Time-Cost Trade-Off

(Time Reduction = Time Compression = Time Shortening)

< Why Project Time Reduction

- To meet the customer contractually required time.
- To recover time of delays, that occur in the early stages of the project, to avoid paying liquidated damages, or avoid damaging the company relationship with the customer.
- To complete a project early, free key resources and move on to another project.
- To avoid adverse weather.
- To receive an early-completion bonus. (By the Contract)
- To realize incentive pay. (catch a business season)
- To meet a client’s desire for expediting the project.

< How to Shorten Project Time

1. **Free Time**

- Reviewing the job logic (critical activities in parallel).
- Reviewing duration of critical activities.
- Use overlap.
- Use subcontractor.

< How to Shorten Project Time

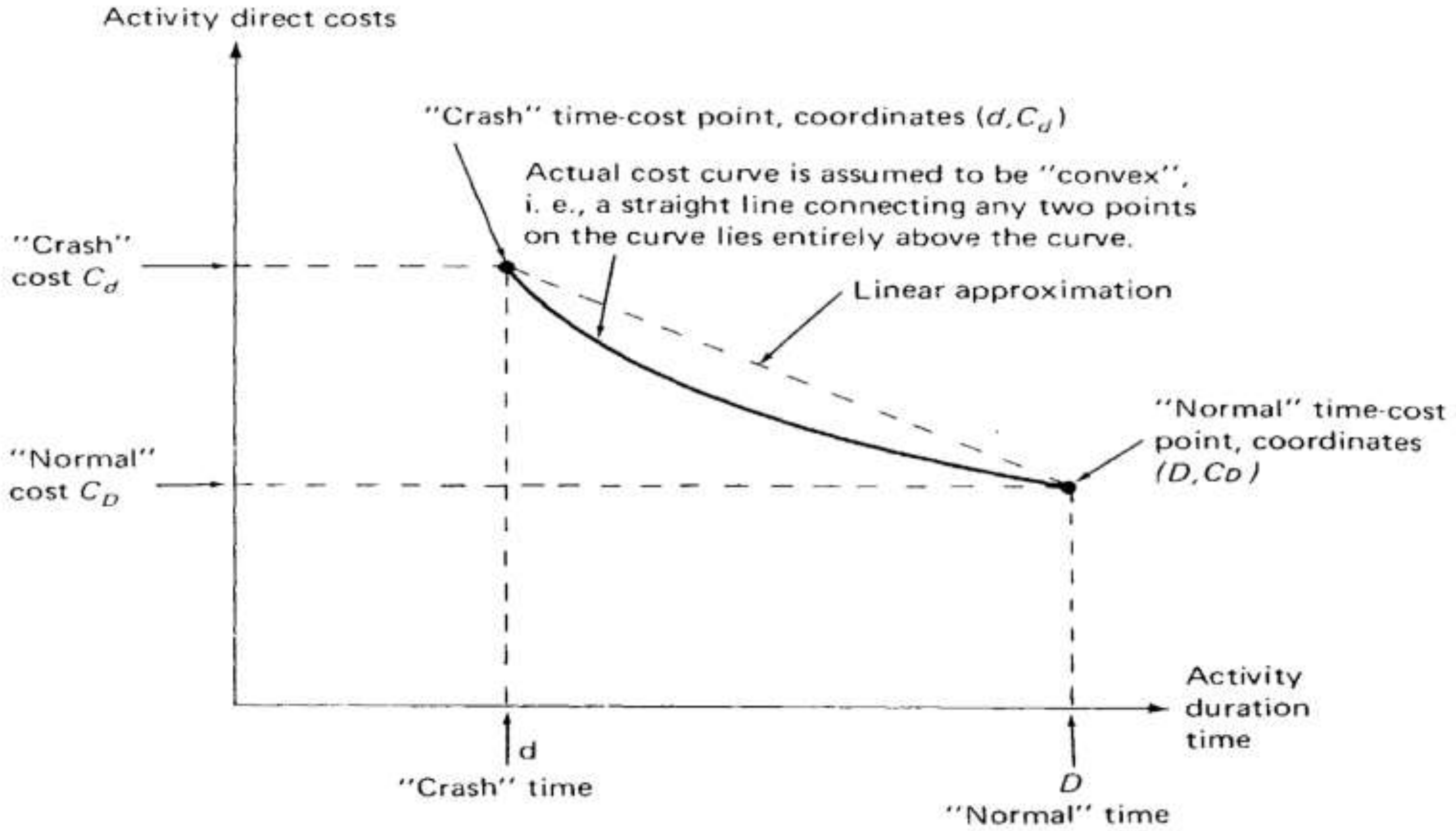
2. Buy Time

- Have the existing crew work overtime.
- Bring in additional workers (resources) up to practical limit.
- Work on multiple shifts.
- Achieve more output by offering incentive payments.
- Use better/more advanced equipment.
- Use more quickly installed materials.
- Use subcontractors.
- Change construction method.

< Purpose of Time Reduction Technique

The main purpose of this topic is to demonstrate a procedure to determine activity schedules to reduce the project duration time with a minimum increase in the project direct costs, by buying time along the critical path (s) where it can be obtained at least cost.

