Session 1: Introduction to Operations Management

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UIC Business
IDS 532: Introduction to Operations Management

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What is Operations Management?

Operations Management is the business function that plans, coordinates, and controls the resources needed to produce a company's products and services.

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Business Process Flows

A **business process flow** is a collection of recurring economic activities that takes one or more kinds of input and creates an output that is of value to the customer.

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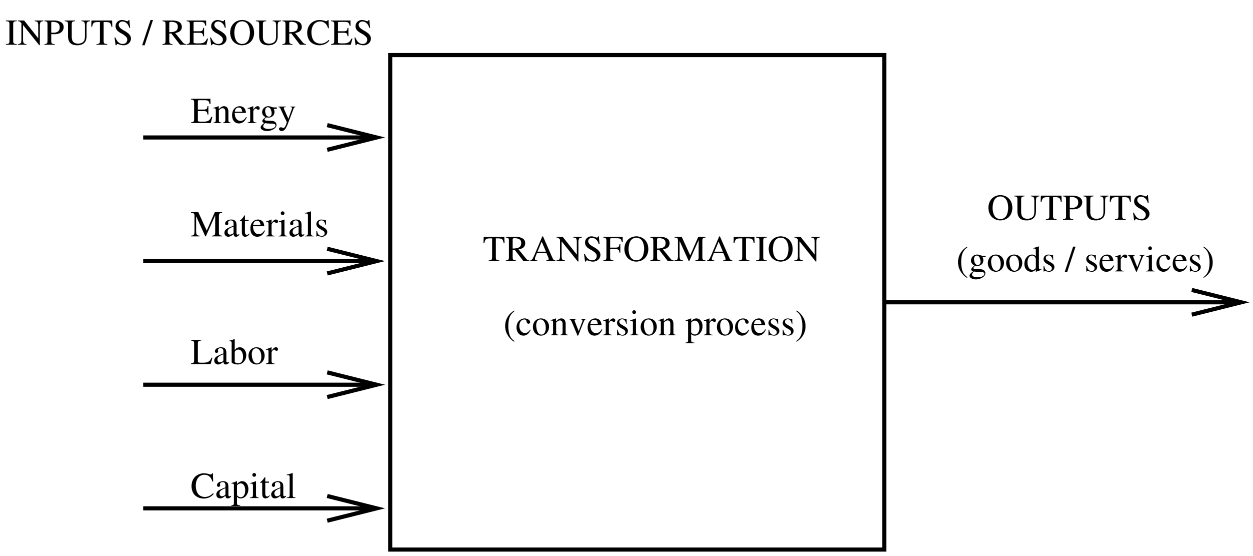
Transformation Process



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All businesses as a Process Flow

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A Hospital is a Process Flow

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UIC is a process flow

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Basic Dimensions of Customer Value

- Time
- Price
- Quality
- Variety

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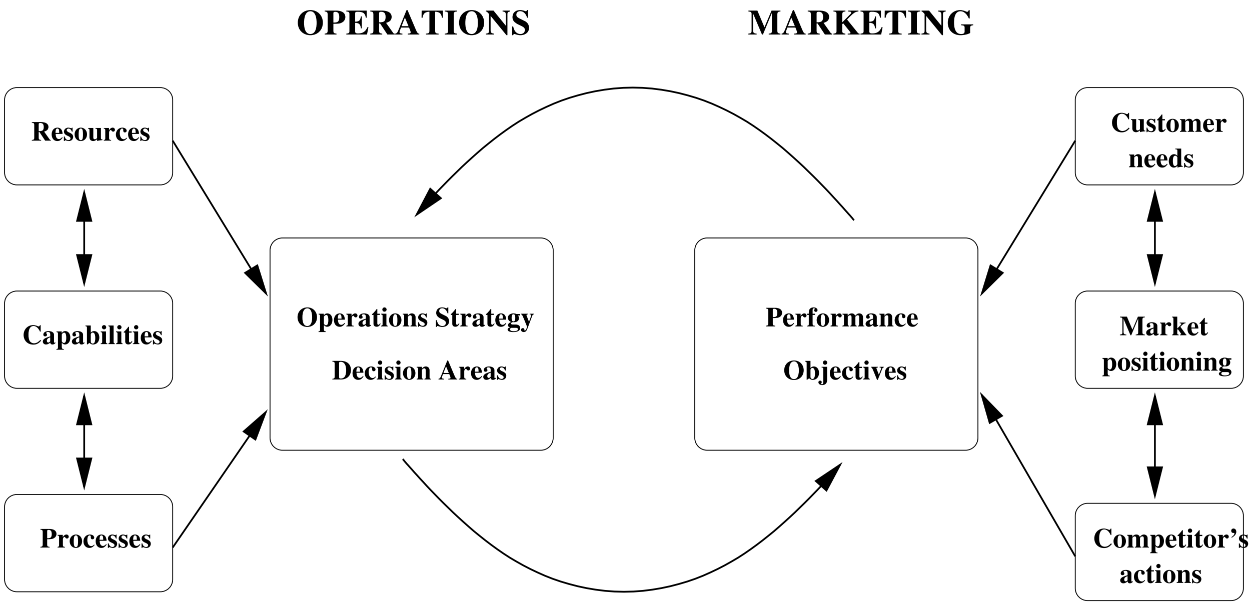
Reconciliation with Marketing



