NPTEL lectures

(Week-5) Time-Cost Tradeoff (Crashing)

1) Fast-Tracking v/s Crashing

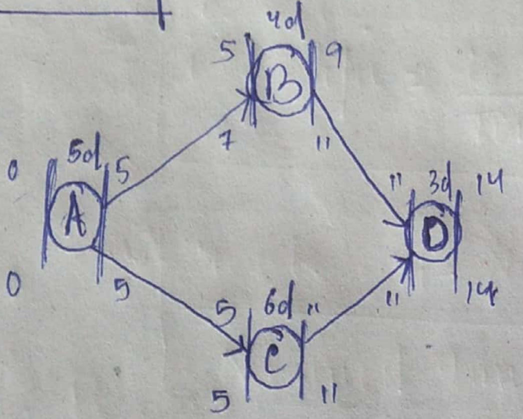
Relⁿ b/w Activity Direct Cost & Activity Duration

– Assumptions

Crashing: Reducing the duration of a project by reducing duration of activity

↳ Also called "Time-cost tradeoff".

Example: ABCD Project.



Activi	Dur.	Predecess
A	5	–
B	4	A
C	6	A
D	3	B, C

current duration: 14d

expected duration: 10 days.

How can it be done?

→ Focus on the critical activities.

→ Reduce the duration of the critical activities.

→ 2 ways to reduce project duration:

i) Fast tracking: Performing activities in parallel

ii) Crashing: Reducing the duration of activity.

* Change of execution sequence or duration like in above 2 cases will have cost implication.

⇒ Note : Time cost trade off analysis is used to find the minm overall project cost for a specified project duration.

* Crashing is performed by expending additional resources.

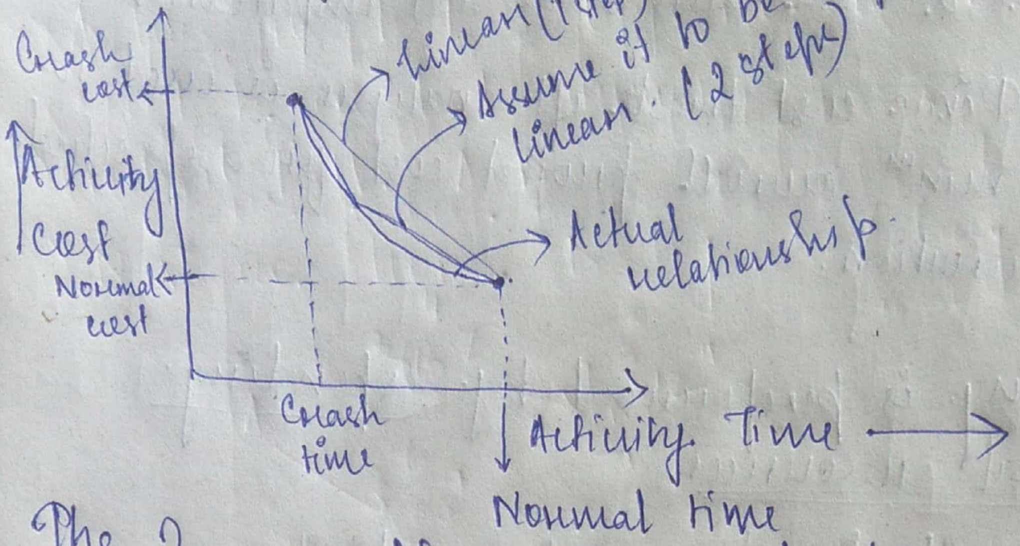
* 2 types of duration wrt an activity.
→ Normal duration : Normal activity duration
→ Crash duration : Minimum duration.

* 2 types of cost :
→ Normal cost : Cost of completing activity in normal duration.
→ Crash cost : Cost of completing activity in minimum duration.