< Definitions



Activity time-cost trade-off input for the CPM procedure

< Definitions

1. **Activity Direct Costs**: include the cost of the material, equipment, and direct labor required to perform the activity in question. If the activity is being performed in its entirety by a subcontract, plus any fee that may be added.

1. **Project indirect costs***:* may include, supervision and other customary overhead costs, the interest charges on the cumulative project investment, penalty costs for completing the project after a specified date, and bonuses for early project completion.

< **Definitions**

Normal Activity Time-cost Point

3. **Normal Activity Time (*D*):** It is the normal time that is used in the basic critical path planning and scheduling based on the normal level of resource.

4. **Normal Activity Cost (C_D):** The normal activity cost is equal to the minimum of direct costs required to perform the activity, and the corresponding activity duration is called the normal time.

The normal time is actually the shortest time required to perform the activity under the minimum direct cost constraint.

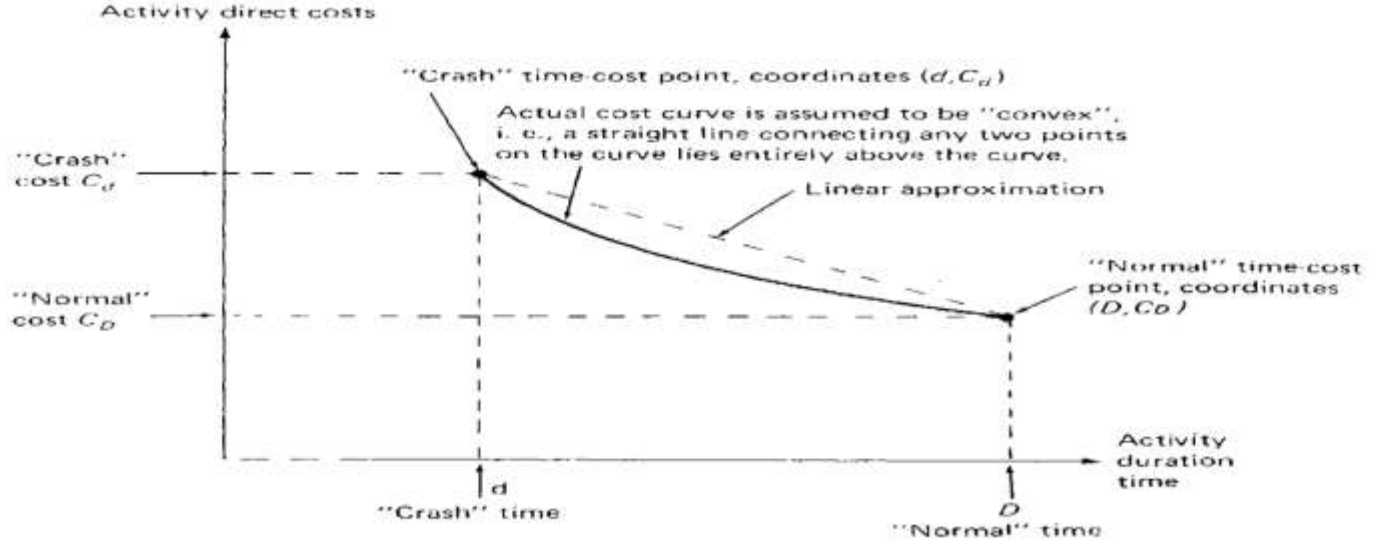
< Definitions

Crash Activity Time-cost Point

5. **Crash Activity Time (*d*):** is fully expedited or minimum activity duration time that is technically possible.
6. **Crash Cost (C_d):** is assumed to be the minimum direct cost required to achieve the crash performance time.

