Cost-Time Optimization

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What is Cost-Time Optimization?

Cost-time optimization, or cost-time planning, is a process by which an attempt is made to optimize both the project duration and the project cost

The main objective is to determine the optimum trade-off of project duration and total project cost. It amounts to the determination of the duration of a project that minimizes the sum of the direct costs and indirect costs

The major factors dominating the selection of the best combination may be cost, time, or both

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What is Cost-Time Optimization?

Also known as “least-cost expediting”, “project compression” and “time-cost trade-off”

The term “least-cost” is a little unfortunate because often times when a job is in progress, an owner may request that the contractor quote a price for expediting the work

A common motivation for time acceleration is when substantial delays must be recovered by the end of the project

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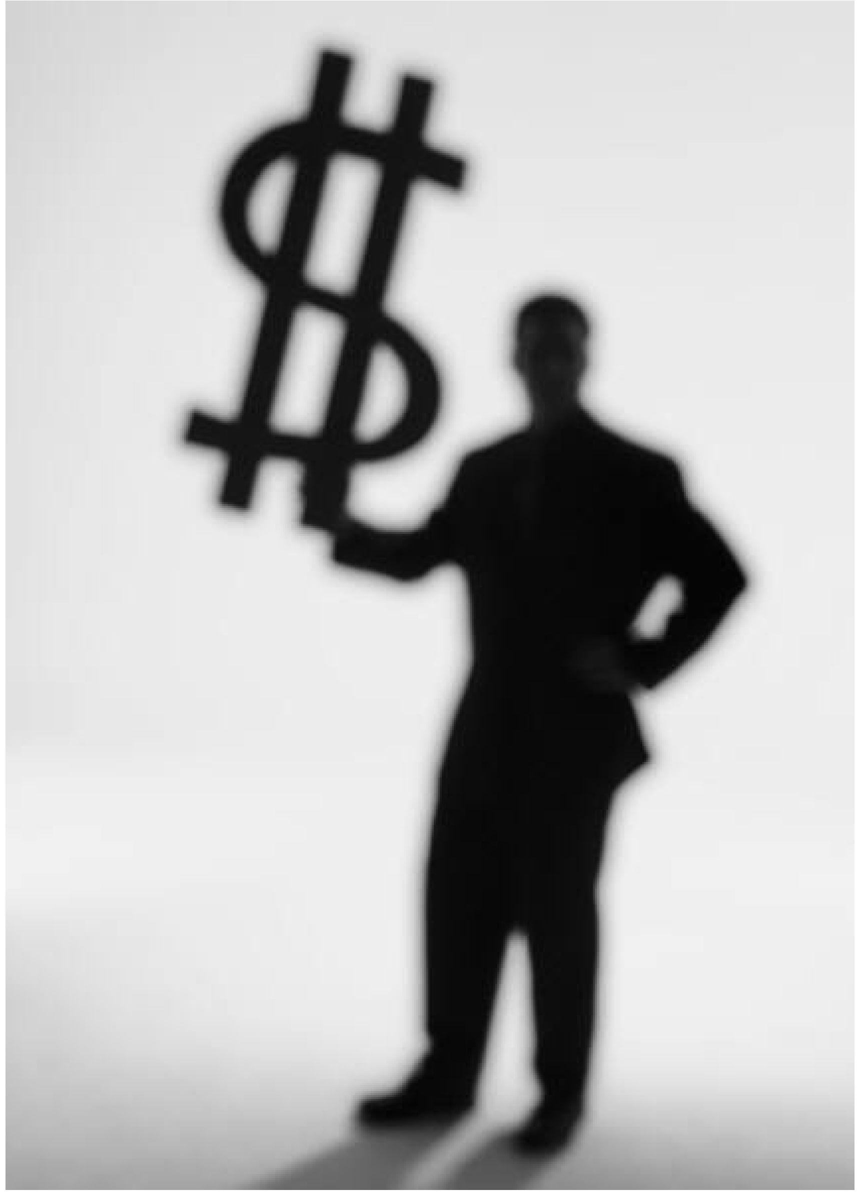
Activity Costs

The duration and the direct cost of an activity depend on the amount of resources allocated to it, the time for which the resources are used, and the unit rate of using the resources

The direct cost of an activity is made up of the expense of labour, plant, materials and subcontracts, but exclusive of additions for site overheads, head office overheads and profits

Each activity has its normal cost and normal duration. The normal cost is the least direct cost (customarily used in estimates). The normal duration is the activity duration determined during the scheduling phase



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Utility Data

An activity may be carried out in many ways by changing the resources allocated to it.

Utility Data is data regarding the various combinations of: (a) resources used; (b) duration; and, (c) direct cost for performing the activity

Suppose 20 men, working normally at 8 hr/day, can perform an activity in 10 days.