* To reduce duration : (of an activity only)
↳ add extra resources
↳ use advanced technology → Premium
↳ Alt. construction materials (cost ↑)
↳ multiple shifts demand more cost.
↳ overtime work (late hrs or weekends)
↳ Bring in higher capacity equipment.
↳ increase manpower / equipment

⇒ In all the above scenarios; reducing cost will require additional expenditure.

Activity Time - cost relⁿ



The 2 assumptions are made for calculation purpose.

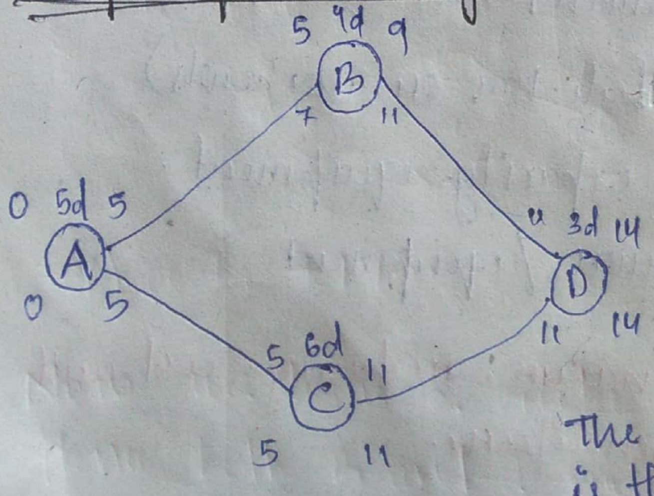
Slope of the line ~~...~~

$\Rightarrow$ cost slope = $\frac{\text{Cost}}{\text{Time}}$

$\Rightarrow$ $\frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal Time} - \text{Crash Time}}$

Lesson 2:

Time - cost tradeoff: ABCD Example Project, Steps of crashing



Cost of crashing: ?
Determine minimum cost of completing project in 13, 12, ... 8 day
Maxᵐ the project can be crashed to: ?
The CD given in the question is the least an activity that can be crashed.

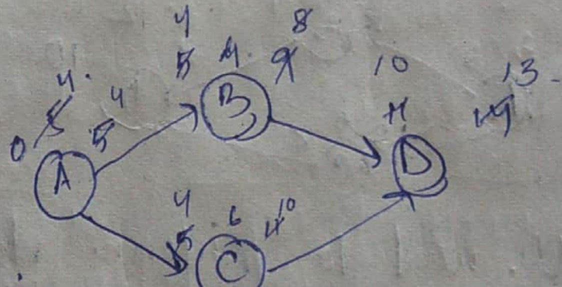
Act	ND	Pred	CD	NC	CC	Crash days	CC/day
A	5	-	3	250	300	2	25
B	4	A	3	300	375	1	75
C	6	A	3	350	875	3	175
D	3	B, C	2	300	350	1	50

① A → C → D is the critical path.
Find unit cost of crashing A, C, D & use it as the benchmark.

② Find Crash Days
= ND - CD. (Normal duration - Crash duration)

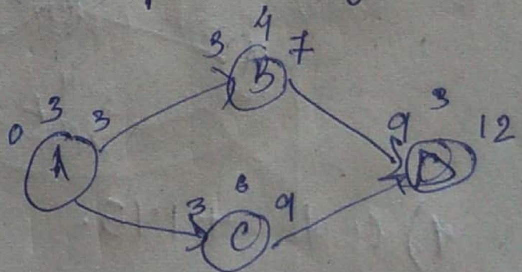
③ Crash cost / day $= \frac{(CC - NC)}{(ND - CD)}$

Need not use B.
A - 25/day
C - 175/d
D - 50/d
} Choose to crash A.



⇒ It cost us 25/day.
⇒ In 14 days, the normal cost.
" 13 days, " " + 25

NOW FOR 12 days:
① In above diagram, the critical path is again ACD
② CC/day = 25/day.
③ Hence reduce A by 1.