< Activity Direct Cost / Time Relationship

- The relationship between the activity direct cost and activity time may be straight line, continuous curve, discrete values, or point.
- The direct cost tends to increase if less time is available for activity.
- Time reduction approach (learned here) will be based on simple linear time-cost trade-off curves for each activity



Activity time-cost trade-off input for the CPM procedure

< Equations

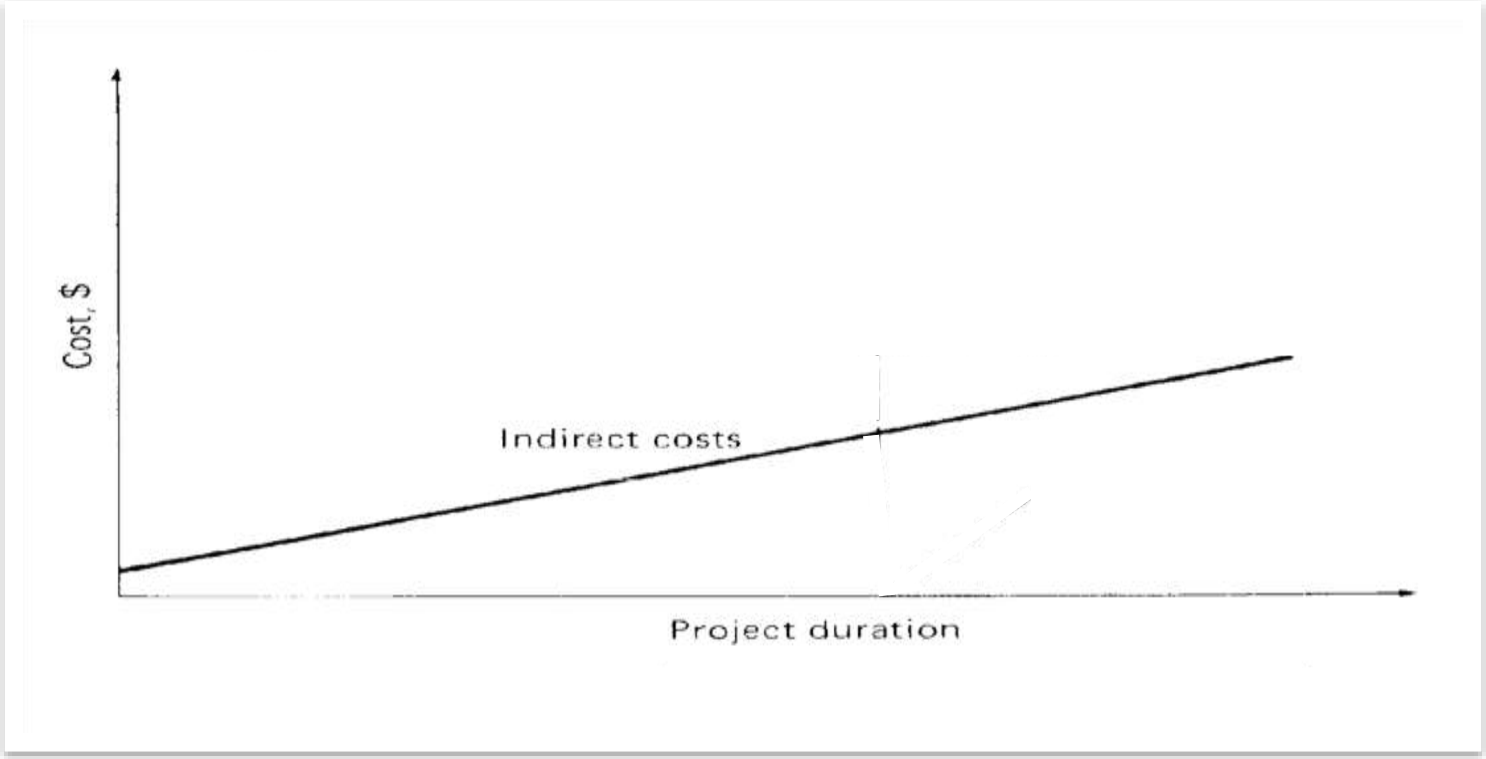
$$\text{Cost slope } (C_{ij}) = \frac{\text{Crash cost } (C_d) - \text{Normal cost}(C_D)}{\text{Normal duration } (D) - \text{Crash duration}(d)}$$

