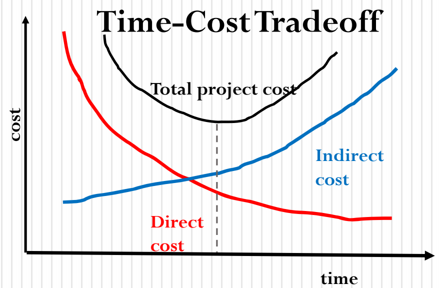
Time-cost trade-off analysis (crash costing)



Crashing Projects

- For any project the two most important aspects to be considered are project cost and project time.
- The project time can be determined by the critical path.
- Many time it becomes necessary to complete the project earlier than the normal time. Project managers may have the option or requirement to **crash** the project, or **accelerate** the completion of the project.
- Accelerating a project means shortening the normal duration of the project schedule (**schedule crashing, schedule compression, Schedule acceleration**)

Why Accelerate a Project?

- The contractor's "normal" finish date in the planned schedule does not meet the imposed finish date of the contract.
- After starting construction and completing a certain percentage of the project, the contractor realizes that the project is behind schedule.
- when the contractor may have a contractual monetary incentive to finish ahead of schedule.
- Sometimes, especially when the economy is doing well, finishing early means—to the contractor—starting another job earlier and, thus, making more profit.

Time /cost trade-off analysis

Time /cost trade –off analysis is the compression of the project schedule to achieve a more favorable outcome in term of project duration , and cost.

Objective of time /cost trade-off
-compress project to an acceptable duration
-minimize total project costs

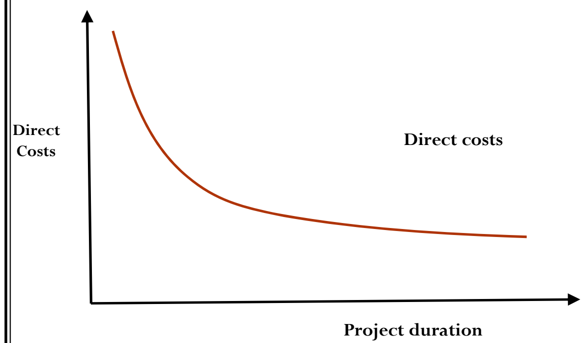
Done by selectively crashing specific activities to shorten project duration

Crash Costing

- The length of the critical path is reduced by reducing the duration of the activities on the critical path.
- If each activity requires the expenditure of an amount of money to reduce its duration by one unit of time, then the project manager selects the least cost critical activity, reduces it by one time unit, and traces that change through the remainder of the network. (Crash costing)
- As an example, if two activities on the critical path can be shorten by 1 week and the costs of shortening are 1000 unit and 1500 units/week each, then the former takes priority for crashing costing.

Logic of Time-Cost Trade-Off

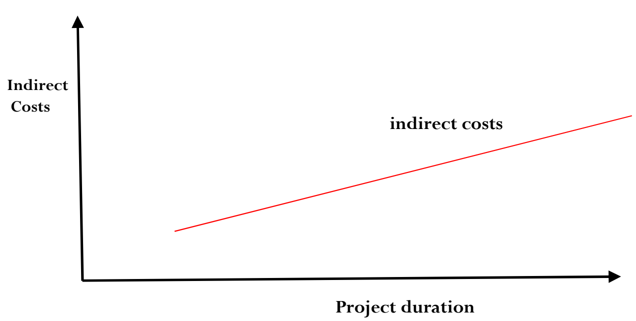
Assumption: *decreasing an activity's duration will lead to increased direct costs for that activity. Direct cost : productive resources (material, labor, equipment, etc..)*



General relation of direct costs to project duration

Logic of Time-Cost Trade-Off

Assumption: *decreasing a project's duration will lead to lower indirect costs. Indirect costs : (overheads, rent, mgt., insurance, salaries)*



