# Week 9

Crashing Projects

Gantt Charts with Resources

# Recall: Project Scheduling

***Project scheduling:***

- Represents the conversion of project goals into an achievable methodology for their completion; a ***timetable*** and the ***network logic*** that relates ***project activities*** to each other in a coherent fashion
- Clearly illustrates the ***interdependence*** of all tasks and work packages
- Helps with ***master scheduling*** of organizational ***resources***
- Identification of ***critical activities*** & distinguishes them from the less critical
- Provides ***expectation*** for when the project will be ***completed*** & ***dates*** on which various project activities must ***start & end***
- Helps with ***coordination of activities*** that are dependent on each other

# Reducing the Critical Path



When might we want to accelerate a project's finish time?

- Often the TE (estimated time) for a project is not acceptable to the sponsors
- Market needs change and the completion of the project is required earlier than anticipated
- The project has slipped significantly behind schedule
- The contractual situation provides more incentive to avoid schedule slippage (e.g., late delivery penalties)

The process of accelerating a project is referred to as ***crashing***

# Crashing the project

**Primary methods for crashing:**

- Work overtime
- Allocating additional resources to specific activities (increase the quantity of resources)
- Hiring additional resources
- Incentive payments for early completion
- Improving existing resources' productivity
- Compromise quality and/or reduce project scope
- Outsourcing portions of the project to be completed within a shorter period than would have been possible if the same work was to be completed by internal resources

# Crashing the Project

- Optimize ***time/cost trade-offs***
- Shorten activities on the ***critical path***
- Cease crashing when:
  - the ***target completion time*** is reached
  - the ***crashing cost exceeds the penalty cost***

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# Crashing process

- Define the project logic
- Add the duration for each activity
- Establish the project critical path
- Calculate the cost of crashing each activity
- Calculate the cost of crashing per unit time
- Calculate the most cost-effective crash sequence
- Check the critical path
- Crash the network up to crash limit

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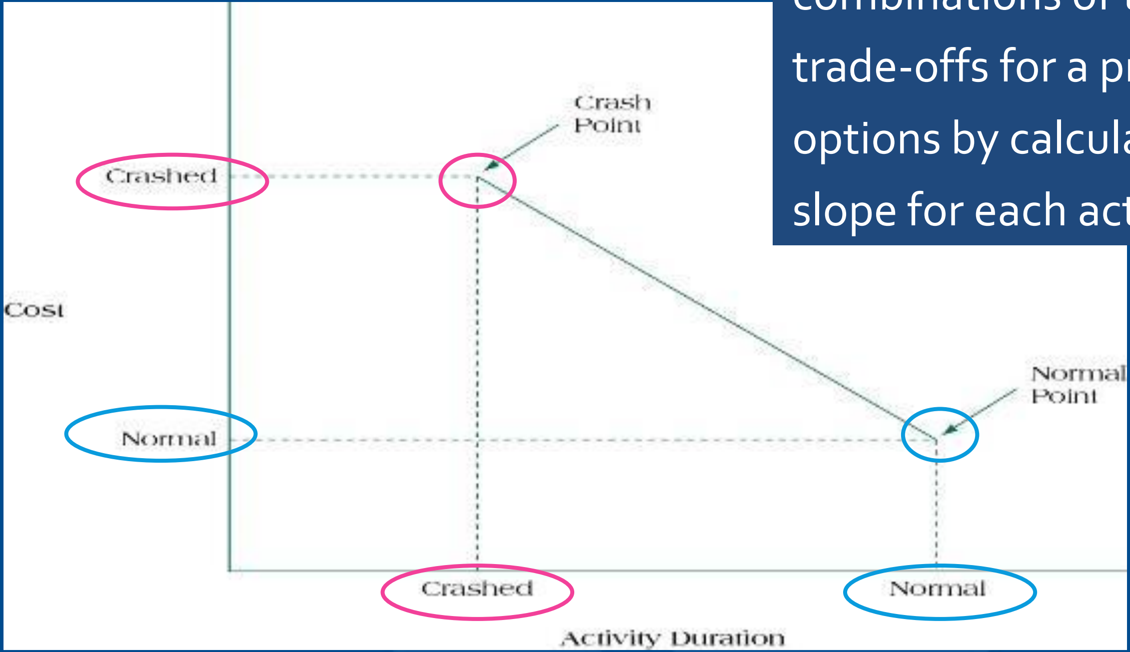
# Time/Cost Trade-Offs for Crashing Activities

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

We can calculate various combinations of time/cost trade-offs for a project's crash options by calculating the slope for each activity

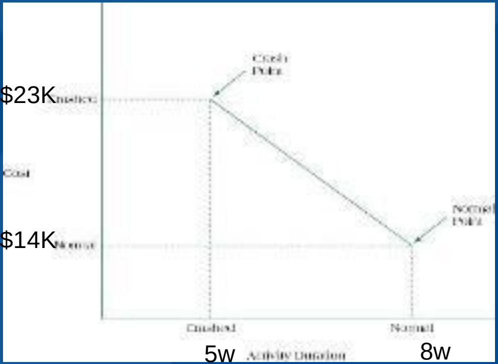


# Example – Crash Slope

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

SUPPOSE:
NORMAL ACTIVITY DURATION = 8 WEEKS
NORMAL COST = $14,000

CRASHED ACTIVITY DURATION = 5 WEEKS
CRASHED COST = $23,000




$$\text{Slope} = \frac{\$23{,}000 - \$14{,}000}{8 \text{ weeks} - 5 \text{ weeks}}$$

Slope = $9,000/3weeks

Slope = $3,000/week

## Example – Project Crashing

Suppose we have a project with the following 8 activities and we want to accelerate our project by crashing.
What do we need to do?

| | | Normal | | Crashed | |
|---|---|---|---|---|---|
| Activity | Predecessors | Duration | Cost | Duration | Cost |
| A | — | 5 days | $ 1,000 | 3 days | $ 1,500 |
| B | A | 7 days | 700 | 6 days | 1,000 |
| C | A | 3 days | 2,500 | 2 days | 4,000 |
| D | A | 5 days | 1,500 | 5 days | 1,500 |
| E | C, D | 9 days | 3,750 | 6 days | 9,000 |
| F | B | 4 days | 1,600 | 3 days | 2,500 |
| G | D | 6 days | 2,400 | 4 days | 3,000 |
| H | E, F, G | 8 days | 9,000 | 5 days | 15,000 |
| Total costs = | | | $22,450 | | $37,500 |

