Service Operations Management (SOM)

Managing Waiting Lines

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Who's the biggest villain in Operations?

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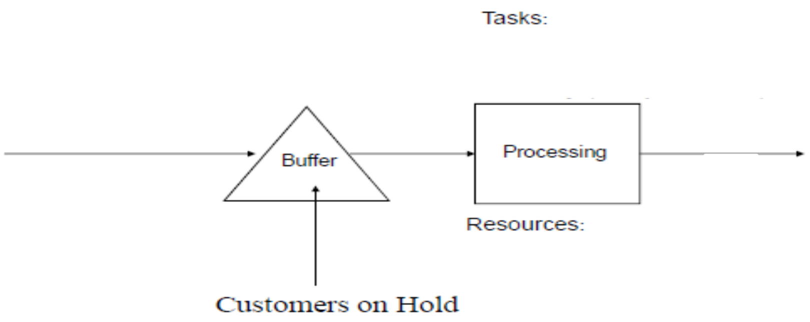
Where does variability come from?

- Arrival variability
  - Provide generous staffing or require reservations
- Capability variability
  - Adapt to customer skill levels or target customers based on capability
- Request variability
  - Cross-train employees or limit service breadth
- Effort variability
  - Do work for customers or reward increased effort
- Subjective preference variability
  - Diagnose expectations or persuade customers to adjust

Need to understand waiting lines

- Customers waiting are like WIP inventory
- Waiting times can have a halo effect on how customers view the rest of the service encounter
- Staffing decisions needs to consider the impact of waiting
- Every second waiting in the queue is a non-value added activity

Elements of a waiting line

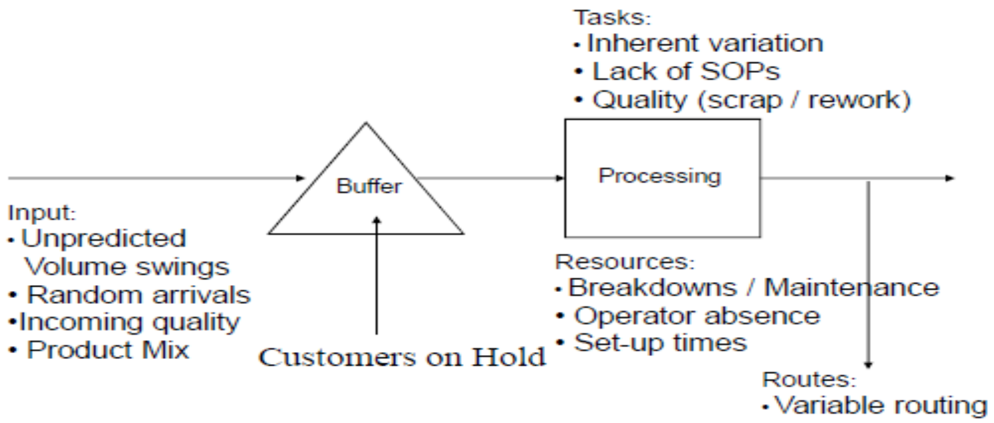


Little's Law : Number in system = arrival rate X average time spent in system

Agree?

- If service rate is higher than arrival rate then there would not be any queue
- With one server if X is the average number of people in the queue, with two servers, the average number of people in the queue would be X/2

Where does the variability come from?



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Essential features of queuing systems

- Arrival process: rate and population
- Service process: rate and capacity
- Queue configuration
- Queue discipline

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In-class exercise

- To understand the impact of queue pooling

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Typical capacity decisions

- How many additional beds should a hospital add to limit patient backlog below 50?
- What should be the size of a call centre such that no calling customer waits more than 30 seconds?
- What is the probability that when a customer walks into a bank she finds at least one teller free?
- How will an additional runway at Mumbai airport reduce aircraft waiting time?

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The psychology of waiting

- Waiting is an integral part of our lives
  - But causes so much grief!
- Perception is more important than reality
- Unoccupied time feels longer than occupied time
  - Distract and entertain

The psychology of waiting

- Pre-process waits feel longer than in-process waits
  - Communicate as soon as possible and get customers in process
  - Wait in the bar!
- Uncertain or unexplained waits feel longer than known waits
  - Communicate frequently
  - Impact of anchoring and prospect theory
- Solo Waits feel longer than group waits