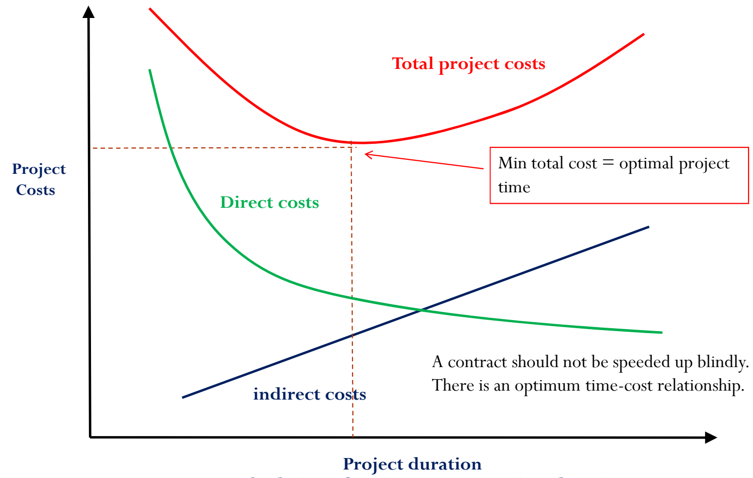
General relation of indirect costs to project duration

Logic of Time-Cost Trade-Off

Assumption: *A project's duration can be decreased by decreasing the duration of one or more critical activities on the critical path.*

Assumption: *Decreasing a project's duration may increase or decrease the total cost of a project depending upon whether the additional direct costs required to decrease the activity duration are greater or less than indirect costs savings of decreasing the project's duration.*

Time-Cost Tradeoff



General relation of project costs to project duration

Graph analysis

- A project's total costs combines direct costs and indirect costs. Therefore, the curve of total costs versus duration involves adding the cost amounts of direct and indirect costs curves.
- Remember, the direct costs curve has a negative slope (*direct costs increase as duration decrease*) and indirect costs curve has a positive slope (indirect costs decrease as duration decreases).
- So, the slope of the total costs curves at any point depends whether the slope of direct costs curve less than that of indirect cost curve.

Activity crashing

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

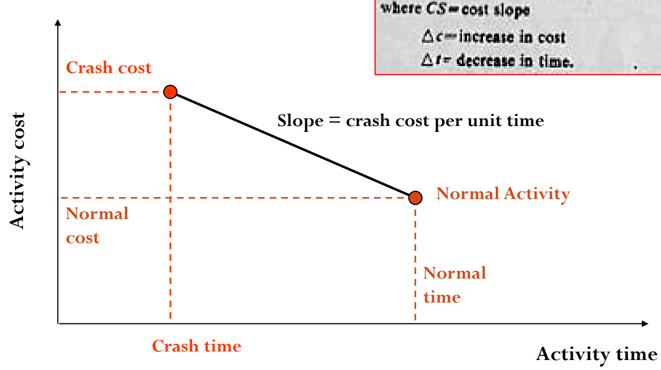
or

$$CS = \frac{C_c - C_n}{t_n - t_c} = \frac{\Delta c}{\Delta t}$$

where CS = cost slope

Δc = increase in cost

Δt = decrease in time.



Definitions

1. **Normal cost (c_n):** this is direct cost required to complete an activity in normal time duration.
2. **Crash cost (c_c):** it is the cost required to complete a project in the minimum possible time.
3. **Normal time (t_n):** normal time is the standard time that an estimator would usually allow for an activity.
4. **Crash time (t_c):** it is the minimum possible time in which an activity can be completed, by employing extra resources. Crash time is that time , beyond which the activity cannot be shortened by any amount of increase in resources.

Four Different Solutions:

- The schedule can be viewed in several different ways in order to satisfy the client.
- A client may wish to perform the project in the lease cost, or in the least time or in any manner satisfies him.

1) ***All Normal:*** the original network and activity duration result in all normal solution, based on each activity being performed in its "NORMAL" least cost manner.

Remember, it is not necessarily the least cost or least time solution to schedule a project.

Four Different Solutions:

2) ***Least Cost:*** considering both direct and indirect costs, it may be possible to find a project duration that minimizes these total costs. By paying more to decrease one or more critical activity (direct cost) and save greater indirect costs. (Means that the result will be total cost saving.)

