**Layout Strategy - Line Balancing**

**Layout** – the configuration of departments, work centers, and equipment, with particular emphasis on movement of work (customers or materials) through the system.

When we design manufacturing facilities, what are we trying to move through the system?

Most organizations use a combination of layouts. Product Layout is most common in mass manufacturing. One of the biggest challenges is how to coordinate, group, and schedule tasks.

**Line Balancing**

Line balancing is the process of assigning tasks to workstations, so that workstations have approximately equal time requirements. We use line balancing to

- minimize idle time
- balance bottlenecks

What is a bottleneck? Literally what is it? Imagine pouring out a bottle of coke. What does the neck of the bottle do to the flow of the coke out of the bottle? Does the neck of the bottle have the same capacity as the base?

1. In product layouts, when we want to improve productivity, we need to find and improve critical operations, known as bottlenecks. Productivity improvements to any non-bottleneck operation will NOT improve productivity of the system. Why?

**Example of Bottlenecks and the rule of productivity improvements on non-bottlenecks**

Operations and times required in the production of sweatshirts

<table>
<thead>
<tr>
<th>Operation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Side Seam Left</td>
<td>1 minute</td>
</tr>
<tr>
<td>2. Side Seam Right</td>
<td>1 minute</td>
</tr>
<tr>
<td>3. Shoulder Left</td>
<td>.5 minutes</td>
</tr>
<tr>
<td>4. Shoulder Right</td>
<td>.5 minutes</td>
</tr>
<tr>
<td>5. Arm Left</td>
<td>1.2 minutes</td>
</tr>
<tr>
<td>6. Arm Right</td>
<td>1.2 minutes</td>
</tr>
<tr>
<td>7. Cuff Left</td>
<td>.5 minutes</td>
</tr>
<tr>
<td>8. Cuff Right</td>
<td>.5 minutes</td>
</tr>
<tr>
<td>9. Waistband</td>
<td>1.3 minutes</td>
</tr>
<tr>
<td>10. Neck and Tag</td>
<td>2 minutes</td>
</tr>
</tbody>
</table>

1. Where is the bottleneck?
2. Why?
3. If you improve the productivity of the cuff operations by better methods and equipment, and reduce the operation time to .25 minutes on each side, will you improve sweatshirt productivity? Why or why not?

4. What are we ultimately trying to do on this production line? Eliminate bottlenecks through line balancing…..having approximately the same amount of time at each workstation

_Sweat Shirt Manufacturing:_

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<td>1 min</td>
</tr>
<tr>
<td>Left Shoulder</td>
<td>.5 min</td>
</tr>
<tr>
<td>Right Shoulder</td>
<td>.5 min</td>
</tr>
<tr>
<td>Arm Left</td>
<td>1.2 min</td>
</tr>
<tr>
<td>Arm Right</td>
<td>1.2 min</td>
</tr>
<tr>
<td>Cuff Left</td>
<td>.5 min</td>
</tr>
<tr>
<td>Cuff Right</td>
<td>.5 min</td>
</tr>
<tr>
<td>Wasistband</td>
<td>1.4 min</td>
</tr>
<tr>
<td>Neck and Tag</td>
<td>2.0 min</td>
</tr>
</tbody>
</table>

We have 10 operations? How many workstations could we have? ________________

How do we decide the optimal number of workstations to use?

**Cycle time** – the maximum time allowed at each workstation before the work moves on. Cycle time determines the rate of output.

_In Sweatshirt production:_

**Minimum Cycle Time** = ____________________
(longest task time)

**Maximum Cycle Time** = ____________________
(sum of all times)

\[
\text{Output Capacity} = \frac{\text{Operating Time}}{\text{Cycle Time}} \quad \text{(be sure that time units are same for numerator and denominator)}
\]

Output Capacity = \(\frac{480 \text{ minutes}}{2.0 \text{ minutes}}\) \((8 \text{ hrs/day} \times 60 \text{ minutes})\)

= 240 sweatshirts

Output Capacity = \(\frac{480 \text{ minutes}}{9.8 \text{ minutes}}\)

= 48.9 sweatshirts

Output for sweatshirts can range from 49 – 240 units/day.
**Cycle Time for a specific level of Production:** If we wanted a daily output of 150 sweatshirts, what would cycle time need to be?

