Estimating and Reducing Labor Costs

Chapter 4

These slides are based in part on slides that come with Cachon & Terwiesch book *Matching Supply with Demand* [http://cachon-terwiesch.net/3e/](http://cachon-terwiesch.net/3e/). If you want to use these in your course, you may have to adopt the book as a textbook or obtain permission from the authors Cachon & Terwiesch.
The Role of Labor Costs in Manufacturing: The Auto Industry

- While labor costs appear small at first, they are important
  - look relative to value added
  - role up costs throughout the value chain

- Implications
  - also hunt for pennies (e.g. line balancing)
  - spread operational excellence through the value chain
Scooter Mania
Scooters by Xootr, Stafford, PA

www.xootr.com/xootr/tour/nfactorytour.htm

3 main processes: All labor-paced.
1. Steer and fork assembly  2. Frame wheel assembly  3. Deck assembly
Xootr Roma sold at $200

Weekly demand

- March
- April
- May
- June
- July
- August
- September
- October
- November
- December
- January
## Utilizations with demand of 125 units/week

<table>
<thead>
<tr>
<th></th>
<th>Worker 1 Steer</th>
<th>Worker 2 Frame</th>
<th>Worker 3 Deck</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity time</strong></td>
<td>13 min/unit</td>
<td>11 min/unit</td>
<td>8 min/unit</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>60/13= 4.61 units/hour</td>
<td>60/11= 5.45 units/hour</td>
<td>60/8= 7.5 units/hour</td>
</tr>
<tr>
<td><strong>Process capacity</strong></td>
<td>Min{4.61, 5.45, 7.50}= 4.61 units/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>125 units/week = 125/35 = 3.57 units/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thruput=Min{4.61, 3.57}= 3.57 units/hour, demand-constrained system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cycle time (requested)</strong></td>
<td>(1/3.57) x 60= 16.8 min/unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1/4.61) x 60= 13 min/unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Idle time/unit</strong></td>
<td>16.8-13= 3.8 min/unit</td>
<td>16.8-11= 5.8 min/unit</td>
<td>16.8-8= 8.8 min/unit</td>
</tr>
<tr>
<td><strong>Utilization</strong></td>
<td>3.57/4.61=13/16.8= 77%</td>
<td>3.57/5.45=11/16.8= 65.5%</td>
<td>3.57/7.5=8/16.8= 47.6%</td>
</tr>
</tbody>
</table>
Let us generalize:
Cycle Time: Time to process 1 unit

- **OT**: Operating Time per week
- **D**: Demand per week
- **Requested Cycle Time** = **RCT** = **OT** / **D**
- **Designed Cycle Time** = **DCT** = 1 / Process capacity

- If **RCT** > **DCT**, then we can produce at the requested level.
  Design is feasible.

- If **RCT** < **DCT**, then we cannot produce at the requested level.
  Design is infeasible. Capacity must be expanded.

Example: If a student can answer a multiple choice question in 2 minutes but gets a test with 30 questions and is given only 30 minutes then
**OT**=30 minutes; **D**=30
Requested cycle time = 1 minute < 2 minutes = Cycle time from the process (design) capability
Let us generalize: Labor Productivity Measures for a Demand-Constrained System: $RCT > DCT$

Overall Performance Measures

- **Capacity**
  \[ Capacity_i = \frac{\text{Number of Resources}_i}{\text{Activity Time}_i} \]

- **Utilization**
  \[ Utilization_i = \frac{\text{Thruput}}{\text{Capacity}_i} \]

Labor Productivity Measures

- **Direct Labor Content**
  \[ \text{Direct Labor Content} = a_1 + a_2 + a_3 + a_4 \]

  If one worker per resource:
  \[ \text{Direct Idle Time} = (RCT - a_1) + (RCT - a_2) + (RCT - a_3) + (RCT - a_4) \]

- **Average labor utilization**
  \[ \frac{\text{lab content}}{\text{lab content} + \text{direct idle time}} \]
Time to complete X units starting with an empty system

\[
\text{Time to make X units} = \text{Time through empty system} + \frac{X - 1 \text{ units}}{\text{Process Capacity}}
\]

\[
= \text{Time through empty system} + (X - 1) \text{ Cycle time}
\]

- For continuous flow processes: The first unit also take cycle time so “(X-1)=X”.