$$\text{Time Available } (TA_{ij}) = [\text{Normal duration } (D) - \text{Crash duration}(d)]_{ij}$$

$$\text{Effective Cost Slope } (EC_{ij}) = \frac{\text{Cost slope } (C_{ij})}{\text{Number of inadequately shortened paths } (N_{ij})}$$

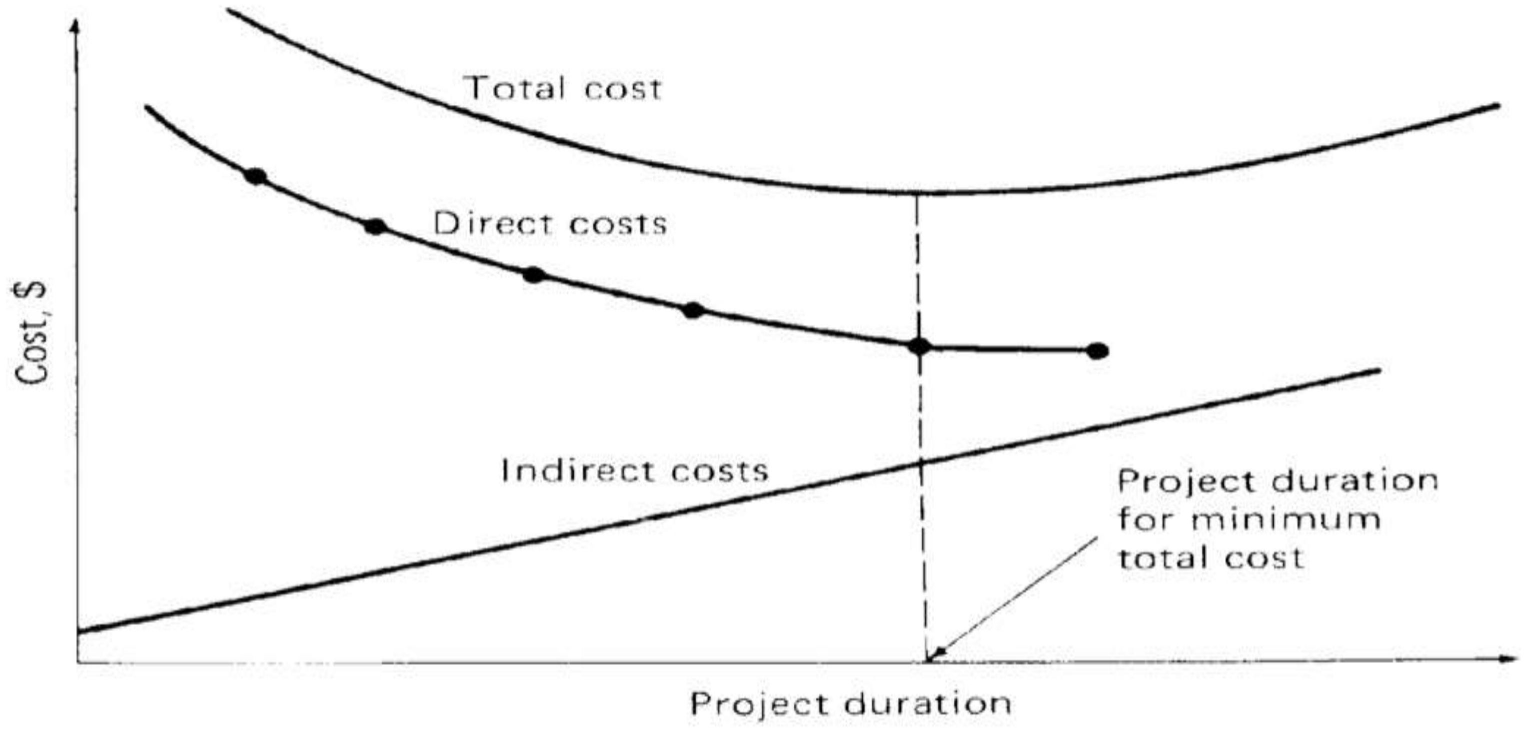
< Indirect Cost / Time Relationship

The indirect cost tends to increase if more time is consumed for the project.
The indirect cost is generally vary approximately linearly with the time.



