Understanding the Supply Process: Evaluating Process Capacity

Chapter 3

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.
Learning Objectives

◆ Process flow chart (diagram)
◆ Capacity, bottleneck, utilization
◆ Chase and level production plans
Trinidad’s “circored iron ore” plant

Fluidized bed based Circored® technology: The process uses hydrogen from natural gas to reduce iron ore fines, significantly decreasing the costs of the steelmaking process due to the elimination of the agglomeration step. The high quality, low cost product can be used as pure scrap substitute in electric arc furnaces as well as for increasing the capacity of existing blast furnaces with corresponding coke savings.
Why Metal Makers locate around Port Lisas?

◆ "Natural gas and a port."
  – According to Les Hart, Manager of Nucor Corp.’s Iron Refinery.

◆ Series of fat pipelines bringing cheap, abundant natural gas from an undersea fields to Claxton Bay and Port Lisas.

◆ “The fuel supply's economics are so compelling that Nucor cut a refinery into pieces and shipped it [on 13 barges] across the sea from its original home near New Orleans to take advantage of the lower costs.” Luckily, transfer was completed 5 days before Hurricane Katrina.
  – According to the WSJ article titled “Metal makers go far for cheap fuel” published on July 6, 2007.

◆ Port Lisas in the Claxton Bay, most dependable port in the Caribbean

◆ Risks:
  – Some estimate Trinidad has only 30 years of natural-gas reserves left. Ken Julien, chairman of Trinidad's Natural Gas Task Force, says: “more untapped deposits could be discovered”.
    » As the gas prices rise so do the economically extractable deposits.
    » Another option: Gas purchases from Venezuela.
  – Highly skilled labor shortage:
    » University of Trinidad and Tobago, with an engineering focus, started
Circored plant in Trinidad  

Case at inseed.edu/alliance/faculty/CircoredPlantinTrinidad-w.pdf
To Create a Process Flow Chart (Diagram)
To Create a Process Flow Chart (Diagram)

Activities
• Carried out by resources
• Add value and are required for completion of the flow unit
• May or may not carry inventory
• Have a capacity (maximum number of flow units that can flow through the activity within a unit of time)

Arrows
• Indicate the flow of the flow unit
• Multiple flow unit types possible

Inventory / Buffers
• Do NOT have a capacity; however, there might be a limited number of flow units that can be put in this inventory space at any moment of time
• Multiple flow unit types possible
To Create a Process Flow Chart (Diagram)

We can eliminate bucket elevator, it is cheap and so not constraining. Thus, it is not necessary to consider.

Natural iron ore particles as mined. Pelletizing fines have particle size less than 12 mm.

Fe₂O₃ + 3H₂ → 3H₂O + 2Fe

Hydrogen gas from natural gas

Water

HBI: Hot Briquetted Iron. 90-94% iron by weight. Rest is Carbon, Phosphor, Metal Oxides.
Service systems are not that different!
Case in Point: Criminal Justice
Bottleneck process and capacity

- **Capacity**: Number (amount) of units that can be processed per time
  - A student can solve 30 multiple choice questions per hour.
  - Each briquetting machine has a capacity of 55 tons per hour.

- Overall capacity of a sequence of processes is determined by the slowest process, i.e. the resource with the smallest capacity.
  - Process capacity = Min{Capacity of Res 1, ..., Capacity of Res 2}

- Incorporating available input rate and demand rate,
  - Thruput = Min{Input rate, Process capacity, Demand rate}

**Diagram**:
- Supply constrained
- Demand constrained

**Flow Chart Diagrams**

Input → Flow Rate → Bottleneck Capacity → Excess capacity → Demand

Input → Flow Rate → Bottleneck Capacity → Excess capacity → Demand
Choosing the Unit of Analysis: Tons of BI equivalent

Capacity of each equipment in terms of the weight of input it can process. See equipment manuals.

<table>
<thead>
<tr>
<th>PreHeater</th>
<th>LockHoppers</th>
<th>1st Reactor</th>
<th>2nd Reactor</th>
<th>FlashHeater</th>
<th>Discharge</th>
<th>Briquetting</th>
</tr>
</thead>
<tbody>
<tr>
<td>169.58 ton/hr</td>
<td>143.79 ton/hr</td>
<td>36.6 ton/15 min</td>
<td>444 ton/4hr</td>
<td>135 ton/hr</td>
<td>118 ton/hr</td>
<td>165 ton/hr</td>
</tr>
<tr>
<td>169.58 ton/hr</td>
<td>143.79 ton/hr</td>
<td>146.4 ton/hr</td>
<td>111 ton/hr</td>
<td>135 ton/hr</td>
<td>118 ton/hr</td>
<td>165 ton/hr</td>
</tr>
</tbody>
</table>

2nd Reactor can take in 111 tons but gives $0.9 \times 111 = 100$ tons of output that will eventually become BI.

1st Reactor can take in 146.4 tons but gives $0.85 \times 0.9 \times 146.4 = 112$ tons of output that will become BI.