Normal rate - $5 per hr. Overtime rate - $7.50 per hr. Time required for activity = 1600 hr

Assume that if the activity is to be speeded up, then 20 men will do the work by working overtime

Table 1 gives the resulting Utility Data

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Utility Data

Table 1. Utility Data

Duration (Days)	Normal Hours	Overtime Hours	Direct cost ($)
10	1600	0	8 000
8	1280	320	8 800
6	960	640	9 600

The direct cost and the corresponding duration (days) will form a set of utility data for the activity under consideration

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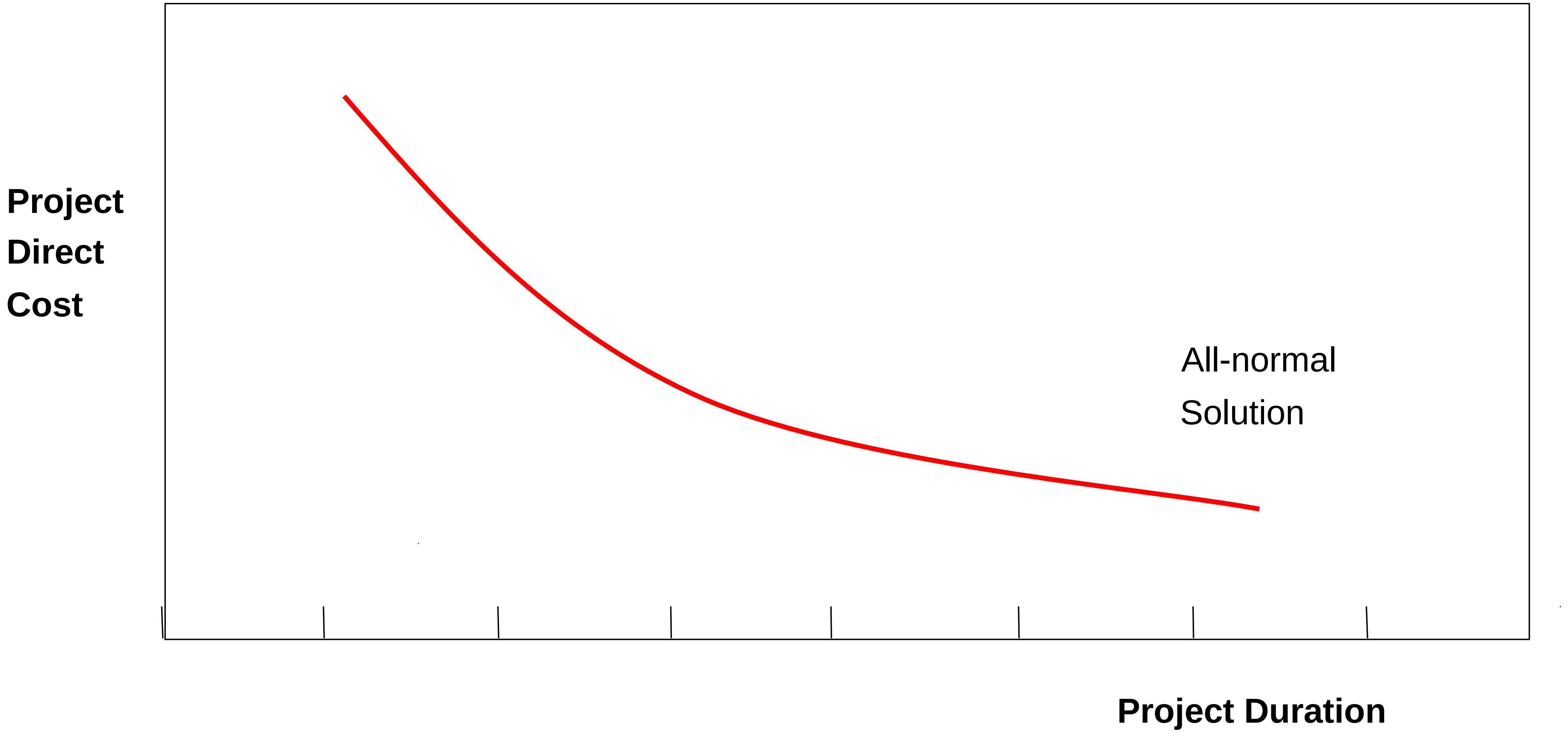
Project Cost vs. Project Duration



