Introduction

- The AOA and AON networks were presented, also the time and cost of individual activities based were calculated.
- The total project duration is still unknown, however the early and late times at which activities start and finish are still need to be evaluated.
- In addition, since real-life projects involve hundreds of activities, it is important to identify the group of critical activities so that special care is taken to make sure they are not delayed.
Introduction (cont’d)

- All previous statements are the basic objectives of the scheduling process, which adds a time dimension to the planning process.
- In other words, it can be briefly stated that:

  **Scheduling = Planning + Time**

**The project scheduling issued for:**

- Knowing the activities timing and the project completion time.
- Having resources available on site in the correct time.

Introduction (cont’d)

- Making correction actions if schedule shows that the plan will result in late completion.
- Assessing the value of penalties on project late completion.
- Determining the project cash flow.
- Evaluating the effect of change orders on the project completion time.
- Determining the value of project delay and the responsible parties.
1. Critical Path Method (CPM)
2. Precedence Diagram Method (PDM)
3. Time-Scaled Diagram (TSD)

1. CPM

- Most Widely used method for project scheduling.
- Calculates the minimum completion time for a project.
- Calculates activities timings.
- Computer programs use for handling large projects.
1. CPM (cont’d)

The CPM is a systematic scheduling method for a project network and involves four main steps:
1. A forward path to determine activities early-start times,
2. A backward path to determine activities late-finish times,
3. Float calculations, and
4. Identifying critical activities.

1. CPM (cont’d)

Calculations for the Critical Path Method
The inputs to network scheduling of any project are simply the AOA or the AON networks with the individual activity duration defined. The network scheduling process for AOA and AON networks. To demonstrate these two techniques, let’s consider a simple 5-activity project, with activity A at the start, followed by three parallel activities B, C, and D; which are then succeeded by activity E. The AOA or the AON networks of this example are presented in Figure 1.
1. CPM (cont’d)

Forward Path
The forward path determines the early-start (ES) times of activities. The forward path proceeds from the most left node in the network (node 1 – Figure 2) and moves to the right, putting the calculations inside the shaded boxes to the left.

Figure 1. Network example

Figure 2. Preparation for the forward path
1. CPM (cont’d)

Backward Path
The backward path determines the late-finish (LF) times of activities by proceeding backward from the end node to the starting node. The LF values were put in the right side boxes adjacent to the nodes, as shown in Figure 3.

Figure 3. Backward path calculations in AOA networks

1. CPM (cont’d)

Float Calculations
Once forward path and backward path calculations are complete, it is possible to analyze the activity times. First, tabulate the information as shown in Table 1. Total-Float (TF) calculations, which determine the flexibility of an activity to be delayed. Notice that some activities such as activity A has ES time = LS time, and its EF time = LF time, indicating no slack time for the activity. Other activities such as B can start early at time 3 and late at time 6, indicating a 3-day of total float.
1. CPM (cont’d)

Table 1. CPM results

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Early Start (ES)</th>
<th>Late Finish (LF)</th>
<th>Late Start (LS)</th>
<th>Early Finish (EF)</th>
<th>Total Float (TF)</th>
<th>Critical Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td>D</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>Yes</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Also, with the ES and LF times directly read from the boxes used in forward and backward path calculations, the total float can also be calculated as:

\[ TF = LF - ES - d \]

Figure 4 shows two ways of scheduling each activity using its activity times. One way is to schedule it as early as possible (using its ES time). The other way is as late as possible (using its LS time).

Figure 4. Float calculations
1. CPM (cont’d)

Identifying the Critical Activities
Activities with zero total floats mean that they have to be constructed right at their schedule times, without delays. These activities are considered to be critical. They deserve the special attention of the project manager because any delay in critical activities causes a delay in the project duration.

1. CPM (cont’d)

In our example, activities A, D, and E (excluding dummy activities) are critical and the critical path is indicated by bold lines on Figure 3. Notice that among the 3 paths in this example (A-B-E, A-C-E, and A-D-E), the critical path is the longest one, an important characteristic of the critical path. In real-life projects with many activities, it is possible that more than one critical path are formed.
2. PDM

Precedence Diagram Method is the CPM scheduling method used for AON networks and it follows the same four steps of the CPM for AOA method.