Four Different Solutions:

3) Least Time: A project can be shortened beyond its least cost duration. Until a point reached where no activities in the critical path can be physically shortened regardless of how many resources are applied. (results in higher costs)

4) All crash: in this solution, every activity has been shortened as much as physically possible. Its duration the same as the least time solution, but its costs greater. Because the direct cost increases without further reductions in the indirect costs. (not efficient approach)

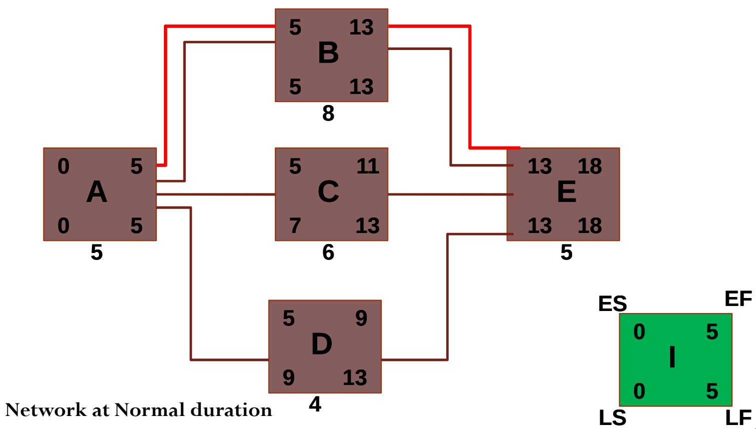
- A fully crashed schedule occurs when all activities shortened to their shortest possible duration

Logically reducing Project Duration

- The logical approach is to shorten those activities that contribute to reduce the project duration.
- To begin the time-cost trade-off in a rational manner, basic calculations needed.
- First compute the early start and early finish times for each activity

Project Crashing example-1

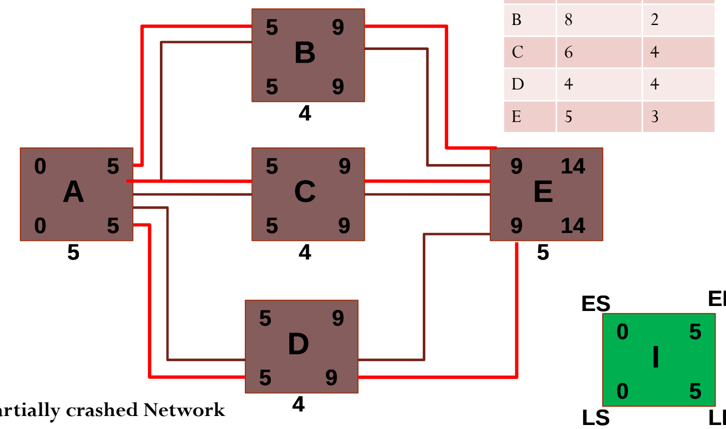
Consider the network below with normal and crash duration as given in the Table



Network at Normal duration

Project Crashing example-1

Act.	Normal dur.	Crash dur.
A	5	3
B	8	2
C	6	4
D	4	4
E	5	3



Partially crashed Network

Project Crashing example-1

- Duration of the crashed network in the above case is 14 weeks and there are three critical paths.
- Shortening either activity A or E would reduce the duration but in the middle area all the three activities would have to be shortened simultaneously to effect further reduction.

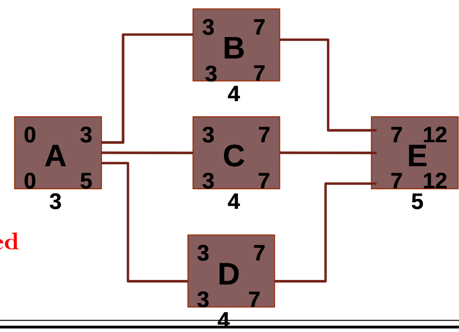
Project Crashing example

- Given the crash cost, crash time, and normal cost for the project below:
- Find optimum time/cost

