The Goal

Discussion slides based on those prepared by
Prof. Charles Fine

What are your take away's from The Goal? Your critiques?

What are the key principles? How applicable are they in class context?

Measuring Operations Performance

(Language of Money   vs.   Language of Physical Operations)

FINANCIAL MEASURES
-NET INCOME
-RETURN ON INV
-CASH FLOW

The goal is to make money:
increase net profit, while simultaneously increasing both ROI and cash flow

OPERATIONAL MEASURES
-THROUGHPUT
-INVENTORIES
-OPERATIONAL EXPENSE

▸ **Throughput:** Rate at which the system generates money through sales

▸ **Inventory:** All money that the system has invested in purchasing things that it intends to sell

▸ **Operational Expense:** All money that the system spends in order to turn inventory to throughput

Dependent Events and Statistical Fluctuations

Jonah – "Impossible to perfectly balance capacity to demand, there even exists a mathematical proof showing if you did, inventories go through the roof?"
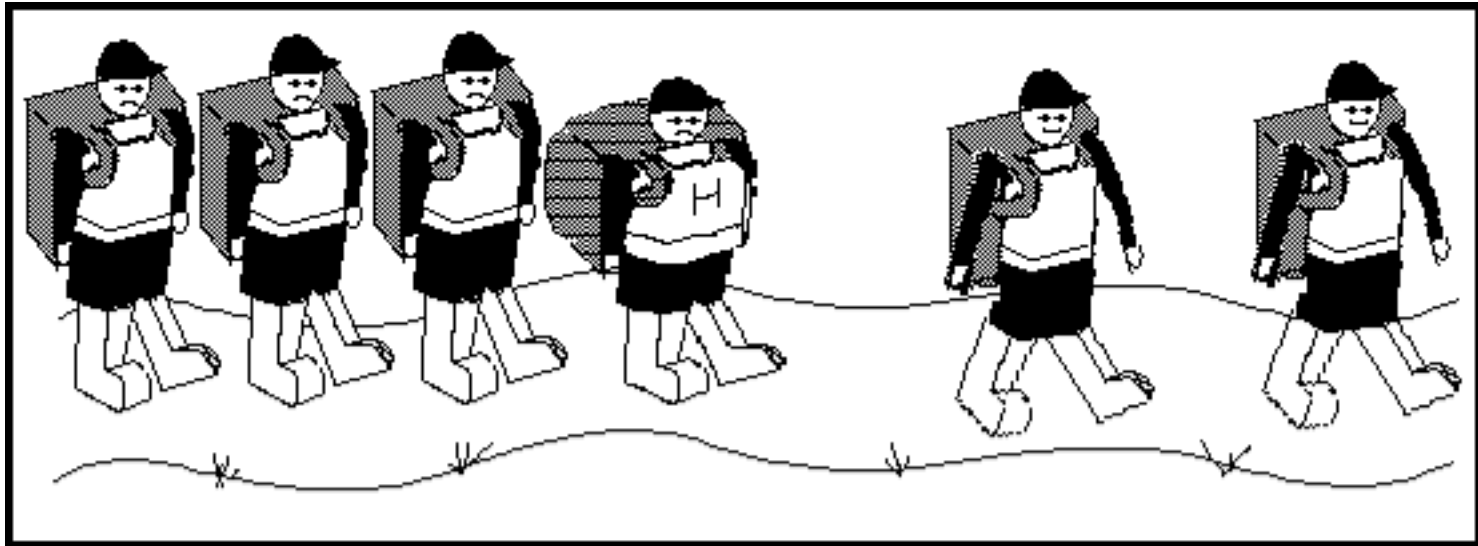
Alex – "How's this possible"

Jonah – "Due to two phenomenon:

1. Dependent events – a series of events must take place before another begins.

2. Statistical Fluctuations – the length of events and outcomes are not completely deterministic.
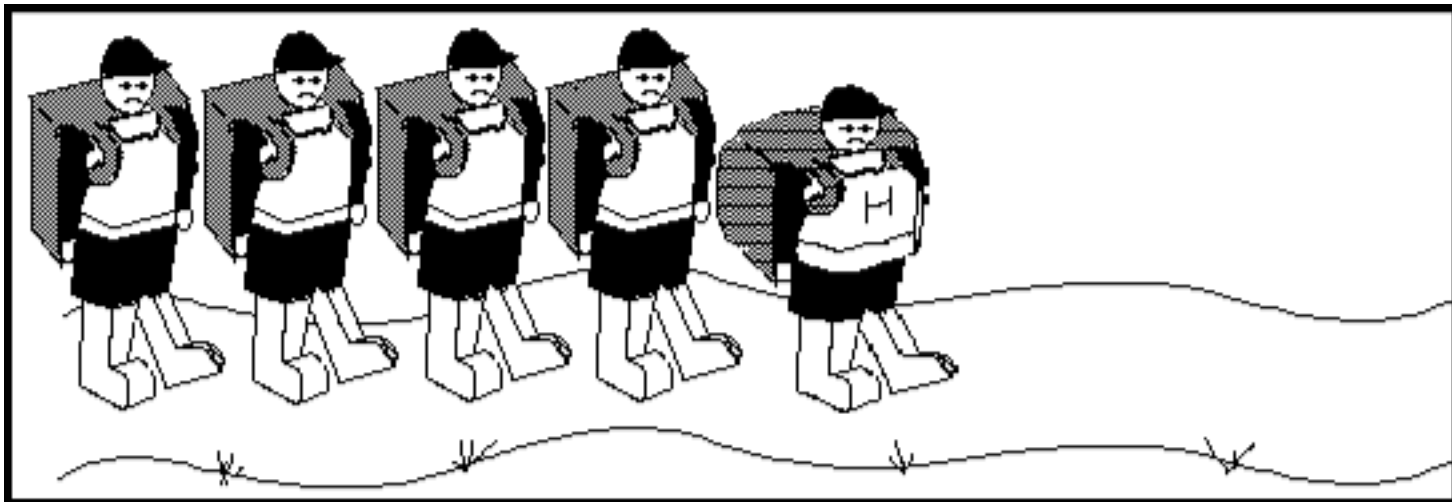
The combination of these phenomenon are the issue."

What are dependent events?

How can we control and improve a system with dependent events?
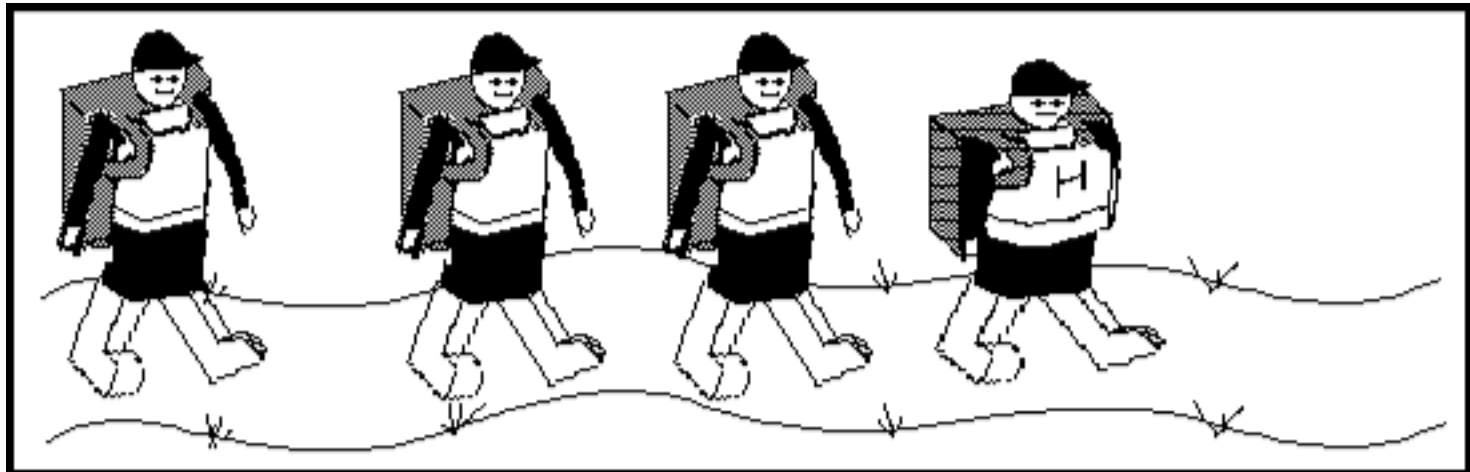
▶ Step 1: Identify the system's bottleneck

▶ Step 2: Exploit the system's bottleneck

▶ Step 3: Subordinate everything else to the bottleneck

▶ Step 4: Elevate the system's constraint.