< Optimum Contract Duration

Optimum contract duration = project schedule for minimum total cost



Determining project schedule for minimum total cost

< Procedure for Shortening Project Time

1. Prepare the project Network and time estimates, and list in columns all paths through the network whose expected lengths are greater than the desired (schedule) project duration, T_s. The length of a path in question. Also, note at the bottom of each path column (row marked iteration 0), the time reduction that is required, i.e. expected path length minus T_s.
2. List (in row) all activities present in at least one of the listed paths noting for each activity its cost slope, C_{ij} , and time reduction available, TA_{ij}.
3. Compute the effective cost slopes, EC_{ij}, and record them in the column headed iteration 1.

< Procedure for Shortening Project Time

4. For the path(s) with the most remaining time reduction required, select the activity with the lowest effective cost slope. Break ties by considering the following ordered list:
    1. Give preference to the activity which lies on the greatest number of inadequately shortened paths.
    2. Give preference to the activity which permits the greatest amount of shortening.
    3. Choose an activity at random.
5. Shorten the selected activity (i-j) as much as possible, which will be equal to the minimum of the following:
    1. The unallocated time remaining for the selected activity (i-j), or
    2. The smallest demand of those inadequately shortened paths containing the activity (i-j).

< Procedure for Shortening Project Time

6. Sell back, or deshorten, as much time possible on paths that have been overcut, as long as this action does not cause any new paths to become inadequately shortened.
7. Stop of all paths have been adequately shortened. If not, recalculate those effective cost-slopes where any of the following have occurred:
    1. A path which was inadequately shortened prior to this iteration, has been adequately shortened, or
    2. All unallocated time for the activity just shortened has been consumed and there are one or more additional cost-slope/supply pairs for this activity.
8. Return to Step 4.