Act.	Normal time	Normal cost	Crash time	Crash cost	Cost slope	Priority
A	5	2000	3	2400	200	1
B	8	2500	2	4500	333	2
C	6	3000	4	4500	750	3
D	4	2000	4	2000	0	
E	5	1000	3	3500	1250	4
		10,500		11,070		

Project Crashing example

- If we want to reduce the contract duration to, say, 12 weeks
  - Shorten activity A by 2 weeks (least cost slope)
  - Shorten activity B by 2 weeks
  - Shorten activities B and C by 2 weeks



The crashed Network

Project Crashing example

- The increase in direct cost with weeks saved shown below

	Total cost	Time saved	Cost/week	Contract duration
Shorten Activity A	400	2	200	16
Shorten Activity B	666	2	333	14
Shorten Activity B and C	2166	2	1083	12

sum = 3,232

- If we assume an indirect cost of 500 units/week (linear)

Project Crashing example

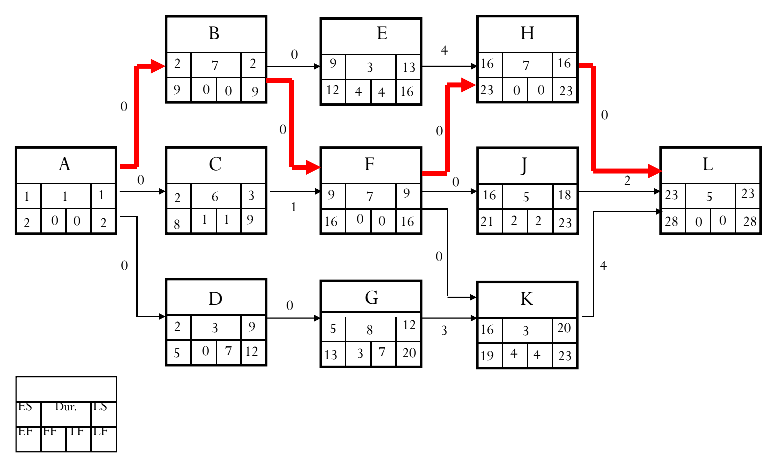
- The table below shows the time/cost relationships

	12	14	16	18	20
Normal contract sum	10,500	10,500	10,500	10,500	10,500
Increase in direct cost	3,232	1,066	400	-	-
Indirect cost saving	-3,000	-2,000	-1,000	-	1,000
Total contract cost	10,732	9,566	9,900	10,500	11,500

- The optimum time/cost relationships is 14 weeks duration resulting in a cost of 9,566. Plot the above curve.

Example-2

Reducing Project Duration to shortest possible duration



Example-2 calculations

- By computing the link lag values between activities.
(Lag = ES(i+1) – EF(i)). It is logical that there is at least one path between the first activity and last activity where lag values are 0.

- These activities forming the critical path. (other solution can be derived by computing TF).

- In the previous network. Activity **A,B,F,H and L** forming the **critical path**.

Example-2 calculations

- To shorten the project's duration it is essential to shorten on of the critical activities. A or B or F or H or L.

- Without shortening the project will end after 28 days with a cost of 5300 $.

- This is the normal duration cost. And any decrease in duration will increase the direct cost.

- The following table shows information about activities.

Example-2 data

Activity	Cost / day	Normal Duration	Crash Duration	Normal Cost	Crash Cost	Days to shorten
A	-	1	1	800	800	0
B	200	7	4	1000	1600	3
C	100	6	4	300	500	2
D	400	3	2	400	800	1
E	50	3	1	100	200	2
F	150	7	5	500	800	2
G	300	8	4	200	1400	4
H	250	7	6	350	600	1
J	75	5	3	700	850	2
K	500	3	2	500	1000	1
L	350	5	4	450	800	1