Subway vs. Jimmy Johns

Subway vs. Jimmy Johns

Fast Food

Time

Price

Quality

Variety

"...saving six seconds at a drive-through brings a 1% increase in sales." – CEO Jack M. Greenberg[1]

[1] Business Week, March 3, 2003

Jefferson Pilot Financial

JEFFERSON PILOT FINANCIAL A Century of Excellence 1903 ♦ 2003

Applied the principles of lean production to their policy issuance processes...

Achievement metric	Result
Turnaround time	Reduced by 70-84%
Total labor costs	Reduced by 26%
Reissues due to errors	Reduced by 40%

Achieved a 60% increase in new annualized life premiums in just 2 years.

Source: Harvard Business Review, October 2003.

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Goals of the course

1. How does one structure and manage an operation so that these operational capabilities are best achieved?
2. How to "think" operationally?

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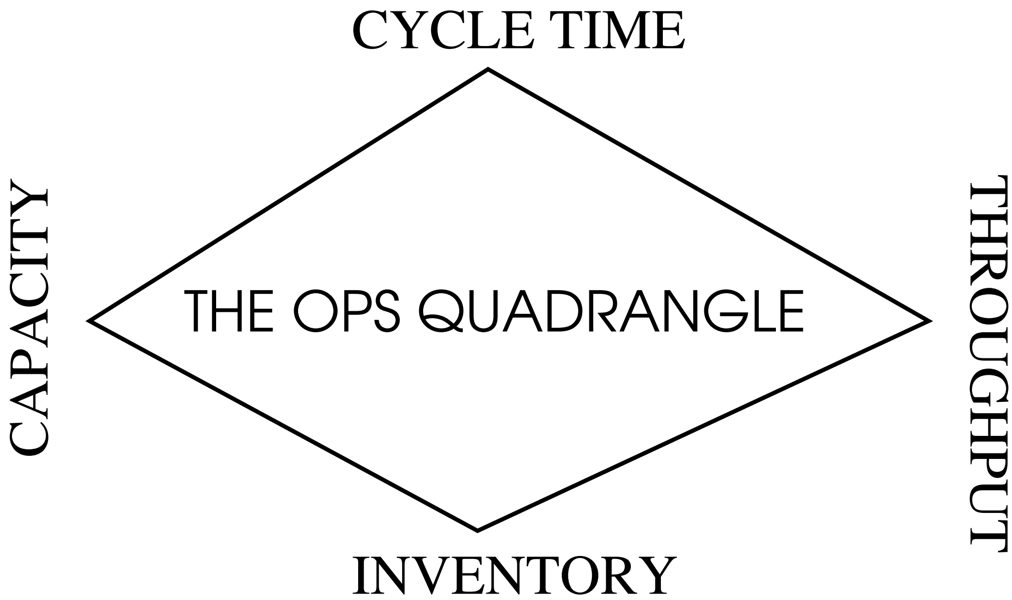
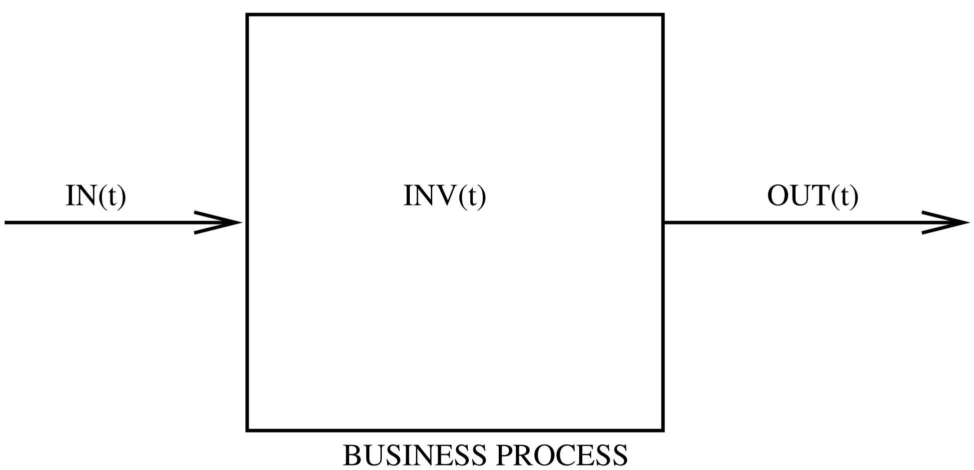
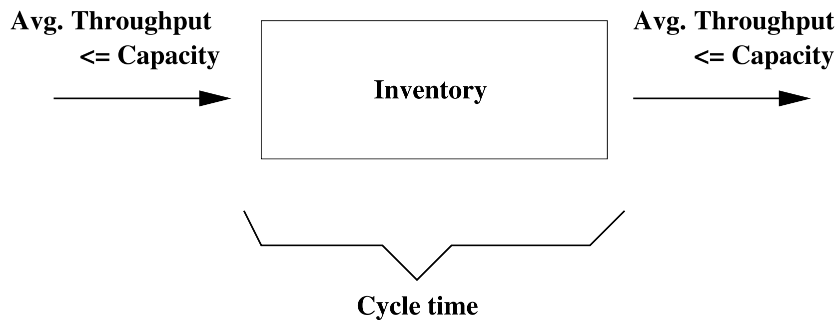
Ops Quadrangle



