Resources Management

What a resource?

- Any thing that is used by an activity to get the work done,
  such as: Material, Equipment, Labor, Money,.....

- Resources can be classified as:
  - Consumable (Money, Material,.....)
  - Non Consumable (Labor, Equipment,....)
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Duration-Driven Schedule

- All CPM scheduling techniques are duration driven schedules
- Basic units: activities, durations, relationships
- Assumes resources are available whenever needed
- Also, resources can be classified as:
  - Key or constrained resources (Skilled labor, Equipment, ...)
  - Secondary or non-constrained resources (Labor, ...)
  - General resources, used by all activities

Resource aggregation or Resource loading

- The summation, on a period-by-period basis, of the resources required to complete all activities based on the schedule carried out in the previous stage
- The results are usually shown graphically as a histogram
- A separate graph will be required for each resource
Resources Management

Resource aggregation or Resource loading

- Consider the following activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration (Weeks)</th>
<th>Resources (units/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td></td>
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<tr>
<td>B</td>
<td>3</td>
<td></td>
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<tr>
<td>C</td>
<td>2</td>
<td></td>
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<td>D</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>Shown in the histogram</td>
</tr>
</tbody>
</table>

- Resource limit = 10 units /week

Resources Management

Resource aggregation or Resource loading

<table>
<thead>
<tr>
<th>Activity</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
<th>Week 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>10</td>
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<td>6</td>
</tr>
</tbody>
</table>

Total resource units requirement:
- Week 1: 10
- Week 2: 18
- Week 3: 8
- Week 4: 10
- Week 5: 10
- Week 6: 14
- Week 7: 6
- Week 8: 6

Resource limit: 10 units /week
Resources Management

Resource aggregation or Resource loading

Resource profile with high resource fluctuation
(High hiring and firing)

Resource profile with less hiring and firing
(More stable work conditions)

Problems Associated with Resource

- Resource Fluctuation (Resource leveling)
- Resource Over allocation (Resource Scheduling)
Resources Management

Methods for Resolving Resource conflicts (Problems)

- Optimization Models (Utilize optimization techniques):
  - Linear programming models
  - Advantages: Provide optimum solution
  - Limitations: Cannot be applied to large problems
- Heuristic Models (Utilize rule of thumb based on experience):
  - Heuristic or rules of thumb
  - Advantages: Can be applied to large problems
  - Limitations: Do not provide optimum solution

Resource Leveling (Smoothing)

Unconstrained resource scheduling (Constrained time)

Resource Leveling

- Resource unconstrained (No limits on resources)
- Time (Project completion) constrained; project duration not be delayed
- Reduce the difference between the peaks and the valleys
- Average resource usage
- The objective is to smooth the use of the resources to avoid the resource fluctuation
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Resource Leveling (Smoothing)

Minimum Moment Algorithm = \( \sum Y_i \cdot \frac{Y_i}{2} \)
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Resource Leveling (Smoothing)

Heuristic Method Procedure

- Prepare a complete activity schedule
- Draw a bar chart based on ES timings
- Draw the FF as dashed line beside the upper side of the bar and the TF beside the lower side
- Put the resource usage in each bar of the related activity
- Critical activities to be drawn first (do not move them)
- Aggregate the resources in each time period

Procedure

- Calculate the total usage of resources = \( \sum \) unit period usage
- Calculate the average resource usage = \( \sum \) usage / utilization period
- Shift non-critical activities within their FF first, then their TF to decrease the peaks and raise the valleys
- Revise the activities float
- Aggregate the resources in each time period
## Resources Management