Example: How many minutes are required to make 100 xootrs?

13+11+8=32 mins required for the first scooter

(99)(13)=1287 mins required for the remaining 99 units
Utilizations with demand of 125 units/week

<table>
<thead>
<tr>
<th>Utilization</th>
<th>Worker 1</th>
<th>Worker 2</th>
<th>Worker 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>77%</td>
<td>65.5%</td>
<td>47.6%</td>
</tr>
</tbody>
</table>

- No worker is fully utilized at the demand of 125 units/week.
- There is an imbalance in the amount of work done by workers.
- Upon balancing the assembly line, the process capacity improves.
- But the throughput does not change as the line is demand constrained.
## Utilizations with demand of 200 units/week

<table>
<thead>
<tr>
<th></th>
<th>Worker 1</th>
<th>Worker 2</th>
<th>Worker 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity time</strong></td>
<td>13 min/unit</td>
<td>11 min/unit</td>
<td>8 min/unit</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>$\frac{60}{13} = 4.61$ units/hour</td>
<td>$\frac{60}{11} = 5.45$ units/hour</td>
<td>$\frac{60}{8} = 7.5$ units/hour</td>
</tr>
<tr>
<td><strong>Process capacity</strong></td>
<td>$\text{Min}{4.61, 5.45, 7.50} = 4.61$ units/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>200 units/week = $\frac{200}{35} = 5.714$ units/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thruput</strong></td>
<td>$\text{Min}{4.61, 5.714} = 4.61$ units/hour, capacity-constrained system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cycle time (requested)</strong></td>
<td>$(1/5.714) \times 60 = 10.5$ min/unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cycle time (designed)</strong></td>
<td>$(1/4.61) \times 60 = 13$ min/unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Idle time/unit</strong></td>
<td>13-13 = 0 min/unit</td>
<td>13-11 = 2 min/unit</td>
<td>13-8 = 5 min/unit</td>
</tr>
<tr>
<td><strong>Utilization</strong></td>
<td>$\frac{4.61}{4.61} = 13/13 = 100%$</td>
<td>$\frac{4.61}{5.45} = 11/13 = 84.6%$</td>
<td>$\frac{4.61}{7.5} = 8/13 = 61.5%$</td>
</tr>
</tbody>
</table>
Labor Productivity Measures for a Capacity-Constrained System: RCT < DCT

Since the system is capacity-constrained, line balancing can improve the capacity.

Labor Productivity Measures

- If one worker per resource:
  
  \[ \text{Direct Idle Time} = (DCT-a_4) + (DCT-a_1) + (DCT-a_2) + (DCT-a_3) \]
Balancing an Assembly Line without Resequencing Operations

1: Prepare cable
2: Move cable
3: Assemble washer
4: Apply fork, threading cable end
5: Assemble Socket head screws
6: Steer pin nut
7: Brake shoe, spring, pivot bolt
8: Insert front wheel
9: Insert axle bolt
10: Tighten axle bolt
11: Tighten brake pivot bolt
12: Assemble handle-cap
13: Assemble brake lever + cable
14: Trim and cap cable
15: Place first rib
16: Insert axles and cleats
17: Insert rear wheel
18: Place second rib and deck
19: Apply grip tape
20: Insert deck fasteners
21: Inspect and wipe-off
22: Apply decal and sticker
23: Insert in bag
24: Assemble carton
25: Insert Xootr and manual
26: Seal carton
### Utilizations after Line Balancing with demand of 200 units/week

