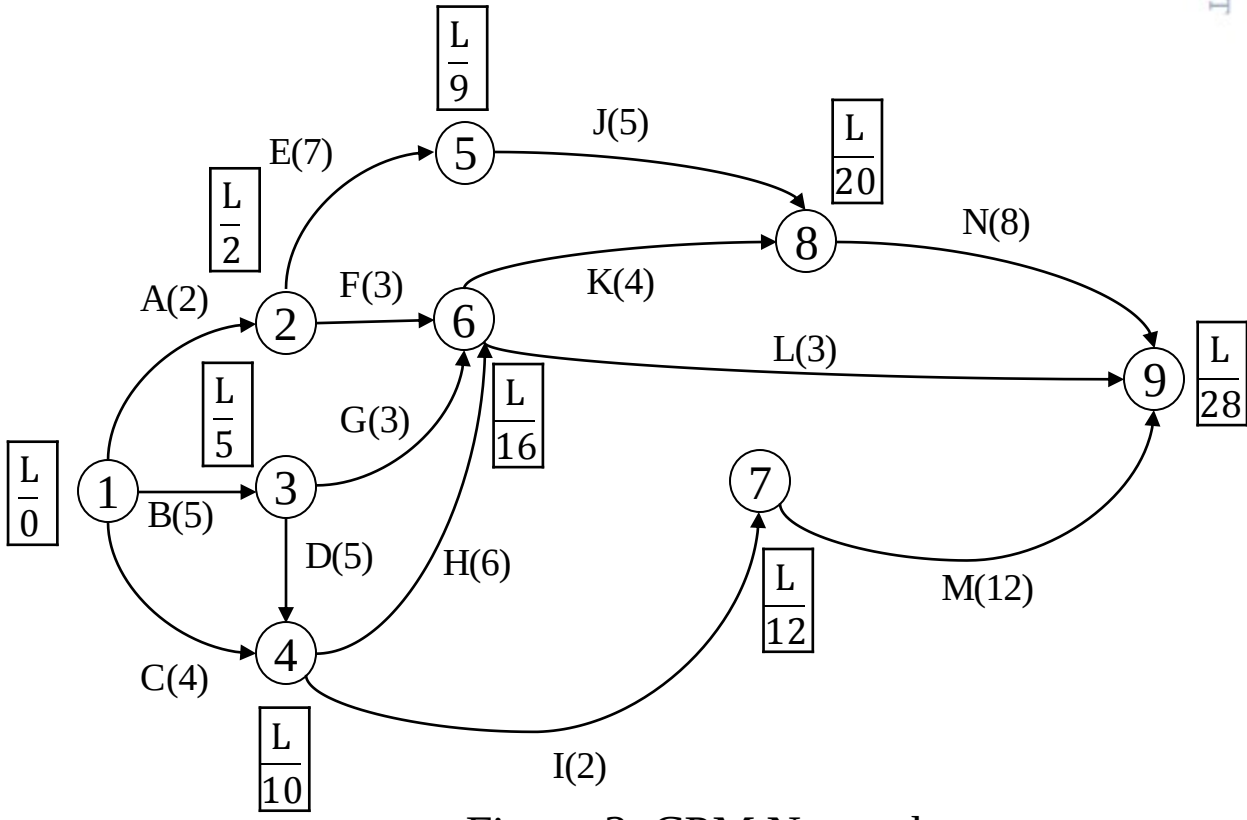



Figure 3: CPM Network

# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Critical Path
    - LC for Node 9: 28
    - LC for Node 8

      $\text{LC} = Min(28 - 8) = 20$
    - LC for Node 7

      $\text{LC} = 16$
    - LC for Node 6

      $\text{LC} = Min(20 - 4, 28 - 3) = 16$
    - LC for Node 5

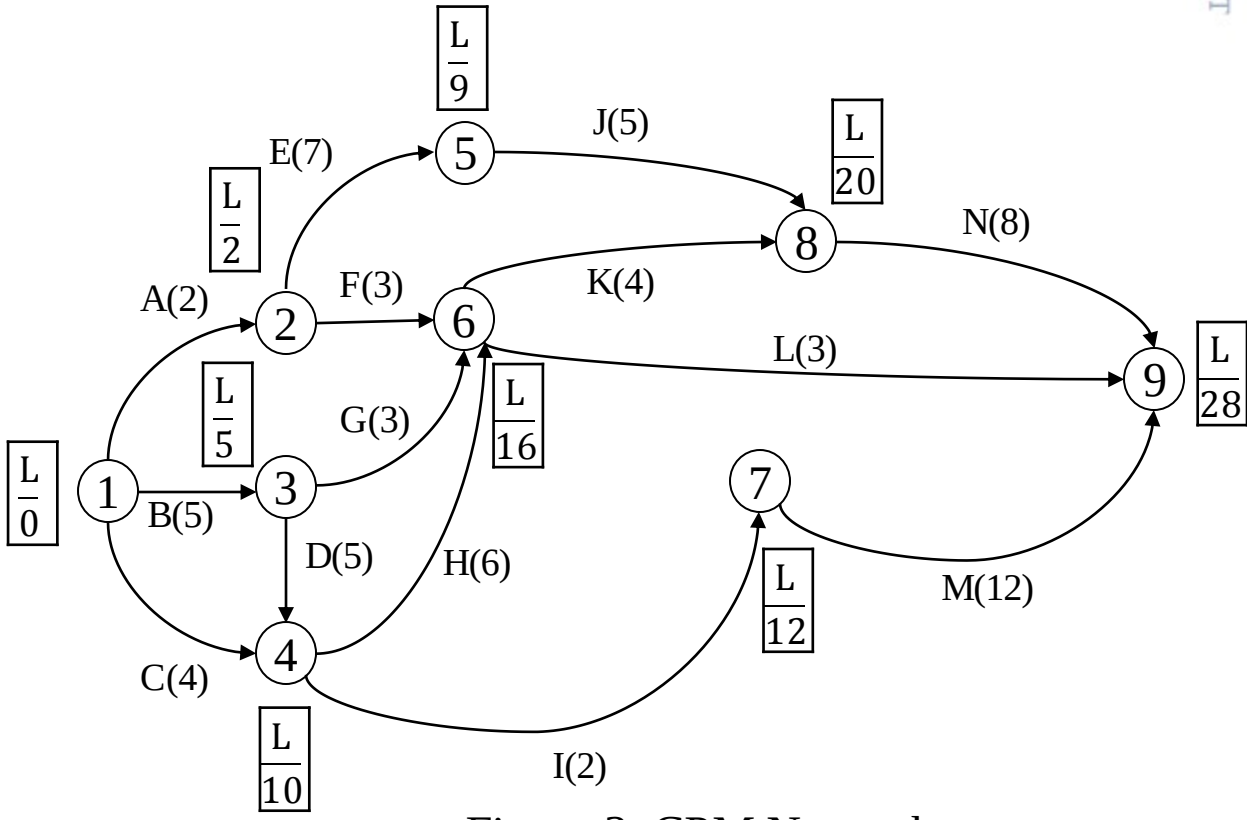
      $\text{LC} = 15$
    - LC for Node 4