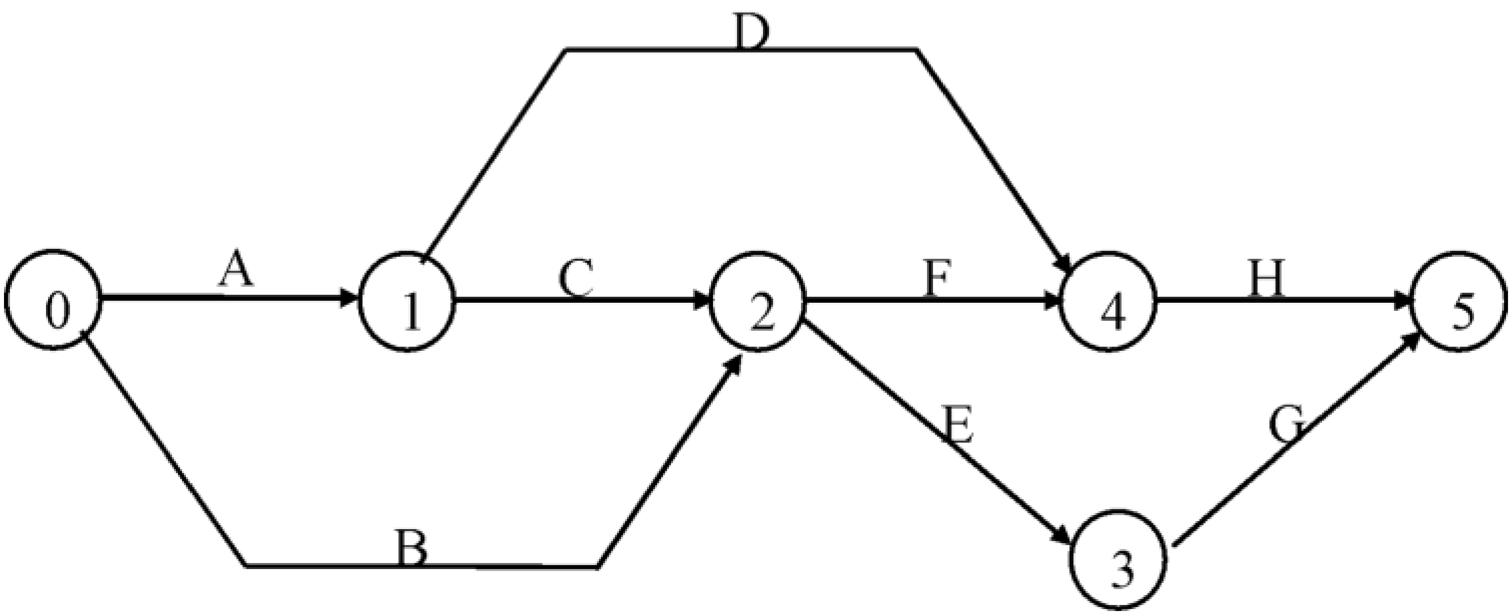
< Example

The below network shows the activities of a small engineering project. Data of the project is given in the below table. The indirect cost is estimated to be SR100/day. Draw the contract total cost/time curve and determine the optimum contract duration.

Activity code	Time (day)		Cost (SR)	
	normal	crash	normal	Crash
A	4	3	210	280
B	8	6	400	560
C	6	4	500	600
D	9	7	540	600
E	4	1	500	1,100
F	5	4	150	240
G	3	3	150	150
H	7	6	600	750

< Example

Project Network



< Example

Activity	Normal		"Crash"		Cost Slope
	Time	Cost	Time	Cost	
A (0,1)	4 days	SR210	3 days	SR280	SR70
B (0,2)	8 days	400	6 days	560	80
C (1,2)	6 days	500	4 days	600	50
D (1,4)	9 days	540	7 days	600	30
E (2,3)	4 days	500	1 days	1,100	200
F (2,4)	5 days	150	4 days	240	90
G (3,5)	3 days	150	3 days	150	**
H (4,5)	7 days	600	6 days	750	150
		∑SR3,050		∑SR4,280	

** This Activity can not be expected.

Reduction project time from 22 to 17 day

Activity	Paths Requiring Reduction			Cost Slop	Effective Cost Slop	Time Reduction Available
	A-C-F-H	A-D-H	B-F-H			
A (0,1)	1	1		70	35	~~1~~ 0
B (0,2)			2	80	80	~~2~~ 1
C (1,2)	2			50	50	~~2~~ 0
D (1,4)		2		30	30	~~2~~ 1
F (2,4)	1		1	90	45	~~1~~ 0
H (4,5)	1	1	1	150	50	~~1~~ 0

Initial Path Length	22	20	20	Iterat-ion	Action	Iteration Cost	Cumulative Cost
Remaining	5	3	3	0	——	——	3050
Time	4	2	3	1	Cut A by 1 day	1 x 70=70	3120
Reduction	3	2	2	2	Cut F by 1 day	1 x 90= 90	3210
Required	2	1	1	3	Cut H by 1 day	1 x 150=150	3360
(17 day	0	1	1	4	Cut C by 2 days	2 x 50=100	3460
project	0	0	1	5	Cut D by 1 day	1 x 30= 30	3490
duration)	0	0	0	6	Cut B by 1 day	1 x 80= 80	3570

< Reduction project time from 22 to

Activity	Paths Requiring Reduction	Cost Slop	Effective Cost Slop	Time Reduction Available
A (0,1)				
B (0,2)				
C (1,2)				
D (1,4)				
F (2,4)				
H (4,5)				

Initial Path Length		Iterat-ion	Action	Iteration Cost	Cumulative Cost
Remaining					
Time					
Reduction					
Required					
(day					
project					
duration)					