The process flow over time



Ops Quadrangle Parameters



- **Cycle time**: Time a job spends in a process flow (time)
- **Inventory**: Jobs that accumulate inside a process flow (jobs)
- **Throughput**: Rate at which jobs "come and go" through a process (jobs/time)
- **Capacity**: Maximum achievable average throughput (jobs/time)

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How to calculcate

Suppose N jobs "come and go" over time duration T.

- λ = **Throughput** $= N/T$
- CT = **Average Cycle Time** $= \frac{\sum_{i=1}^{N} \mathrm{CT}_i}{N}$, where CT_i is the cycle-time of job i
- INV = **Average Inventory** $= \frac{\int_0^T \mathrm{INV}(t)dt}{T} = \frac{\mathrm{AREA}}{T}$

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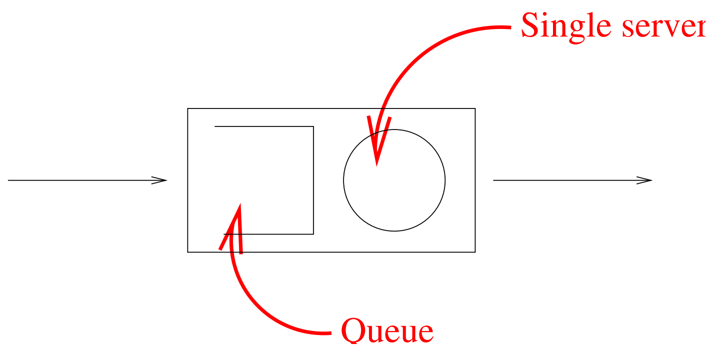
Lemonade Stand Example



Assume the customers arrive and are served as follows.

Interarrival Times	Service Times
1 min.	1 min.
2 min.	3 min.
1 min.	1 min.

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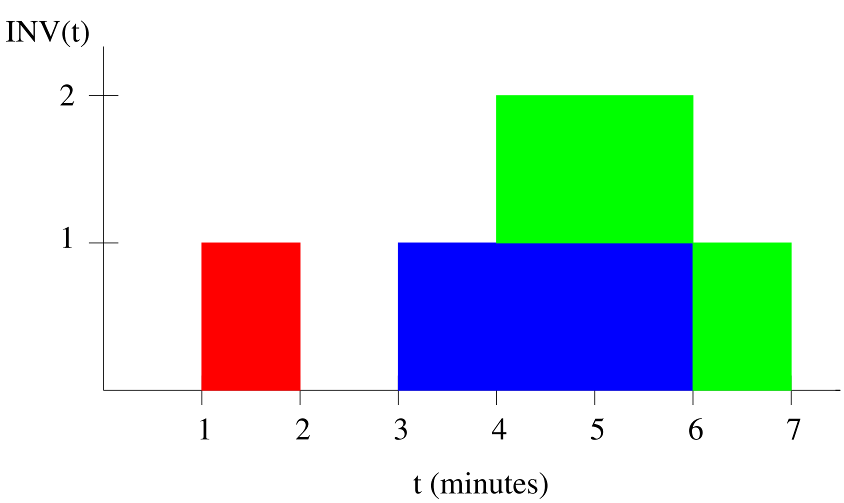
Lemonade Stand Example