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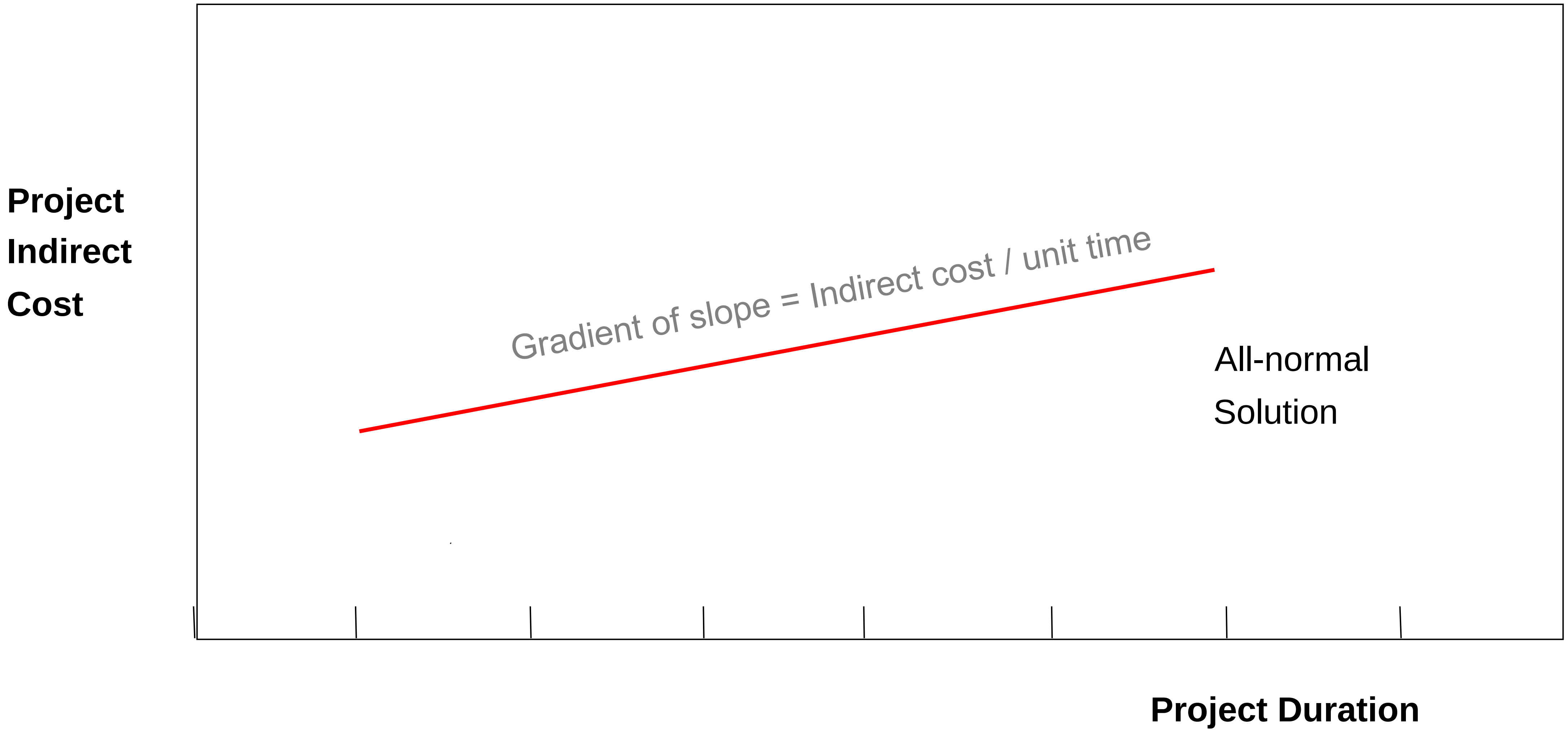
Project Cost vs. Project Duration



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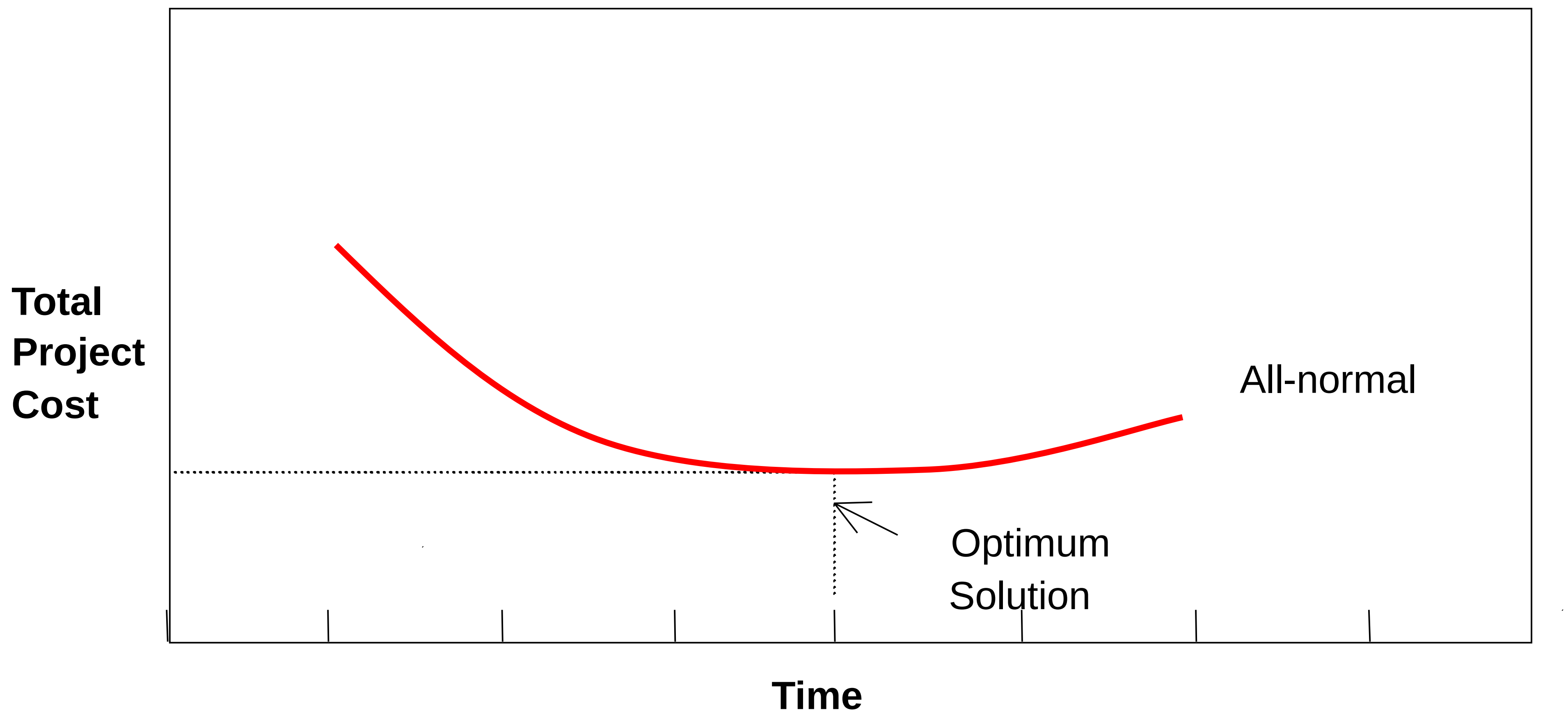
If the direct cost and the indirect cost are superposed on each other, then the total project cost curve is obtained as in the figure below