<table>
<thead>
<tr>
<th></th>
<th>Worker 1</th>
<th>Worker 2</th>
<th>Worker 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity time</strong></td>
<td>10.383 min/unit</td>
<td>10.033 min/unit</td>
<td>11.083 min/unit</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>60/10.383=</td>
<td>60/10.033=</td>
<td>60/11.083=</td>
</tr>
<tr>
<td></td>
<td>5.78 units/hour</td>
<td>5.98 units/hour</td>
<td>5.41 units/hour</td>
</tr>
<tr>
<td><strong>Process capacity</strong></td>
<td></td>
<td>Min{5.78, 5.98, 5.41}=</td>
<td>5.41 units/hour</td>
</tr>
<tr>
<td><strong>Demand</strong></td>
<td>200 units/week</td>
<td>5.714 units/hour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.714 units/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thruput</strong></td>
<td>Min{5.41, 5.714}=</td>
<td>5.41 units/hour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.41 units/hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cycle time (requested)</strong></td>
<td>(1/5.714) x 60=</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.50 min/unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cycle time (designed)</strong></td>
<td>(1/5.41) x 60=</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.083 min/unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Idle time/unit</strong></td>
<td>11.083-10.383=</td>
<td>11.083-11=</td>
<td>11.083-11.083=</td>
</tr>
<tr>
<td></td>
<td>0.7 min/unit</td>
<td>0.083 min/unit</td>
<td>0 min/unit</td>
</tr>
<tr>
<td><strong>Utilization</strong></td>
<td>10.383/11.083=</td>
<td>10.033/11.083=</td>
<td>11.083/11.083=</td>
</tr>
<tr>
<td></td>
<td>93.7%</td>
<td>90.5%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*utdallas.edu/~metin*
Demand of **700 units/week** after line balancing

- With the rate of 5.41/hour, weekly production in 35 hours is about 189.5 units < 700 units.
  - Capacity constrained system

- **Capacity expansion options:**
  - Replicate the assembly line
  - Selectively add workers to the line
    » Add generalists
    » Add specialists
Replicate the assembly line

◆ How many lines do we need?
  – Roundup(700/189.5)=Roundup(3.69)=4
Selectively add generalists

- **How many generalists do we need?**
  - **Steer assembly:** 1 worker provides $35(5.78)=202.3$ units
    » Roundup($700/202.3)=4$ needed for Steer assembly
  - **Frame assembly:** 1 worker provides $35(5.98)=209.3$
    » Roundup($700/209.3)=4$ needed for Frame assembly
  - **Deck Assembly:** 1 worker provide $35(5.41)=189.5$
    » Roundup($700/189.5)=4$ needed for Deck assembly
Selectively add specialists

- How many specialists do we need?
  - Need 700 units in 2100 (=35x60) minutes or 1 unit in 180 secs = RCT.
- Group tasks so that total task time is less than or equal to 180 secs.

<table>
<thead>
<tr>
<th>Worker</th>
<th>Task</th>
<th>Duration(secs)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prepare cable</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Move cable</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assemble washer</td>
<td>100</td>
<td>155</td>
</tr>
<tr>
<td>2</td>
<td>Apply fork</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assemble socket</td>
<td>114</td>
<td>180</td>
</tr>
<tr>
<td>3</td>
<td>Steer pin nut</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brake shoe, etc.</td>
<td>66</td>
<td>115</td>
</tr>
<tr>
<td>4</td>
<td>Insert front wheel</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insert axle bolt</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tighten axle bolt</td>
<td>43</td>
<td>173</td>
</tr>
</tbody>
</table>
Selectively add specialists

- Completing the table, we observe that 12 workers are needed for 26 tasks.
Summary

- Cycle time, requested and designed, Idle time
- Capacity-constrained vs. Demand-constrained systems
- Line balancing
- Line capacity expansion strategies
Key-points to remember:

Where do process times / cost estimates quoted by production managers come from?

How to make labor related decisions
• pricing
• hiring

Impact of process design on productivity
• Line balance
• Idle time
• Direct labor content

Calculations:
- Determining resource requirements to support a volume target.
- Estimating direct labor content.
- Calculating direct manufacturing cost
- Adjusting for idle time

The Importance of Process DESIGN

Mechanics of a worker-paced line

Mechanics of a work cell