- $\lambda = 3$ customers/7 min. $= 3/7$ cust/min.
- CT $= \frac{1+3+3}{3} = 7/3$ min.
- INV $= \frac{1+3+(2+1)}{7} = 1$ customer

INV $= \lambda$ CT!

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Little's Law

$$\text{INV} \;=\; \lambda \;\; CT$$

- relates the means of parameters
- holds even when there is variance
- holds for broad range of complex systems
- holds over a finite time horizon, and in steady-state

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Practice Example: Pearle Vision

- Consider a Pearle Vision Retailer
- Suppose customers spend 2 hours on average in the retailer
- The facility has an average throughput rate of 5 customers per hour

Which Little's law parameters do we know? What can we calculate?

- Solution:
  - CT = 2 hours
  - λ = 5 cust/hr
  - so from Little's Law,
    INV = λ CT = 5 cust/hr * 2 hrs = 10 customers.

$$\longrightarrow \quad |\; x\;x\;x\;x\;x \;|\; x\;x\;x\;x\;x \;| \quad \longrightarrow$$

TIME: 0 1 2

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Practice Example: McIhenny

The McIhenny Company produces Tabasco Sauce from peppers only harvested on Avery Island in LA. The bulk of the process flow of the production process is in storing the sauce in wood barrels for 2 years. The plant ships 1000 cases per week.

Which Little's law parameters do we know?
How much work in process inventory is stored in barrels?

- Solution:
  - CT = 2 years
  - λ = 1000 cases/wk. $\to$ 52,000 cases/year
  - so from Little's Law,
    INV = λ CT = 104,000 cases

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Inventory Turns

- Measures how fast firms sell their inventory.

$$\text{Financial Accounting:} \quad \frac{\text{Cost of Goods Sold}}{\text{Average Inventory}}$$

$$\text{Operational Equivalent:} \quad \frac{\lambda}{\text{INV}}$$

- McIhenny Example:

$$\text{Inventory Turns} = 52000 \text{ cases/yr} \div 104{,}000 \text{ cases} = \frac{1}{2 \text{ yr.}}$$

- You turn a case once every two years.

Using Little's Law we also get:

$$\text{Inventory Turns} = \frac{1}{\text{CT}}$$

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Practice Example: Cash Flow (Accounts Receivable)

- A firm sells $300M worth of goods per year.
- The average in Accounts Receivables is $45M.

Which Little's law parameters do we know?

- Solution:
  - $\lambda = \$300M/\text{year}$.
  - INV=$45M.
  - CT $= 45/300 = .15$ year $\rightarrow$ 1.8 months.
  - That is, on average it takes 1.8 months from the time a customer is billed to the time payment is received.

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Customer Flow

The Burger Hut outlet processes on average 2000 customers per day (15 hours). On average, there are 50 customers in the restaurant (waiting to place the order, waiting for the order to arrive, eating, going back to the counter to order another serving, etc.) In this case we focus on the customer inventory in the system, since we are interested in customer cycle time. We have:

CT $=$ 22.5 minutes

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Practice Example: Covid-19

- 2.7M people live in the city of Chicago.
- There are 454 Covid cases per day.
- On average a person is contagious for 10 days.

Which Little's law parameters do we know?

- λ = 454 cases/day.
- CT = 10 days
- INV = 4540 cases

What is the probability that at least one person is infectious in the classroom?

- Probability that a random person is infectious: INV/2.7M = 4540/2.7M $\approx$ 0.2%
- Probability that at least one person is infectious in the classroom: $1 - (1 - 0.002)^{75} = 0.13$

[1] Covid Dashboard: https://www.chicago.gov/city/en/sites/covid-19/home/covid-dashboard.html

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Practice Exercise: O'Hare Problem

It is estimated that up to 120 planes per hour can take-off. However, a plane taxis for 45 minutes on average after pushing off from the gate until finally taking off. Over the course of a day, on average 110 planes per hour actually take-off.

