Short-Term Scheduling

Strategic Implications of Short-Term Scheduling

- By scheduling effectively, companies use assets more effectively and create greater capacity per dollar invested, which, in turn, lowers cost.
- This added capacity and related flexibility provides faster delivery and therefore better customer service.
- Good scheduling is a competitive advantage which contributes to dependable delivery.

Examples:

<table>
<thead>
<tr>
<th>Today</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>E</td>
</tr>
</tbody>
</table>

For Forward Scheduling, the order is B followed by E, indicating that current (B) goes before the due date (E).

For Backward Scheduling, the order is E followed by B, indicating that the later (B) comes before the due date (E).
Short-Term Scheduling

Forward and Backward Scheduling

- Forward scheduling: begins the schedule as soon as the requirements are known
  - jobs performed to customer order
  - schedule can be accomplished even if due date is missed
  - often causes build-up of WIP
- Backward scheduling: begins with the due date of the final operation; schedules jobs in reverse order
  - used in many manufacturing environments, catering, scheduling surgery

The Goals of Short-Term Scheduling

- Minimize completion time
- Maximize utilization (make effective use of personnel and equipment)
- Minimize WIP inventory (keep inventory levels low)
- Minimize customer wait time
Short-Term Scheduling

Capacity Planning
1. Facility size
2. Equipment procurement

Aggregate Scheduling
1. Facility utilization
2. Personnel needs
3. Subcontracting

Master Schedule
1. MRP
2. Disaggregation of master plan

Short-term Scheduling
1. Work center loading
2. Job sequencing

Long-term

Intermediate-term

Short-term
Sequencing

Sequencing

- Specifies the order in which jobs should be performed at work centers
- Priority rules are used to dispatch or sequence jobs
  - FCFS: First come, first served
  - SPT: Shortest processing time
  - EDD: Earliest due date
  - LPT: Longest processing time

Priority Rules for Dispatching Jobs

- First come, first served
  - The first job to arrive at a work center is processed first
- Earliest due date
  - The job with the earliest due date is processed first
- Shortest processing time
  - The job with the shortest processing time is processed first
- Longest processing time
  - The job with the longest processing time is processed first
- Critical ratio
  - The ratio of time remaining to required work time remaining is calculated, and jobs are scheduled in order of increasing ratio.
Sequencing

First Come, First Served Rule

- Process first job to arrive at a work center first
- Average performance on most scheduling criteria
- Appears ‘fair’ & reasonable to customers
  - Important for service organizations (Example: Restaurants)

Earliest Due Date Rule

- Process job with earliest due date first
- Widely used by many companies
  - If due dates important
  - If MRP used (Due dates updated by each MRP run)
- Performs poorly on many scheduling criteria
Critical Ratio (CR)

- Ratio of time remaining to work time remaining
- Process job with smallest CR first
- Performs well on average lateness

\[ CR = \frac{\text{Time remaining}}{\text{Work days remaining}} \]

\[ = \frac{\text{Due date} - \text{Today's date}}{\text{Work (lead) time remaining}} \]
Average completion time = $\frac{\sum \text{Flow times}}{\# \text{Jobs}}$

Utilization = $\frac{\sum \text{Process time}}{\sum \text{Flow time}}$

Average number of jobs in system = $\frac{\sum \text{Flow time}}{\sum \text{Processing time}}$

Average job lateness = $\frac{\sum \text{Late times}}{\text{Number of Jobs}}$
Apply the four popular sequencing rules to these five jobs

<table>
<thead>
<tr>
<th>Job</th>
<th>Job Work (Processing) Time (Days)</th>
<th>Job Due Date (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>23</td>
</tr>
</tbody>
</table>
## FCFS: Sequence A-B-C-D-E

<table>
<thead>
<tr>
<th>Job Sequence</th>
<th>Job Work (Processing) Time</th>
<th>Flow Time</th>
<th>Job Due Date</th>
<th>Job Lateness</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>16</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>19</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>28</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>77</td>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>
Example

**FCFS: Sequence A-B-C-D-E**

Average completion time = \( \frac{\text{Total flow time}}{\text{Number of jobs}} \) = \( \frac{77}{5} \) = 15.4 days

Utilization = \( \frac{\text{Total job work time}}{\text{Total flow time}} \) = \( \frac{28}{77} \) = 36.4%

Average number of jobs in the system = \( \frac{\text{Total flow time}}{\text{Total job work time}} \) = \( \frac{77}{28} \) = 2.75 jobs

