

ESE GATE PSUs

State Engg. Exams

MADE EASY
WORKBOOK 2027



**Detailed Explanations of
Try Yourself Questions**

Civil Engineering

Construction Practice, Planning
& Management



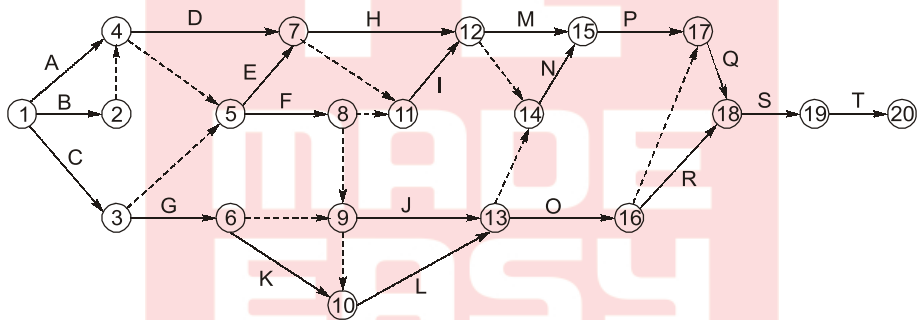
1

Basics of Project Management & Network Analysis



Detailed Explanation of Try Yourself Questions

T1 : Solution



2

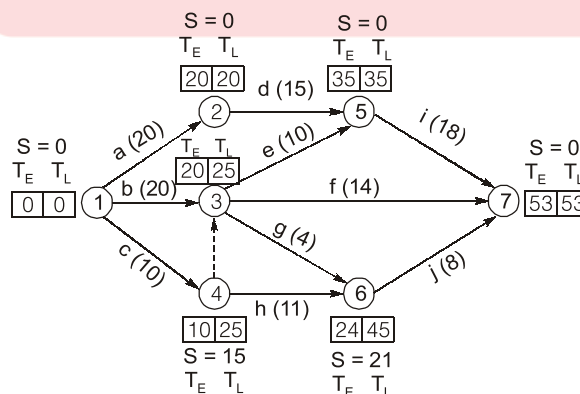
PERT Analysis



Detailed Explanation of Try Yourself Questions

T1 : Solution

| Activity | t_0 | t_m | t_p | t_e | Variance (σ^2) | σ |
|----------|-------|-------|-------|-------|-------------------------|----------|
| a | 10 | 22 | 22 | 20 | 4 | 2 |
| b | 20 | 20 | 20 | 20 | 0 | 0 |
| c | 4 | 10 | 16 | 10 | 4 | 2 |
| d | 2 | 14 | 32 | 15 | 25 | 5 |
| e | 8 | 8 | 20 | 10 | 4 | 2 |
| f | 8 | 14 | 20 | 14 | 4 | 2 |
| g | 4 | 4 | 4 | 4 | 0 | 0 |
| h | 2 | 12 | 16 | 11 | 5.4 | 2.32 |
| i | 6 | 16 | 38 | 18 | 28.4 | 5.33 |
| j | 2 | 8 | 14 | 8 | 4 | 2 |



Critical path is 1-2-5-7 and schedule completion time of project = 53 days

Standard deviation,

$$\sigma = \sqrt{\sigma_a^2 + \sigma_d^2 + \sigma_i^2} = \sqrt{4 + 25 + 28.4} = 7.576$$

Probability factor,
$$z = \frac{T_s - T_E}{\sigma}$$

For 95% probability
$$z = 1.5 + \frac{2.0 - 1.5}{97.92 - 93.92} (95 - 93.92) = 1.635$$

$$\therefore 1.635 = \frac{T_s - 53}{7.576} \Rightarrow T_s = 65.38 \approx 66 \text{ days}$$

\therefore Time for 95% probability completion is 66 days.