It can be seen that there exists an OPTIMUM solution. The optimum solution gives the least total project cost along with shorter project duration compared to the all-normal solution



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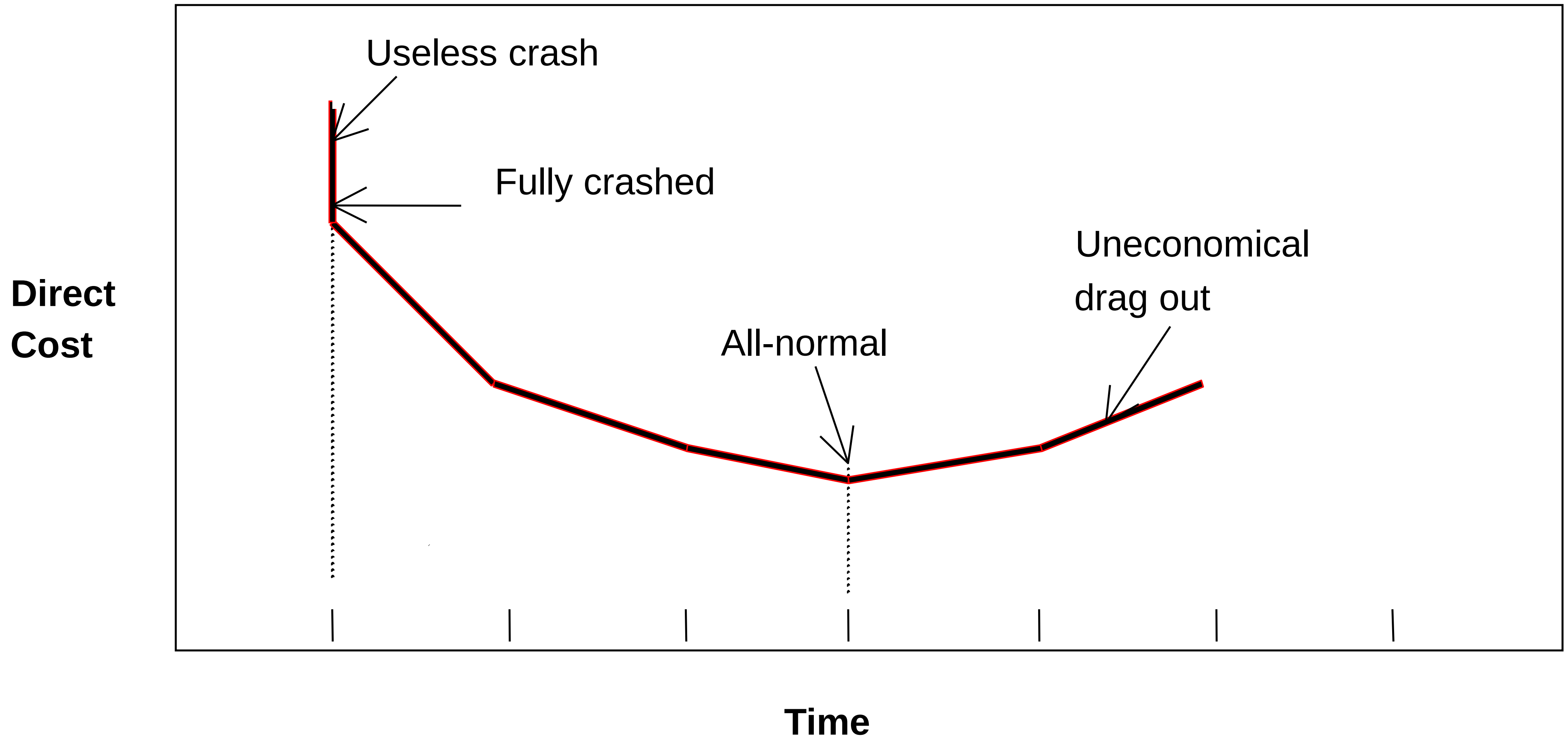
Utility Curve for an Activity



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All Normal Solution

This refers to the situation if the allocation of the resources is such that the activity is carried out at the lowest possible direct cost

This set-up results in the All-Normal Duration and the corresponding All-Normal Direct Cost

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Crashing or Compression of Activities

The all-normal solution forms the basis for comparison. If any other method uses resources that reduces the activity duration, then the activity is said to be Crashed or Compressed

Activity durations faster than all-normal duration must cost more because of added expenses of:

- Overtime
- Shift work
- Use of more equipment/plant
- Reduced operational efficiency

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Crashing or Compression of Activities

The extent to which an activity can be crashed

Range (of Crashing) = All-Normal duration - Crashed duration

Cost slope is additional direct cost for crashing the activity by unit time. Assuming a linear variation of direct cost within the range:

$$\text{Cost slope (of crashing)} = \frac{\text{Crashed direct cost - All-normal direct cost}}{\text{Range}}$$