1. What is the capacity? 120 planes/hr
2. What is the throughput? 110 planes/hr
3. What is the average cycle-time for a plane? 3/4 hr
4. What is the average inventory of planes trying to take-off? INV = 110 planes/hr (3/4 hr) = 82.5 planes

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Practice Exercise: Emergency Room

Patients arrive to UC Hospital Emergency at an average rate of 40 per hour. There are two types of patients: Those who enter the system and eventually see a doctor, and those who balk immediately without entering the system (if they perceive that the wait will be too long). Patients who enter the system first delay in a wait area before seeing a doctor. The wait area has 80 chairs. The average number of patients in the wait area is 50 (this does not include the balkers who do not enter the wait area). All the patients who have entered the wait area will eventually see a doctor, and the average delay for these patients in the wait area is 2 hours. There are always 15 doctors on staff at all times, and we can consider that they are 80% utilized on average.

Practice Exercise: Emergency Room, Questions

1. What is the average rate (in patients/hr) at which potential patients BALK?
   15 patients / hr
2. What is the average time (in hours) spent seeing a doctor?
   0.48 hours → 28.8 minutes

Varsity Subs

- Read the varsity sub case.
- What is the capacity of the operation?
  - That is, what is the largest, long run, sustainable output of subs from the process?

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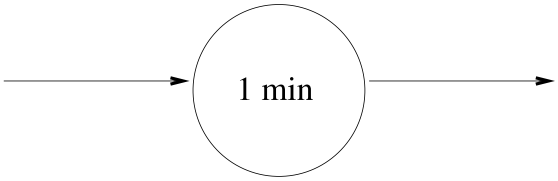
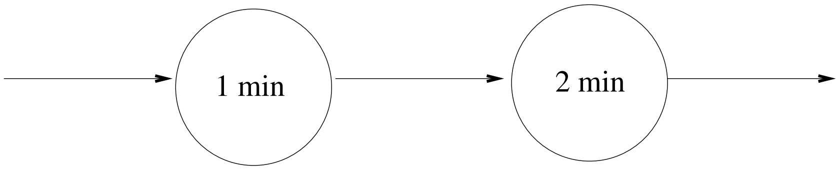
Capacity Analysis: Examples I



capacity = 1 job/min
CT = 1 min



capacity = 1/2 job/min
CT = 3 min

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Capacity Bottleneck

A capacity bottleneck is a resource or resource pool that limits the maximum average sustainable throughput.

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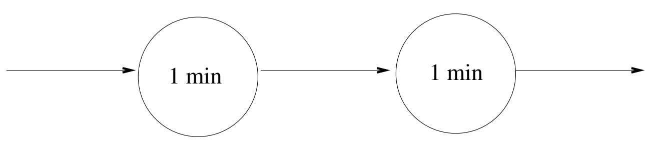
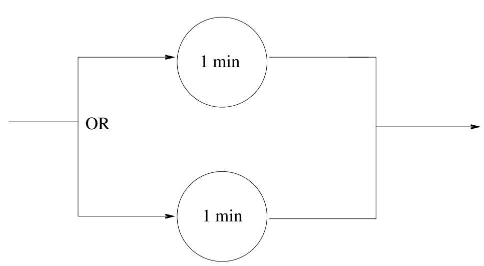
Capacity Analysis: Examples II

Assume deterministic, constant job interarrival and service times, and $\lambda =$ capacity.



capacity $=$ 1 job/min

CT $=$ 2 min



capacity $=$ 2 job/min

CT $=$ 1 min

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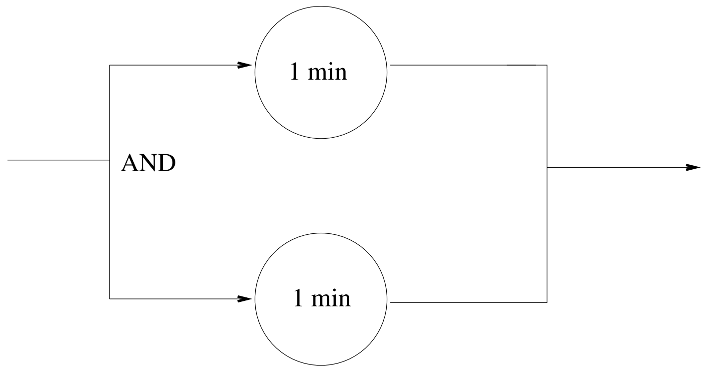
Capacity Analysis: Examples III



capacity = 1 job/min

CT = 1 min

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Steady-state

We are often interested in steady-state behaviour.
A business process is in steady-state if the start-up effects are statistically negligible or non-existent.