Lock Hoppers can take in 143.79 tons but gives $0.85 \times 0.9 \times 143.79 = 110$ tons of output measured in terms of BI.

Pre-Heater can take in 169.58 tons but gives $0.925 \times 0.85 \times 0.9 \times 169.58 = 120$ tons of BI equivalent.

The distinction between capacity units on this slide is highlighted upon the suggestion from OPRE 6302 student Devender Ponnama in 2013.
The process capacity of circored plant in Trinidad

Capacities in terms of BI equivalent

<table>
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<td>120 ton/hr</td>
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<td>112 ton/hr</td>
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<td>135 ton/hr</td>
<td>118 ton/hr</td>
<td>165 ton/hr</td>
</tr>
</tbody>
</table>

◆ **Process Capacity**

\[
= \min\{120, 110, 112, 100, 135, 118, 165\}
\]

\[
= 100 \text{ tons/hour} = 24 \times 360 \times 100 \text{ tons/year} = 864,000 \text{ tons/year}
\]
The cycle time of circored plant in Trinidad

- **Cycle time**: Amount of time taken to process 1 unit in repetitive processing.
  - Since different units can be processed in parallel, cycle time is not the flow time.

- **Cycle time (designed) = 1 / Process Capacity**

- **How long does it take to process 1 ton of iron ore?**
  - Since 1 hour is required for 100 tons, 1/100 hour suffices for 1 ton.
  - That is, the cycle time is 0.01 hour = 0.6 min = 36 seconds
  - Every 36 seconds 1 ton of iron briquet is completed.
The utilization with demand of 657,000 tons/year

- Utilization of a resource = Thruput/(Capacity of the resource)
The utilization with demand of 1,095,000 tons/year

- Implied (requested) Utilization of a resource = Demand / Capacity of the resource
Different units flowing in the same system

- Outsourcing business processes is common
  - Billing, Recruiting, Maintenance, Customer call centers, etc
- The company which handles the outsourced process is likely to deal with various kinds of units
- Case in point: A company that provides resume validation service:
An application as a unit

Demand per hour for validation: 3 for consulting; 11 for staff; 4 for internship.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity Time (min) Per applct</th>
<th>Number of workers</th>
<th>Available Capacity Applct/hr</th>
<th>Consulting Workload Per hour</th>
<th>Staff Workload Per hour</th>
<th>Intern Workload Per hour</th>
<th>Total</th>
<th>Implied Utilization</th>
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<tr>
<td>File</td>
<td>3</td>
<td>1</td>
<td>20</td>
<td>3</td>
<td>11</td>
<td>4</td>
<td>18</td>
<td>18/20= 90%</td>
</tr>
<tr>
<td>Contact Persons</td>
<td>20</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3/6= 50%</td>
</tr>
<tr>
<td>Contact Employers</td>
<td>15</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>11</td>
<td>0</td>
<td>14</td>
<td>14/12= 117%</td>
</tr>
<tr>
<td>Benchmark Grades</td>
<td>8</td>
<td>2</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>4/15= 27%</td>
</tr>
<tr>
<td>Confirmation Letter</td>
<td>2</td>
<td>1</td>
<td>30</td>
<td>3</td>
<td>11</td>
<td>4</td>
<td>18</td>
<td>18/30= 60%</td>
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### An application as a unit

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<td>18</td>
<td>18/30=60%</td>
</tr>
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</table>

- What is the minimum number of people to hire so that the implied utilization of contact employers is below 100%?
- What happens to implied utilizations when staff applications decrease to 8 per hour? Compute the new utilizations.
A minute as a unit

Demand per hour for validation: 3 for consulting; 11 for staff; 4 for internship.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity Time Per applct</th>
<th>Number of workers</th>
<th>Available Capacity Minute/hr</th>
<th>Consulting Workload Per hour</th>
<th>Staff Workload Per hour</th>
<th>Intern Workload Per hour</th>
<th>Total</th>
<th>Implied Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>File</td>
<td>3</td>
<td>1</td>
<td>60</td>
<td>3 x 3</td>
<td>11 x 3</td>
<td>4 x 3</td>
<td>54</td>
<td>54/60 = 90%</td>
</tr>
<tr>
<td>Contact Persons</td>
<td>20</td>
<td>2</td>
<td>120</td>
<td>3 x 20</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>60/120 = 50%</td>
</tr>
<tr>
<td>Contact Employers</td>
<td>15</td>
<td>3</td>
<td>180</td>
<td>3 x 15</td>
<td>11 x 15</td>
<td>0</td>
<td>210</td>
<td>210/180 = 117%</td>
</tr>
<tr>
<td>Benchmark Grades</td>
<td>8</td>
<td>2</td>
<td>120</td>
<td>0</td>
<td>0</td>
<td>4 x 8</td>
<td>32</td>
<td>32/120 = 27%</td>
</tr>
<tr>
<td>Confirmation Letter</td>
<td>2</td>
<td>1</td>
<td>60</td>
<td>3 x 2</td>
<td>11 x 2</td>
<td>4 x 2</td>
<td>36</td>
<td>36/60 = 60%</td>
</tr>
</tbody>
</table>
Production Management to Handle Demand Fluctuations

Chase strategy

- In a chase production plan, a firm produces quantities exactly to match the demand.
- If there is regular time and overtime possibility, sum of the regular time and overtime capacity is set equal to the demand. Since the regular time is cheaper, no overtime is scheduled before entire regular time is used up.
- Example with a regular time capacity of 4000 units/week.