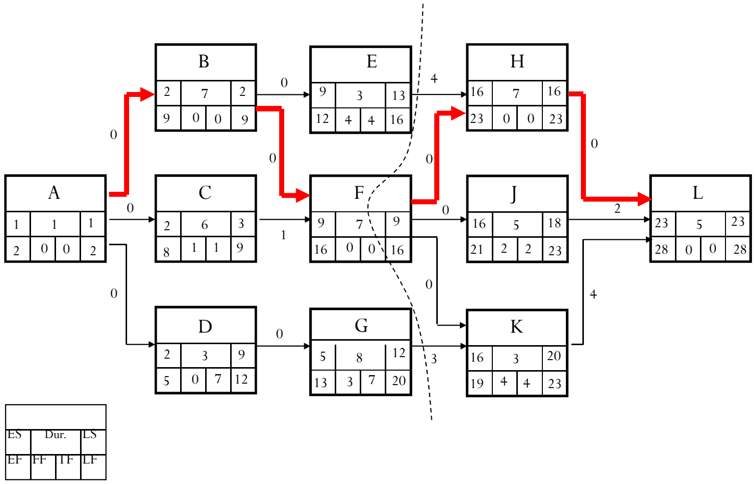
Identifying activities for 1st compression cycle

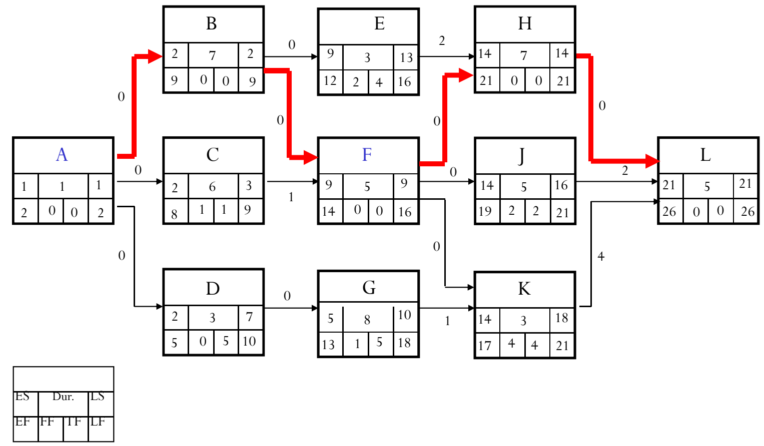
Activity	A	B	F	H	L
(slope) Cost/day	-	200$	150$	250$	350$

F : Least cost activity to shorten

Shortening F for 2 days costs 150 x 2 = 300 $.

- So, reducing activity F by 2 days will affect the link lag values of the succeeding activities and TF of parallel activities