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

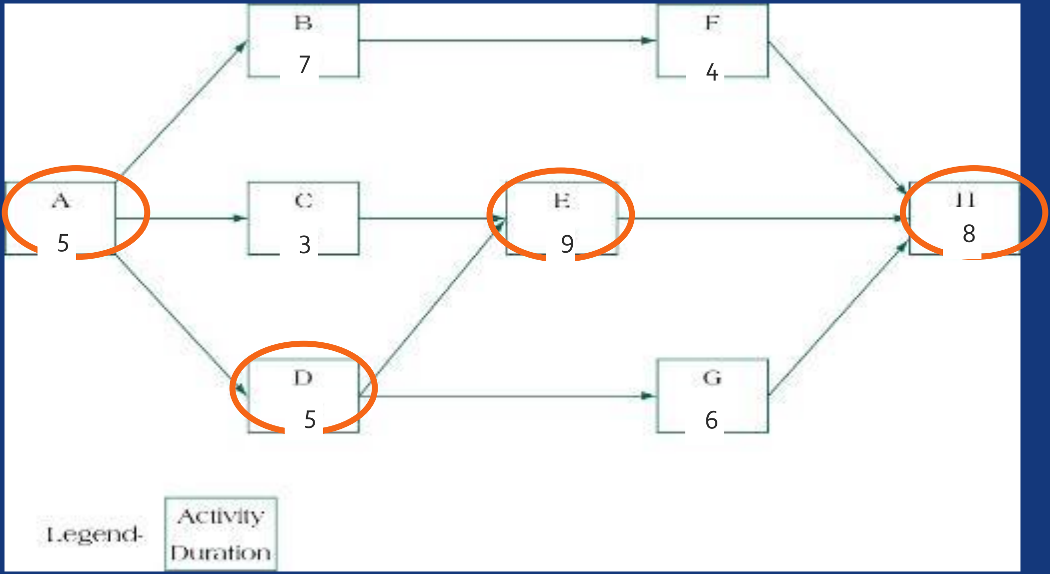
***Which activities are optimal for crashing?***

1) Calculate the crash cost of each activity (slope)
2) Decide which activities we should crash

| Activity | Predecessors | Normal | | Crashed | | Crash cost |
|---|---|---|---|---|---|---|
| | | Duration | Cost | Duration | Cost | |
| A | — | 5 days | $ 1,000 | 3 days | $ 1,500 | $250/day |
| B | A | 7 days | 700 | 6 days | 1,000 | $300/day |
| C | A | 3 days | 2,500 | 2 days | 4,000 | $1,500/day |
| D | A | 5 days | 1,500 | 5 days | 1,500 | ------------ |
| E | C, D | 9 days | 3,750 | 6 days | 9,000 | $1,750/day |
| F | B | 4 days | 1,600 | 3 days | 2,500 | $900/day |
| G | D | 6 days | 2,400 | 4 days | 3,000 | $300/day |
| H | E, F, G | 8 days | 9,000 | 5 days | 15,000 | $2,000/day |
| Total costs = | | | $22,450 | | $37,500 | |

***What is the critical path?*** A – D – E – H

***How many days is it?*** 27 days

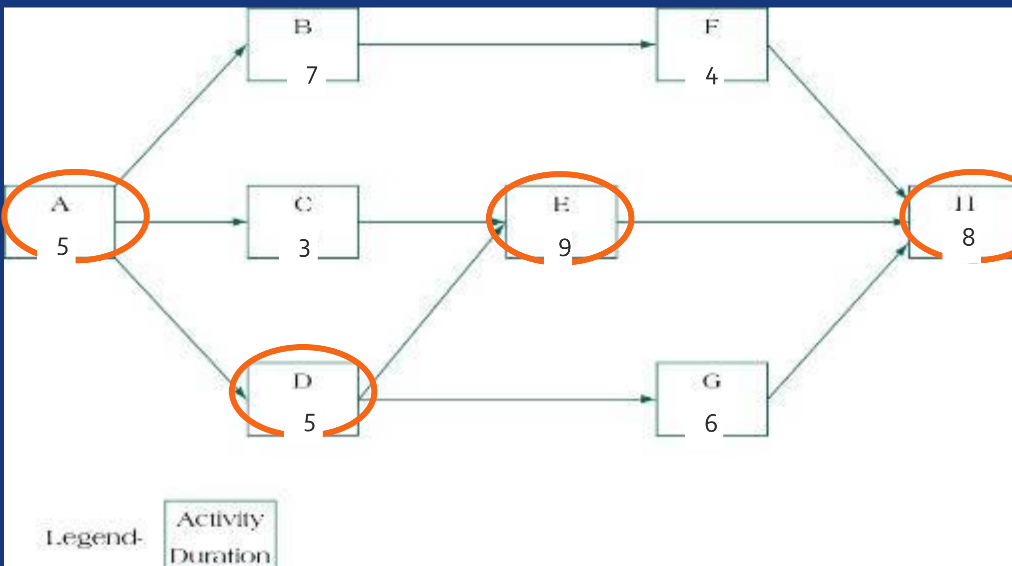


# Original CP: A – D – E – H
27 days

Activity

***If we crash all activities– does CP remain the same?***

A (3), B (6), C (2), D (5), E (6), F (3), G (4), H (5)




**Crash cost**

**A:** $250/day

**B:** $300/day

**C:** $1,500/day

**D:** -------------

**E:** $1,750/day

**F:** $900/day

**G:** $300/day

**H:** $2,000/day

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# *Recall: normal cost = $22,450*
# *normal time = 27 days*

| Critical path activities we can crash | Project duration | Project cost |
| --- | --- | --- |
| | 27 days | $22,450 |
| A (2 days @ $250/day) | 26 days<br>25 days | $22,700<br>$22,950 |
| E (3 days @ $1,750/day) | 24 days<br>23 days<br>22 days | $24,700<br>$26,450<br>$28,200 |
| H (3 days @ $2,000/day) | 21 days<br>20 days<br>19 days | $30,200<br>$32,200<br>$34,200 |

<u>**Crash cost**</u>

**A:** $250/day

**B:** $300/day

**C:** $1,500/day

**D:** -------------

**E:** $1,750/day

**F:** $900/day

**G:** $300/day

**H:** $2,000/day

## Activity – Budget Effects of Crashing the Project

**The cost of crashing a project must always be considered against the time saved in expediting the activity's schedule.**

Assume the critical path is A-C-D-H (57 days)

| | Normal | | Crashed | | |
|---|---|---|---|---|---|
| Activity | Cost | Duration | Extra Cost | Duration | Crash Cost |
| A | $2,000 | 10 days | $2,000 | 7 days | |
| B | $1,500 | 5 days | $3,000 | 3 days | |
| C | $3,000 | 12 days | $1,500 | 9 days | |
| D | $5,000 | 20 days | $3,000 | 15 days | |
| E | $2,500 | 8 days | $2,500 | 6 days | |
| F | $3,000 | 14 days | $2,500 | 10 days | |
| G | $6,000 | 12 days | $5,000 | 10 days | |
| H | $9,000 | 15 days | $3,000 | 12 days | |