Output Capacity = \[\frac{\text{Operating Time}}{\text{Cycle Time}}\]

\[
\begin{align*}
150 & = \frac{480}{CT} \\
150CT & = 480
\end{align*}
\]

\[
\begin{align*}
\frac{150}{150} & = \frac{480}{CT} \\
\frac{150}{CT} & = 3.2 \text{ minutes}
\end{align*}
\]

So, if we wanted to produce 150 sweatshirts, we would need a cycle time of 3.2 minutes. THEN, how many workstations would we need?

\[\text{N}_{\text{min}} = \frac{\sum t}{CT} = \frac{9.8 \text{ minutes}}{3.2 \text{ minutes}} = 3.06 \text{ workstations}\]

Can you have .06 of a workstation? How many workstations do we need? ______________

We know (1) we want a daily output of 150 sweatshirts, AND (2) cycle time should be 3.2 minutes, AND (3) we need 4 workstations. Now we must decide HOW to assign task to our 4 workstations (line balancing).

**Line Balancing Formulas:**

Minimum Cycle Time = longest single task time
Maximum Cycle Time = sum of all task times
\(N_{\text{min}} = \text{theoretical minimum number of stations}\)
\(\text{OT} = \text{operating time/day}\)
\(\text{CT} = \text{cycle time}\)
\(D = \text{desired output rate}\)

\[
\text{N}_{\text{min}} = \frac{3t}{CT} \quad \text{CT} = \frac{\text{OT}}{D} \quad \text{Output capacity} = \frac{\text{OT}}{\text{CT}}
\]

**Rules for Line Balancing**

1. Identify the cycle time and minimum number of work stations.

2. Make assignments to work stations in order, beginning with Station 1. Tasks are assigned to work stations moving left to right through the precedence diagram.
3. Before each assignment, use the following criteria to determine which tasks are eligible to be assigned to a workstation: See Table 9.4 page 350 for a complete list of heuristics.
   a. all proceeding tasks in the sequence have been assigned.
   b. the task time does not exceed the time remaining at the workstation
If no tasks are eligible, move to the next workstation.

4. After each task assignment, determine the time remaining at the current workstation by subtracting the sum of task times already assigned to it from the cycle time.

5. Break ties that occur using rules:
   a. assign the task with the longest task time.
   b. assign the task with the greatest number of followers.
   If there is still a tie, choose one task arbitrarily.

6. Continue until all tasks have been assigned to work stations.

7. Compute appropriate measures (percent idle time and efficiency) for the set of assignments.

**Line Balancing for Sweatshirts**

4 workstations
CT=3.2 minutes

Put tasks (operations) for sweatshirt manufacturing into each workstation (called loading the workstation) following the Rules for Line Balancing.

**Work Station 1**

CT = 3.2 minutes
Side Seam Left = 1.0
\[ \frac{2.2 \text{ minutes remaining}}{2.2 \text{ minutes remaining}} \]

Side Seam Right = 1.0
\[ \frac{1.2 \text{ minutes remaining}}{1.2 \text{ minutes remaining}} \]

Left Shoulder = .5
\[ \frac{.7 \text{ minutes remaining}}{.7 \text{ minutes remaining}} \]

Right Shoulder = .5
\[ \frac{.2 \text{ minutes remaining (Idle Time}}{.2 \text{ minutes remaining (Idle Time)}} \]

**Work Station 2**

CT= 3.2 minutes
Arm Left = 1.2
\[ \frac{2.0 \text{ minutes remaining}}{2.0 \text{ minutes remaining}} \]

Arm Right = 1.2
\[ \frac{.8 \text{ minutes remaining}}{.8 \text{ minutes remaining}} \]

Cuff Left = .5
\[ \frac{.3 \text{ minutes remaining (Idle Time)}}{.3 \text{ minutes remaining (Idle Time)}} \]
Work Station 3
CT= 3.2 minutes
Cuff Right = .5
 2.7 minutes remaining
Waistband = 1.4
 1.3 minutes remaining
Will the next operation, Neck and Tag fit into this workstation?
How much idle time is here?

