Process View of the Organization

Chapter 2

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

- Terminology: Inventory, Thruput, Flowtime
- Little’s Law
- Reasons for holding inventory
- Types of processes
Presbyterian Hospital

- Interventional radiology flowchart:

- After reading the associated section, you should have a sense of a Gantt chart, which is a depiction of activities (jobs) over time.

- Patients wait even when all the activity durations are predictable, why?
In Describing the Processes
Inventory - Flowtime - Thruput

◆ **Inventory**: Number (amount) of units within (before and after) the process
  » Number of patients in the interventional radiology waiting room.
  » Number of students in the OPRE 6302 classroom.
  » Number of plasma TVs at a circuit city store.
  » Tons of crude oil stored at Houston refineries.
  » In Revenue Management Context: Number of seats on a Southwest flight.

◆ **Flowtime**: Amount of calendar time consumed to complete a process, includes waiting and idle time.
  » 12 months is the minimum flowtime for the SCM concentration.
  » 25 minutes is the flowtime for my hair cut.
  » 4 hours is the flowtime to drive to Houston from Dallas.

◆ **Thruput**: Number (amount) of units output from a process
  » 45 cohort students graduate per year from SOM
  » 5 cars enter the UTD campus from Campbell street every minute
  » 17 M barrels of oil is refined per year in the U.S.
Inventory - Flowtime on Cumulative Inflow and Outflow graphs

Patients at the radiology

7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00

Cumulative Inflow

Cumulative Outflow

Flow Time

Patient Arrival

Patient Departure

Inventory = Cumulative Inflow - Cumulative Outflow
Thruput on Cumulative Inflow and Outflow graphs

Slope is the thruput

Thruput is 11 patients per day of 11 working hours.
Little’s law

Long run averages = Expected values

\[ I = R \times T \]

I=Inventory; R=Thruput; T=Flowtime

1 minute is the flow time, \( T=1 \) minute
10 per minute is the thruput, \( R=10/\text{minute} \)
10=10x1 units is the inventory
Little’s powerful law

- Powerful formula: Does not depend on
  - The sequence of the service
    » First-in-first-out or Last-in-first-out
  - Distribution of the service times
    » Uniform or Normal
    » Formula is for the averages, anyway

- Out of the three measures (I,R,T), two can be chosen by management, the other is given by the formula.

- When throughput is constant
  - Reducing inventory = Reducing flow time

- Burger King:
  - Burger Throughput=50kg/day, Inventory=25kg
    » Burger flowtime=T=I/R=
  - Customer Throughput=60/hour, Inventory=18
    » Customer flowtime=18 minutes
More interesting observations:

Little’s powerful law with Cost of Goods Sold

- Dell has a **COGS of $20 B per year**
  - The cost of the Dell’s annual sales is $20 B
  - Dell annually spends $20 B, which can be thought as the throughput in terms of dollars. Hence, throughput=$20 B
  - Dell keeps $391 M worth of inventory, what is the flowtime of Dell products?
    - $391/20,000 = 0.01955 year = 0.23 months = **7 days**
- Compaq, COGS=$25.263 B per year, inventory $2 B, so flowtime of Compaq products is
  - $2/25.263 = 0.079 year = 0.95 months = **28 days**
- **7 days vs. 28 days** is a measurement of Dell’s supply chain efficiency vs. Compaq’s.
- What is Dell’s secret in Roundrock, TX?
Even more interesting observations: Inventory turns vs. Gross margin

- **Inventory turns (turnover)** is the reciprocal of the flowtime
  - Dell turns inventory 52 times a year (once a week)
  - Compaq turns inventory ~12 times a year (once a month)

- Frequent inventory turns indicate that inventory is kept for a short amount of time before it is sent to the customer.

- While an item is in the inventory, we incur a percentage of its costs as inventory holding cost to compensate for the capital costs and
  - Obsoleteness, Perishing, Pilferage, Security, Administration, Storage costs.

- If the inventory holding cost is 30% per year, what is the holding cost per unit?
  - $0.3/52 = 0.0058 = 0.58\%$. The **0.58\%** of the cost of each unit sold is due to inventory holding cost.