**The cost of crashing a project must always be considered against the time saved in expediting the activity's schedule.**

Assume the critical path is A-C-D-H (57 days)

**Balancing act:**

**At what point is it no longer economically viable to continue crashing activities?**

| | Normal | | Crashed | | |
|---|---|---|---|---|---|
| Activity | Cost | Duration | Extra Cost | Duration | Crash Cost |
| A | $2,000 | 10 days | $2,000 | 7 days | $667/day |
| B | $1,500 | 5 days | $3,000 | 3 days | $1,500/day |
| C | $3,000 | 12 days | $1,500 | 9 days | $500/day |
| D | $5,000 | 20 days | $3,000 | 15 days | $600/day |
| E | $2,500 | 8 days | $2,500 | 6 days | $1,250/day |
| F | $3,000 | 14 days | $2,500 | 10 days | $625/day |
| G | $6,000 | 12 days | $5,000 | 10 days | $2,500/day |
| H | $9,000 | 15 days | $3,000 | 12 days | $1,000/day |

## Activity – Budget Effects of Crashing the Project

**Balancing act:**
**At what point is it no longer economically viable to continue crashing activities?**

Total normal project days = 57 days

Also suppose that the project team will be charged the following:

1) Overhead at $200/day fixed rate
2) A series of late penalties will kick in if the project is not completed in 50 days

| Project duration | Direct costs | Late penalties | Overhead costs | Total costs |
|---|---|---|---|---|
| 57 days (normal) | $32,000 (normal) | $5,000 | $11,400 | $48,400 |
| 54 days | $33,500 (crashed C) | $3,000 | $10,800 | $47,300 |
| 51 days | $35,500 (crashed A) | $1,000 | $10,200 | $46,700 |
| 48 days | $38,500 (crashed H) | $0 | $9,600 | $48,100 |

**Exercise:** This project duration is 63 weeks. What is the lowest cost to complete this project in 53 weeks? Times are in weeks and costs in dollars.

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

What other considerations may be relevant for deciding which activities to crash?

| Activity | Pred | Normal Time | Crash Time | Normal Cost | Crash Cost | $/week |
|---|---|---|---|---|---|---|
| A | -- | 14 | 9 | 500 | 1500 | |
| B | A | 5 | 4 | 1000 | 1600 | |
| C | A | 10 | 8 | 2000 | 2900 | |
| D | B, C | 8 | 5 | 1000 | 2500 | |
| E | D | 6 | 5 | 1300 | 1900 | |
| F | D | 9 | 6 | 1500 | 3000 | |
| G | E, F | 7 | 4 | 600 | 1800 | |
| H | G | 15 | 11 | 1600 | 3600 | |

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CP: A, C, D, F, G, H

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|---|---|---|---|---|---|---|
| A | -- | 14 | 9 | 500 | 1500 | 200 |
| B | A | 5 | 4 | 1000 | 1600 | 600 |
| C | A | 10 | 8 | 2000 | 2900 | 450 |
| D | B, C | 8 | 5 | 1000 | 2500 | 500 |
| E | D | 6 | 5 | 1300 | 1900 | 600 |
| F | D | 9 | 6 | 1500 | 3000 | 500 |
| G | E, F | 7 | 4 | 600 | 1800 | 400 |
| H | G | 15 | 11 | 1600 | 3600 | 500 |

**Exercise:** This project duration is 63 weeks. What is the lowest cost to complete this project in 53 weeks? Times are in weeks and costs in dollars.

What other considerations may be relevant for deciding which activities to crash?

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| C | A | 10 | 8 | 2000 | 2900 | 450 |
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| E | D | 6 | 5 | 1300 | 1900 | 600 |
| F | D | 9 | 6 | 1500 | 3000 | 500 |
| G | E, F | 7 | 4 | 600 | 1800 | 400 |
| H | G | 15 | 11 | 1600 | 3600 | 500 |

**Exercise:** This project duration is 63 weeks. What is the lowest cost to complete this project in 53 weeks? Times are in weeks and costs in dollars.

$3100 (5 x $200 + 3 x $400 + 2 x $450)

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

What other considerations may be relevant for deciding which activities to crash?

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$3100 (5 x $200 + 3 x $400 + 2 x $450)

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| H | G | 15 | 11 | 1600 | 3600 | 500 |

# Gantt Charts and Resource Levelling

# B. Gantt Charts & Resource Levelling

Frequently used in project management, a Gantt chart provides a graphical illustration of a schedule that helps to plan, coordinate, and track specific tasks in a project.

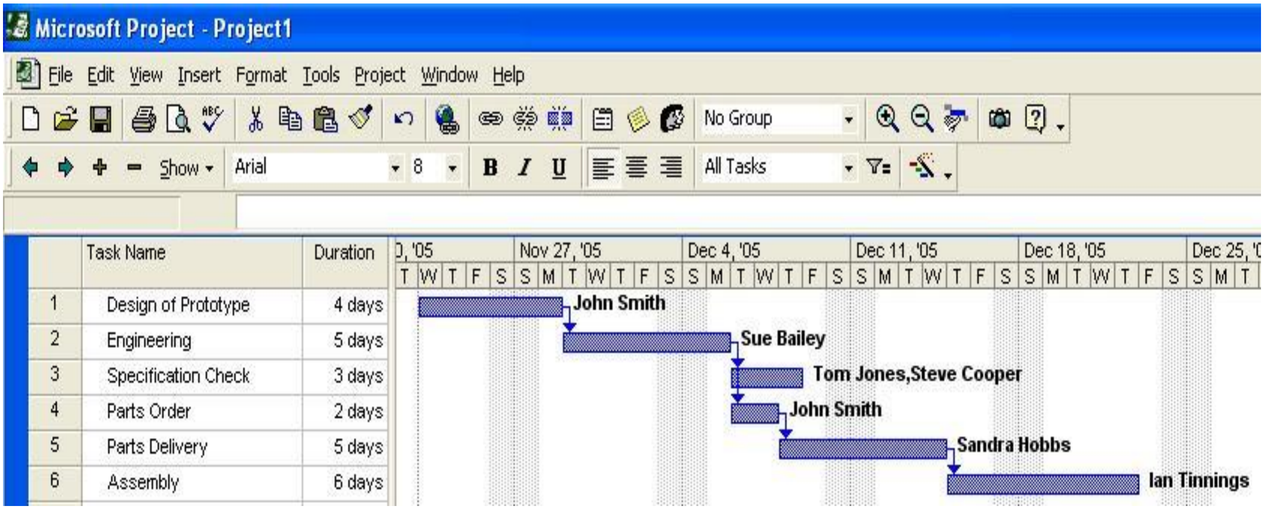
# Gantt Chart Advantages

- They provide an excellent presentation tool for illustrating groups of milestones and demonstrating individual resources scheduled to time
- They can be used in status reporting to show how much of the plan has been completed by displaying the progress of an activity in the same or a parallel bar, or using colour
- They provide graphic illustration of resource levelling
- They are easy to create, comprehend, and update