      $\text{LC} = Min(16 - 6, 16 - 2) = 10$
    - LC for Node 3

      $\text{LC} = Min(16 - 3, 10 - 5) = 5$
    - LC for Node 2

      $\text{LC} = Min(15 - 7, 16 - 3) = 8$
    - LC for Node 1

      $\text{LC} = Min(8 - 2, 5 - 5, 10 - 4) = 0$

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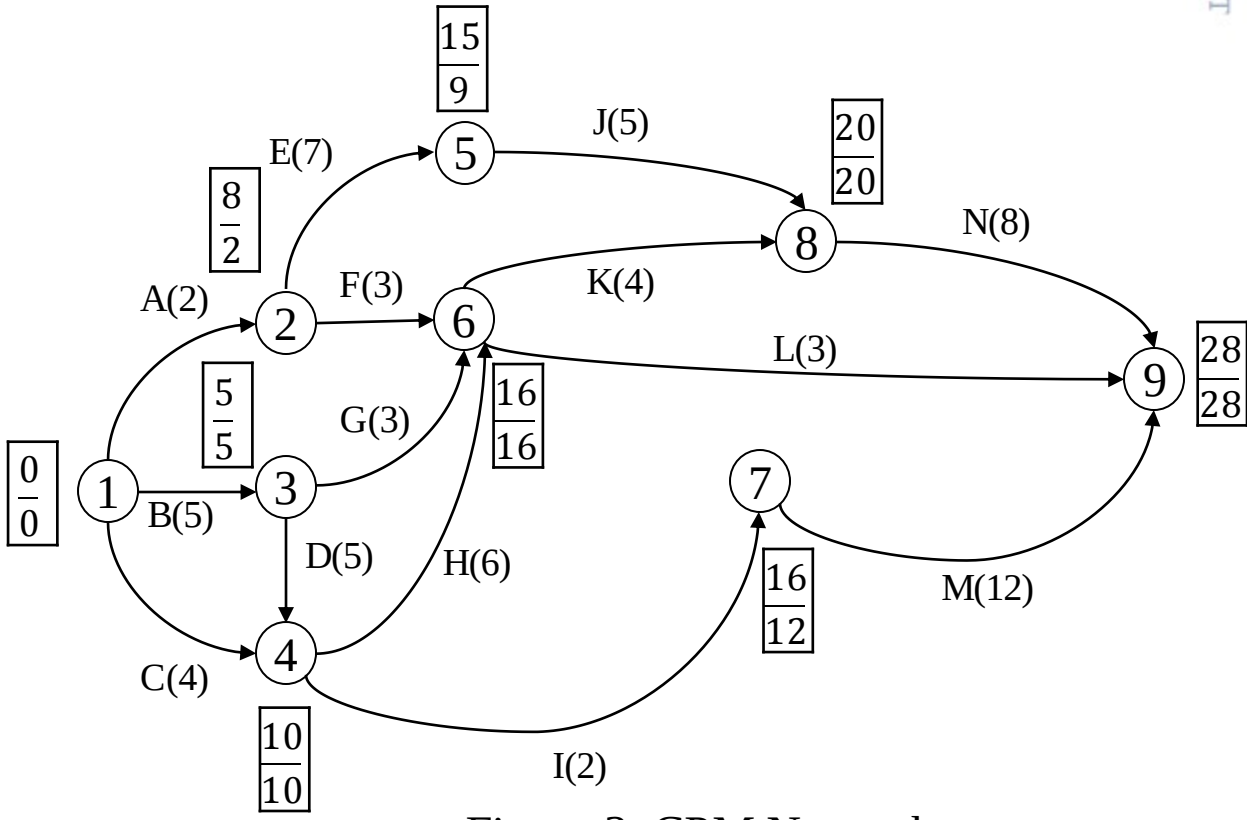


Figure 3: CPM Network

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# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Critical Path
    - $ES_i = LC_i$
    - $ES_j = LC_j$
    - $ES_j - ES_i = LC_j - LC_i = D_{ij}$

    - 1-3
    - 3-4
    - 4-6
    - 6-8
    - 8-9

    - Path
    - 1-3-4-6-8-9
    - B-D-H-K-N

    - Distance (time)
    - 5+5+6+4+8=28 months [expected project completion time]

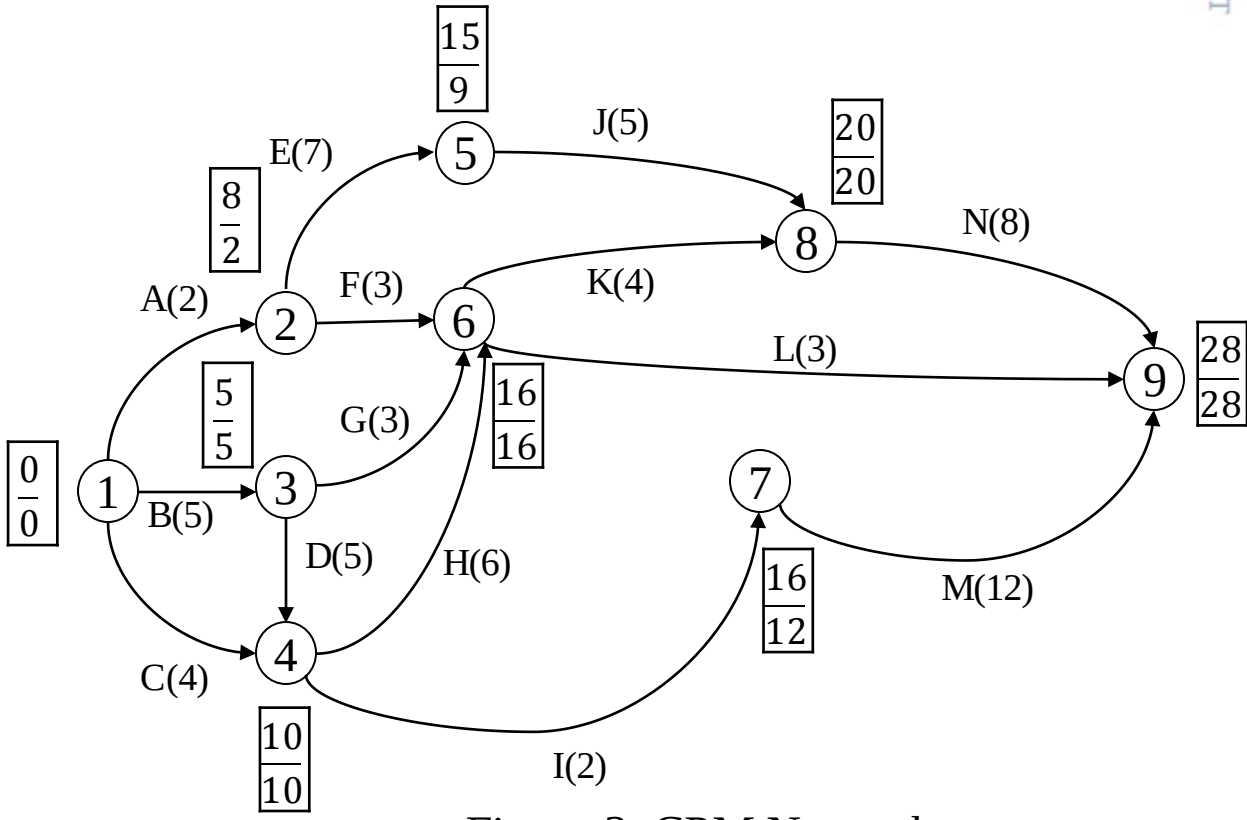


Figure 3: CPM Network

# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Total floats
    - $TF_{ij} = LC_j - ES_i - D_{ij}$
  - Free floats
    - $FF_{ij} = ES_j - ES_i - D_{ij}$

| Activity | Duration (Months) | Total Floats | Free Floats |
|---|---|---|---|
| A | 2 | 6 (8-0-2) | 0 (2-0-2) |
| B | 5 | 0 (5-0-5) | 0 (5-0-5) |
| C | 4 | 6 (10-0-4) | 6 (10-0-4) |
| D | 5 | 0 (16-10-6) | 0 (16-10-6) |
| E | 7 | 6 (15-2-7) | 0 (9-2-7) |
| F | 3 | 11 (16-2-3) | 11 (16-2-3) |
| G | 3 | 8 (16-5-3) | 8 (16-5-3) |

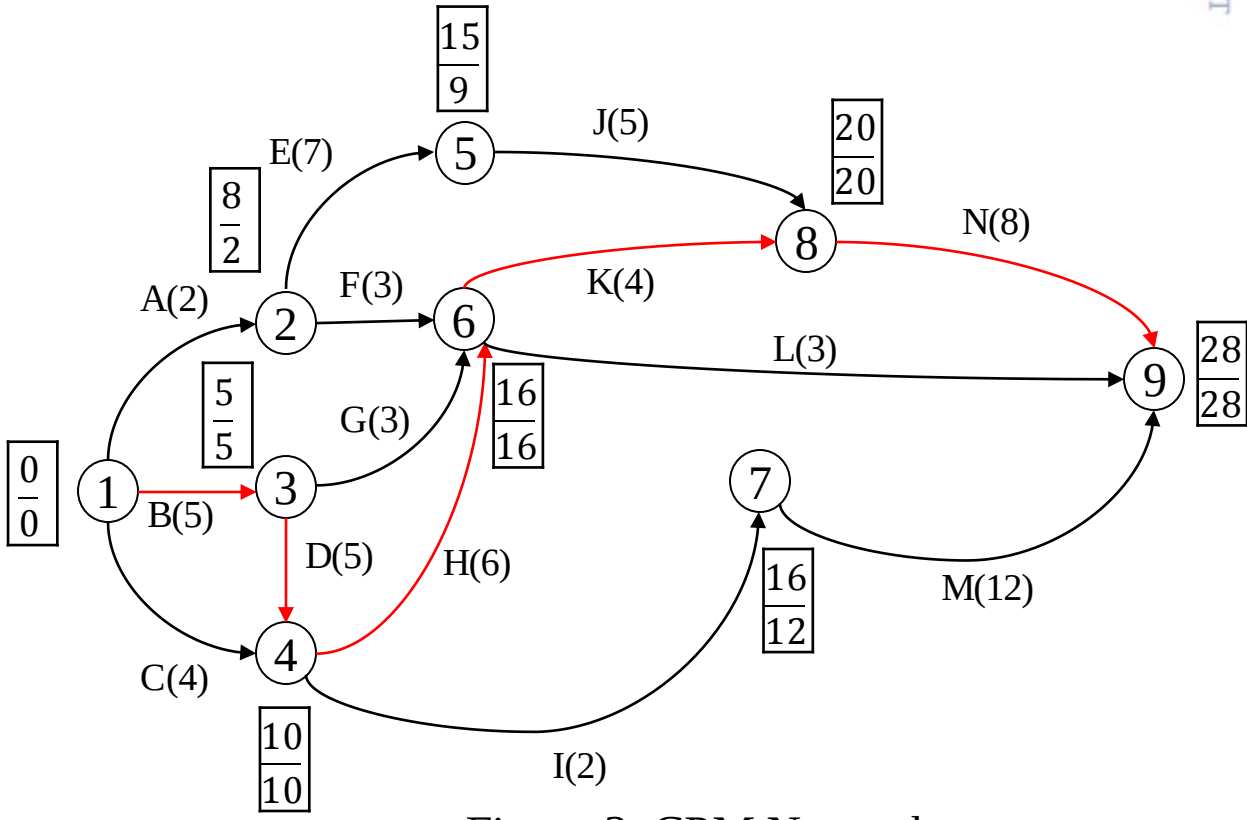


Figure 3: CPM Network

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# Project Scheduling and Tracking