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Project Compression

Project Compression is the process of shortening the project duration given by the All Normal solution. This can be achieved by crashing in turn, selected activities on the critical path

Each compression gives:

(a) A new project duration
(b) A new project direct cost
(c) New critical path(s) may arise

When multiple critical paths are involved, all such paths must be shortened simultaneously

Shortening one critical path, but not another, accomplishes nothing except to provide the shortened path with unneeded float

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Project Compression

If compression of activities on the critical path is carried out:

(a) The extent of the compression should be limited so as to ensure that the critical activities are not made non-critical. The amount of crashing must not exceed the float available in any one of the non-critical chains

(b) Shortening an activity will normally result increase its direct cost

(c) The inability to discriminate between those activities that truly control, and those of little or no consequences, can result in a more expensive solution than necessary

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Principles of Project Compression

- Crashing activities along critical path may shorten project duration.
- If an activity is crashed by 1 unit of time, then

Increase in project direct cost = Cost slope of that activity

- If project duration is shortened, then there is a saving in indirect cost of the project
- Net saving in total cost if the project duration is shortened by one unit of time

= (Indirect cost / unit time) - cost slope

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Principles of Project Compression

- To reduce total cost, only those activities that have cost slope less than Indirect cost /unit time should be selected for crashing

- Crashing of non-critical activities will not change project duration

- Compression should be done in stages taking into account the float available in non critical chains. If two or more parallel chains are critical, then they should all be compressed together by the same amount

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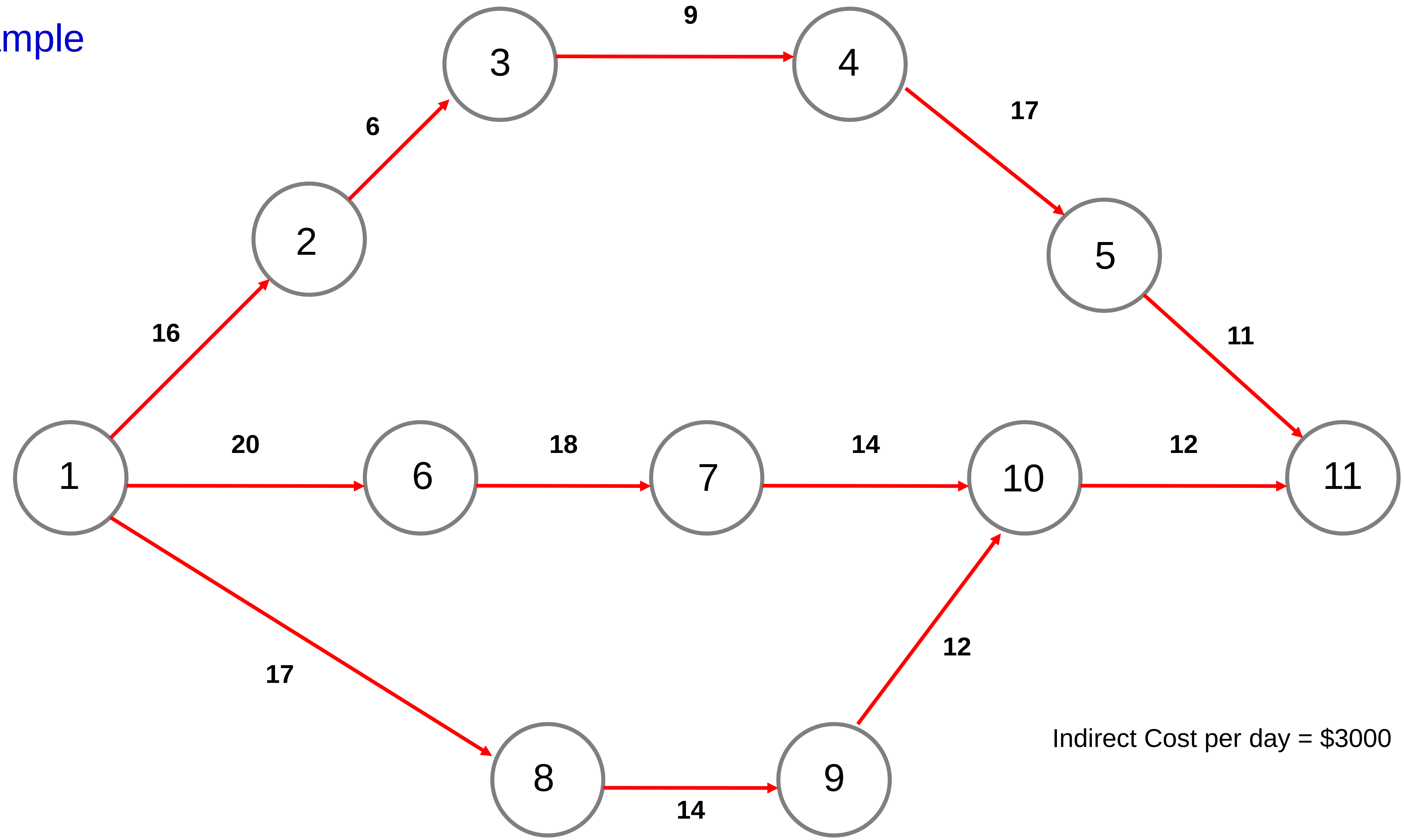
Example