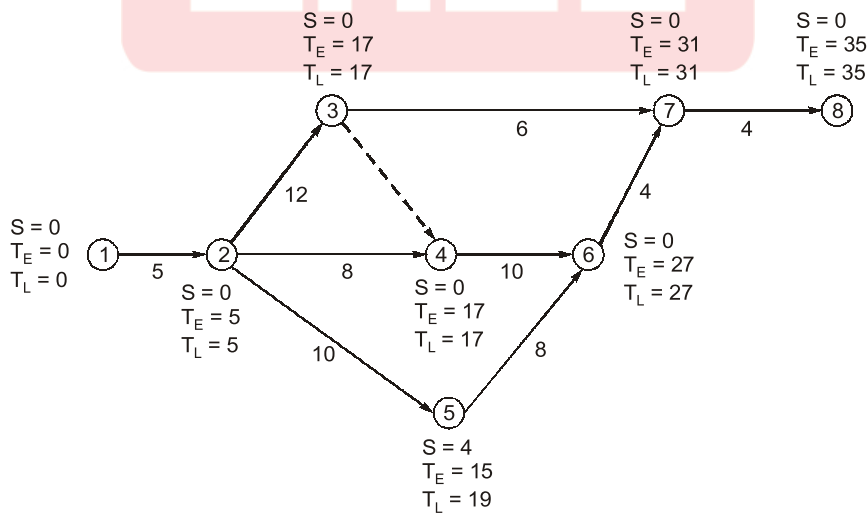
T2 : Solution

Calculation of expected time and standard deviation is done in table below:

Where, $t_e = \frac{t_0 + 4t_m + t_p}{6}$, $\sigma = \frac{t_p - t_0}{6}$

| Activity | t_0 | t_m | t_p | t_e | σ |
|----------|-------|-------|-------|-------|----------|
| 1 - 2 | 2 | 5 | 8 | 5 | 1 |
| 2 - 3 | 8 | 11 | 20 | 12 | 2 |
| 2 - 4 | 4 | 7 | 16 | 8 | 2 |
| 2 - 5 | 4 | 9 | 20 | 10 | 2.67 |
| 3 - 4 | 0 | 0 | 0 | 0 | 0 |
| 3 - 7 | 3 | 5 | 13 | 6 | 1.67 |
| 4 - 6 | 7 | 10 | 13 | 10 | 1 |
| 5 - 6 | 3 | 7 | 17 | 8 | 2.33 |
| 6 - 7 | 2 | 3 | 10 | 4 | 1.33 |
| 7 - 8 | 2 | 4 | 6 | 4 | 0.67 |

Calculation of T_E , T_L and slack has been done in network diagram below:



$$\sigma = \sqrt{1^2 + 2^2 + 0^2 + 1^2 + 1.33^2 + 0.67^2} = 2.867$$

$$Z = \frac{T_S - T_E}{\sigma}$$

For 95% probability,

$$Z = 1.6 + \frac{0.1}{95.54 - 94.52} \times 0.48 = 1.647$$

$$1.647 = \frac{T_S - 35}{\sigma}$$

$$T_S = 1.647 \times 2.567 + 35 = 39.72$$

◆◆◆◆



3

CPM Analysis

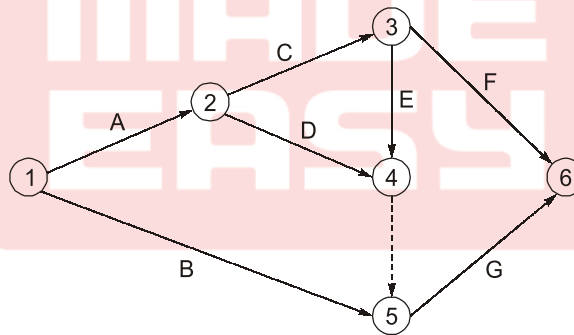


Detailed Explanation of Try Yourself Questions

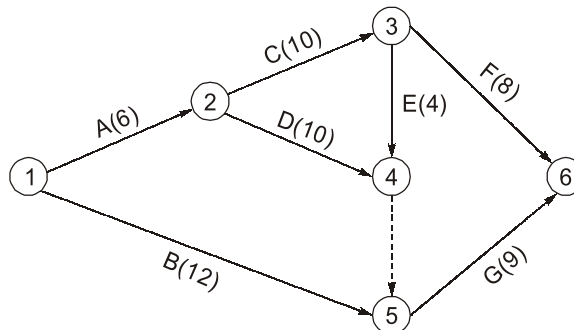
T1 : Solution

| Activity | A | B | C | D | E | F | Dummy | G |
|----------------|---|----|----|----|---|---|-------|----------|
| Depends upon | - | - | A | A | C | C | D, E | B, Dummy |
| Duration, days | 6 | 12 | 10 | 10 | 4 | 8 | - | 9 |

(i) Network diagram

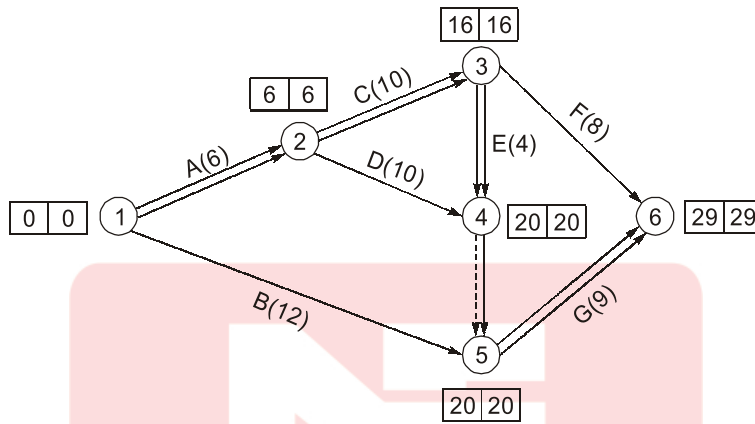


(ii) Project duration

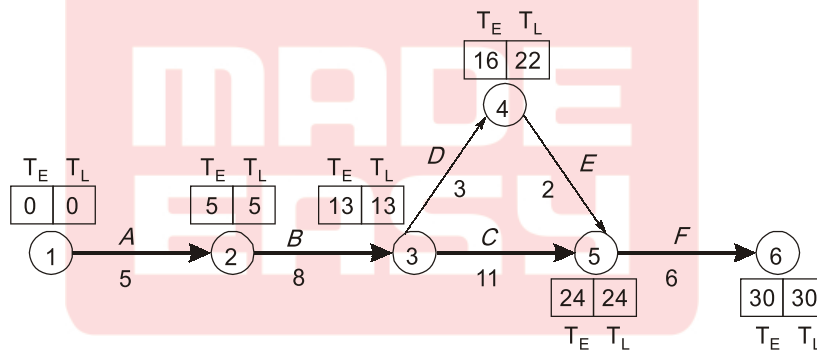


Calculation of critical path:

- (1)-(2)-(3)-(6) $\equiv 6 + 10 + 8 = 24$ days
- (1)-(2)-(3)-(4)-(5)-(6) $\equiv 6 + 10 + 4 + 9 = 29$ days
- (1)-(2)-(4)-(5)-(6) $\equiv 6 + 10 + 9 = 25$ days
- (1)-(5)-(6) $\equiv 12 + 9 = 21$ days
- Critical path $\equiv (1)-(2)-(3)-(4)-(5)-(6)$
- Project duration = 29 days