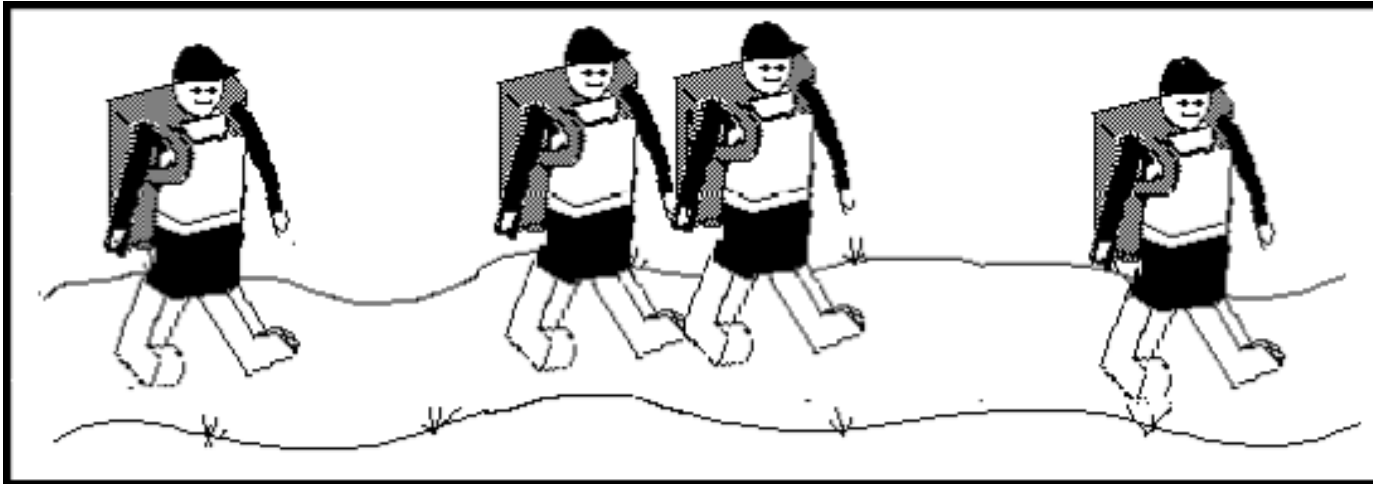# Economics of the bottleneck

- What is time worth on the bottleneck?
- What is time worth on the non-bottlenecks?

What is the effect of statistical fluctuations?

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▸ Jonah: Balance flows not capacities
▸ Why?

Jonah: Balance flow not capacity

- It is good to have a bottleneck?

- Control production through the bottleneck.

- Subordinate the production in non-bottlenecks to assure that the bottleneck is never delayed.

Drum, Buffer, Rope Scheduling System

▸ **"We've got a line of kids on a hike in the woods. In the middle of the line, we've got Herbie. We've already taken the pack off Herbie's back to help him go faster, but he's still the slowest. Everybody wants to go faster than Herbie. But if that happens, the line will spread out and some of the kids will get lost. For one reason or another, we can't move Herbie from the middle of the line. Now, how do we keep the line from spreading?"**

Drum, Buffer, Rope Scheduling System

- **Sharon says, "A drummer."**

- **"You know . . . like in a parade.”**

- **"Oh, I know what you mean. There aren't any gaps in a parade. Everybody is marching in step.”**

- **"So everybody's marching in step ... to a beat," I say, thinking out loud. "Sure. But how do you keep the people in front of Herbie from setting a faster pace?"**

- **"You have Herbie beat the drum," says Sharon.**

Drum, Buffer, Rope Scheduling System

- "Okay, wise guy, what's your idea?"
- "Tie ropes to everyone," says Dave.
- "Ropes?"
- "You know, like mountain climbers," he says. "You tie everyone together at the waist with one long rope. So, that way, no one could get left behind, and nobody could speed up without everybody speeding up."

How is the rope and drum concept implemented in the plant?

▸ Identified that it takes about 2 weeks from when parts are released to the floor until they get to bottleneck.

▸ Setup a system that monitors when inventory is processed at the bottleneck. Material required 2 weeks later is then released to the floor.

▸ Non-bottleneck parts are released according using the same principle but tied to assembly.