Work Station 4
CT= 3.2 minutes
Neck and Tag = 2.0
 1.2 minutes remaining (Idle Time)

Percent Idle Time and Efficiency
Percentage of Idle time (balance delay) = \( \frac{\text{Idle time per cycle}}{\text{N}_{\text{actual}} \times \text{Cycle time}} \) * 100

Efficiency of a line = 100 - Percentage of Idle time
Efficiency is also calculated as:

\[ \text{Efficiency} = \frac{\sum \text{task times}}{(\text{actual # of workstations}) \times (\text{cycle time})} \]

Line Balancing Examples #1

Precedence Diagram

A 6 B
.1 min. 1.0 min.

C 6 D 6 E
.7 min. .5 min .2 min

Arrange tasks into 3 workstations. Use a cycle time of 1 minute.
Use the Rules for Line Balancing to set up your three workstations.
**Work Station 1**
Cycle Time = 1.0 minutes

**Work Station 2**
Cycle Time = 1.0 minutes

**Work Station 3**
Cycle Time = 1.0 minutes

Total Idle time =

Percentage of Idle time (balance delay) = \( \frac{\text{Idle time per cycle}}{N_{\text{actual}} \times \text{Cycle time}} \times 100 \)

Efficiency of a line = 100 - Percentage of Idle time
**Line Balancing Examples #2**

Use the information contained in the table below to do each of the following:

<table>
<thead>
<tr>
<th>Task</th>
<th>Immediate Follower</th>
<th>Task Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>b</td>
<td>.2</td>
</tr>
<tr>
<td>b</td>
<td>e</td>
<td>.2</td>
</tr>
<tr>
<td>c</td>
<td>d</td>
<td>.8</td>
</tr>
<tr>
<td>d</td>
<td>f</td>
<td>.6</td>
</tr>
<tr>
<td>e</td>
<td>f</td>
<td>.3</td>
</tr>
<tr>
<td>f</td>
<td>g</td>
<td>1.0</td>
</tr>
<tr>
<td>g</td>
<td>h</td>
<td>.4</td>
</tr>
<tr>
<td>H</td>
<td>end</td>
<td>.3</td>
</tr>
</tbody>
</table>

1. **Draw a precedence diagram.** Begin with activities with no predecessors (hint, hint a and c).

2. **Compute the cycle time needed to obtain an output of 400 units per day.** Assume an eight hour work day.

\[
CT = \frac{OT}{D} \quad OT = \text{operating time per day in minutes} \\
D = \text{desired output}
\]
3. Determine the minimum number of workstations required.

\[ N_{\text{min}} = \frac{\sum t}{CT} \]

Where, \( \sum t \) equals the sum of times in the precedence diagram and \( CT \) equals the cycle time.

Does it make sense for your answer to include a decimal? Why or why not? What should you do?

4. Assign workstations using this rule: Assign tasks according to the greatest number of following tasks. In case of a tie, assign the task with the longest processing time first.

**Station 1**
Cycle time = ________________

**Station 2**
Cycle time = ________________

**Station 3**
Cycle time = ________________

**Station 4**
Cycle time = ________________
5. Calculate total idle time, percent idle, and efficiency.

Total Idle Time ____________________

Percent Idle Percentage of Idle time (balance delay) = \[ \frac{\text{Idle time per cycle}}{\text{N}_{\text{actual}} \times \text{Cycle time}} \times 100 \]

= ________________

Efficiency of a line = 100 - Percentage of Idle time

= ________________

Homework:

Example #2 above, if we didn’t complete it in class.
Page 256 - 257

Problem 1
Problem 5 - make sure you use min. CT to compute number of workstations and to load the line.