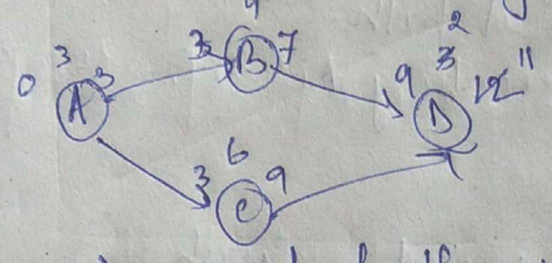
⇒ 14) NC
13) $\cancel{A}$(25)
12d) + 25 Cumulative = 50 (25 + 25)

11 days

⇒ A has reached 3 days i.e. the CD. Hence can't be crashed anymore.

⇒ Critical Path - ACD

⇒ Next we choose D by 50/day. Crash D.



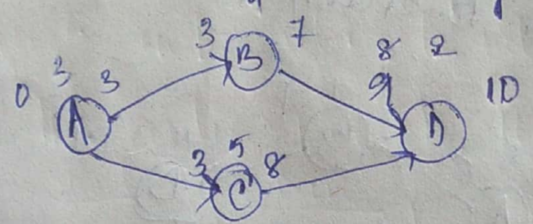
Now D reached the max^m crash.

11) cost = +50.

10 days

⇒ Critical Path stays same.

⇒ Crash C. at 175/day.



C can be crashed further by 3 days after D. But not at a time. Because at 9, there will be 2 Critical Paths.

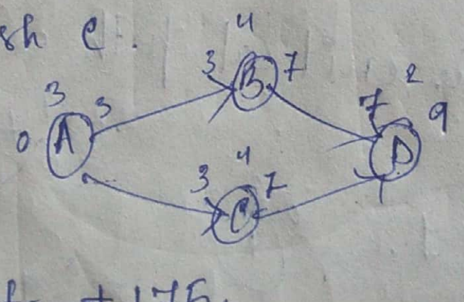
We need to perform step wise reduction.

10) cost = +175.

9 days

Critical Path ACD

Crash C.

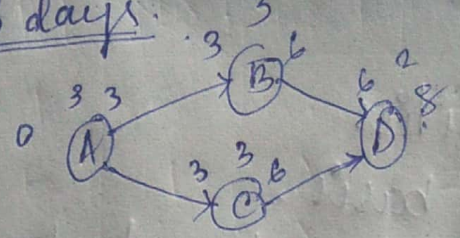


9) cost = +175.

Now we have 2 critical paths.

Hence both B and C are crashed.

8 days.



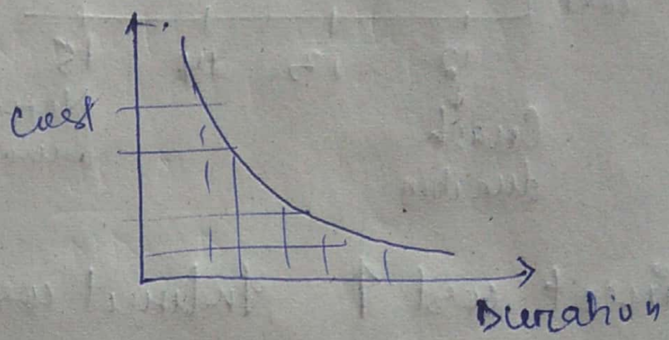
B reached max crash limit.

cost = +175 + 75 = +250.

Now add an attribute "**Direct Cost**"

	Direct cost
14	$\Sigma NC = 1200$
13	+25 = 1225
12	+25 = 1250
11	+50 = 1300
10	+175 = 1475
9	+175 = 1650
8	+250 = 1900
~~7~~	

Total direct cost on the project = 1900.