T2 : Solution



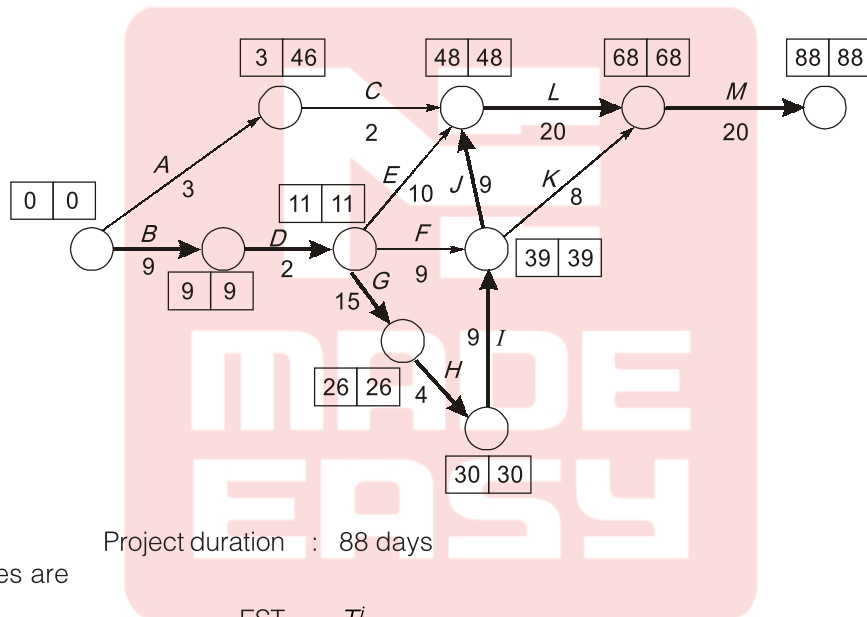
The critical path is 1 – 2 – 3 – 5 – 6
Project duration : 30 days

$$\begin{aligned} \text{EST} &= T_E^i \\ \text{EFT} &= \text{EST} + t^{ij} \\ \text{LST} &= \text{LFT} - t^{ij} \\ \text{LFT} &= T_L^j \end{aligned}$$

Incorporating above formulas, all the activity times of the given network are shown in table below:

| Activity | Tail event | | Head event | | Duration t_L^{ij} | EST | EFT | LST | LFT |
|----------|------------|---------|------------|---------|------------------------|-----|-----|-----|-----|
| | T_E^i | T_L^i | T_E^j | T_L^j | | | | | |
| 1-2 | 0 | 0 | 5 | 5 | 5 | 0 | 5 | 0 | 5 |
| 2-3 | 5 | 5 | 13 | 13 | 8 | 5 | 13 | 5 | 13 |
| 3-4 | 13 | 13 | 16 | 22 | 3 | 13 | 16 | 19 | 22 |
| 3-5 | 13 | 13 | 24 | 24 | 11 | 13 | 24 | 13 | 24 |
| 4-5 | 16 | 22 | 24 | 24 | 2 | 16 | 18 | 22 | 24 |
| 5-6 | 24 | 24 | 30 | 30 | 6 | 24 | 30 | 24 | 30 |

T3 : Solution



Project duration : 88 days

Activity times are

$$EST = T_E^i$$

$$EFT = EST + t^{ij}$$

$$LST = LFT - t^{ij}$$

$$LFT = T_L^j$$

$$\text{Total float, } F_T = T_L^j - T_E^i - t^{ij} = LFT - EFT$$

$$\text{Free float, } F_F = F_T - S_i = F_T - (T_L^i - T_E^i)$$

$$\begin{aligned} \text{Independent float, } F_I &= T_E^j - T_L^i - t^{ij} = F_F - S_i \\ &= F_F - (T_L^i - T_E^i) \end{aligned}$$

Incorporating the above formula, the elements of table given below are calculated:

| Activity | Tail event | | Head event | | Duration t^j | Activity times | | | | F_T | F_F | F_I |
|----------|------------|---------|------------|---------|-------------------|----------------|-----|-----|-----|-------|-------|-------|
| | T_E^i | T_L^i | T_E^j | T_L^j | | EST | EFT | LST | LFT | | | |
| A | 0 | 0 | 3 | 46 | 3 | 0 | 3 | 43 | 46 | 43 | 0 | 0 |
| B | 0 | 0 | 9 | 9 | 9 | 0 | 9 | 0 | 9 | 0 | 0 | 0 |
| C | 3 | 46 | 48 | 48 | 2 | 3 | 5 | 46 | 48 | 43 | 43 | 0 |
| D | 9 | 9 | 11 | 11 | 2 | 9 | 11 | 9 | 11 | 0 | 0 | 0 |
| E | 11 | 11 | 48 | 48 | 10 | 11 | 21 | 38 | 48 | 27 | 27 | 27 |
| F | 11 | 11 | 39 | 39 | 9 | 11 | 20 | 30 | 39 | 19 | 19 | 19 |
| G | 11 | 11 | 26 | 26 | 15 | 11 | 26 | 21 | 26 | 0 | 0 | 0 |
| H | 26 | 26 | 30 | 30 | 4 | 26 | 30 | 26 | 30 | 0 | 0 | 0 |
| I | 30 | 30 | 39 | 39 | 9 | 30 | 39 | 30 | 39 | 0 | 0 | 0 |
| J | 39 | 39 | 48 | 48 | 9 | 39 | 48 | 39 | 48 | 0 | 0 | 0 |
| K | 39 | 39 | 68 | 68 | 8 | 39 | 47 | 60 | 68 | 21 | 21 | 21 |
| L | 48 | 48 | 68 | 68 | 20 | 48 | 68 | 48 | 68 | 0 | 0 | 0 |
| M | 68 | 68 | 88 | 88 | 20 | 68 | 88 | 68 | 88 | 0 | 0 | 0 |

Critical path of the network is B – D – G – H – I – J – L – M



4

CPM Cost Model Analysis



Detailed Explanation of Try Yourself Questions

T1 : Solution

Total direct cost (normal) of the project = 250 + 350 + 300 + 700 = ₹ 1600

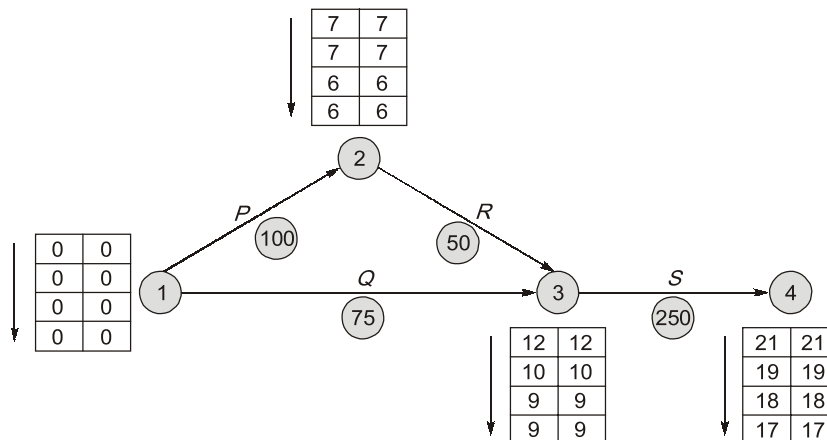
$$\text{Cost slope of } P = \frac{350 - 250}{7 - 6} = ₹100/\text{ day}$$

$$\text{Cost slope of } Q = \frac{500 - 350}{10 - 8} = ₹75/\text{ day}$$

$$\text{Cost slope of } R = \frac{400 - 300}{5 - 3} = ₹50/\text{ day}$$

$$\text{Cost slope of } S = \frac{950 - 700}{9 - 8} = ₹250/\text{ day}$$

Normal duration, crash duration and cost slope of each activity is indicated on the arrow diagram as shown below.



