LEAST COST CALCULATIONS

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CONSTRUCTION COST

Generally construction costs are divided into two

- Direct costs
- Indirect costs

Direct costs

Direct costs are associated with the physical construction of the project including

- Materials,
- Equipment and
- Labor and
- Subcontractor (if exists)
INDIRECT COSTS

• INDIRECT COSTS ARE NOT EASY TO VISUALIZE.

• THEY ARE GENERALLY BROKEN DOWN INTO TWO CATEGORIES:
  – HEAD OFFICE OVERHEAD AND
  – GENERAL CONDITIONS (PROJECT OR SITE OVERHEAD).
DIRECT COST, INDIRECT COST AND TOTAL COST

MINIMUM COST

TOTAL COST

INDIRECT COST

DIRECT COST

COST

TIME

OPTIMUM TIME
CRASHING A PROJECT MEANS THE PROCESS OF ACCELERATING AN ACTIVITY OR MULTIPLE ACTIVITIES TO SHORTEN THE OVERALL DURATION OF A PROJECT.

BY ADDING ADDITIONAL PEOPLE, EQUIPMENT, OR MAN- HOURS, A PROJECT MANAGER CAN SHORTEN AN ACTIVITY’S DURATION.

IF THE ACTIVITY AFFECTED IS CRITICAL, THE PROJECT WILL BE SHORTENED AS WELL.

ACTIVITIES ARE CRASHED FOR DIFFERENT REASONS:

AN ACTIVITY MAY NEED TO BE COMPLETED BY A SPECIFIC DATE FOR CONTRACTUAL REASONS.

SOME ACTIVITIES CAN BE ACCOMPLISHED MORE ECONOMICALLY DURING A CERTAIN TIME OF THE YEAR, ENCOURAGING MANAGERS TO ACCELERATE PRECEDING ACTIVITIES.
LEAST COST CALCULATIONS (continued)

• THE COST TO ACCELERATE AN ACTIVITY WHICH SHORTENS PROJECT’S DURATION MAY BE LESS EXPENSIVE THAN THE COST OF RUNNING THE PROJECT FOR THE SAME PERIOD.

• WHEN AN ACTIVITY IS CRASHED, IT’S DIRECT COSTS INCREASE DUE TO THE FOLLOWING REASONS.
  • THE INEFFECTIVENESS CAUSED BY ACCELERATING THE WORK AT A RATE FASTER THAN NORMAL; (overtime)
  • PEOPLE MAY END UP WORKING IN TIGHTER QUARTERS, OR EQUIPMENT MAY SIT IDLE; crowding effect

• BUT THESE COSTS INCREASES MAY BE JUSTIFIED IF INDIRECT COSTS ARE DECREASED.

• ALTHOUGH THERE IS A CLEAR BENEFIT TO OPTIMIZING A PROJECT’S DURATION ON THE BASIS OF COST, CRASHING IS NOT A ROUTINE STEP IN PROJECT PLANNING.
• THE INTEGRATION OF SCHEDULING AND ESTIMATING INFORMATION CANNOT BE EASILY LINKED SINCE THE ACTIVITY UNITS ARE OFTEN NOT THE SAME.

• IT IS ALSO UNUSUAL TO CALCULATE CRASH COSTS FOR EACH ACTIVITY AND THEN FORMALLY ANALYZE AND COMPARE THOSE COSTS WITH INDIRECT COSTS.

• THIS PROCESS TAKES A CONSIDERABLE AMOUNT OF TIME AND IS DIFFICULT TO AUTOMATE.

• ANOTHER REAL CONCERN IS THAT, AS A PROJECT IS CRASHED, MULTIPLE CRITICAL PATHS ARE CREATED.

• AS MORE CRITICAL PATHS APPEAR, THERE IS A GREATER RISK OF DELAYING COMPLETION TIME.
LEAST COST CALCULATIONS (continued)

• NEVERTHELESS, THE PROCESS OF DETERMINING THE OPTIMUM DURATION FOR A PROJECT IS AN IMPORTANT STEP IN PROPER PLANNING.

• PROPERLY ANALYZING COSTS AND THEN RUNNING THE PROJECT IN THE MOST COST-EFFECTIVE WAY CAN SAVE CONSIDERABLE TIME AND MONEY.

• AS EXPERT SYSTEM TECHNOLOGY IMPROVES AND COST AND SCHEDULE INFORMATION BECOMES MORE FULLY INTEGRATED, THIS KIND OF STUDY BECOMES MORE ROUTINE.
Least Cost (Crash Time) Calculations

Example: 1

Find: Optimum time and least total cost for the project given below.
Overhead cost = £100/day
Least Cost (Crash Time) Calculations

Example: 1

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
<th>Duration (Days)</th>
<th>Direct Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>j</td>
<td>Normal</td>
<td>Crash</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>B</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>C</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>D</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>E</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>F</td>
<td>7</td>
</tr>
</tbody>
</table>
Least Cost (Crash Time) Calculations

Solution of Example: 1

: CRITICAL ACTIVITY
Least Cost (Crash Time) Calculations

Step 1: Find normal duration of the project and normal cost for that normal duration.