# Gantt Chart Disadvantages

- Estimates must be completed before chart can be drawn
- A Gantt chart does not effectively address the dependencies between jobs
- It is difficult to show two sets of dates when using techniques such as earliest start date and latest start
- It is difficult to show slack and critical path
- Changes to the schedule require a redrawing of the chart
- The same chart cannot show several scheduling possibilities
- The Gantt chart does not highlight WBS elements with the highest risk of failure or delay

# Gantt Chart With Resources in MS Project



# Activity – Gantt Chart

| | Description | Predecessor | Activity Duration |
|---|---|---|---|
| A | Contract signing | None | 5 |
| B | Questionnaire design | A | 5 |
| C | Target market ID | A | 6 |
| D | Survey sample | B, C | 13 |
| E | Develop presentation | B | 6 |
| F | Analyse results | D | 4 |
| G | Demographic analysis | C | 9 |
| H | Presentation to client | E, F, G | 2 |

| | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| A | | | | | | | |
| B | | | | | | | |
| C | | | | | | | |
| D | | | | | | | |
| E | | | | | | | |
| F | | | | | | | |
| G | | | | | | | |
| H | | | | | | | |

# Activity – Gantt Chart

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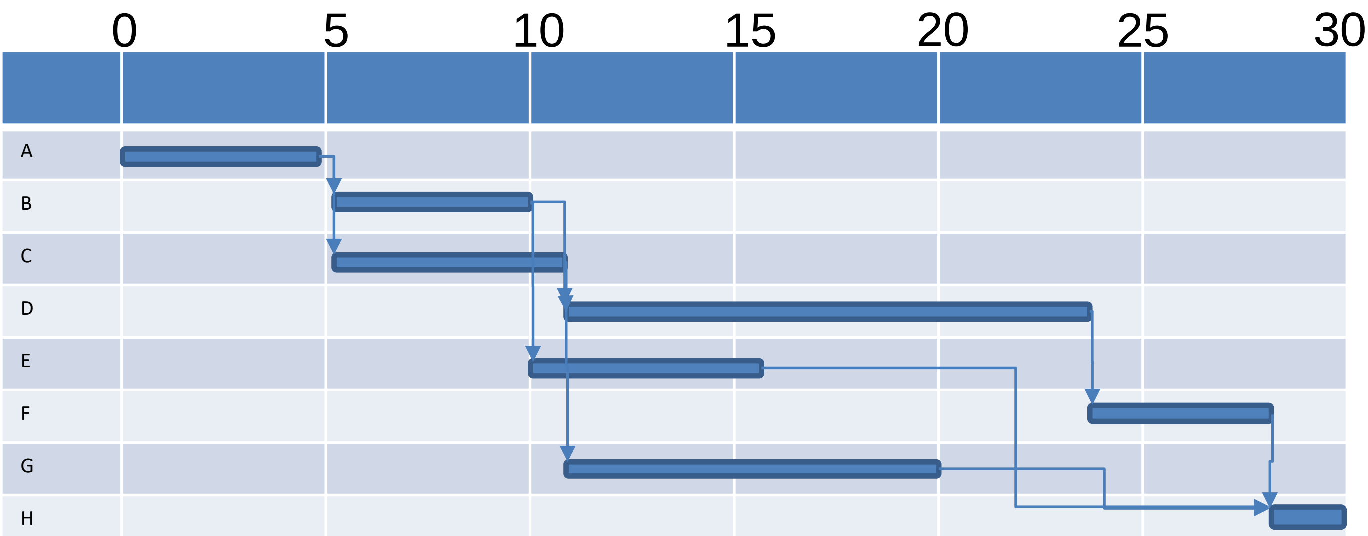
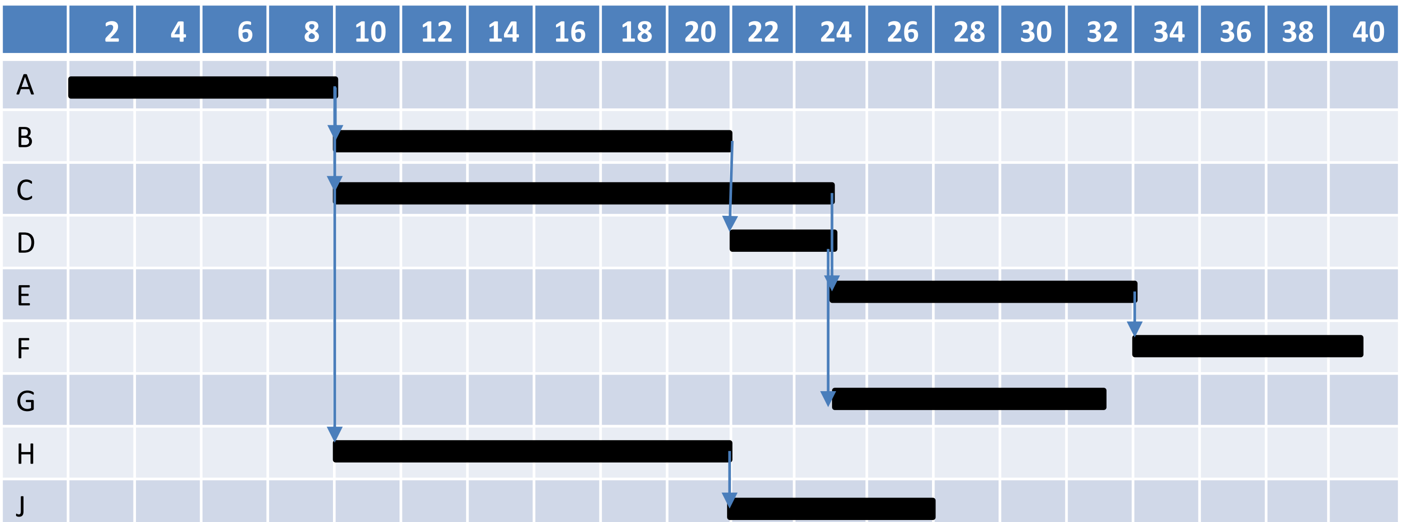