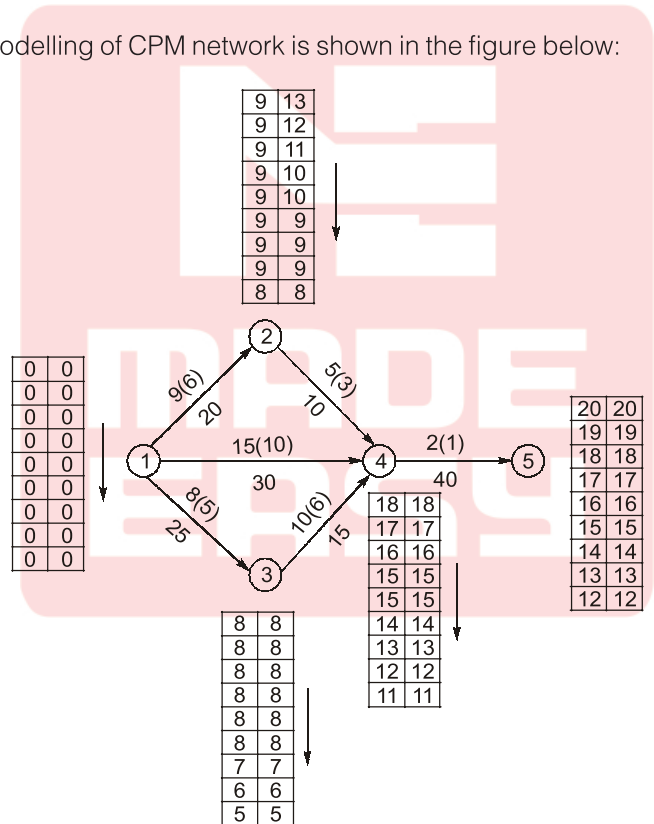
| S.No | Description | Duration (Days) | Indirect Cost (₹) | Direct Cost (₹) | Total Project Cost (₹) | Remarks |
|------|---|-----------------|-------------------|-----------------|------------------------|------------------|
| 1 | All Normal | 21 | 3990 | 1600 | 5590 | Normal duration |
| 2 | Crashing R by 2 days | 19 | 3610 | 1700 | 5310 | |
| 3 | Crashing P and Q each by 1 day simultaneously | 18 | 3420 | 1875 | 5295 | Optimum duration |
| 4 | Crashing S by 1 day | 17 | 3230 | 2125 | 5355 | Minimum duration |

Optimum duration of the project=18 days

Minimum (all crash) duration of the project = 17 days

T2 : Solution

The mathematical modelling of CPM network is shown in the figure below:



| Sl. No. | Description | Project duration (days) | Indirect cost (₹) | Direct cost due to crashing (₹) | Total cost (₹) | Remarks |
|---------|--|-------------------------|-------------------|---------------------------------|----------------|----------------|
| 1. | All normal | 20 | 1200 | — | 1200 | Normal Length |
| 2. | Crashing (3-4) by 1 day | 19 | 1140 | 15 | 1155 | |
| 3. | Crashing (3-4) by 1 day | 18 | 1080 | 30 | 1110 | |
| 4. | Crashing (3-4) by 1 day | 17 | 1020 | 45 | 1065 | |
| 5. | Crashing (4-5) by 1 day | 16 | 960 | 85 | 1045 | |
| 6. | Crashing (3-4) and (1-4) by 1 day | 15 | 900 | 130 | 1030 | Optimum Length |
| 7. | Crashing (1-3) (2-4) and (1-4) each by 1 day | 14 | 840 | 195 | 1035 | |
| 8. | Crashing (1-3) (2-4) and (1-4) each by 1 day | 13 | 780 | 260 | 1040 | |
| 9. | Crashing (1-3) (1-2) and (1-4) each by 1 day | 12 | 720 | 335 | 1055 | Minimum Length |

No further crashing since one of parallel critical paths is saturated.

Normal project length = 20 days

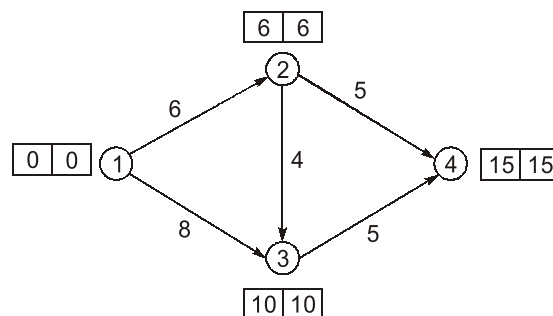
Optimum project length = 15 days

Minimum project length = 12 days.