- What about Compaq?
  - $0.3/12 = 2.5\%$. 
Much more interesting observations:
Inventory turns vs. Gross margin of Retailers

- **Statement**: Companies which turn inventory less frequently has higher gross margin.
- **Better statement**: Companies which turn inventory less frequently sell unpopular, rare, slow moving items. They charge a premium to consumers who want such items. That is why their gross margin is higher.
- **We must be careful while making generalizations from the graph on the left.**
- **However**, these graphs are beneficial for benchmarking purposes.
- **For example**, it is very interesting to know that food stores have an average of 10.78 inventory turns per year while jewelry stores have 1.68 turns per year.

Source: Gaur, Fisher, Raman (ManSci 2005)
AMR research [http://www.amrresearch.com](http://www.amrresearch.com) publishes reports on supply chains and other issues.

The Top 25 supply chains report comes out in November.

The table on the right-hand side is from *The Second Annual Supply Chain Top 25* prepared by Kevin Riley and released in November 2005.
Why to hold Inventory?

Pipeline inventory: Work in process or in transit

In view of Little’s formula, how can we make pipeline inventory=0?

» Set throughput=0 or set flowtime=0.

» That is, do not process at all or process instantaneously.

– Smoothing cumulative inflow and outflow graphs:

```
<table>
<thead>
<tr>
<th>Time</th>
<th>Cumulative Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00</td>
<td>1</td>
</tr>
<tr>
<td>8:00</td>
<td>2</td>
</tr>
<tr>
<td>9:00</td>
<td>3</td>
</tr>
<tr>
<td>10:00</td>
<td>4</td>
</tr>
<tr>
<td>11:00</td>
<td>5</td>
</tr>
<tr>
<td>12:00</td>
<td>7</td>
</tr>
</tbody>
</table>
```

1.5 Patients
1.5 hours
Why to hold Inventory?

Seasonal inventory: Unstable demand or supply

Unstable demand

stable supply

Seasonal demand

» Planners starting on Jan 1 and Sep 1 (academic year)

Unstable supply

stable demand

Seasonal (Agricultural) supply

Sugar beets inventory

at a sugar producer, Monitor Sugar

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![Graph showing seasonal inventory with unstable demand or supply. The graph compares undated planners with seasonal events and inventory levels.]
Why to hold Inventory?

Cycle inventory: **Economies of scale in processing**

- Number of eggs in my fridge: Stable demand, stable supply
- Number of trays, which is required for interventional radiology, received once in a week
Two steps, two machines, one for each step:
First step takes 1 min or 3 mins with equal probability. Second step always takes 2 mins.
Consider an instance of 6 parts to process, whose first step processing times are 1,1,1,3,3,3.
Why to hold Inventory?

Safety inventory: To absorb variability

Demand between ordering epochs can be stochastically variable. The inventory should be increased to absorb this variability.

Why is not the tray inventory zero just before the receipt of the shipment?
What if we reduce the safety inventory by 2 trays?

There is no inventory of trays on the 14th day. If the delivery is late or one more patient comes, the next patient cannot be served. Such a shortage can have mortal consequences.
Process Types

**Job Shops:** Small lots, low volume, general equipment, skilled workers, high-variety.
   Ex: tool and die shop, veterinarian’s office

**Batch Processing:** Moderate volume and variety. Variety among batches but not inside.
   Ex: paint, food, pharma production, OPRE 6302 sections

**Repetitive/Assembly:** Semicontinuous, high volume of standardized items, limited variety. Textbook calls this worker/machine paced line.
   Ex: auto plants, cafeteria

**Continuous Processing:** Very high volume and no variety.
   Ex: steel mill, steel production from iron ore, chemical plants

**Projects:** Nonroutine jobs.
   Ex: preparing OPRE 6302 quiz

Turning a Project into Repetitive process.
Example: 39DollarGlasses.com

Lens Taping and Surface Blocking
Finished front surface of lenses are protected by a removable wrap film (taping). Lenses are sent to a computer preparing them for the next cutting step by placing a lens stabilizer (block) on the coated surface.

Lens Generating
A computerized lens cutter uses a special blade to thin the lenses by cutting a prescription into its back surface.

Lens Fining and Polishing
A buffing pad smooths the back. A soft pad and polishing solution makes the lens crystal-clear. Surface blocks and protective tape removed from the front.