- CPM (Critical Path Method)
  - Total floats
    - $TF_{ij} = LC_j - ES_i - D_{ij}$
  - Free floats
    - $FF_{ij} = ES_j - ES_i - D_{ij}$

| Activity | Duration (Months) | Total Floats | Free Floats |
|---|---|---|---|
| H | 6 | 0 (16-10-6) | 0 (16-10-6) |
| I | 2 | 4 (16-10-2) | 0 (12-10-2) |
| J | 5 | 6 (20-9-5) | 6 (20-9-5) |
| K | 4 | 0 (20-16-4) | 0 (20-16-4) |
| L | 3 | 9 (28-16-3) | 9 (28-16-3) |
| M | 12 | 4 (28-12-12) | 4 (28-12-12) |
| N | 8 | 0 (28-20-8) | 0 (28-20-8) |

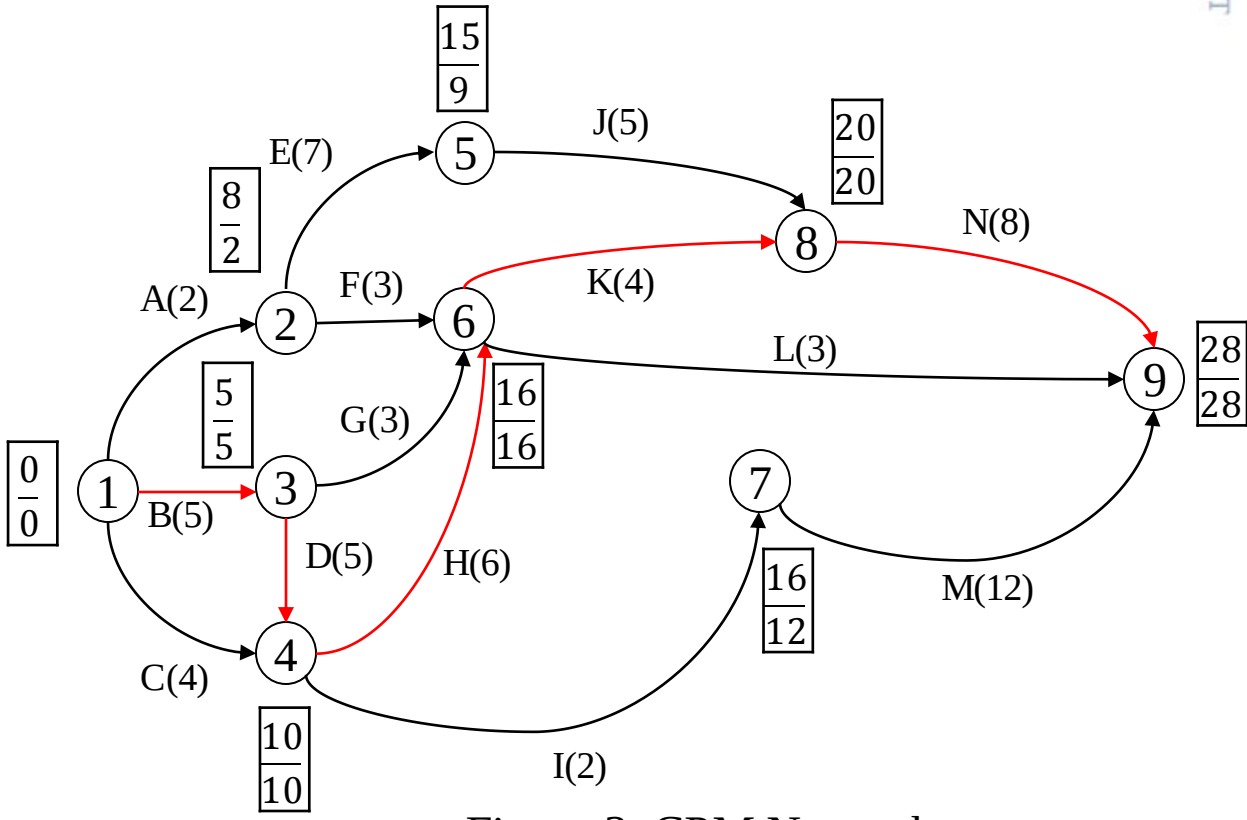


Figure 3: CPM Network



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# Project Scheduling and Tracking

- CPM (Critical Path Method)

| Activity | Duration | Total F. | Free F. |
|---|---|---|---|
| A | 2 | 6 (8-0-2) | 0 (2-0-2) |
| B | 5 | **0** (5-0-5) | **0** (5-0-5) |
| C | 4 | 6 (10-0-4) | 6 (10-0-4) |
| D | 5 | **0** (16-10-6) | **0** (16-10-6) |
| E | 7 | 6 (15-2-7) | 0 (9-2-7) |
| F | 3 | 11 (16-2-3) | 11 (16-2-3) |
| G | 3 | 8 (16-5-3) | 8 (16-5-3) |
| H | 6 | **0** (16-10-6) | **0** (16-10-6) |
| I | 2 | 4 (16-10-2) | 0 (12-10-2) |
| J | 5 | 6 (20-9-5) | 6 (20-9-5) |
| K | 4 | **0** (20-16-4) | **0** (20-16-4) |
| L | 3 | 9 (28-16-3) | 9 (28-16-3) |
| M | 12 | 4 (28-12-12) | 4 (28-12-12) |
| N | 8 | **0** (28-20-8) | **0** (28-20-8) |