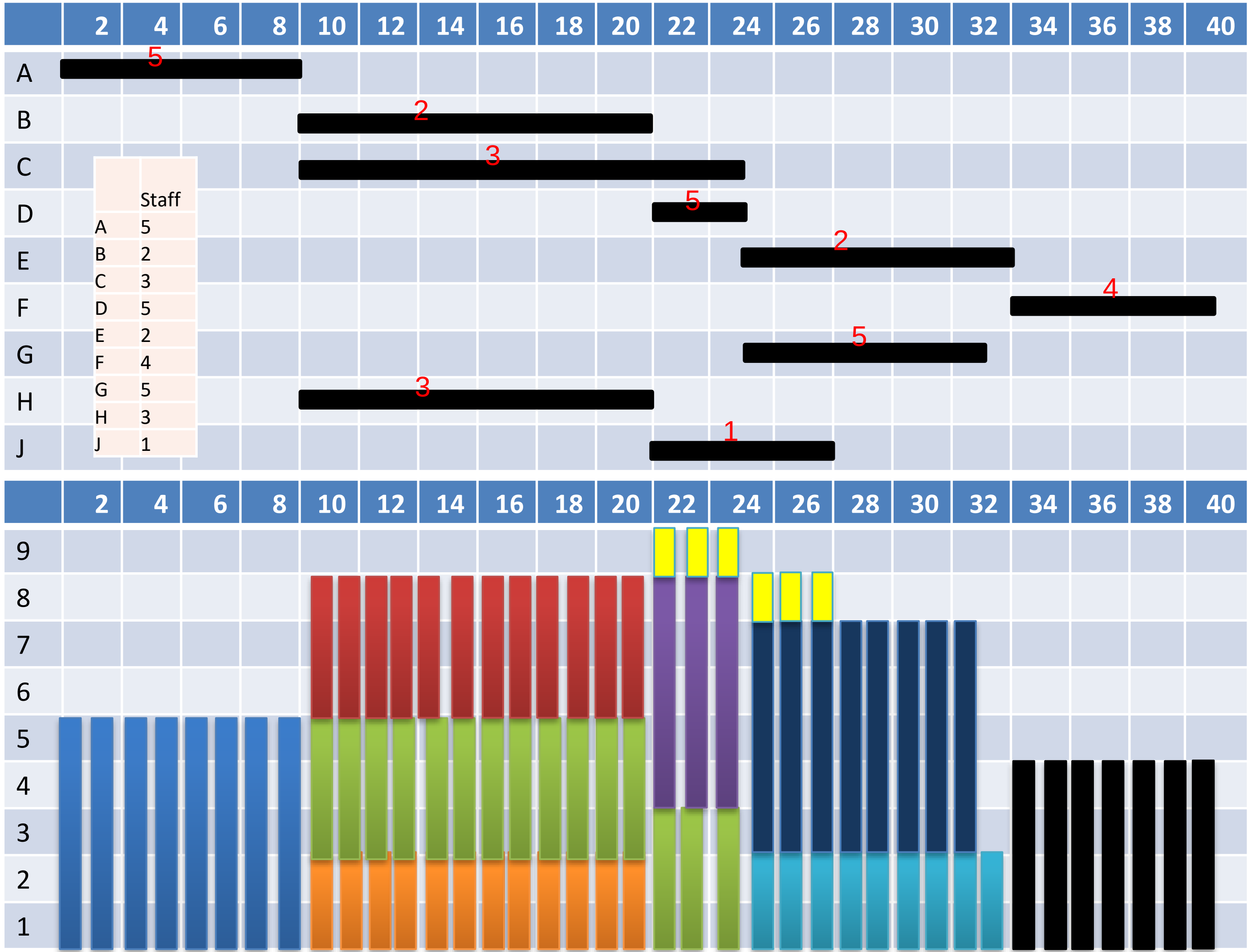
# Resource Leveling

| Activity | Pred | Duration | Staffing |
|---|---|---|---|
| A | - | 8 | 5 |
| B | A | 12 | 2 |
| C | A | 15 | 3 |
| D | B | 3 | 5 |
| E | C | 9 | 2 |
| F | E | 7 | 4 |
| G | D | 8 | 5 |
| H | A | 12 | 3 |
| J | H | 6 | 1 |

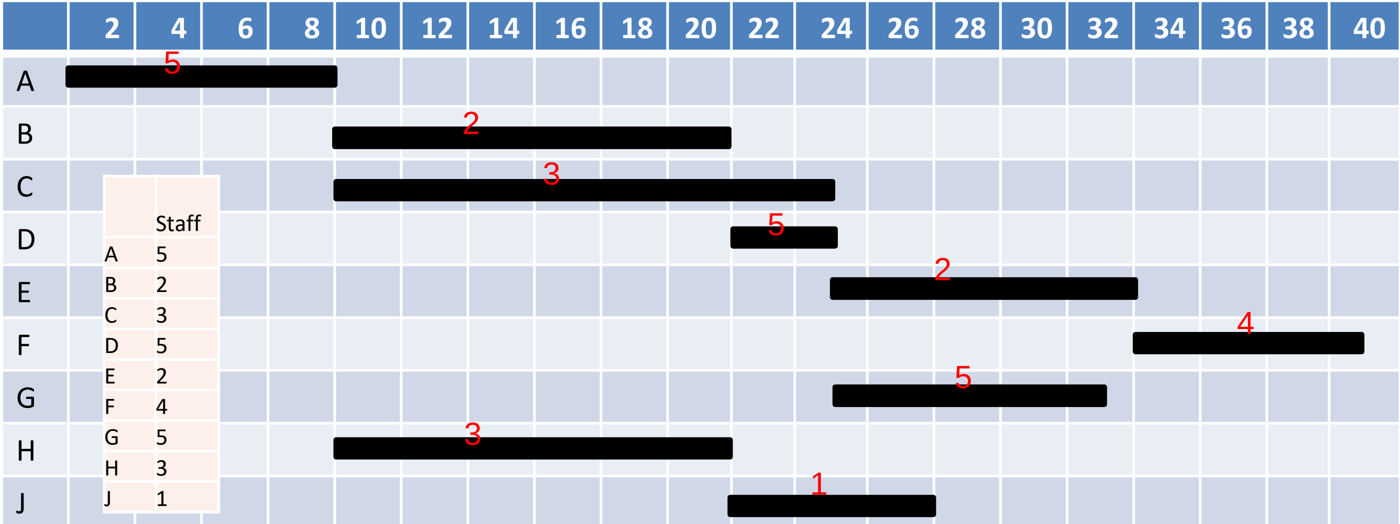
| | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | | | | | | | | | | | |
| B | | | | | | | | | | | | | | | | | | | | |
| C | | | | | | | | | | | | | | | | | | | | |
| D | | | | | | | | | | | | | | | | | | | | |
| E | | | | | | | | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | | | | | | | | |
| G | | | | | | | | | | | | | | | | | | | | |
| H | | | | | | | | | | | | | | | | | | | | |
| J | | | | | | | | | | | | | | | | | | | | |

| Activity | Pred | Duration | Staffing |
|---|---|---|---|
| A | - | 8 | 5 |
| B | A | 12 | 2 |
| C | A | 15 | 3 |
| D | B | 3 | 5 |
| E | C | 9 | 2 |
| F | E | 7 | 4 |
| G | D | 8 | 5 |
| H | A | 12 | 3 |
| J | H | 6 | 1 |