Communicate release

| Material Release | 2 weeks lead time | Bottleneck |
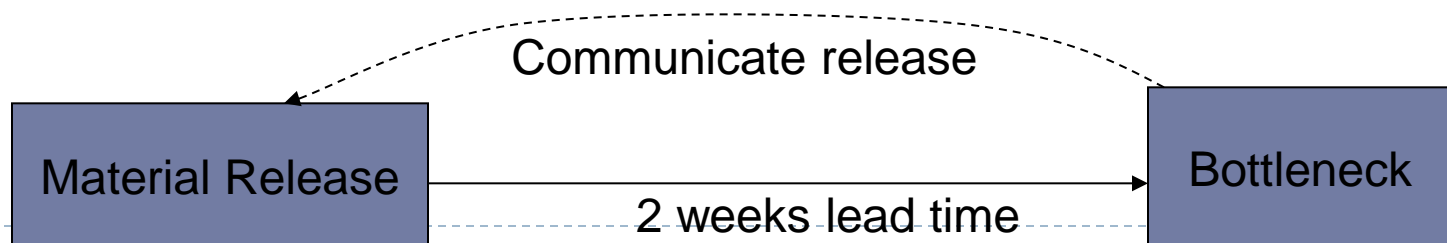
Buffer stocks and pull systems
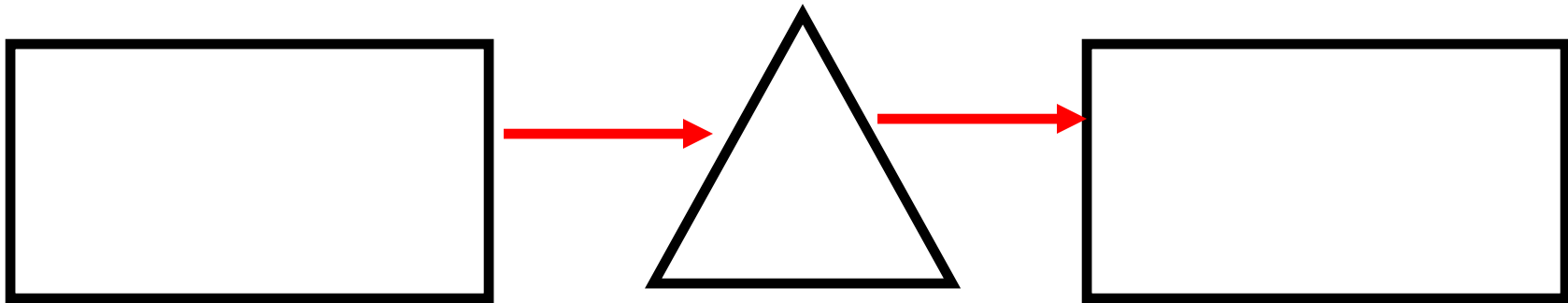
"An hour lost at a bottleneck is an hour lost for the entire system."

Profit on Output: $100 per unit

Investment Opportunity: For $100K, get 25 units/wk more capability of B which also saves $20k/yr in direct labor
From the perspective of the manager of Department B, this is an investment with a five-year payback

However, systemwide value added by the investment =
$2500 x 52 wks = $130,000K/yr;

Payback: 8-9 months

A	B	C
100 units/wk	75 units/wk	110 units/wk
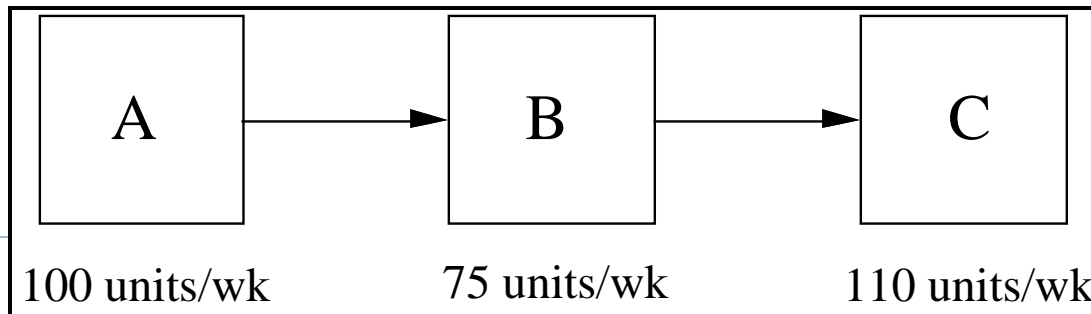
"An hour saved at a non-bottleneck is a mirage."