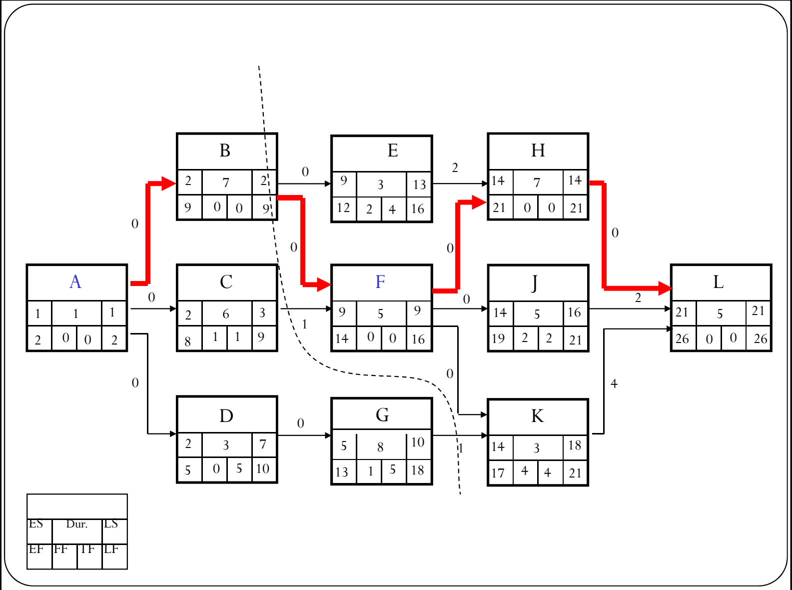
Summary of the first compression cycle

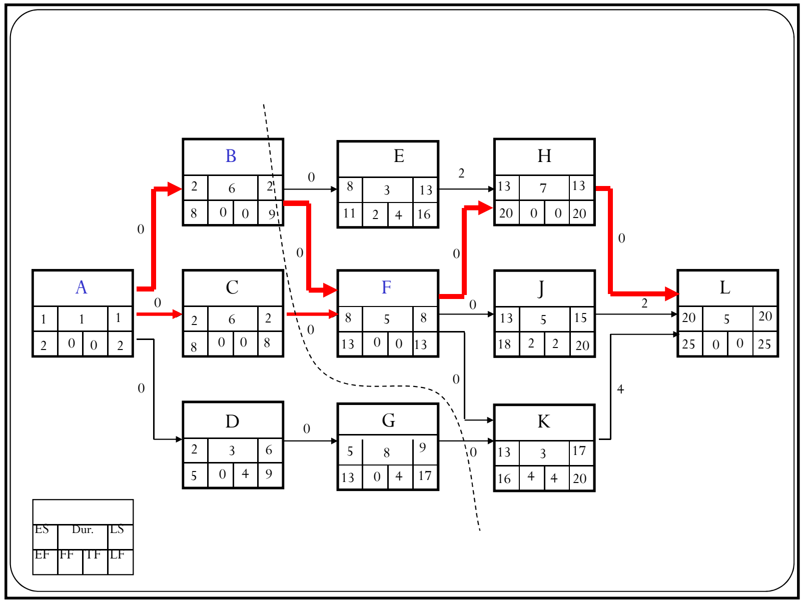
Cycle #	Activity to shorten	Can be shortened	Days shortened	Cost per day	Cost per cycle	Total cost	Project duration
0	--	--	--	--	--	5300	28
1	F	2	2	150 $	300 $	5600	26