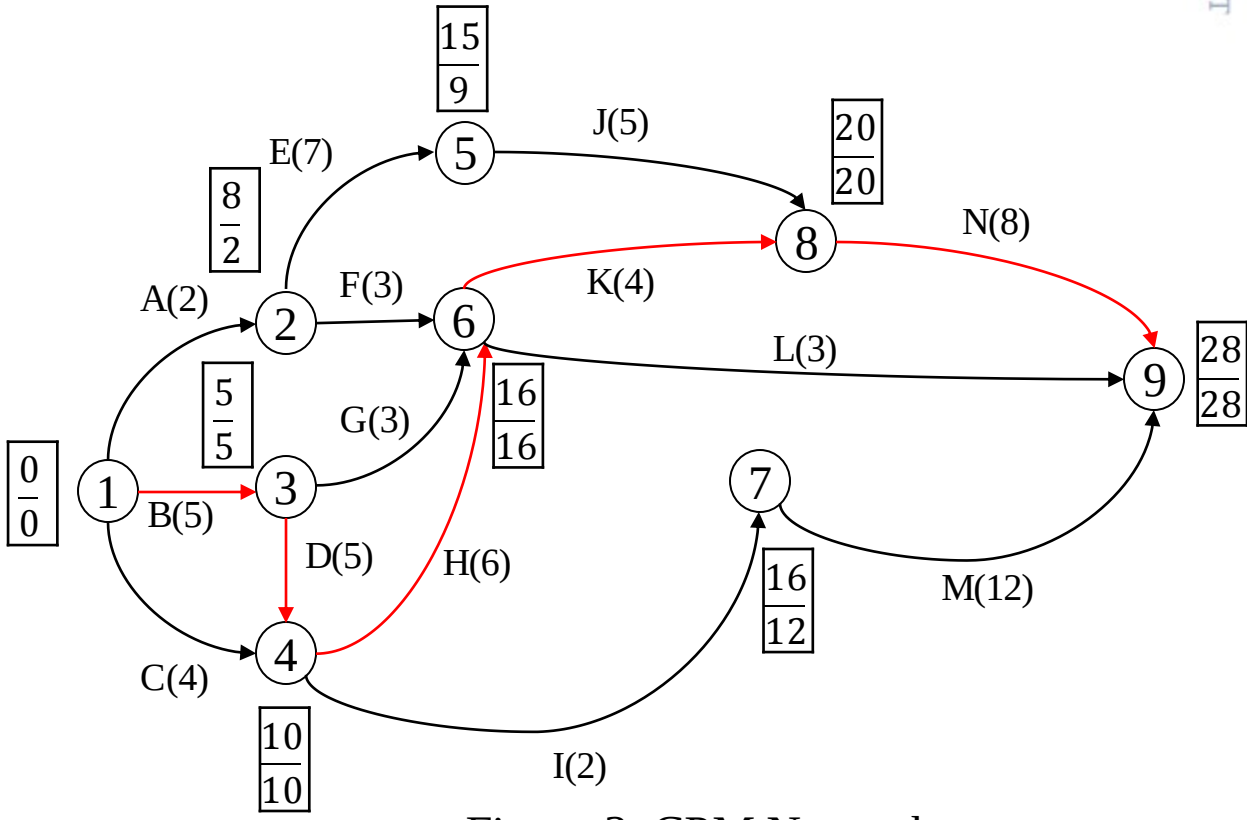



Figure 3: CPM Network

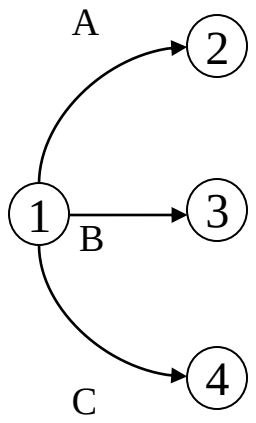


https://www.youtube.com/watch?v=vUMGvpsb8dc&ab_channel=KauserWise

# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - CPM: Each activity---One estimate
  - PERT: Each activity---Three estimates (optimistic, most likely, pessimistic)

| Activity | Immediate Predecessor(s) | Duration (Months) | | |
|---|---|---|---|---|
| | | O | M | P |
| A | --- | 5 | 6 | 7 |
| B | --- | 1 | 3 | 5 |
| C | --- | 1 | 4 | 7 |
| D | A | 1 | 2 | 3 |
| E | B | 1 | 2 | 9 |
| F | C | 1 | 5 | 9 |
| G | C | 2 | 2 | 8 |
| H | E,F | 4 | 4 | 10 |
| I | D | 2 | 5 | 8 |
| J | H,G | 2 | 2 | 8 |




https://www.youtube.com/watch?v=WrAf6zdteXI&ab_channel=KauserWise

# Project Scheduling and Tracking

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  - PERT: Each activity---Three estimates (optimistic, most likely, pessimistic)

| Activity | Immediate Predecessor(s) | Duration (Months) | | |
|---|---|---|---|---|
| | | O | M | P |
| A | --- | 5 | 6 | 7 |
| B | --- | 1 | 3 | 5 |
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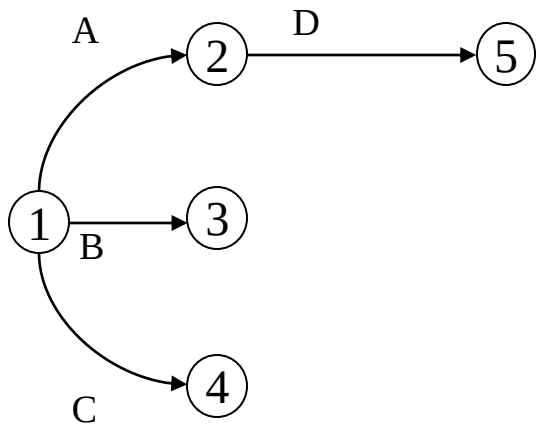


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# Project Scheduling and Tracking

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|---|---|---|---|---|
| | | O | M | P |
| A | --- | 5 | 6 | 7 |
| B | --- | 1 | 3 | 5 |
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| H | E,F | 4 | 4 | 10 |
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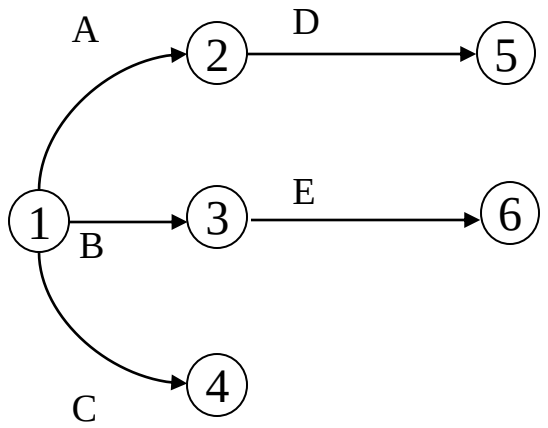


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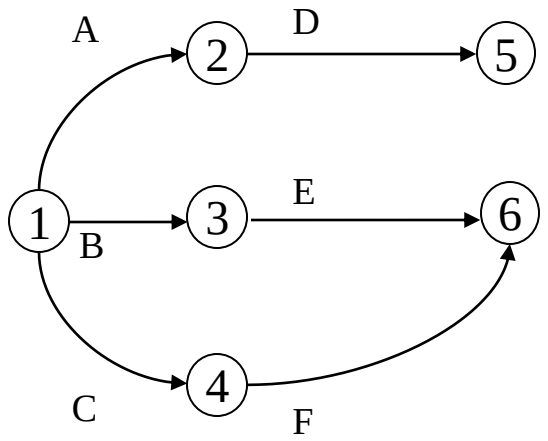


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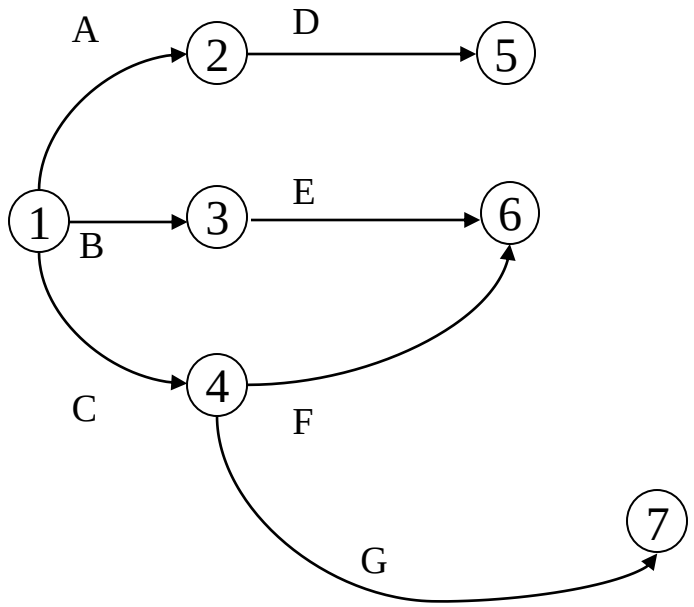


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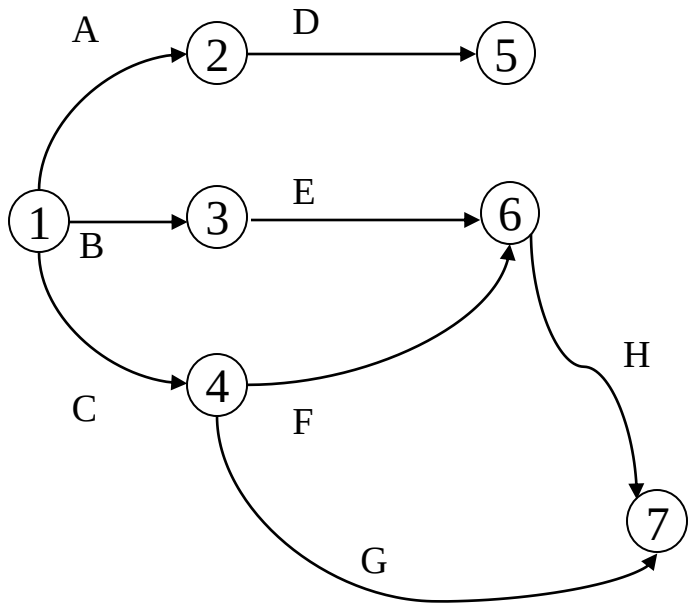
| H | E,F | 4 | 4 | 10 |
| I | D | 2 | 5 | 8 |
| J | H,G | 2 | 2 | 8 |

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# Project Scheduling and Tracking