Performance Metrics
Relationships

Server utilisation

In the case of single server: $\rho = \frac{\lambda}{\mu}$

In the case of multiple servers: $\rho = \frac{\lambda}{S\mu}$

Little's Formula

Average time customer spends in system $W_s = \frac{L_s}{\lambda}$

Average time customer spends in queue $W_q = \frac{L_q}{\lambda}$

In the case of a Single Server

Average number of customers in system $L_s = L_q + \frac{\lambda}{\mu}$

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Single Server Queue
Formulae for L_q

L_s	Average number of customers in the system (waiting to be served)
L_q	Average number of customers in the waiting line
W_s	Average time a customer spends in the system (waiting and being served)
W_q	Average time a customer spends waiting in line
λ	mean arrival rate
μ	mean service rate
S	Number of servers in a multi-server queue

Single server Queue (Exponential service time) $L_q = \frac{\lambda^2}{\mu(\mu - \lambda)}$

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Probability of n people in queue

$$P_n = \left(1 - \frac{\lambda}{\mu}\right)\left(\frac{\lambda}{\mu}\right)^n$$

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Example

- The teller facility of a bank has a one-man operation at present. Customers arrive at the bank at the rate of one every 4 minutes to use the teller facility. The service time varies randomly across customers on account of some parameters. However, based on the observations in the past, it has been found that the teller takes on an average 3 minutes to serve an arriving customer. The arrivals follow Poisson distribution and the service times follow exponential distribution.
  - What is the probability that there are at most three customers in front of the teller counter?
  - Assess the various operational performance measures for the teller facility.
  - Of late the bank officials notice that the arrival rate has increased to one every three and a half minutes. What is the impact of this change in the arrival rate? Do you have any observation to make?

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Solution to Example
Operational Performance Measures

Avg. No. of customers in the waiting line: $L_q = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{15^2}{20(20-15)} = 2.25$

Avg. No. of customers in the system: $L_s = L_q + \frac{\lambda}{\mu} = 2.25 + \frac{15}{20} = 3.00$

Avg. time a customer spends waiting in line: $W_q = \frac{L_q}{\lambda} = \frac{2.25}{15} = 0.15\,Hr = 9 \min$

Avg. time a customer spends in the system: $W_s = \frac{L_s}{\lambda} = \frac{3.00}{15} = 0.20\,Hr = 12 \min$

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Solution to Example
Impact of Arrival Rate

	Arrival rate = 15 per hour	Arrival rate = 17.143 per hour
Utilisation of the teller facility	75%	85.7%
Avg. number of customers in waiting line	2.25	5.14
Avg. number of customers in the system	3.00	6.00
Average time a customer spends waiting in line	9 minutes	18 minutes
Average time a customer spends in the system	12 minutes	21 minutes

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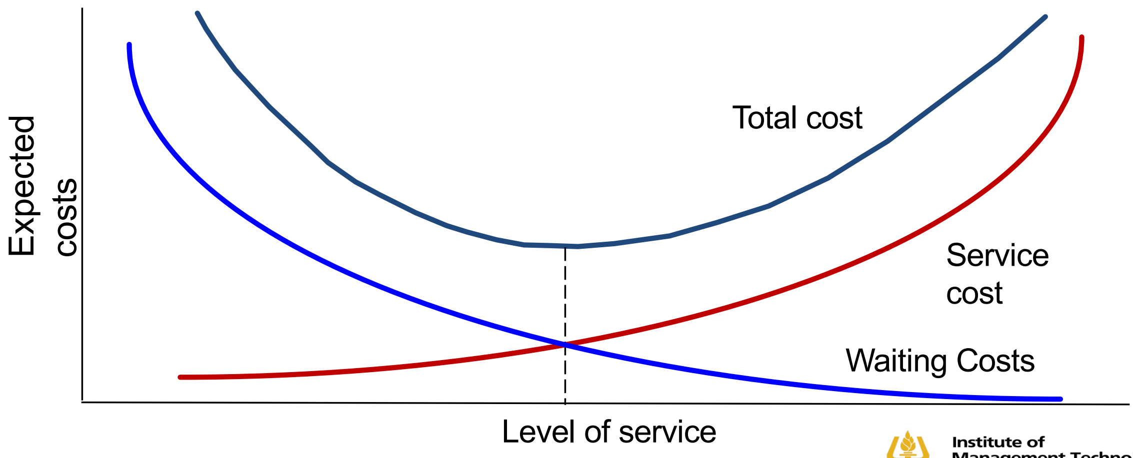
Cost Relationship in Queuing



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Case studies

- Tirumala Tirupati
- Disneyland

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What's new in queuing theory

- Diseconomies of queue pooling in the emergency department http://hbswk.hbs.edu/item/7425.html

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