Identifying activities for 2nd compression cycle

Activity	A	B	F	H	L
Cost/day	-	200$	-	250$	350$

B : Least cost activity to shorten





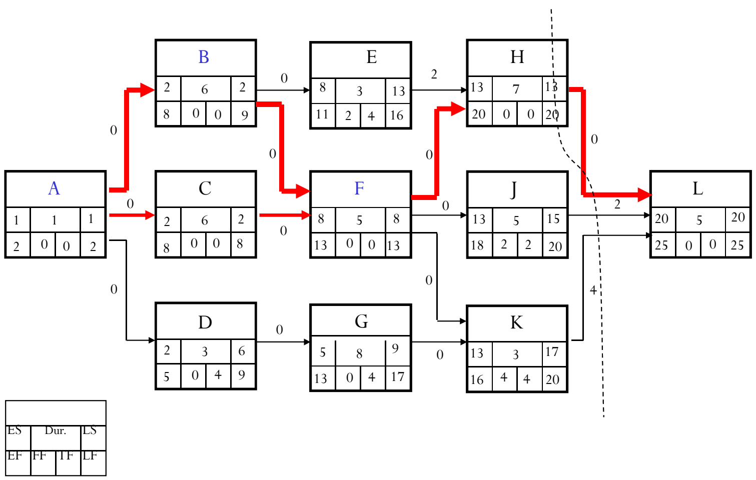
Summary of the 2nd compression cycle

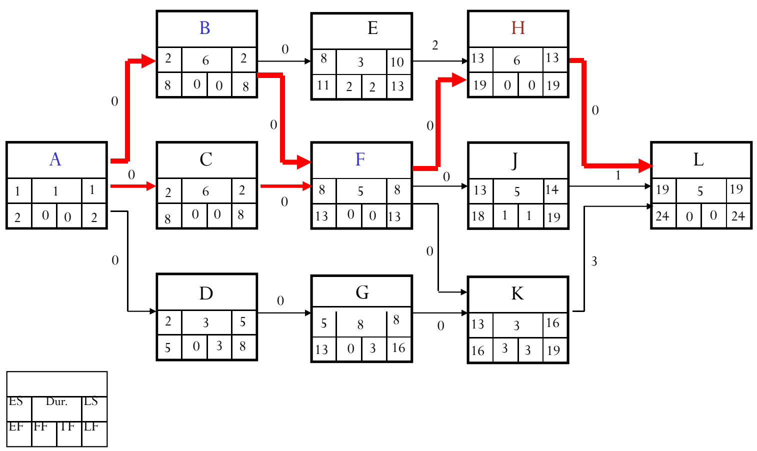
Cycle #	Activity to shorten	Can be shortened	Days shortened	Cost per day	Cost per cycle	Total cost	Project duration
0	**--**	**--**	**--**	**--**	**--**	**5300**	**28**
1	**F**	**2**	**2**	**150 $**	**300 $**	**5600**	**26**
2	**B**	**3**	**1**	**200**	**200**	**5800**	**25**

Identifying activities for 3rd compression cycle

Activity	A	B,C	F	H	L
Cost/day	-	300$	-	250$	350$

H : Least cost activity to shorten





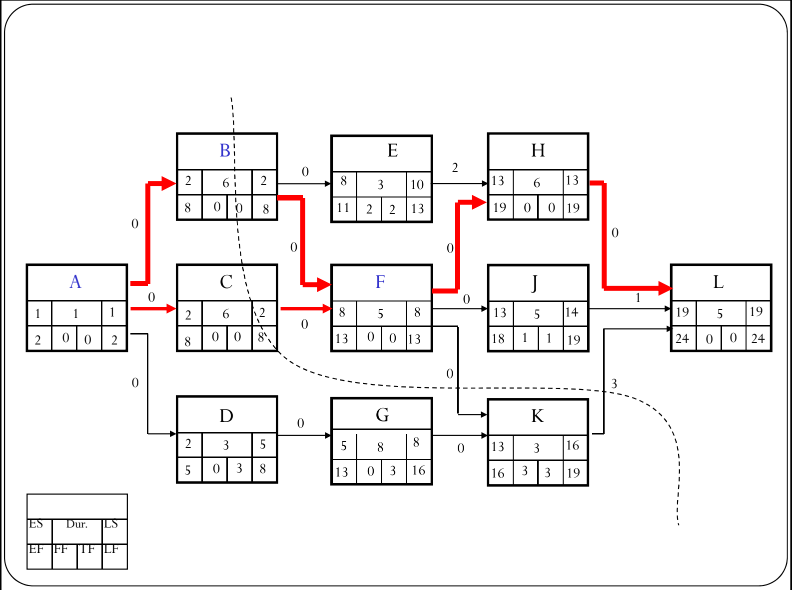
Summary of the 3rd compression cycle

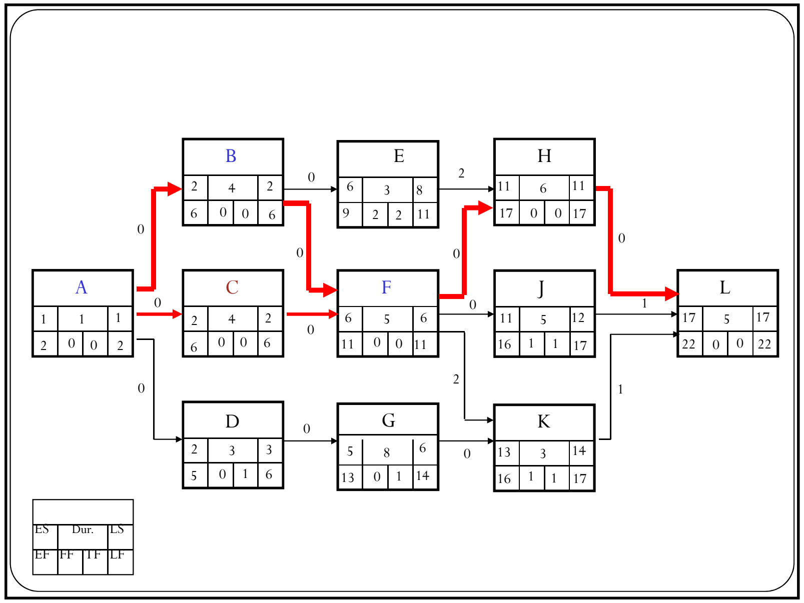
Cycle #	Activity to shorten	Can be shortened	Days shortened	Cost per day	Cost per cycle	Total cost	Project duration
0	--	--	--	--	--	5300	28
1	F	2	2	150 $	300 $	5600	26
2	B	3	1	200	200	5800	25
3	H	1	1	250	250	6050	24