Indirect Cost per day = $3000

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Example

Table 1: All-normal and Crashed data

	Duration (days)		Direct Costs ($)	
Activity	*All-Normal*	*Crashed*	*All-normal*	*Crashed*
1-2	16	12	30,000	38,000
2-3	6	5	12,000	12,500
3-4	9	7	13,000	15,000
4-5	17	14	33,000	39,000
5-11	11	11	24,000	24,000
1-6	20	17	38,000	39,500
6-7	18	17	33,000	39,000
7-10	14	11	30,000	33,000
10-11	12	12	24,000	24,000
1-8	17	13	25,000	27,000
8-9	14	14	21,000	21,000
9-10	12	8	18,000	24,000
		Total	**301,000**	

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Solution

Step 1: Calculate the Range and Cost Slope for the various activities

Range = All-normal duration - Crashed duration

$$\textbf{Cost Slope} = \frac{\text{(Crashed direct cost - All Normal direct cost)}}{\text{Range}}$$

Put simply,

Cost slope = additional direct cost per day for accelerating the work

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Solution

Step 1:

Activity	Range (days)	Cost slope ($ per day)
1 – 2	4	2000
2 – 3	1	500
3 – 4	2	1000
4 – 5	3	2000
5 – 11	0	0
1 – 6	3	500
6 – 7	1	6000
7 – 10	3	1000
10 – 11	0	-
1 – 8	4	500
8 – 9	0	-
9 – 10	4	1500

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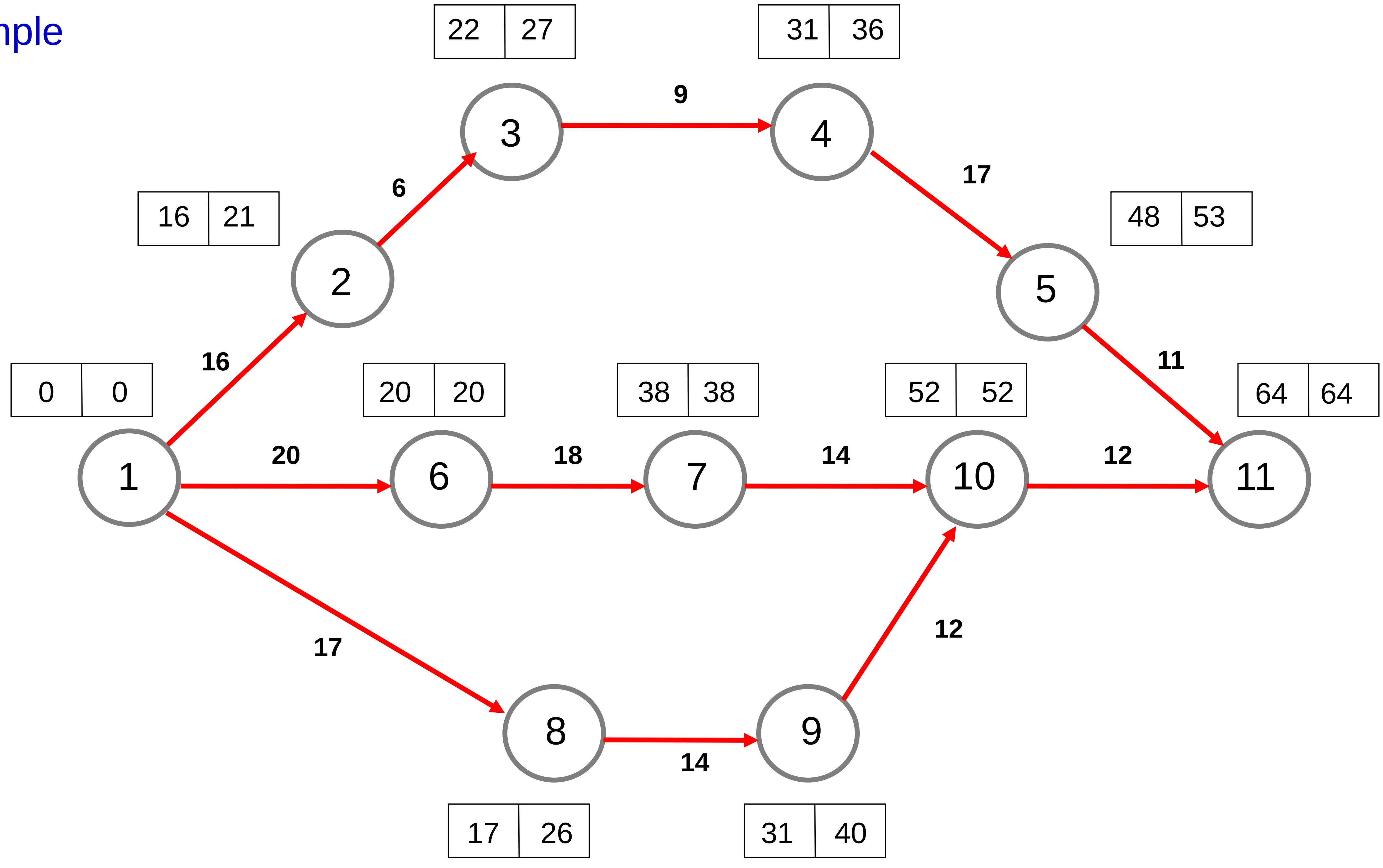
Example



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Solution

Step 2: Consider the All-normal solution.