Everything is going well now except that it looks like part costs are going up. However, in reality all costs have gone down. How can this be?

The accounting rules:

▸ **Cost per part = raw material + direct labor + allocated burden cost**

▸ **Burden cost is all the indirect labor costs.**

▸ **Allocated Burden = direct labor x burden factor**

Allocated cost per part has risen because more setups (using more (previously idle) labor hours) are occurring because of smaller batch sizes.

However, since the workers were idle, the increased number of setups didn't really increase costs.

From the "cost world" to the "throughput world"

The Theory of Constraints

Step 1: **Identify** the system's constraints (NCX10 and oven)

Step 2: Decide how to **Exploit** the system's constraint (don't take lunch break on bottleneck machines)

Step 3: **Subordinate** everything else to the above decision (red tags and green tags)

Step 4: **Elevate** the systems constraint (bring back old Zmegma machine, outsource heat treat)

Step 5: If in a previous step, a bottleneck has been broken, **Repeat** step 1 (material release system, marketing), *but do not allow inertia to cause a system's constraint* (red and green tags eventually caused problems).

Identify the System's Constraints

- ▸ **Prioritize by impact on the goal – otherwise too much trivia**

- ▸ **Specifically identify the active constraint**

- ▸ **Find a numeric capacity value if possible**

Exploit the system's constraints

▸ **Find ways to maximize output of bottlenecks – aka active constraints**

▸ **Find ways to offload and maximize effectiveness of this resource**

Subordinate everything else to the above decision

‣ **Priorities for**

    ‣   _____

    ‣   _____

    ‣   _____

‣ **Do you need to run other resources at full capacity?**

Elevate the system's constraints

- **Can you…**
  - **Increase the capacity of the bottleneck?**
    - Speed up?
    - Add more available time?
    - Reduce setup time and other downtime?
  - **Cut the constraint resource out of some processes?**
  - **Use alternate resources?**
  - **Improve the effectiveness**
    - Inspection prior to bottleneck?
  - **Break the constraint?**

Bottleneck Management

Ten ways to manage output and capacity at a bottleneck

1. Add more of the limited resource
2. Use alternate equipment or routing
3. Reduce setup time
4. Run larger lot sizes
5. Clean up area
6. Work Overtime
7. Subcontract bottleneck work
8. Delay promised due date of BN intensive orders
9. Invest in faster equipment or higher skilled people
10. Put quality control in front of the bottleneck

Once a constraint has been broken, Repeat step 1

▸ **Once you break the critical / active constraint there will be a new one**

▸ **Find the new one and repeat the process**

To improve throughput by another 15%:
Cut batch sizes for <u>non-bottleneck</u> parts *in half. (This reduced total throughput time and enable increased sales.)*

What is the impact of reducing these batch sizes?

▸ **WIP for non-bottleneck parts reduced by half.**

▸ **Significantly reduce time parts spend in plant. Leads to increased responsiveness (from 6-8 weeks to 3-4 weeks).**

What about the time to handle increased number of setup? Doesn't matter if occurs on non-bottleneck operations.

Process Time	Setup Time	Queue Time	Wait for Assembly Time

Time parts spend in the plant

Time a piece of material spends inside a plant.

▸ **Setup Time** -- the time the part spends waiting for a resource, while the resource is preparing itself to work on the part.

▸ **Process Time** -- the amount of time the part spends being modified into a new, more valuable form.

▸ **Queue Time** -- the time the part spends in line for a resource while the resource is busy working on something else ahead of it.

▸ **Wait Time** -- the time the part waits, not for a resource, but for another part so they can be assembled together.

▸ **Setup and process are a small portion** of the total elapsed time for any part. But **queue and wait often consume large amounts of time**—in fact, the majority of the elapsed total that the part spends inside the plant.

▸ **For parts that are going through *bottlenecks,* queue is the dominant portion.**

▸ **For parts that are only going through *non-bottlenecks,* wait is dominant,** because they are waiting in front of assembly for parts that are coming from the bottlenecks.

SetupTime	ProcessTime	Queue Time	Wait for Assembly Time

"Sacred Cows" Slaughtered?

▶   **Maximize worker efficiency**

▶   **Maximize equipment productivity**

▶   **Optimal batch size = EOQ**

▶   **Release work to keep people busy**

▶   **Accounting rules represent Economic principles**

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