Identifying activities for 4th compression cycle

Activity	A	B,C	F	H	L
Cost/day	-	300$	-	-	350$

B,C : Least cost activities to shorten





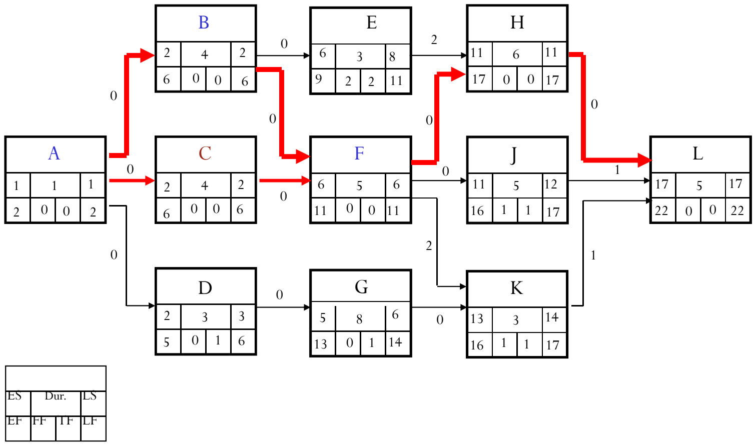
Summary of the 4th compression cycle

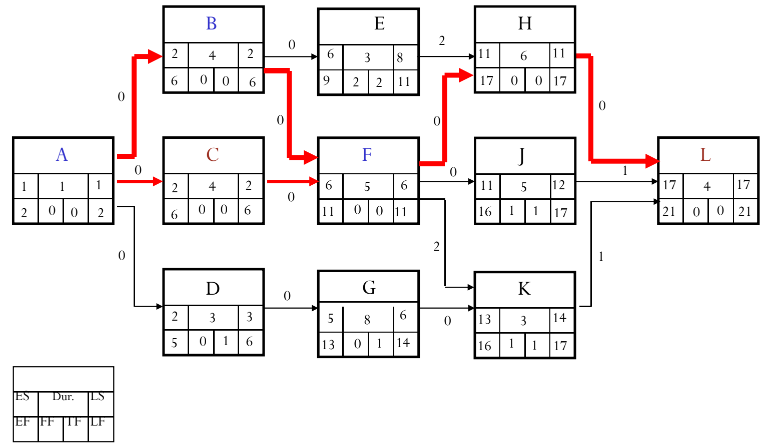
Cycle #	Activity to shorten	Can be shortened	Days shortened	Cost per day	Cost per cycle	Total cost	Project duration
0	--	--	--	--	--	5300	28
1	F	2	2	150 $	300 $	5600	26
2	B	3	1	200	200	5800	25
3	H	1	1	250	250	6050	24
4	B,C	2	2	300	600	6650	22

Identifying activities for 5th compression cycle

Activity	A	B,C	F	H	L
Cost/day	-	-	-	-	350$

L : Least cost activity to shorten





Summary of the 5th compression cycle

Cycle #	Activity to shorten	Can be shortened	Days shortened	Cost per day	Cost per cycle	Total cost	Project duration
0	--	--	--	--	--	5300	28
1	F	2	2	150 $	300 $	5600	26
2	B	3	1	200	200	5800	25
3	H	1	1	250	250	6050	24
4	B,C	2	2	300	600	6650	22
5	L	1	1	350	350	7000	21

Identifying activities for 5th compression cycle

Activity	A	B,C	F	H	L
Cost/day	-	-	-	-	-

NO Crashing