• Project duration	=	64 days
• Critical path		1 - 6 - 7 - 10 - 11
• All-normal direct costs		$ 301 000
• Indirect cost = 64 x $ 3000 =		$ 192 000
• Total project cost		$ 493 000

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Solution

Step 3: First Compression.

Study the floats of activities on the non-critical chains

Chain 1 - 2 - 3 - 4 - 5 - 11 has float 5 days
Chain 1 - 8 - 9 - 10 has float 9 days

First compression of the critical chain 1 - 6 - 7 - 10 - 11 should not be more than 5 days

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Solution

Step 3: First Compression.

Only the activities on the critical path are considered for crashing, i.e. Activities 1-6; 6-7; 7-10 and 10-11. Of these 4 activities,

(a) Activity 10 - 11 cannot be crashed.

(b) Activity 6 - 7 has cost slope (= $6000/day) > indirect cost /day (= $3000/day). Such activities should not be crashed, unless ABSOLUTELY because of time!

(c) Activities 1 - 6 and 7 - 10 could be crashed

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Solution

Step 3: First Compression.

Activity 1 - 6 has the least cost slope. It takes priority in the crashing but it can be crashed by only 3 days

Therefore it is also possible to crash Activity 7 - 10 by 2 days so that the total compression in this step is 5 days

Decision: crash Activity 1 - 6 by 3 days

crash Activity 7 - 10 by 2 days

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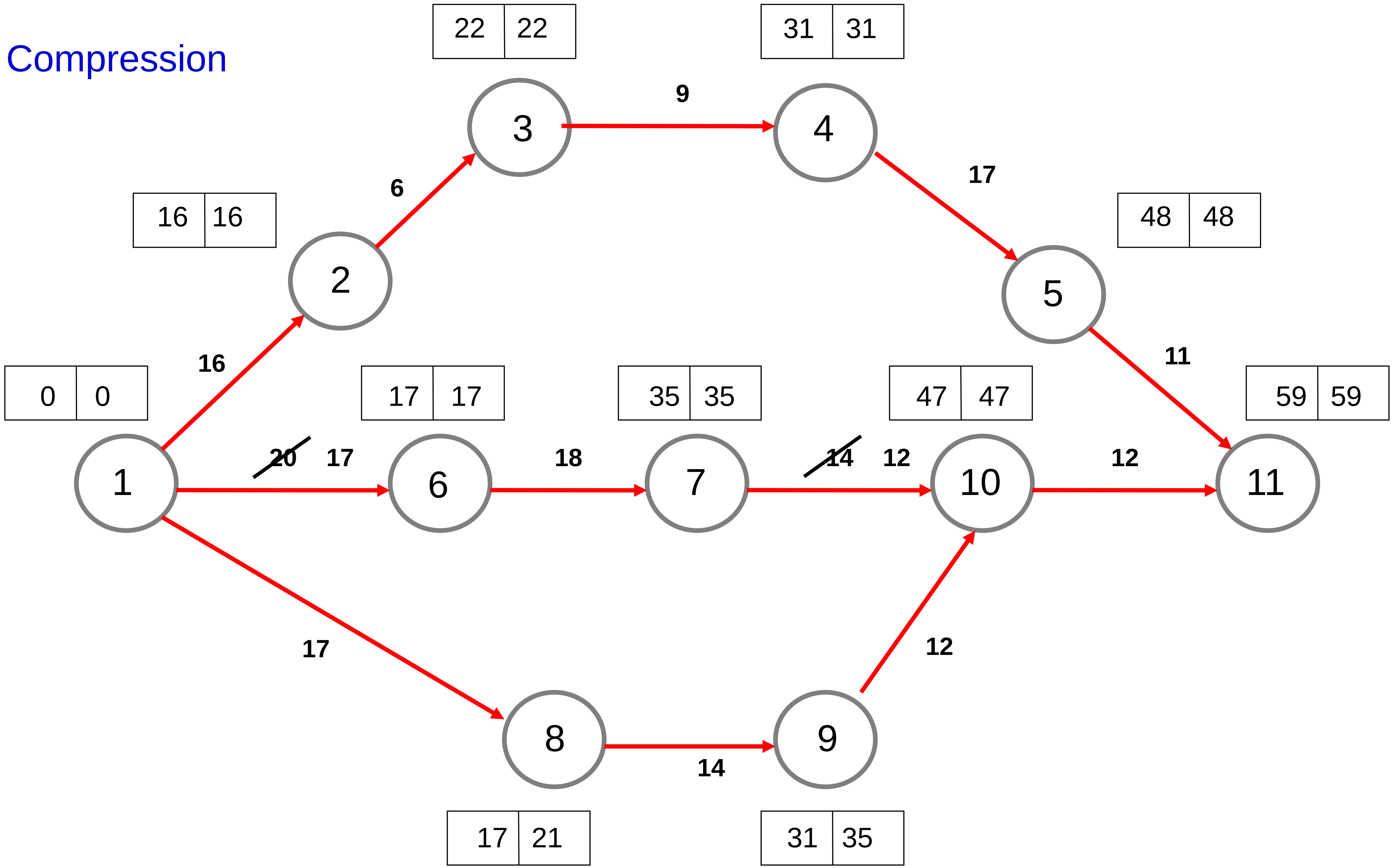
First Compression



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Solution

Step 4: Second Compression.