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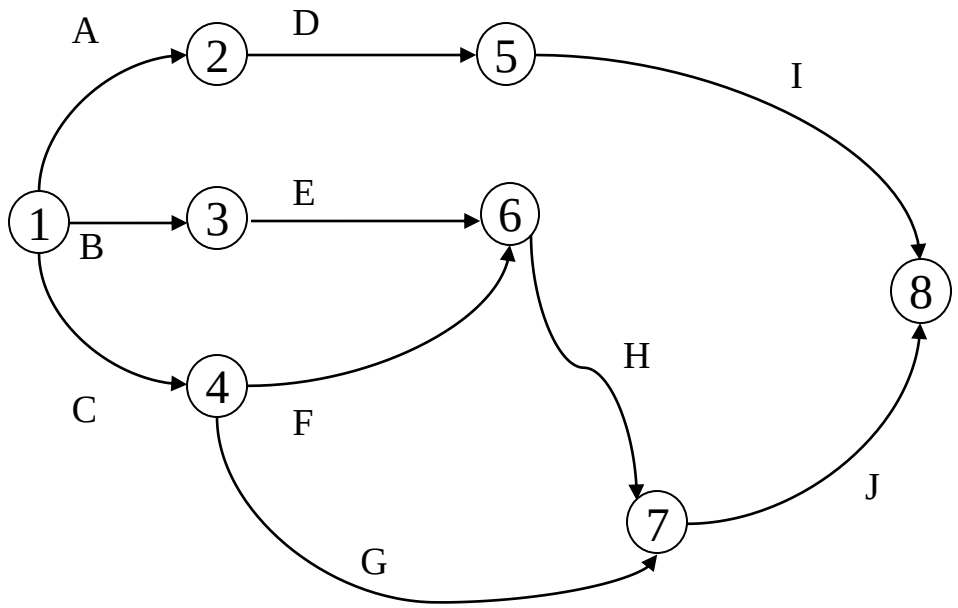


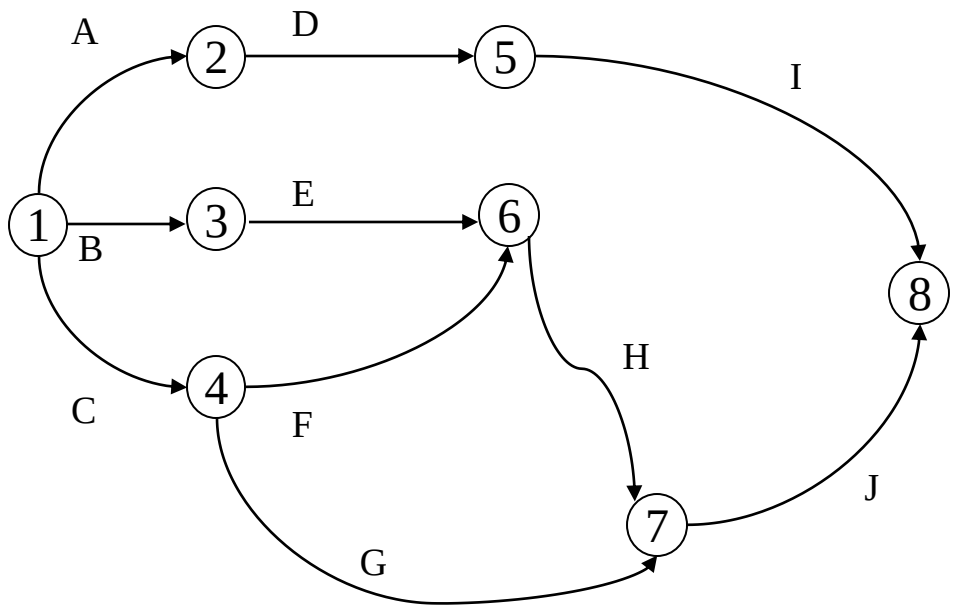

Figure 4: Project Network

https://www.youtube.com/watch?v=WrAf6zdteXI&ab_channel=KauserWise

# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Mean (expected duration): $t_e = \frac{t_0 + 4t_m + t_p}{6}$
  - Variance: $\sigma^2 = (\frac{t_p - t_0}{6})^2$

| Activity | Immediate Predecessor(s) | Duration (Months) | | | | |
|---|---|---|---|---|---|---|
| | | O | M | P | Mean | Variance |
| A | --- | 5 | 6 | 7 | 6 | 0.11 |
| B | --- | 1 | 3 | 5 | 3 | 0.44 |
| C | --- | 1 | 4 | 7 | 4 | 1.00 |
| D | A | 1 | 2 | 3 | 2 | 0.11 |
| E | B | 1 | 2 | 9 | 3 | 1.78 |
| F | C | 1 | 5 | 9 | 5 | 1.78 |
| G | C | 2 | 2 | 8 | 3 | 1.00 |
| H | E,F | 4 | 4 | 10 | 5 | 1.00 |
| I | D | 2 | 5 | 8 | 5 | 1.00 |
| J | H,G | 2 | 2 | 8 | 3 | 1.00 |

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| Activity | Immediate Predecessor(s) | Duration (Months) | | | | |
|---|---|---|---|---|---|---|
| | | O | M | P | Mean | Variance |
| A | --- | 5 | 6 | 7 | 6 | 0.11 |
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| G | C | 2 | 2 | 8 | 3 | 1.00 |
| H | E,F | 4 | 4 | 10 | 5 | 1.00 |
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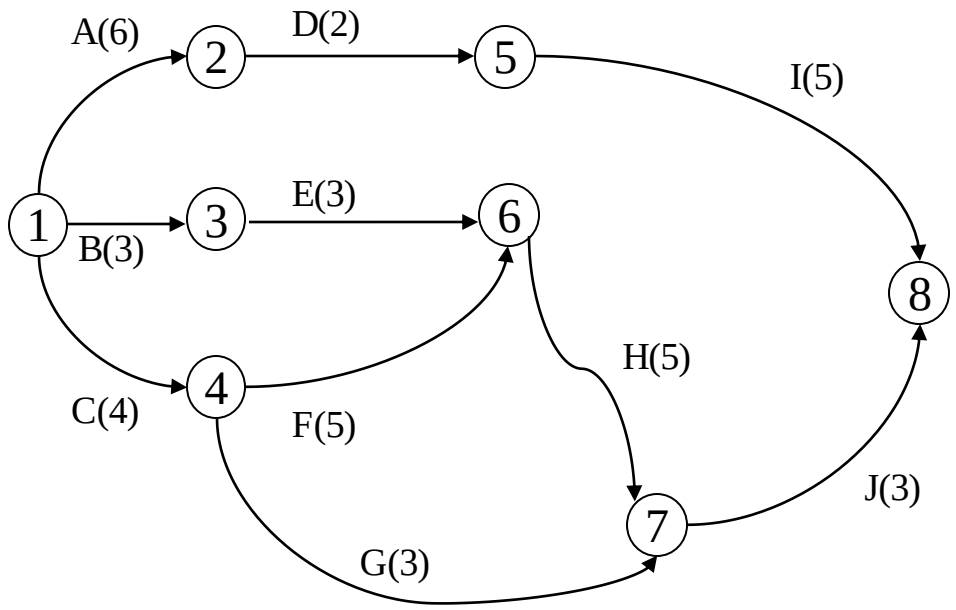


Figure 4: Project Network

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# Project Scheduling and Tracking

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  - Mean (expected duration): $t_e = \frac{t_0 + 4t_m + t_p}{6}$
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| Activity | Immediate Predecessor(s) | Duration (Months) | | | | |
|---|---|---|---|---|---|---|
| | | O | M | P | Mean | Variance |
| A | --- | 5 | 6 | 7 | 6 | 0.11 |
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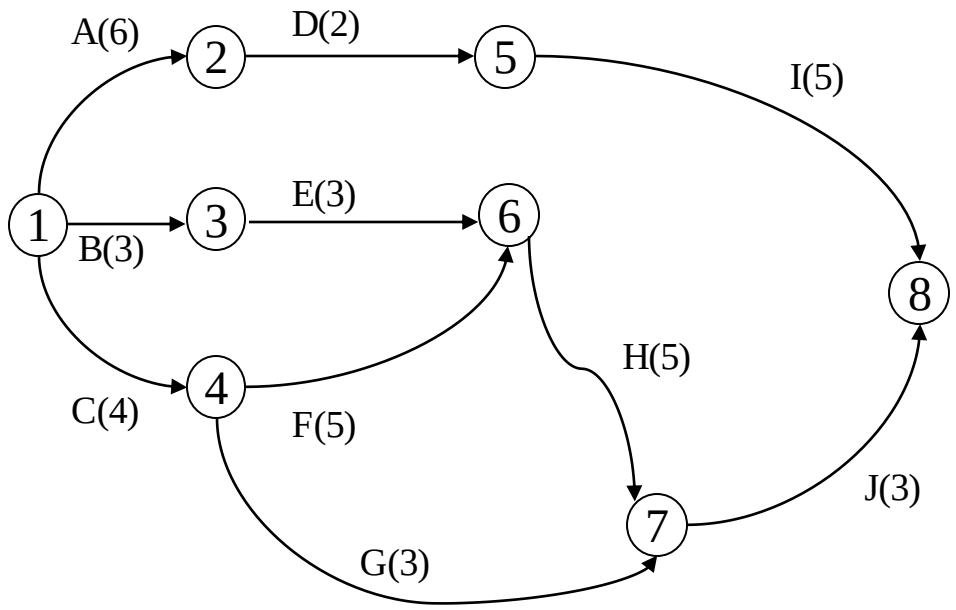
| G | C | 2 | 2 | 8 | 3 | 1.00 |
| H | E,F | 4 | 4 | 10 | 5 | 1.00 |
| I | D | 2 | 5 | 8 | 5 | 1.00 |
| J | H,G | 2 | 2 | 8 | 3 | 1.00 |