Lens Edging
The shape of the lenses sent to a lens edger. The large lens is cut on a diamond-blade wheel with pinpoint accuracy. Stabilizer are removed.

Lens Blocking
A computer attaches a lens stabilizer to the front. Stabilizer holds the lens steady in the lens edger. The block never touches the lenses as they are protected by a soft rubber buffer.

Hard Coating and Intermediate Inspection
A machine places a hard scratch coat on lenses (unless to be tinted). Lenses are inspected.

Edge Polishing & Frame
New edges are buffed for a thinner look. They are coated with scratch resistant and UV protective barrier.

Assembly
Manually insert the lenses into frame and tighten the frame.

Final Verification and Inspection
A computer passes light through the lenses to inspect prescription and alignment accuracy in the assembled pair.

Output
Coated, polished finished lens
Edged, coated lens
Assembled frame
Frame in micro-fiber cleaning pouch
Questions Before Selecting A Process

- How much variety of products and services?
- How much flexibility of the process; volume, mix, technology?

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Job Shop</th>
<th>Batch</th>
<th>Repetitive</th>
<th>Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job variety</td>
<td>Very High</td>
<td>Moderate</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>Process flexibility</td>
<td>Very High</td>
<td>Moderate</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>Unit cost</td>
<td>Very High</td>
<td>Moderate</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>Volume of output</td>
<td>Very low</td>
<td>Low</td>
<td>High</td>
<td>Very high</td>
</tr>
</tbody>
</table>
## Variety, Flexibility & Volume

<table>
<thead>
<tr>
<th>Product Variety</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
<th>Very Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment flexibility</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Low Volume</td>
<td>Job Shop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Volume</td>
<td>Batch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Volume</td>
<td></td>
<td>Repetitive assembly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high Volume</td>
<td></td>
<td>Continuous Flow</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Product – Process Matrix

<table>
<thead>
<tr>
<th>Process Type</th>
<th>High variety</th>
<th></th>
<th>Low variety</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Job Shop</strong></td>
<td>Appliance repair</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergency room</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Batch</strong></td>
<td>Commercial bakery</td>
<td></td>
<td>Automotive assembly</td>
</tr>
<tr>
<td></td>
<td>Classroom Lecture</td>
<td></td>
<td>Automatic carwash</td>
</tr>
<tr>
<td><strong>Repetitive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Continuous (flow)</strong></td>
<td></td>
<td></td>
<td>Oil refinery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water purification</td>
</tr>
</tbody>
</table>
## Product - Process Matrix

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>Quality</th>
<th>Dependability</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Volume</td>
<td>Multiple Major</td>
<td>Few</td>
<td>High Volume, High Standardization</td>
</tr>
<tr>
<td>One of a Kind</td>
<td>Products, Low Volume</td>
<td>Products, Higher Volume</td>
<td></td>
</tr>
</tbody>
</table>

- **Job Shop**
  - Book Writing
  - Movie Theaters
  - Automobile Assembly
  - Sugar Refinery

- **Batch**

- **Assembly Line**

- **Continuous Flow**

Flexibility-Quality | Dependability-Cost
Product - Process Matrix

<table>
<thead>
<tr>
<th></th>
<th>Low Volume (unique)</th>
<th>Medium Volume (high variety)</th>
<th>High Volume (lower variety)</th>
<th>Very high volume (standardized)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job Shop</td>
<td>Coronary artery bypass graft (CABG) Surgery</td>
<td>Unit variable costs generally too high</td>
<td>van Heusen Shirts</td>
<td></td>
</tr>
<tr>
<td>Batch Process</td>
<td></td>
<td></td>
<td>Manzana Insurance</td>
<td>Toshiba Toyota</td>
</tr>
<tr>
<td>Worker-paced line</td>
<td></td>
<td></td>
<td></td>
<td>National Cranberry</td>
</tr>
<tr>
<td>Machine-paced line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous process</td>
<td></td>
<td>Utilization of fixed capital generally too low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There exists a long-term drift from the upper left to the lower right.
Summary

- Terminology: Inventory, Thruput, Flowtime
- Little’s law
- Reasons for holding inventory
- Types of processes