<table>
<thead>
<tr>
<th>Week</th>
<th>Demand</th>
<th>Regular time production</th>
<th>Overtime production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2800</td>
<td>2800</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4300</td>
<td>4000</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>3800</td>
<td>3800</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>5100</td>
<td>4000</td>
<td>1100</td>
</tr>
</tbody>
</table>
Production Management to Handle Demand Fluctuations

- In a level production, a firm produces in constant quantities during regular time.
- If the regular time capacity is enough to produce total demand, no overtime.
- Example with a regular time capacity of 4000 units/week.

<table>
<thead>
<tr>
<th>Week</th>
<th>Demand</th>
<th>Beginning Inventory</th>
<th>Regular time production</th>
<th>Overtime production</th>
<th>Ending Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2800</td>
<td>0</td>
<td>4000</td>
<td>0</td>
<td>1200</td>
</tr>
<tr>
<td>2</td>
<td>4300</td>
<td>1200</td>
<td>4000</td>
<td>0</td>
<td>900</td>
</tr>
<tr>
<td>3</td>
<td>3800</td>
<td>900</td>
<td>4000</td>
<td>0</td>
<td>1100</td>
</tr>
<tr>
<td>4</td>
<td>5100</td>
<td>1100</td>
<td>4000</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Production Management to Handle Demand Fluctuations

Level strategy with Insufficient Regular Time

- If the regular time capacity is insufficient, use overtime.
- Example with a regular time capacity of 3000 units/week.

<table>
<thead>
<tr>
<th>Week</th>
<th>Demand</th>
<th>Beginning Inventory</th>
<th>Regular time production</th>
<th>Overtime production</th>
<th>Ending Inventory</th>
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<tr>
<td>1</td>
<td>2800</td>
<td>0</td>
<td>3000</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>4300</td>
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<td>1100</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3800</td>
<td>0</td>
<td>3000</td>
<td>800</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>5100</td>
<td>0</td>
<td>3000</td>
<td>2100</td>
<td>0</td>
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Summary

- Process flow chart (diagram)
- Capacity, bottleneck, utilization
- Chase and level production plans
The fate of the plant as of May 2004

- Outokumpu's new CIRCORED® Technology for Iron Reduction Boosted by the CAL - ISG Deal. ISG Venture Inc., a subsidiary of International Steel Group Inc., has announced its agreement to purchase the idled Circored® Hot Briquette Iron (HBI) facility in Trinidad and Tobago from Cliffs and Associates Limited (CAL).

- The Trinidad and Tobago HBI project began in the mid-1990s as a joint venture between Cleveland Cliffs, Lurgi Metallurgie (then of Germany, but now known as Outokumpu Technology GmbH of Finland), and LTV Steel. Lurgi Metallurgie developed and delivered the first-of-its-kind Circored® plant for the HBI facility in Trinidad.

- The plant is designed to produce 500,000 tons/annum of HBI using Outokumpu's new fluidized bed based Circored® technology. HBI production with Circored® began in 2000 in the first industrial scale plant in Trinidad, but ceased in 2001 due to depressed global HBI prices. Along with increasing steel prices and ISG Venture investing now in the Trinidad HBI production and restarting the plant, Outokumpu Technology sees great possibilities to market the ground-breaking Circored® technology to other steel producers, too, as a highly cost-effective process.
Business process outsourcing (BPO) Local and recent example

- Top Spanish Financial Services Firm la Caixa (lacaixa.es) Extends EDS Relationship
  - Representatives of EDS announced a €200 million agreement for information technology services (IT) and BPO with la Caixa that will extend the relationship for an additional four years. Since 1996, EDS has provided a range of IT services for la Caixa. The nearly decade-long relationship with la Caixa has enabled the financial institution to increase profits while lowering operating costs.
  - EDS will continue managing “la Caixa’s” technology infrastructure using the EDS data center in Barcelona and managing contingency and security services. Additionally, EDS will develop new banking and insurance software solutions and applications architecture and will manage the Contact Centre, providing support to the bank branches. EDS financial BPO solutions afford la Caixa the ability to differentiate itself from its competitors, focus on its core business and increase its efficiency while using world-class technology platforms.
  - With almost 4,800 branches across Spain, the agreement enables la Caixa to continue its market share growth by opening new branches and increasing sales while reducing overall costs. The agreement provides operational efficiencies by allowing EDS to integrate mainframe, midrange and network operations and improve processes for managing risk.
  - The renewed relationship with la Caixa, on the heels of the contract with First International Bank of Israel, demonstrates EDS’ global operational excellence in the financial services industry, said Rafael Roa, President EDS Iberia.

Announced in the second week of Jan 2006.