**Forward Path**
Forward path can proceed from one activity to the other, the results as shown in Figure 5.

2. PDM (cont’d)

**Forward Path**
Forward path can proceed from one activity to the other, the results as shown in Figure 5.

*Figure 5. Forward path in PDM analysis*
2. PDM (cont’d)

Backward Path
Once the forward path is finished, the backward path can start, moving from the last activity to the first, putting the calculations in the bottom two boxes of each activity, as shown in Figure 6.

Figure 6. Forward path in PDM analysis

2. PDM (cont’d)

Identifying Critical Activities
Critical activities can also be easily determined as the ones having zero float times, activities A, D, and E. The critical path is then shown in bold as Figure 6. The PDM analysis, as explained, is a straight forward process in which each activity is considered as an entity that stores its own information.
3. TSD

Time-scaled diagrams are used extensively in the construction industry. The diagrams are enable to determine immediately which activities that scheduled to proceed at any point in time and to monitor field progress. Also, it can be used to determine resources need. The time scale used in time-scaled diagrams can be either the calendar dates or the working periods (ordinary dates), or using both at the same time.

3. TSD (cont’d)

- The activities are represented as arrows that drawn to scale to reflect the activity duration it represents.
- The horizontal dashed lines represent total float for groups of activities and free float for the immediate activity to the left of the dashed line.
- The precedence of an activity is the immediate activities before it or that linked to it through vertical dashed lines.
- The name and the duration of an activity are written above and below the arrow representing it respectively.
3. TSD (cont’d)

Figure 7 shows the time-scaled diagram for the same example project solved previously using AOA and AON networks.

The TF for activity A equals the smallest of the sum of the floats along all paths from the end of activity A to the end of the project. The float on path A-B-E = 3, path A-C-E = 2, and path A-D-E = 0, then the TF of activity A = 0. The calculations are shown in Table 2.

Table 2. Time-scaled diagram calculations

<table>
<thead>
<tr>
<th>Activity</th>
<th>ES</th>
<th>EF</th>
<th>FF</th>
<th>TF</th>
<th>LF=EF-TF</th>
<th>LS=LF-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>
Schedule Presentation

After the AOA and AON calculations are made, it is important to present their results in a format that is clear and understandable to all the parties involved in the project. The simplest form is the Bar chart or Gantt chart, named after the person who first used it. A bar chart is a time versus activity chart in which activities are plotted using their early or late times, as shown in Figures 8. Early bar chart is drawn using the ES times of activities, while the late bar chart is drawn using the LS times.

Schedule Presentation (cont’d)

Figure 8. Bar chart
The bar chart representation shows various details. Float times of activities, critical activities can be shown in a different color, or bold borders, as shown in Figure 8. The bar chart can also be used for accumulating total daily resources and/or costs, as shown at the bottom part of Figure 9. In this figure, the numbers on each activity represent the number of labors needed. One additional benefit of the bar chart is its use on site to plot and compare the actual progress in the various activities to their scheduled times.
Critics to Network Techniques

The CPM and PDM analyses for network scheduling provide very important information that can be used to bring the project to success. But they share some drawbacks that require special attention from the project manager. These drawbacks are:

- **Assume all required resources are available**: the calculations do not incorporate resources into their formulation and deal with activity durations only. It can result in large resource fluctuations. Dealing with limited resources and resource leveling has to be done separately after the analysis.

**Critics to Network Techniques (cont'd)**

- **Ignore project deadline**: the formulations do not incorporate a deadline duration to constrain project duration.
- **Ignore project costs**: since their methods deal mainly with activities durations, they do not deal with any aspects related to minimize project cost.
- **Use deterministic durations**: the basic assumption use is that activity durations are deterministic. In reality, it takes certain probability distribution that reflect the effect of project conditions on resource productivity and the level of uncertainty.
Thanks for the Attention, and Success for Your Study!