### Resource Leveling (Example)

#### Example

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration (Weeks)</th>
<th>Predecessors</th>
<th>Resource (units/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<tr>
<td>D</td>
<td>3</td>
<td>2</td>
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<tr>
<td>E</td>
<td>2</td>
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<tr>
<td>F</td>
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<tr>
<td>G</td>
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<tr>
<td>H</td>
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<td>4</td>
<td>0</td>
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<tr>
<td>I</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>J</td>
<td>2</td>
<td>5, 6</td>
<td>4</td>
</tr>
<tr>
<td>K</td>
<td>7</td>
<td>6, 7</td>
<td>2</td>
</tr>
<tr>
<td>L</td>
<td>3</td>
<td>2, 8</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>2</td>
<td>2, 8, 9</td>
<td>4</td>
</tr>
<tr>
<td>N</td>
<td>2</td>
<td>10, 11, 12, 13</td>
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![Resource Leveling Diagram]
Resources Management

Resource Leveling (Example)

<table>
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<tr>
<th>Activity</th>
<th>ES</th>
<th>EF</th>
<th>FF</th>
<th>TF</th>
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<tbody>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
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<td>C</td>
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<tr>
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<td>G</td>
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<td>11</td>
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<td>H</td>
<td>3</td>
<td>9</td>
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<tr>
<td>I</td>
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<tr>
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<td>K</td>
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<tr>
<td>L</td>
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<tr>
<td>M</td>
<td>9</td>
<td>11</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>N</td>
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<td>20</td>
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<td>0</td>
</tr>
</tbody>
</table>

Σ = 90
Resources Management

Resource Leveling (Example)

\[
\begin{array}{cccccccccccccccc}
0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 \\
\hline
\end{array}
\]

\[\Sigma = 90\]
### Resources Management

#### Resource Leveling (Example)

<table>
<thead>
<tr>
<th></th>
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<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<td>6</td>
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<td>6</td>
</tr>
<tr>
<td>H (2 days)</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
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<td>6</td>
</tr>
<tr>
<td>F (1 days)</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>6</td>
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</tbody>
</table>

\[ \sum = 90 \]

---

### Resources Management

#### Resource Leveling (Example)

![Resource Leveling Chart]

|       | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|
|       | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

\[  \sum = 90 \]
Resources Management

Resource Scheduling

Constrained resource scheduling (Unconstrained time)

Resource Scheduling

- Constrained Resources
- Unconstrained project completion; project time may be delayed
- Reduce the resource usage to be less than the resource availability
- The objective is to meet the resources limits
Resources Management

Resource Scheduling

Is there a way to prioritize activities
That compete for the limited resources
so that the net project delay is
minimized?

Resource Scheduling Rules of Thumb

- Many rules have been experimented with
- Least TF were found to be most effective
- Least LS has the same effect as the least TF and doesn't require network recalculations
- In case of a tie use least TF
Resources Management

Resource Scheduling

Procedure

- Prepare a complete activity schedule
- Aggregate the daily resource demand
- If demand greater than available then determine activities compete for resources
- Prioritize these activities based on their LS
- Allocate resources to some activities and delay the others
- Put your solution in table format

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration (Weeks)</th>
<th>Predecessors</th>
<th>Resource (units/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>R1 ≤ 3</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>-</td>
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</tr>
<tr>
<td>B</td>
<td>4</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>-</td>
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<tr>
<td>D</td>
<td>8</td>
<td>A</td>
<td>0</td>
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<td>E</td>
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<td>F</td>
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<td>B</td>
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<td>I</td>
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<td>E, H</td>
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<tr>
<td>J</td>
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<td>C</td>
<td>5</td>
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<tr>
<td>K</td>
<td>10</td>
<td>G, J</td>
<td>2</td>
</tr>
</tbody>
</table>
Resources Management

Resource Scheduling (Example)

<table>
<thead>
<tr>
<th>Current Time</th>
<th>Eligible Activities</th>
<th>Resources</th>
<th>Duration</th>
<th>Earliest LS</th>
<th>Decision</th>
<th>Finish Time</th>
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<tbody>
<tr>
<td>0</td>
<td>B</td>
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<td>Earliest LS</td>
<td>Decision</td>
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<td>0 0</td>
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