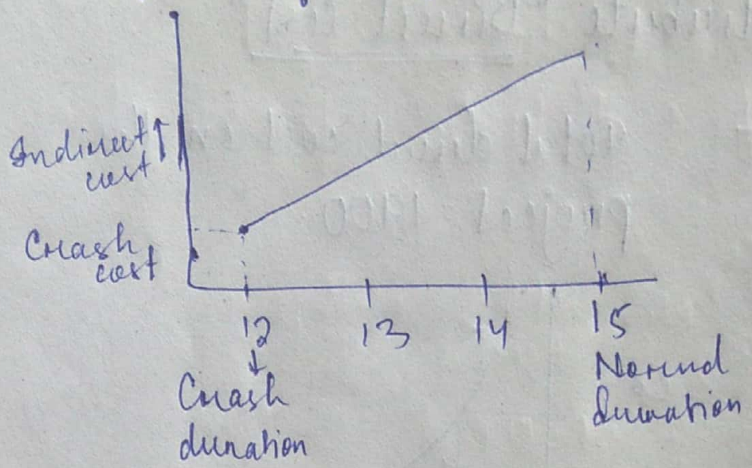
Crashing cost - Summary

Step no	Project duration days.	Activity crashed	Crash cost	Cumulative cost	Total project Direct cost
0	14	None	0	0	1200
1	13	A by 1	25	25	1225
2	12	A by 1	25	50	1250.
⋮	⋮	⋮	⋮	⋮	⋮

* We can plot the max^{m} cost graph too
* Not used in real world. Because the linear assumption might lead to variations.

Indirect Costs

* Not related to any of the activities.
* Remain same on a daily basis.
* ⇒ If no. of days reduced, indirect cost also ↓

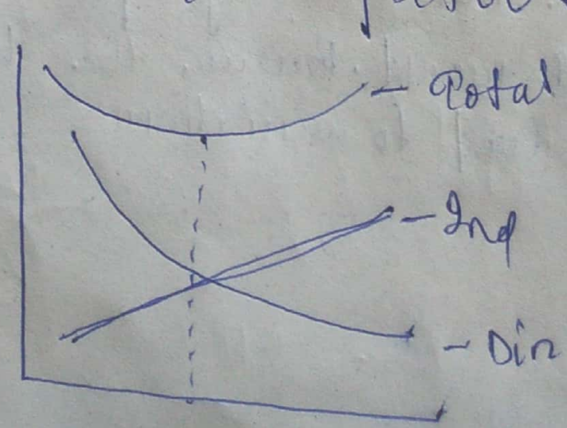


Direct cost ↑ Indirect cost ↓ Duration ↓

⇒ There must be an optimum value of both direct and indirect where project cost is min.

* let the Indirect cost = 100/day.

Ind.	Dir	Sum	
14 – 1400	1200	2600	decrease
13 – 1300	1225	2525	
12 – 1200	1250	2450	
11 – 1100	1300	2400	→ minimum.
10 – 1000	1475	2475	increase
9 – 900	1650	2550	
8 – 800	1900	2700	



Scanned by CamScanner

List of Indirect Costs

→ Project overhead.
- Staff, manager, project engineer salary.
- Office equipment and temporary utilities like electricity, phone.

→ General overhead.
- Main office expence, rent, maintainance.
- Site equipment and vehicles.
- Lawyers and accountants
- Advertising and social activities.

→ Contigency fees.
- Additional cost allocated for unknown events.

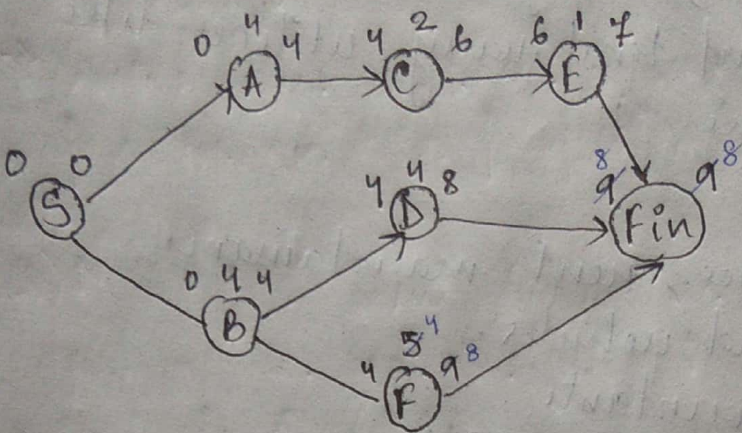
Steps of crashing (from example)