2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
A B C D E F G H J
5 2 3 5 2 4 5 3 1
Staff
A 5
B 2
C 3
D 5
E 2
F 4
G 5
H 3
J 1
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
9 8 7 6 5 4 3 2 1



2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
A
B
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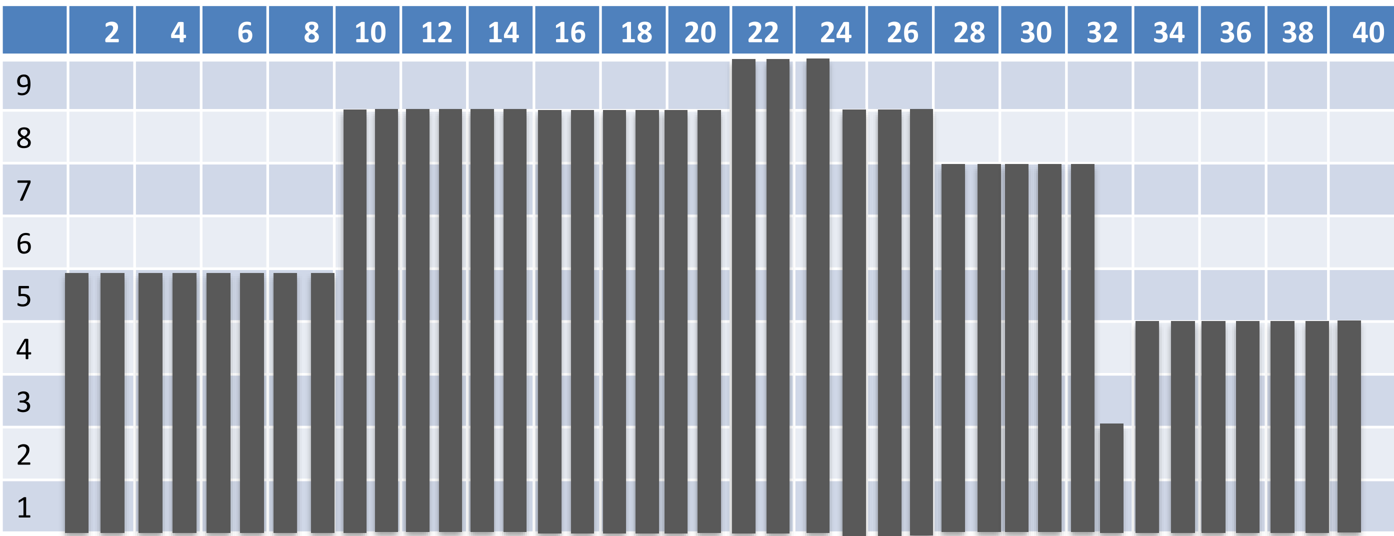
Staff
A 5
B 2
C 3
D 5
E 2
F 4
G 5
H 3
J 1

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
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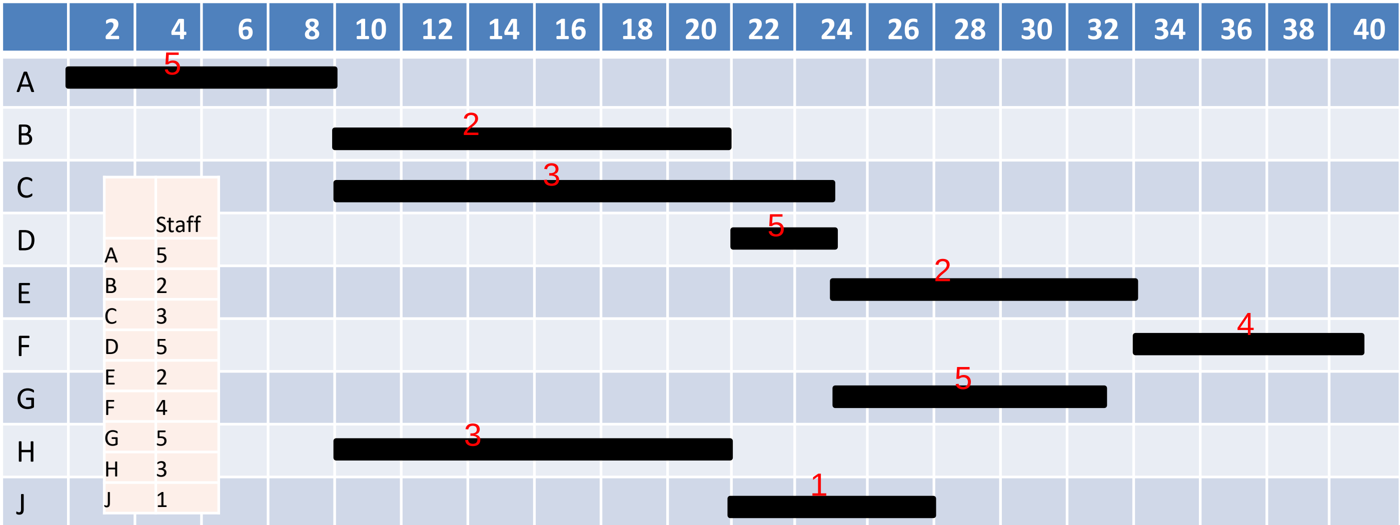
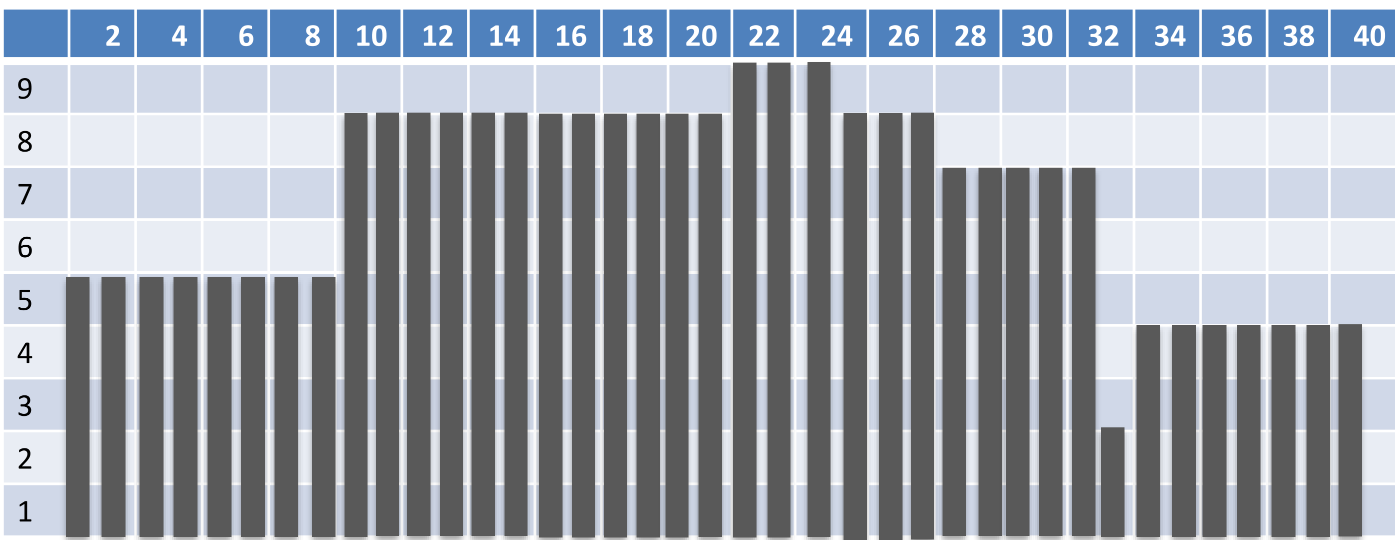