Seven days scheduling (each by one day) is from s.no. 2 to 8 in the table.

T3 : Solution

Network diagram corresponding to the given data:

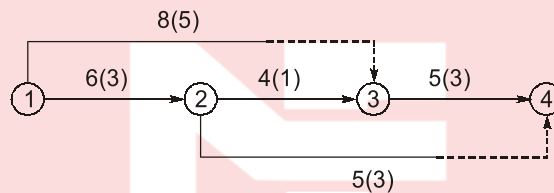


So critical path is 1-2-3-5

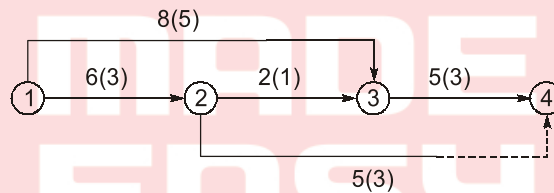
Now, cost slopes for the various activities can be found out as,

| Activity | Cost slope = $\left(\frac{C_c - C_n}{t_n - t_c}\right)$ |
|----------|---|
| 1-2 | 2500 |
| 1-3 | 1500 |
| 2-3 | 1000 |
| 2-4 | 3500 |
| 3-4 | 3000 |

Cost of project = DC + IC
 DC = Rs. 30,000
 IC = 15 × 3000 = Rs. 45000
 TC = Rs. 75000



1st stage: Crashing (2)-(3) by 2 weeks.

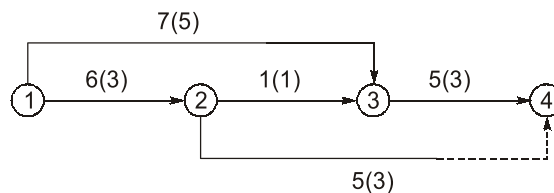


Duration of project = 13 weeks

Cost of project:

DC = 30000 + 2 × 1000 = Rs. 32000
 IC = 13 × 3000 = Rs. 39000
 TC = Rs. 71000

2nd stage: Crashing (1)-(3) and (2)-(3) simultaneously by 1 week



Duration of project = 12 weeks

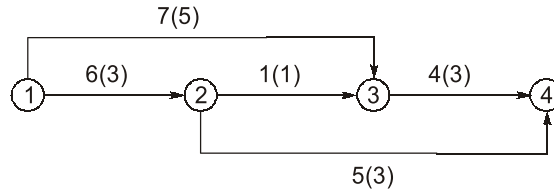
Cost of project:

$$DC = 32000 + 1000 + 1500 = \text{Rs. } 34500$$

$$IC = 12 \times 3000 = \text{Rs. } 36000$$

$$TC = \text{Rs. } 70500$$

3rd stage: Crashing (3)-(4) by 1 week



Duration of project = 11 weeks

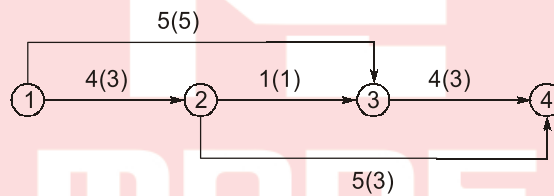
Cost of project:

$$DC = 34500 + 3000 = \text{Rs. } 37500$$

$$IC = 11 \times 3000 = \text{Rs. } 33000$$

$$TC = \text{Rs. } 70500$$

4th stage: Crashing (1)-(2) and (1)-(3)



Duration of project = 9 weeks

Cost of project:

$$DC = 37500 + (2500 + 1500) \times 2 = \text{Rs. } 45500$$

$$IC = 9 \times 3000 = 27000$$

$$TC = 72500$$

Since cost will increasing for further stage of crashing.

∴ Optimum time = 11 weeks

Minimum cost = Rs. 70500