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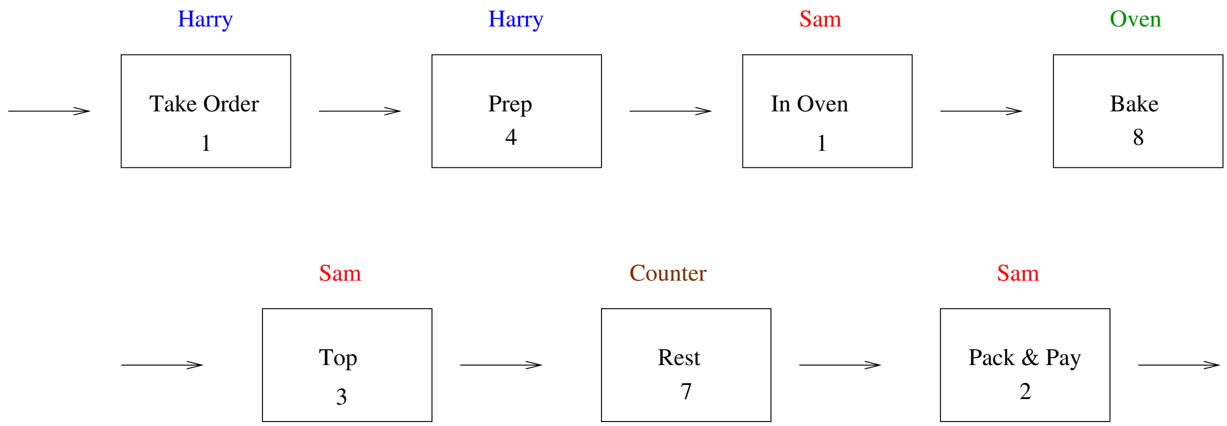
Varsity Subs: Process Flow



What is the capacity of each RESOURCE?

Resource	Capacity(subs/min)
Harry	1/5
Sam	1/6
Oven	10/8
Counter	∞

Sam has the smallest capacity.
He is the BOTTLENECK,
and determines the System
Capacity at 1/6 sub/min.

Varsity Subs — GANTT CHART

- To understand how the system can sustain a production rate at that of its capacity we build a Gantt Chart.
- The Gantt Chart will map the flow of jobs through each resource over time for a given input of jobs into the system.
- We assume in building our chart, that jobs (orders for a single sub) arrive at a steady rate equal to the system capacity.

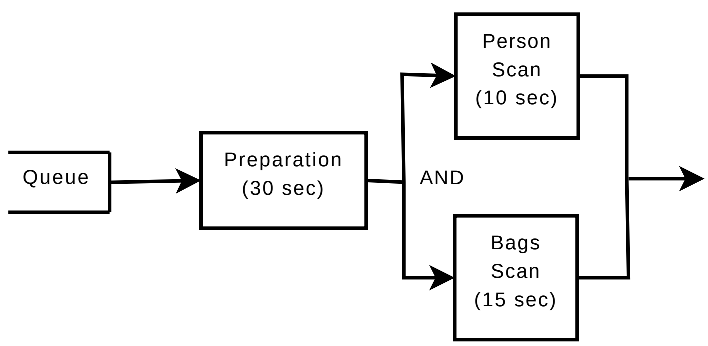
Varsity Subs — Capacity Utilization

The capacity utilization of a resource is its throughput divided by its capacity:

$$\text{Capacity Utilization} = \frac{\text{Throughput}}{\text{Capacity}}$$

Resource	Capacity Utilization
Harry	$\frac{1/6}{1/5} = 5/6$
Sam	$\frac{1/6}{1/6} = 1$
Oven	$\frac{1/6}{10/8} = 8/60$

Airport Wars - Security Screening



- Capacity (passengers per sec)?
- Preparation:
  $\text{INV}_{\text{max}} = 1$, prep capacity $= 1/30$ pass. per sec
- How much space is needed for preparation?
  - $\text{INV}_{\text{max}} = 2$, prep capacity $= 2/30 = 1/15$ pass. per sec
  - $\text{INV}_{\text{max}} = 4$, prep capacity $= 4/30 = 1/7.5$ pass. per sec
    $\Rightarrow$ Capacity $= 1/15$ pass. per sec