| | Staff |
|---|---|
| A | 5 |
| B | 2 |
| C | 3 |
| D | 5 |
| E | 2 |
| F | 4 |
| G | 5 |
| H | 3 |
| J | 1 |



## Class Activity

1. Calculate the expected time for each network task using the table below (unit of analysis = days)

| Activity | Predecessor | Most Optimistic (a) | Most Likely (m) | Most Pessimistic (b) | TE | Staffing |
|---|---|---|---|---|---|---|
| A | - | 13 | 18 | 35 | | 2 |
| B | - | 7 | 17 | 45 | | 3 |
| C | - | 6 | 8 | 22 | | 4 |
| D | A | 12 | 14 | 22 | | 2 |
| E | B,C | 7 | 10 | 13 | | 4 |
| F | B,C | 6 | 12 | 28 | | 3 |
| G | B,C | 2 | 4 | 8 | | 2 |
| H | C | 6 | 10 | 19 | | 5 |
| I | G,H | 6 | 11 | 21 | | 2 |
| J | D,E | 4 | 7 | 18 | | 1 |

| Activity | Predecessor | Most Optimistic (a) | Most Likely (m) | Most Pessimistic (b) | TE | Staffing |
|---|---|---|---|---|---|---|
| A | - | 13 | 18 | 35 | 20 | 2 |
| B | - | 7 | 17 | 45 | 20 | 3 |
| C | - | 6 | 8 | 22 | 10 | 4 |
| D | A | 12 | 14 | 22 | 15 | 2 |
| E | B,C | 7 | 10 | 13 | 10 | 4 |
| F | B,C | 6 | 12 | 28 | 14 | 3 |
| G | B,C | 2 | 4 | 8 | 4 | 2 |
| H | C | 6 | 10 | 19 | 11 | 5 |
| I | G,H | 6 | 11 | 21 | 12 | 2 |
| J | D,E | 4 | 7 | 18 | 8 | 1 |

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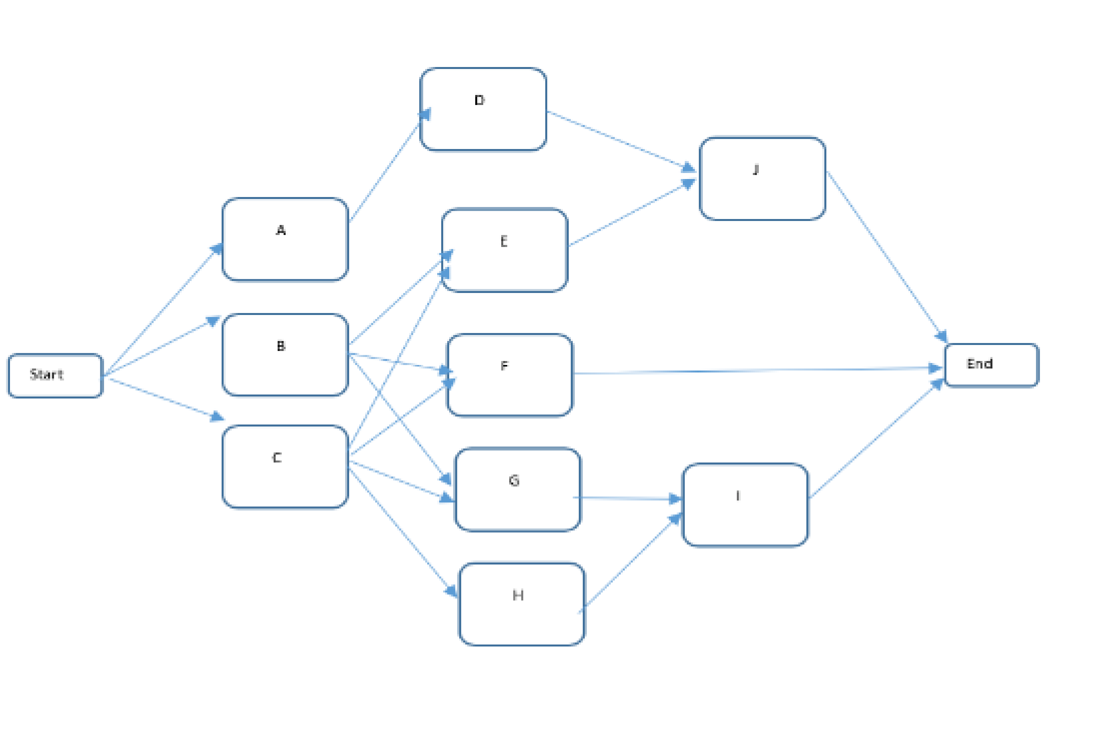
# 2. Draw the network diagram using either AON format.

| Activity | Predecessor |
|---|---|
| A | - |
| B | - |
| C | - |
| D | A |
| E | B,C |
| F | B,C |
| G | B,C |
| H | C |
| I | G,H |
| J | D,E |