1. Identify activities on critical path(s).
2. Compare unit cost of ~~of~~ crashing (critical) activities / combinations available for crashing. *
3. Select activity / combinations with minimum unit cost. In case of a tie, activity which influences more paths.
4. Reduce the duration of activity / combination. (ensure no other path becomes critical if duration reduction is by more than 1 day)
5. Recalculate n/w parameters and go to step 1.

* Repeat steps until activity / combinations cannot undergo further crashing.

Lesson 3

Time-cost tradeoff: Exercise



Assume indirect cost of 125/day.

Act.	ND	CD.	NC	CC	cc/day
A	4	3	100	125	25
B	4	3	250	400	150
C	2	1	150	300	150
D	4	1	150	600	150
E	1	0.5	200	400	400
F	5	2	200	350	50

Critical Path - ~~A~~ S → B → F → Fin.

8 days: cc/day B = 150/day

F = 50/day ✓ → crash.

F reduced from 5 to 4.

7 days: Now 2 critical paths.

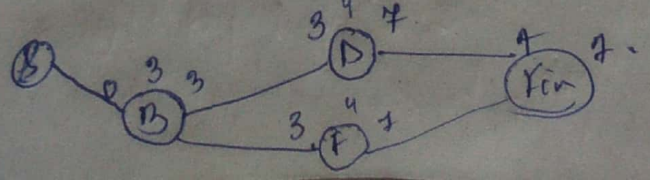
B → D → Fin.

B → F → Fin.

Either B @ 150/day ✓ crash.

D & F @ 150 + 50 = 200/day

B crashed from 4 to 3 (Reached limit)



6 days Now we have 3 critical paths.

A → C → E = 7.

B → D = 7

B → F = 7.

B can't be crashed further.

Hence we can crash ~~A @ 25/day~~.

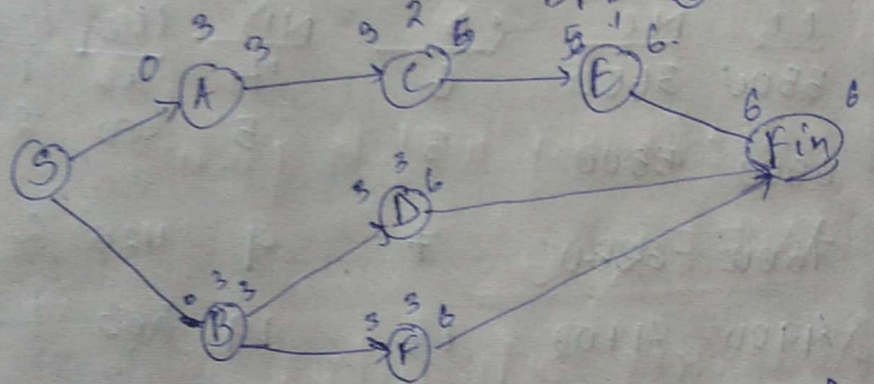
C, D, F @ 350/day

~~F @ 400/day~~

DFA @ 225

DFE @ 600

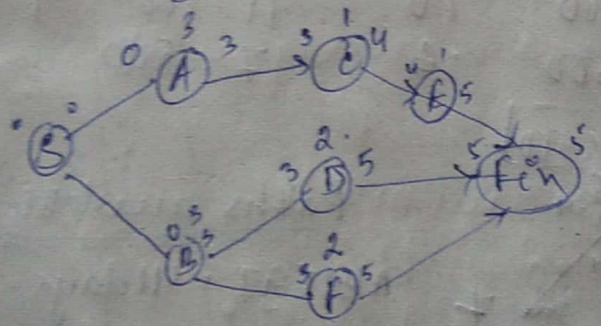
?? Why combinations?