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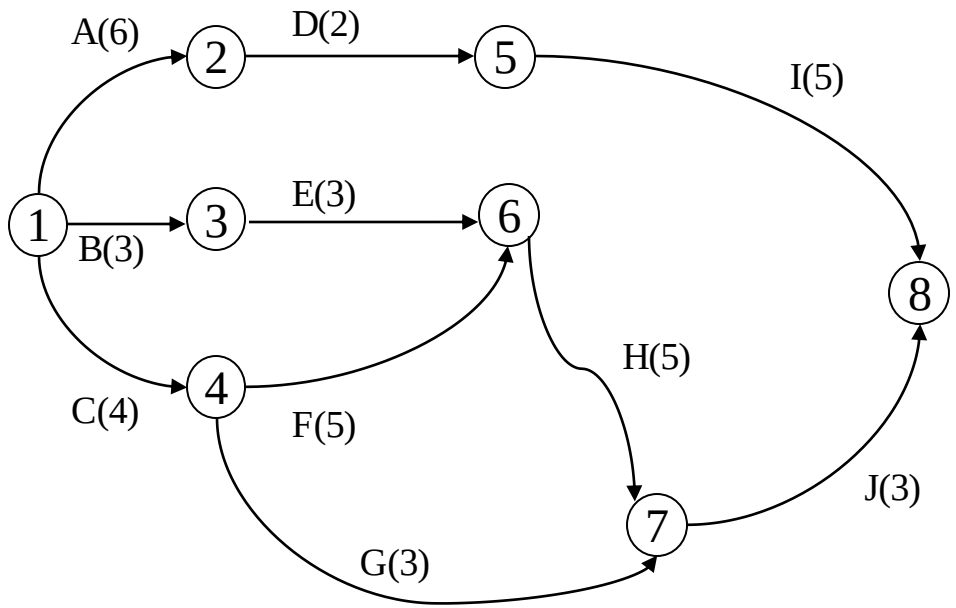
# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - Longest distance between start and end
    - Earliest Start time (ES) [forward pass]
      - $ES_j = Max_i(ES_i + D_{ij})$
    - Latest Completion time (LC) [backward pass]
      - $LC_i = Min_j(LC_j - D_{ij})$

| LC |
|---|
| ES |

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- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - Longest distance between start and end
    - Earliest Start time (ES) [forward pass]
      - $ES_j = Max_i(ES_i + D_{ij})$
    - Latest Completion time (LC) [backward pass]
      - $LC_i = Min_j(LC_j - D_{ij})$

| LC |
|---|
| ES |

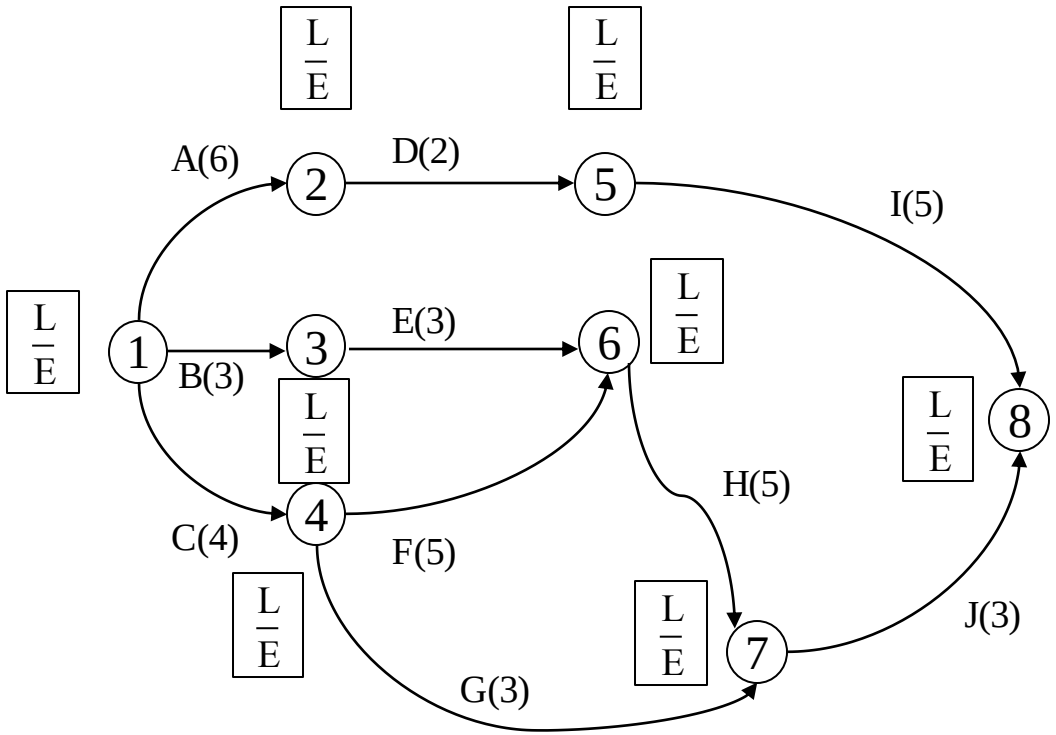


Figure 4: Project Network

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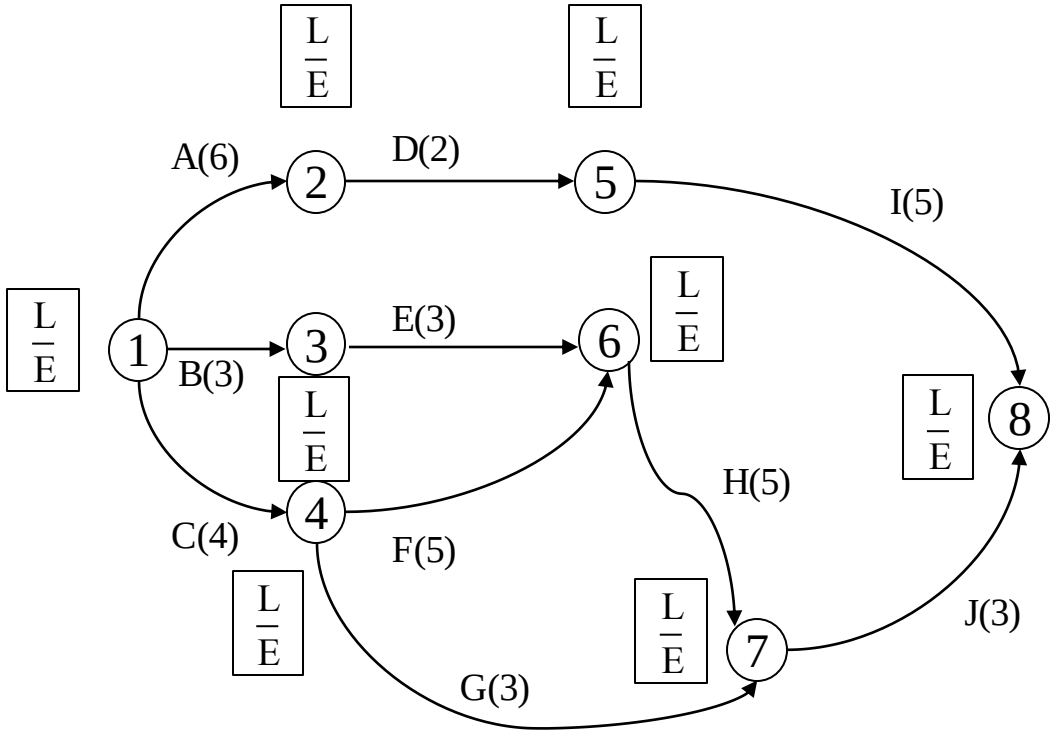
# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - ES for Node 1: 0
    - ES for Node 2: 6
    - ES for Node 3: 3
    - ES for Node 4: 4
    - ES for Node 5: 8
    - ES for Node 6: 9
    - ES for Node 7: 14
    - ES for Node 8: 17

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# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - ES for Node 1: 0
    - ES for Node 2: 6
    - ES for Node 3: 3
    - ES for Node 4: 4
    - ES for Node 5: 8
    - ES for Node 6: 9
    - ES for Node 7: 14
    - ES for Node 8: 17