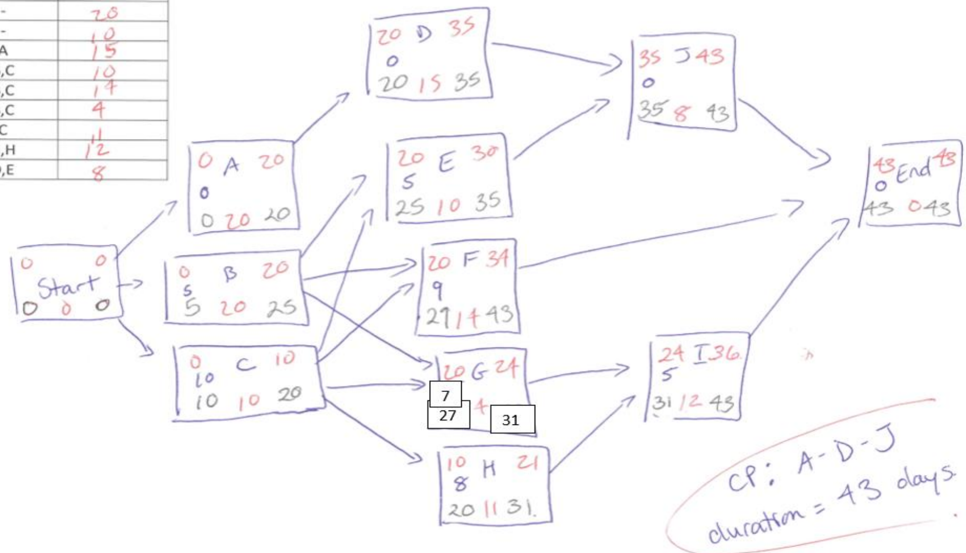

D
J
A
E
B
F
Start
End
C
G
I
H

# Forward pass, backward pass and critical path

3. Calculate the forward pass, backward pass, and float. Illustrate these on the network diagram.

4. What is the critical path and how long does it take to complete this project?

| Activity | Predecessor | TE |
|---|---|---|
| A | - | 20 |
| B | - | 20 |
| C | - | 10 |
| D | A | 15 |
| E | B,C | 10 |
| F | B,C | 14 |
| G | B,C | 4 |
| H | C | 11 |
| I | G,H | 12 |
| J | D,E | 8 |



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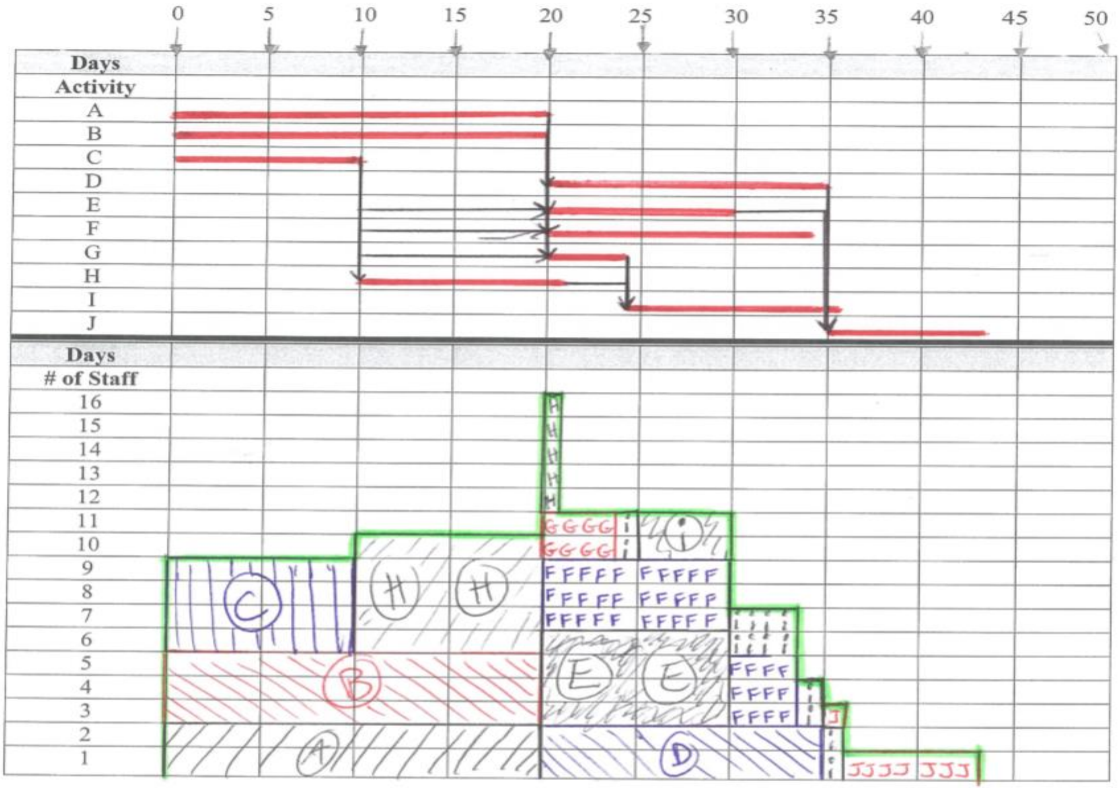
5. Complete the Gantt charts to show activities and the staffing requirements



Complete the table below, by filling in the Slope and the Maximum Crash Time

| Activity | Normal Time | Normal Cost ($) | Crash Time | Crash Cost ($) | Slope | Maximum Crash Time |
|---|---|---|---|---|---|---|
| A | | 2,000 | 18 | 2,500 | | |
| B | | 5,000 | 17 | 6,500 | | |
| C | | 5,500 | 9 | 7,000 | | |
| D | | 1,000 | 11 | 3,000 | | |
| E | | 3,700 | 7 | 5,000 | | |
| F | | 1,300 | 12 | 2,000 | | |
| G | | 2,600 | 3 | 3,400 | | |
| H | | 6,100 | 9 | 6,700 | | |
| I | | 500 | 10 | 2,000 | | |
| J | | 2,200 | 7 | 3,800 | | |

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{normal time} - \text{crash time}}$$

| Activity | Normal Time | Normal Cost ($) | Crash Time | Crash Cost ($) | Slope | Maximum Crash Time |
|---|---|---|---|---|---|---|
| A | 20 | 2,000 | 18 | 2,500 | 250 | 2 |
| B | 20 | 5,000 | 17 | 6,500 | 500 | 3 |
| C | 10 | 5,500 | 9 | 7,000 | 1500 | 1 |
| D | 15 | 1,000 | 11 | 3,000 | 500 | 4 |
| E | 10 | 3,700 | 7 | 5,000 | 433 | 3 |
| F | 14 | 1,300 | 12 | 2,000 | 350 | 2 |
| G | 4 | 2,600 | 3 | 3,400 | 800 | 1 |
| H | 11 | 6,100 | 9 | 6,700 | 300 | 2 |
| I | 12 | 500 | 10 | 2,000 | 750 | 2 |
| J | 8 | 2,200 | 7 | 3,800 | 1600 | 1 |

7. Using direct costs, what is the lowest cost to complete the project 6 days early?

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7. Using direct costs, what is the lowest cost to complete the project 6 days early?

Direct crashed cost, 6 days early = $32,400