Direct cost = 400 + 800 + 600 + 500 + 800 + 700 = £3800

Indirect cost = 16 days * £100/day = £1600

Total normal cost = £5400

Step 2: Calculate cost/day of activities by crashing duration.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Crashing Duration (Days)</th>
<th>Cost per day (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>500-400=100</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>980-800=180</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>700-600=100</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>600-500=100</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>950-800=150</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>1000-700=300</td>
</tr>
</tbody>
</table>
Least Cost (Crash Time) Calculations

It is useful to use a worksheet such as shown below.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Cost (£)</th>
<th>Δ Cost</th>
<th>Δ Days</th>
<th>Δ Cost/Days</th>
<th>Days Shortened</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Crash</td>
<td>Normal</td>
<td>Crash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>2</td>
<td>400</td>
<td>500</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>5</td>
<td>800</td>
<td>980</td>
<td>180</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>2</td>
<td>600</td>
<td>700</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>6</td>
<td>500</td>
<td>600</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>8</td>
<td>6</td>
<td>800</td>
<td>950</td>
<td>150</td>
<td>2</td>
</tr>
<tr>
<td>F</td>
<td>7</td>
<td>4</td>
<td>700</td>
<td>1000</td>
<td>300</td>
<td>3</td>
</tr>
</tbody>
</table>

Days cut: 1 2 3 4 5
Project duration: 16 15 14 13 12 11
Increased cost/day: 60 60 85 100 200
Direct cost/day: 3800 3860 3920 4005 4105 4305
Overhead cost: 1600 1500 1400 1300 1200 1100
Total cost: 5400 5360 5320 5305 5305 5405
Least Cost (Crash Time) Calculations

- **Cycle 1:** Activity which is on critical path and has the smallest cost/day is crashed by 1 day. Activities on critical paths are $B = £60/day$ and $E = £75/day$. Therefore, B is crashed by 1 day. Then calculate direct cost and overhead cost and total cost.
Least Cost (Crash Time) Calculations

- **Cycle 2:** Critical activities are \( B = £60/day \) and \( E = £75/day \). Therefore, activity B is crashed one more day.
- Then calculate direct cost and overhead cost and total cost.
Least Cost (Crash Time) Calculations

- **Cycle 3:** Two paths are critical. Critical activities are **A=£50/day, B = £60/day, D= £25/day** and **E = £75/day.** Crash one day from each path to reduce the project duration to 13.

Activities to be crashed are A or D and B or E. Therefore, crash activities B and D.

![Network Diagram]

1. Start at 0, 0
2. A to 4, 4
3. B to 5, 5
4. C to 3, 3
5. E to 8, 8
6. F to 7, 7
7. D to 9, 9
8. End at 13, 13
Least Cost (Crash Time) Calculations

- **Cycle 5:** Critical activities are **A**= £50/day, **D**= £25/day and **E** = £75/day.

Two paths are critical as in cycle 3. Activities to be crashed are A or D and E. Therefore, crash activities D and E.

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Cycle 5: Critical activities are **D**=£25/day, **E**= £50/day and **F** = £100/day. Therefore, crash activities D, E and F.
Least Cost (Crash Time) Calculations

Example: 2
Crash the following network schedule (arrow diagram) and find the optimum time and least cost. Indirect cost = $100/day.

<table>
<thead>
<tr>
<th>Activity Identity</th>
<th>Duration (Days)</th>
<th>Direct Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Crash</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
Least Cost (Crash Time) Calculations

• Solution:
Least Cost (Crash Time) Calculations

Solution:

• Direct cost = 600+ 500+ 600+ 800+ 600+ 800 = $3900

• Indirect cost = 30 days * $100/day = $3000

• Total normal cost =$6900
Least Cost (Crash Time) Calculations

- Solution:

<table>
<thead>
<tr>
<th>Activity Identity</th>
<th>Duration (Days)</th>
<th>Direct Cost (£)</th>
<th>Crash Cost per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Crash</td>
<td>Normal</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>4</td>
<td>600</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>7</td>
<td>500</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>8</td>
<td>600</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
<td>4</td>
<td>800</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>3</td>
<td>600</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>2</td>
<td>800</td>
</tr>
</tbody>
</table>
Least Cost (Crash Time) Calculations

• Solution:

**Cycle 1:** Crash F and pay $25 extra.

Direct cost = 600+ 500+ 600+ 800+ 600+ 825 = $3925

Indirect cost = 29 days * $100/day = $2900

Total normal cost = $6825
Least Cost (Crash Time) Calculations

• Solution:
Least Cost (Crash Time) Calculations

• Solution:

• **Cycle 2:** Crash F again and pay $25 extra.

Direct cost = 600 + 500 + 600 + 800 + 600 + 850 = $3950

Indirect cost = 28 days * $100/day = $2800

Total normal cost = $6750
Least Cost (Crash Time) Calculations

• Solution:
Least Cost (Crash Time) Calculations

• Solution:

• **Cycle 3**: Crash D and pay $35 extra.