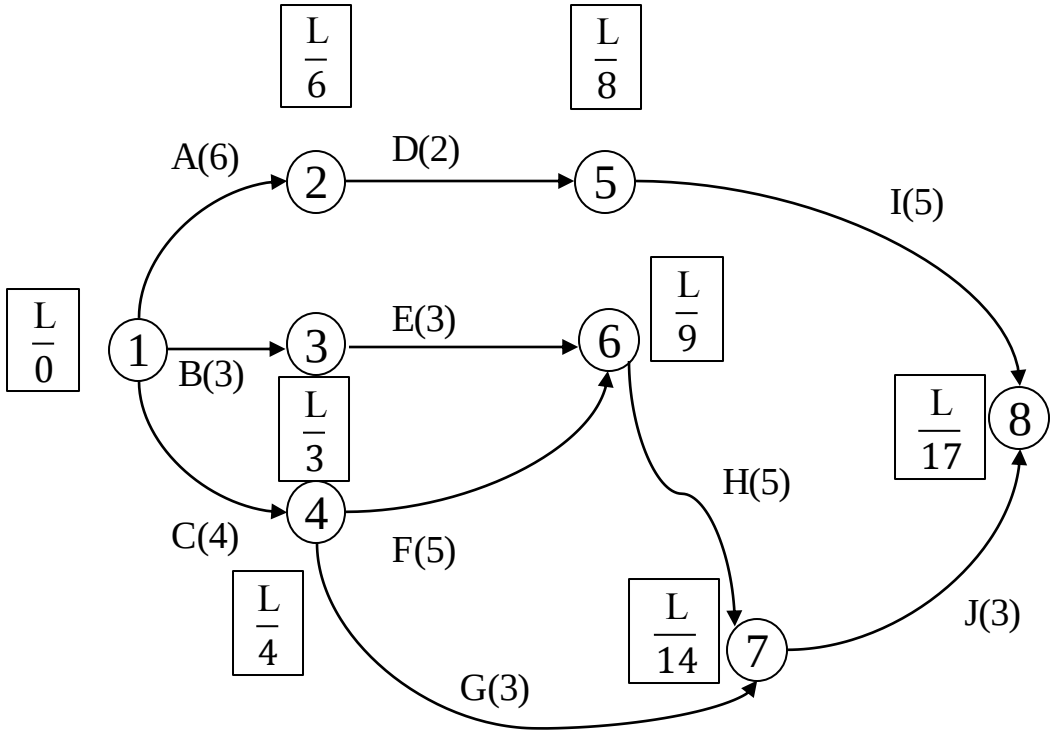


Figure 4: Project Network

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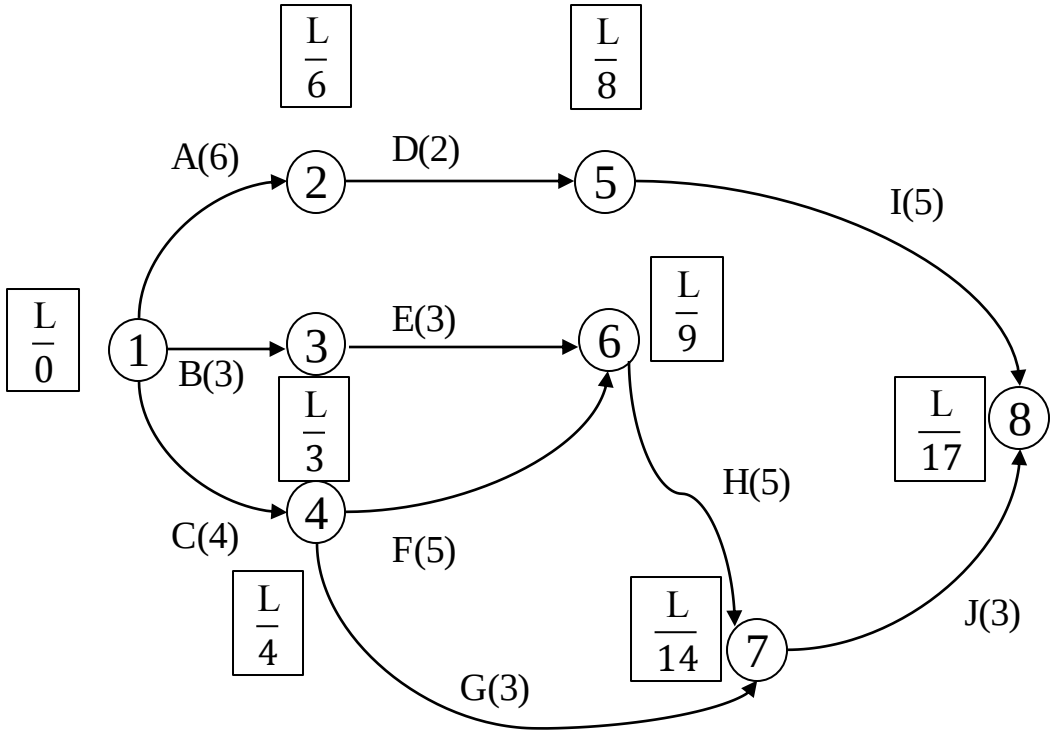
# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - LC for Node 8: 17
    - LC for Node 7: 14
    - LC for Node 6: 9
    - LC for Node 5: 12
    - LC for Node 4: 4
    - LC for Node 3: 6
    - LC for Node 2: 10
    - LC for Node 1: 0

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# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - LC for Node 8: 17
    - LC for Node 7: 14
    - LC for Node 6: 9
    - LC for Node 5: 12
    - LC for Node 4: 4
    - LC for Node 3: 6
    - LC for Node 2: 10
    - LC for Node 1: 0

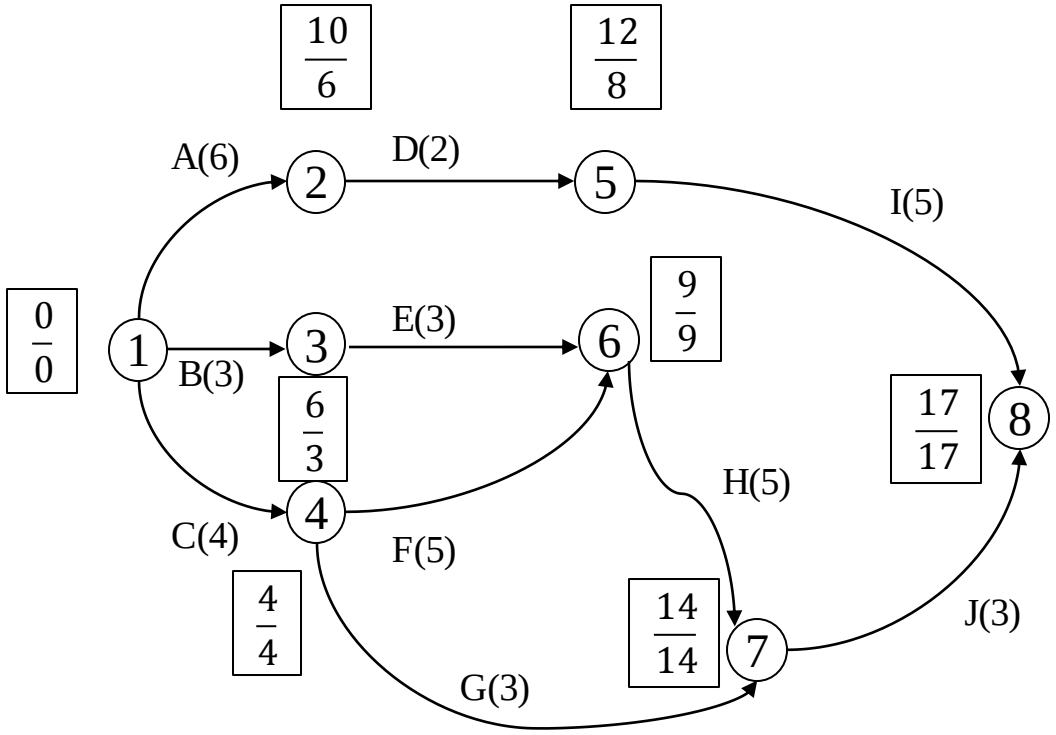


Figure 4: Project Network

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# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - $ES_i = LC_i$
    - $ES_j = LC_j$
    - $ES_j - ES_i = LC_j - LC_i = D_{ij}$

    - 1-4
    - 4-6
    - 6-7
    - 7-8

    - Path
    - 1-4-6-7-8
    - C-F-H-J

    - Distance (time)
    - 4+5+5+3=17 months [expected project completion time]