After First compression,
critical paths: 1 - 6 - 7 - 10 - 11 and 1 - 2 - 3 - 4 - 5 - 11

Non-critical chain: 1 - 8 - 9 - 10 has float 4 days

(a) Any crashing along the original CP 1 - 6 - 7 - 10 – 11 should be accompanied by an equal amount of crashing along the additional CP 1 - 2 - 3 - 4 - 5 - 11.

(b) The cost slope must be less than indirect cost/day ($3000)

(c) Maximum amount of crashing possible on this step is 4 days

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Solution

<u>Step 4:</u> Second Compression.

Along the original CP 7 - 10 has cost slope $1000.
Along CP 1 - 2 - 3 - 4 - 5 - 11, Activity 2 - 3 has the smallest cost slope $500

When Activities 7 - 10 and 2 - 3 are crashed simultaneously, then
Total cost slope = 1000 + 500 = 1500 < 3000 <u>Feasible</u>

Activity 7 - 10 can be crashed by 1 day only now. (Earlier, it has been crashed by 2 days.)

Decision: Crash Activities 7-10 and 2-3 by 1 day each.

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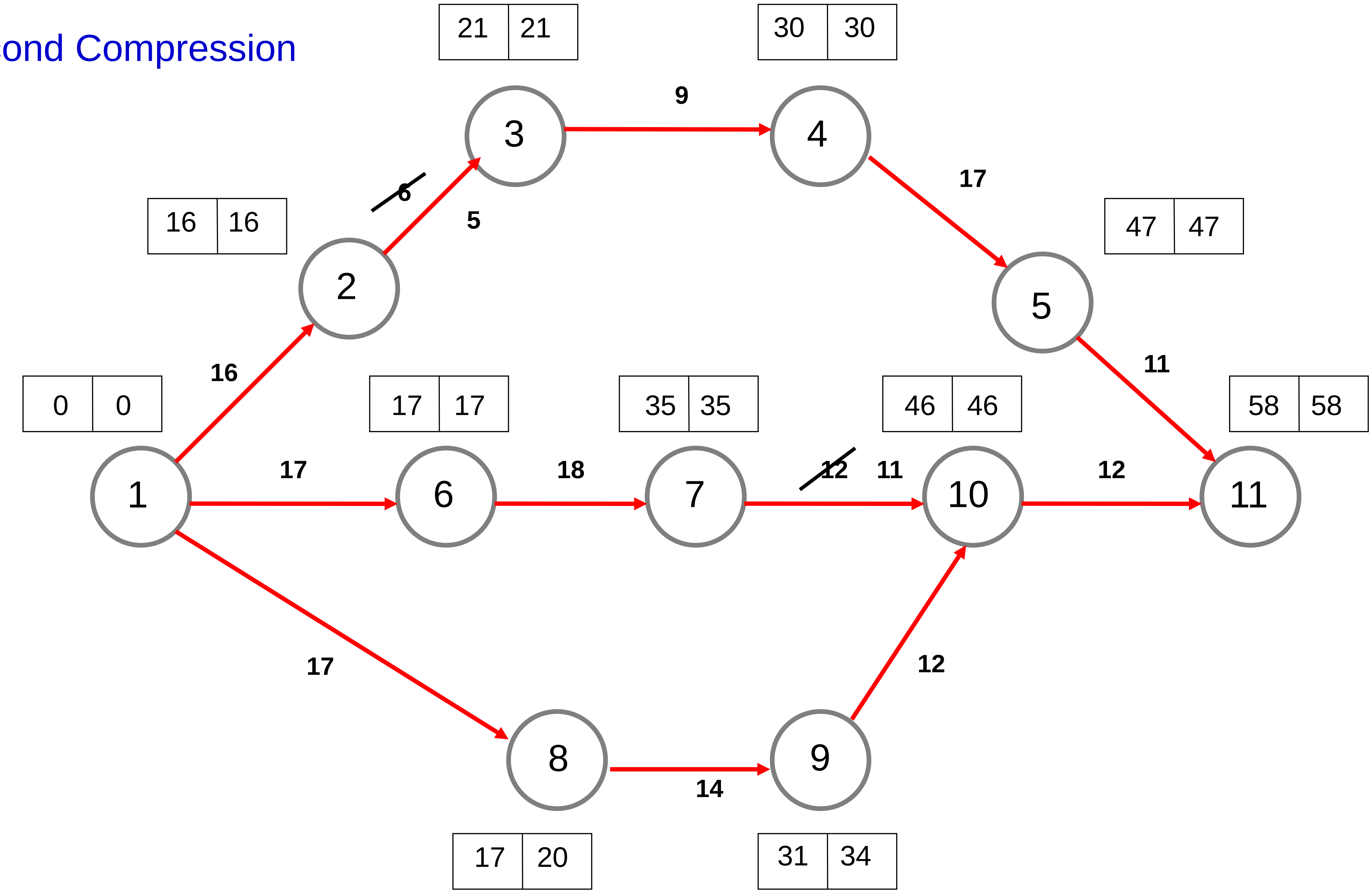
Second Compression



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Optimum Solution

Project duration = 58 days

All-Normal direct cost		=	$301,000
Add	crashing cost of 1 - 6 by 3 days = 3 x 500	=	$ 1,500
Add	crashing cost of 7 - 10 by 3 days = 3 x 1000	=	$ 3,000
Add	crashing cost of 2 - 3 by 1 day = 1 x 500	=	$ 500
New direct cost		=	$306,000
Add indirect cost for 58 days = 58 x 3000		=	$174,000
Total project cost			**$480,000**