Direct cost = 600+ 500+ 600+ 835+ 600+ 850 = $3985

Indirect cost = 27 days * $100/day = $2700

Total normal cost = $6685
Least Cost (Crash Time) Calculations

- Solution:
Least Cost (Crash Time) Calculations

• Solution:
• **Cycle 4**: Crash D again and pay $35 extra.

Direct cost = 600+ 500+ 600+ 870+ 600+ 850 = $4020

Indirect cost = 26 days * $100/day = $2600

Total normal cost = $6620
Least Cost (Crash Time) Calculations

• Solution:

\[\begin{array}{cccccc}
A & B & C & D & F \\
2 & 4 & 6 & 10 & 2 \\
0 & 6 & 6 & 18 & 12 \\
0 & 6 & 18 & 24 & 26 \\
6 & 18 & 18 & 26 & 26 \\
\end{array}\]
PROBLEM 8
Completely crash the following network schedules and find the optimum time and the least cost. Over head costs= $60 per day.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Duration</th>
<th>Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Crash</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

PROBLEM 8: Completely crash the following network schedules and find the optimum time and the least cost. Over head costs = $60 per day.
Critical path: 1-3-5-7-9
Normal project duration=11 days
Direct cost= 300+450+360+600+325+250+310= 2595
Overhead cost= (11*60) = 660
Normal project cost = (2595+660) = $3255

Cycle 1:
Among activities on critical path C-E-F-G, activity E has minimum cost per day.
Thus crash activity E by 1 day at $ 25.
New project duration: 11-1= 10 days
New project cost= 3255+25-60= $3220
## SOLUTION OF PROBLEM 8

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Cost ($)</th>
<th>∆ Cost</th>
<th>∆ Days</th>
<th>∆ Cost/Day</th>
<th>Days Shortened</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Crash</td>
<td>Normal</td>
<td>Crash</td>
<td></td>
<td>Cycle 1</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>3</td>
<td>300</td>
<td>360</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>4</td>
<td>450</td>
<td>500</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>2</td>
<td>360</td>
<td>420</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>6</td>
<td>3</td>
<td>600</td>
<td>675</td>
<td>75</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>2</td>
<td>325</td>
<td>350</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>1</td>
<td>250</td>
<td>285</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>1</td>
<td>310</td>
<td>350</td>
<td>40</td>
<td>1</td>
</tr>
</tbody>
</table>

|                | Days cut |          |        |        |          |        |        |        |
|                |          | 1        | 1      | 1      | 1        | 1      |        |

|                | Project duration |          |        |        |          |        |        |        |
|                |                  | 11       | 10     | 9      | 8        | 7      | 6      |

|                | Increased cost/day |          |        |        |          |        |        |        |
|                |                  | 25       | 35     | 40     | 55       | 80    |

|                | Direct cost       |          |        |        |          |        |        |        |
|                |                  | 2595     | 2620   | 2655   | 2695     | 2750  | 2830   |

|                | Overhead cost     |          |        |        |          |        |        |        |
|                |                  | 660      | 600    | 540    | 480      | 420   | 360    |

|                | Total cost        |          |        |        |          |        |        |        |
|                |                  | 3255     | 3220   | 3195   | 3175     | 3170  | 3190   |
Cycle 2:
Note that there are two critical paths to shorten at the same time, 1-3-5-7-9 and 1-5-7-9.
Crash cost for activities C (1-3) + B (1+5) = 25+30= $55
Crash cost for activity F (5-7) = $35
Crash cost for activity G (5-7) = $40
Activity (5-7) has the cheapest cost slope, potential 1 day. Therefore, crash activity F (5-7) by 1 day.
New project duration: 10-1= 9 days
New project cost= 3220+35-60= $3195
Cycle 3:
Among activities on critical path, activity G (7-9) has the cheapest cost slope $40 per day and potential 1 day. Compress activity G by 1 day.
New project duration: 9-1 = 8 days
New project cost = 3195+40-60 = $3175
Cycle 4:
Simultaneous crash of activities C (1-3) and B (1-5) have the cheapest combined cost slope, with 2 days potential. Full compression (crash) is not possible since non critical activity D (1-7) terminating at 7 has only 1 day Free Float less than the potential available. Hence crash activities C and B by 1 day simultaneously.
New project duration: 8-1= 7 days
New project cost= 3195+ (30+25)-60= $3170
Cycle 5:
Note that now there are multiple critical paths to shorten, 1-3-5-7-9, 1-5-7-9, 1-7-9. 
Crash activities B, C and D by 1 day simultaneously. 
New project duration: 7-1= 6 days 
New project cost= 3170+ (25+30+25)−60= $3190 
The potential available for critical paths (1-3-5-7-9) and (1-5-7-9) is completely crashed. Stop here.
SOLUTION OF PROBLEM 8
Therefore, the optimum project duration is 7 days.
Least cost = $ 3170
THANKS FOR YOUR ATTENTION