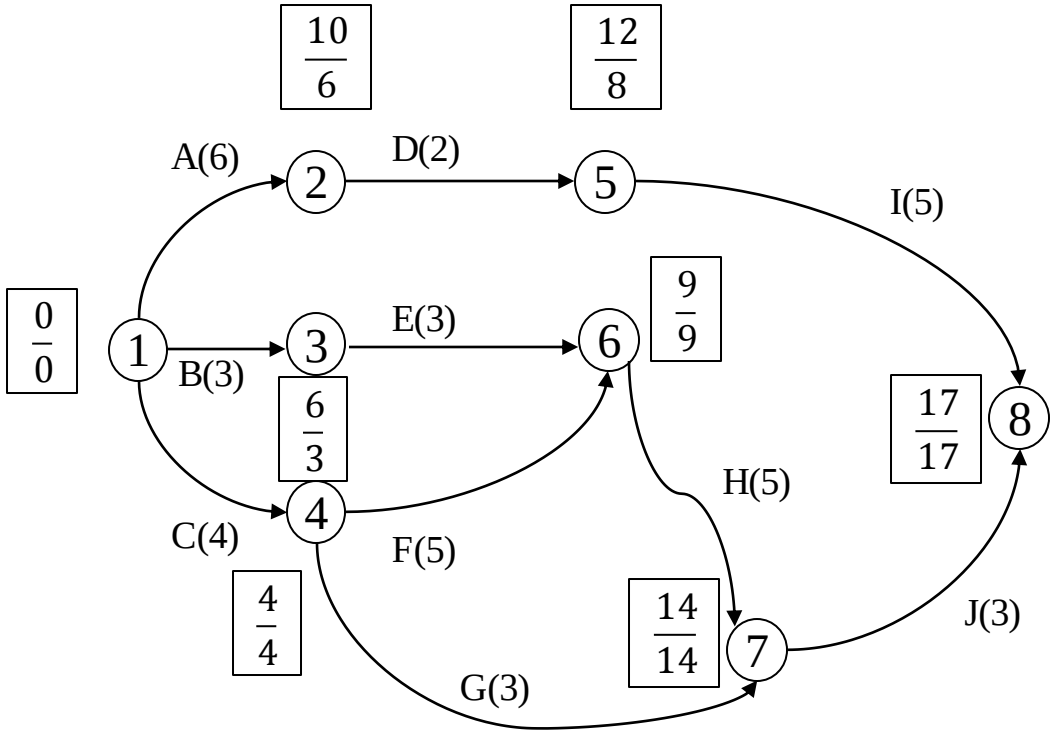


Figure 4: Project Network

https://www.youtube.com/watch?v=WrAf6zdteXI&ab_channel=KauserWise

# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Critical Path
    - C-F-H-J

→Probability of completing the work on or before 19 months

| Activity | Immediate Predecessor(s) | Duration (Months) | | | | |
|---|---|---|---|---|---|---|
| | | O | M | P | Mean | Variance |
| A | --- | 5 | 6 | 7 | 6 | 0.11 |
| B | --- | 1 | 3 | 5 | 3 | 0.44 |
| C | --- | 1 | 4 | 7 | 4 | 1.00 |
| D | A | 1 | 2 | 3 | 2 | 0.11 |
| E | B | 1 | 2 | 9 | 3 | 1.78 |
| F | C | 1 | 5 | 9 | 5 | 1.78 |
| G | C | 2 | 2 | 8 | 3 | 1.00 |
| H | E,F | 4 | 4 | 10 | 5 | 1.00 |
| I | D | 2 | 5 | 8 | 5 | 1.00 |
| J | H,G | 2 | 2 | 8 | 3 | 1.00 |
| ∑ | | | | | 17 | 4.78 |

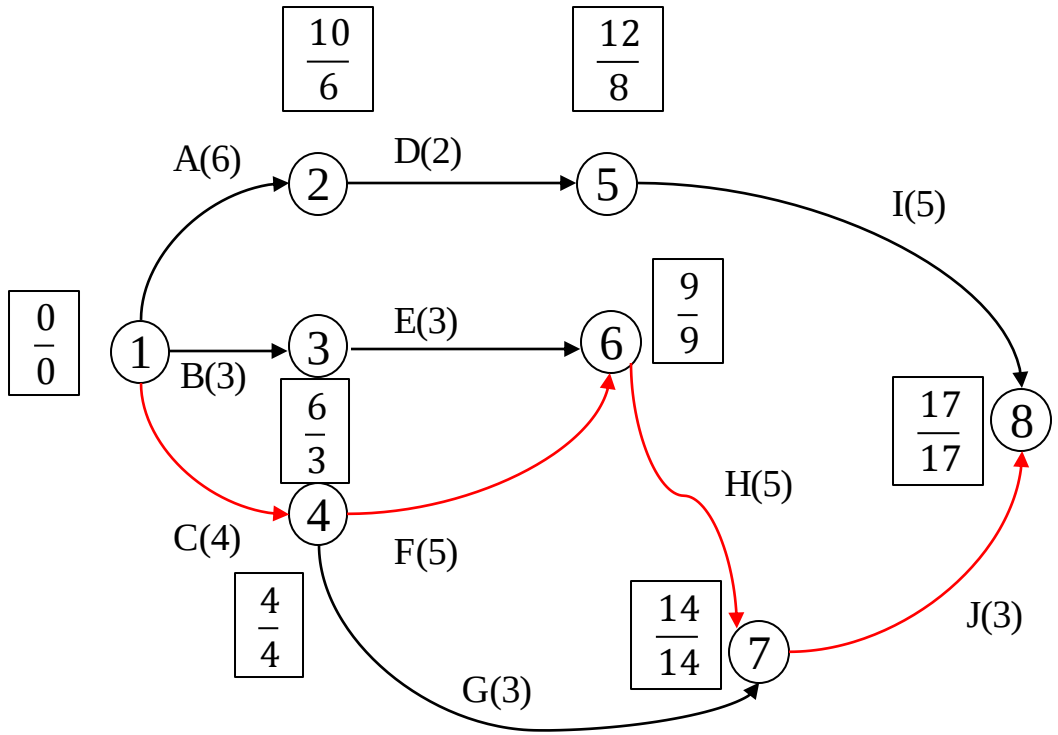


Figure 4: Project Network

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# Project Scheduling and Tracking

- PERT (Project Evaluation and Review Technique)
  - Probability of completing the work on or before 19 months
  - $P(x \leq 19) = P\left(\frac{x-\mu}{\sigma} \leq \frac{19-17}{\sqrt{4.78}}\right) = P(z \leq 0.91) = 0.3186$ [Normal distribution]
  - Probability of completing the work on or before 19 months is 31.86%

| Activity | Duration (Months) | |
|---|---|---|
| | Mean | Variance |
| C | 4 | 1.00 |
| F | 5 | 1.78 |
| H | 5 | 1.00 |
| J | 3 | 1.00 |
| ∑ | 17 | 4.78 |

| z | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.0000 | 0.0040 | 0.0080 | 0.0120 | 0.0160 | 0.0199 | 0.0239 | 0.0279 | 0.0319 | 0.0359 |
| 0.1 | 0.0398 | 0.0438 | 0.0478 | 0.0517 | 0.0557 | 0.0596 | 0.0636 | 0.0675 | 0.0714 | 0.0753 |
| 0.2 | 0.0793 | 0.0832 | 0.0871 | 0.0910 | 0.0948 | 0.0987 | 0.1026 | 0.1064 | 0.1103 | 0.1141 |
| 0.3 | 0.1179 | 0.1217 | 0.1255 | 0.1293 | 0.1331 | 0.1368 | 0.1406 | 0.1443 | 0.1480 | 0.1517 |
| 0.4 | 0.1554 | 0.1591 | 0.1628 | 0.1664 | 0.1700 | 0.1736 | 0.1772 | 0.1808 | 0.1844 | 0.1879 |
| 0.5 | 0.1915 | 0.1950 | 0.1985 | 0.2019 | 0.2054 | 0.2088 | 0.2123 | 0.2157 | 0.2190 | 0.2224 |
| 0.6 | 0.2257 | 0.2291 | 0.2324 | 0.2357 | 0.2389 | 0.2422 | 0.2454 | 0.2486 | 0.2517 | 0.2549 |
| 0.7 | 0.2580 | 0.2611 | 0.2642 | 0.2673 | 0.2704 | 0.2734 | 0.2764 | 0.2794 | 0.2823 | 0.2852 |
| 0.8 | 0.2881 | 0.2910 | 0.2939 | 0.2967 | 0.2995 | 0.3023 | 0.3051 | 0.3078 | 0.3106 | 0.3133 |
| 0.9 | 0.3159 | 0.3186 | 0.3212 | 0.3238 | 0.3264 | 0.3289 | 0.3315 | 0.3340 | 0.3365 | 0.3389 |
| 1.0 | 0.3413 | 0.3438 | 0.3461 | 0.3485 | 0.3508 | 0.3531 | 0.3554 | 0.3577 | 0.3599 | 0.3621 |

https://www.youtube.com/watch?v=WrAf6zdteXI&ab_channel=KauserWise
https://www.mathsisfun.com/data/standard-normal-distribution-table.html