Average job lateness = \( \frac{\text{Total late days}}{\text{Number of jobs}} \) = \( \frac{11}{5} \) = 2.2 days
### SPT: Sequence B-D-A-C-E

<table>
<thead>
<tr>
<th>Job Sequence</th>
<th>Job Work (Processing) Time</th>
<th>Flow Time</th>
<th>Job Due Date</th>
<th>Job Lateness</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>5</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>11</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>19</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>28</td>
<td>23</td>
<td>5</td>
</tr>
</tbody>
</table>

| Total        | 28                        | 65        | 9            |
Example

SPT: Sequence B-D-A-C-E

Average completion time = \( \frac{\text{Total flow time}}{\text{Number of jobs}} = \frac{65}{5} = 13 \text{ days} \)

Utilization = \( \frac{\text{Total job work time}}{\text{Total flow time}} = \frac{28}{65} = 43.1\% \)

Average number of jobs in the system = \( \frac{\text{Total flow time}}{\text{Total job work time}} = \frac{65}{28} = 2.32 \text{ jobs} \)

Average job lateness = \( \frac{\text{Total late days}}{\text{Number of jobs}} = \frac{9}{5} = 1.8 \text{ days} \)
### EDD: Sequence B-A-D-C-E

<table>
<thead>
<tr>
<th>Job Sequence</th>
<th>Job Work (Processing) Time</th>
<th>Flow Time</th>
<th>Job Due Date</th>
<th>Job Lateness</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>11</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>19</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>28</td>
<td>23</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Job Work Time</th>
<th>Total Flow Time</th>
<th>Total Job Lateness</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>68</td>
<td>6</td>
</tr>
</tbody>
</table>
Example

EDD: Sequence B-A-D-C-E

Average completion time = \( \frac{\text{Total flow time}}{\text{Number of jobs}} \) = \( \frac{68}{5} \) = 13.6 days

Utilization = \( \frac{\text{Total job work time}}{\text{Total flow time}} \) = \( \frac{28}{68} \) = 41.2%

Average number of jobs in the system = \( \frac{\text{Total flow time}}{\text{Total job work time}} \) = \( \frac{68}{28} \) = 2.43 jobs

Average job lateness = \( \frac{\text{Total late days}}{\text{Number of jobs}} \) = \( \frac{6}{5} \) = 1.2 days
**Example**

**LPT: Sequence E-C-A-D-B**

<table>
<thead>
<tr>
<th>Job Sequence</th>
<th>Job Work (Processing) Time</th>
<th>Flow Time</th>
<th>Job Due Date</th>
<th>Job Lateness</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>9</td>
<td>9</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>17</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>23</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>26</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>28</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28</strong></td>
<td><strong>103</strong></td>
<td></td>
<td><strong>48</strong></td>
</tr>
</tbody>
</table>
Example

**LPT: Sequence E-C-A-D-B**

Average completion time = \( \frac{\text{Total flow time}}{\text{Number of jobs}} \) = \( \frac{103}{5} = 20.6 \) days

Utilization = \( \frac{\text{Total job work time}}{\text{Total flow time}} \) = \( \frac{28}{103} = 27.2\% \)

Average number of jobs in the system = \( \frac{\text{Total flow time}}{\text{Total job work time}} \) = \( \frac{103}{28} = 3.68 \) jobs

Average job lateness = \( \frac{\text{Total late days}}{\text{Number of jobs}} \) = \( \frac{48}{5} = 9.6 \) days
## Summary of Rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>Average Completion Time (Days)</th>
<th>Utilization (%)</th>
<th>Average Number of Jobs in System</th>
<th>Average Lateness (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCFS</td>
<td>15.4</td>
<td>36.4</td>
<td>2.75</td>
<td>2.2</td>
</tr>
<tr>
<td>SPT</td>
<td>13.0</td>
<td>43.1</td>
<td>2.32</td>
<td>1.8</td>
</tr>
<tr>
<td>EDD</td>
<td>13.6</td>
<td>41.2</td>
<td>2.43</td>
<td>1.2</td>
</tr>
<tr>
<td>LPT</td>
<td>20.6</td>
<td>27.2</td>
<td>3.68</td>
<td>9.6</td>
</tr>
</tbody>
</table>
Examples

Comparison of Sequencing Rules

- No one sequencing rule excels on all criteria
- SPT does well on minimizing flow time and number of jobs in the system
- But SPT moves long jobs to the end which may result in dissatisfied customers
- FCFS does not do especially well (or poorly) on any criteria but is perceived as fair by customers
- EDD minimizes lateness.