Now A and B are fully crashed.

5 days DFC @ 350 crash

DFE @ 600



Now A, B, C, F have crashed to the limit.

Cost table:

Days	Direct cost	Indirect	Total cost
9	1350	125×9=1125	2475
8		1000	2400
7		875	2425
6		750	2525
5		625	2750

Draw graph

Lesson-4

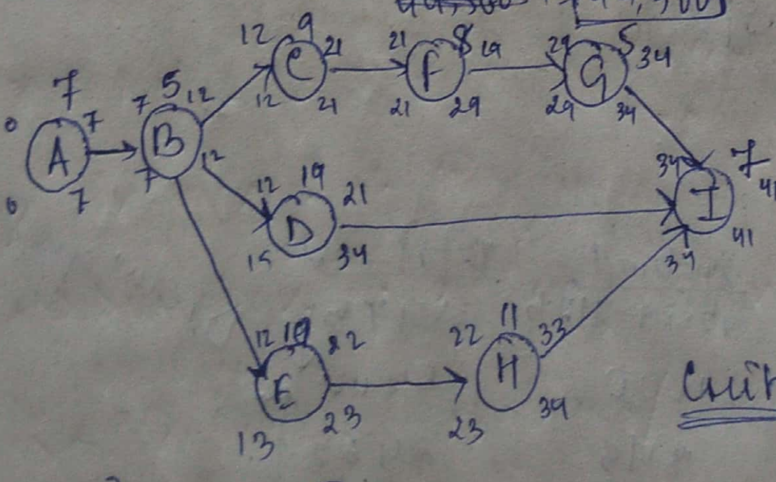
Time Cost Trade off : Problem 3, Tabulation Approach

→ Later we will see influence such as bonus/ penalty on total project cost.

Q) Develop a n/w diagram and develop least cost curve for the project. Assume an indirect cost of 200/day.

Act	Preced by	CC	NC	CD	ND	CC/day	Duration Reduc
A	-	3500	3600	6	7	350	1
B	A	6500	5500	3	5	500	2
C	B	7200	6350	7	9	425	2
D	B	4900	4700	18	19	200	1
E	B	2,200	2050	9	10	150	1
F	C	1700	1200	6	8	250	2
G	F	~~70~~,200	7200	5	5	NA	0
H	E	10000	9400	10	11	600	1
I	D, G, H	4700	4500	6	7	200	1

~~44,500~~ T: $\boxed{44,500}$



Paths available:

ABCFGI = 41 days.

ABDI = 38 days.

ABEHI = 40 days.

Critical = ABCFGI

1) I by 1 @ 200.

I is crashed.. Critical Path remains same.
All the paths reduced by 1. (New diag)

② F by 1 @ 250. (N/w diag)

③ Paths : 39 ✓
37
39 ✓

New combinations / singles :

Possible combinations : CE - 575
CH = 1025
FE = 400
FH - 850.

or singles like A - 300 ✓
B - 500

A by 1 @ 300. (N/w diag).

④. Same critical paths like above.

Possible comb : CE, CH, FE, FH, B.

FE by 1 @ 400 (New diag update).

(Continue the process above)

⇒ Sometimes becomes messy to draw the n/w diagrams all the time and update them.
Hence the tabulation as follows :-

→ Screenshots

Act	Paths requiring redn			Cost slope	Avail crash time ND-CD	Iteration 1	2	3	...	...	0
A	1		0								
B	1										
C											
D											
E											
F											
G											
Init path length	41	38	40	Iteration	Action		Iteration cost				Cum cost
	41	38	40	0							44500
Path length											

Lesson-5 (See again)

Incorporating Factors such as Bonus and Penalty, Problem 4.

* Contranct may specify bonus/or penalty dependin on owner's requirements.
* Specification can vary widely but it is typical to band in on a per day within/excess of normal duration.
* It's an incentive/disinsentive for contractor for early/completion.
* Per day penalty/bonus will be given.