< Accelerating the Critical and Noncritical path

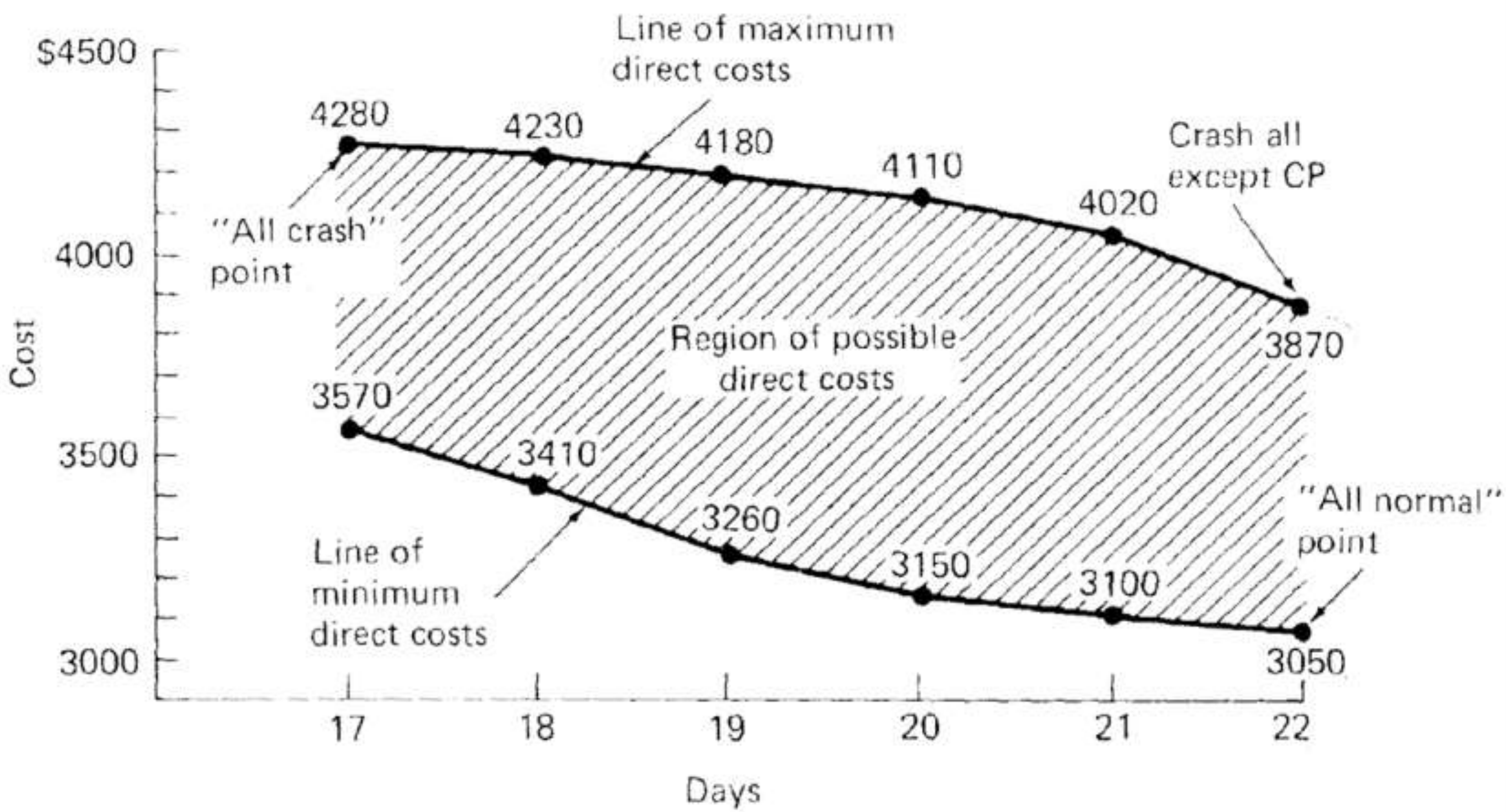
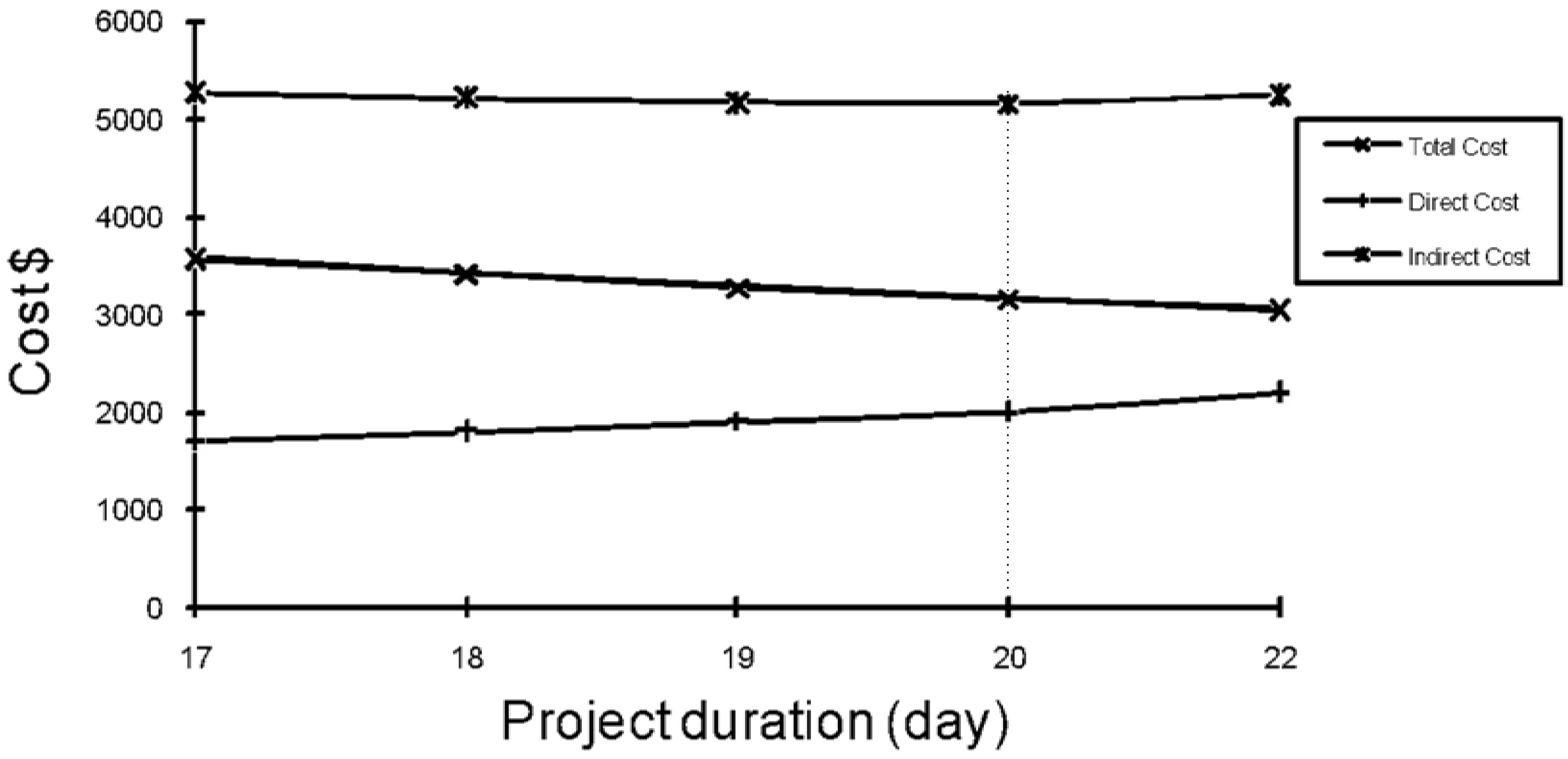


Figure 8-6 Project duration vs. direct cost for sample network in Figure 8-1.

< Optimal Project Duration

Project Duration	17	18	19	20	22
Direct Cost	3570	3410	3260	3150	3050
Indirect Cost	1700	1800	1900	2000	2200
Total Cost	5270	5210	5160	5150	5250



< Class work

Data on small maintenance project is given as below:

Activity	Depends on	Normal		Crash	
		Time	Cost	Time	Cost
A	–	6 days	$700	4 days	$800
B	–	4 days	400	4 days	400
C	–	5 days	650	4 days	700
D	A	8 days	625	5 days	700
E	B	10 days	200	7 days	350
F	B	7 days	500	5 days	700
G	C	3 days	600	3 days	600
H	D, E	6 days	300	5 days	400
I	F, G	7 days	350	4 days	425

On completion, the project will give a return of $110/day. Using time-cost trade-off method, how much would you like to compress the project for maximizing the return? Show all calculations.