Post Graduate Diploma in Management – 2020
Covid – 19 Term

Service Processes and Waiting Line Analysis

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Operations Management

Thursday, October 1, 2020

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Post Mid Topics

- Service Processes and Waiting Line Analysis
- Process Design and Analysis
- Supply Planning & Inventory Management

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Process Flowcharting

- Process flowcharting: the use of a diagram to present the major elements of a process
- The basic elements can include tasks or operations, flows of materials or customers, decision points, and storage areas or queues
- Separating a diagram into different horizontal or vertical bands sometimes is useful
- It is an ideal methodology by which to begin analyzing a process

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Process Flowchart Example (Slot Machine)

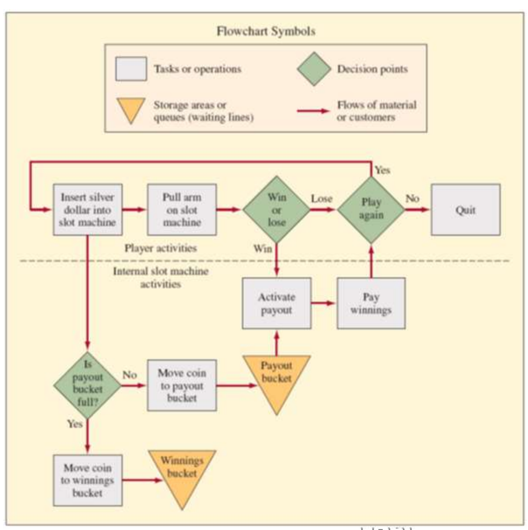

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Exhibit 11.1

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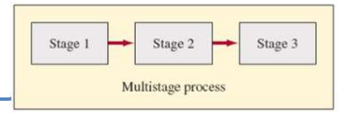
Types of Processes



- One way to categorize a process is single-stage or multiple-stage
- Single-stage: all of the activities could be collapsed and analyzed using a single cycle time to represent the speed of the process
- Multiple-stage: has multiple groups of activities that are linked through flows
- Stage: multiple activities that have been pulled together for analysis purposes

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Opening question

How are services processes different from manufacturing processes?

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The Nature of Services

- The customer is the focal point of all decisions and actions
- The organization exists to serve the customer
- Operations is responsible for service systems
- Operations is also responsible for managing the work of the service workforce

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An Operational Classification of Services

- Customer contact: the physical presence of the customer in the system
  - Extent of contact: the percentage of time the customer must be in the system relative to service time
  - Services with a high degree of customer contact are more difficult to control
- Creation of the service: the work process involved in providing the service itself
- The greater the percentage of contact time between the service system and the customer, the greater the degree of interaction between the two during the production process

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Service-System Design Matrix

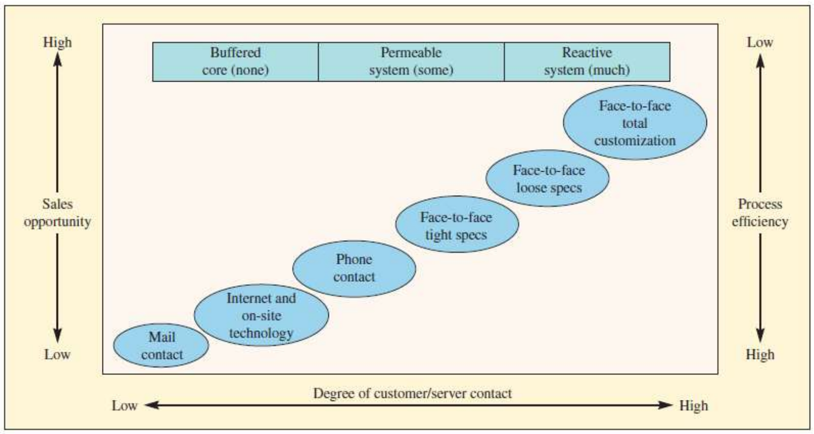

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Exhibit 9.3

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Characteristics Relative to the Degree of Customer/Service Contact

Degree of customer/server contact: Low ← → High

Worker requirements	Clerical skills	Helping skills	Verbal skills	Procedural skills	Trade skills	Diagnostic skills
Focus of operations	Paper handling	Demand management	Scripting calls	Flow control	Capacity management	Client mix
Technological innovations	Office automation	Routing methods	Computer databases	Electronic aids	Self-serve	Client/worker teams

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Designing Service Organizations

- Cannot inventory services
  - Must meet demand as it arises
- Service capacity is a dominant issue
  - "What capacity should I aim for?"
- Marketing can adjust demand
- Cannot separate the operations management function from marketing in services
- Waiting lines can also help with capacity

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Managing Customer-Introduced Variability

- How should services accommodate the variation introduced by the customer?
- Standard approach is to treat this as a trade-off between cost and quality
  - More accommodation → more cost
  - Less accommodation → less satisfaction
- Standard approach may overlook ways to accommodate customer

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Five Types of Variability

Arrival variability
- Customers arriving at times when there are not enough service providers

Request variability
- Travelers requesting a room with a view

Capability variability
- A patient being unable to explain symptoms to doctor

Effort variability
- Shoppers not putting up carts

Subjective preference variability
- Interpreting service action differently

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Three Contrasting Service Designs

The production line approach
- McDonald's
- Service delivery is treated much like manufacturing

The self-service approach
- ATM machines
- Customer takes a greater role in the production of the service

The personal attention approach
- Ritz-Carlton Hotel Company

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Seven Characteristics of a Well-Designed Service System

1. Each element of the service system is consistent with the operating focus of the firm
2. It is user-friendly
3. It is robust
4. It is structured so that consistent performance by its people and systems is easily maintained
5. It provides effective links between the back office and the front office
6. It manages evidence of service quality so that customers see the value of service provided
7. It is cost-effective

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Capacity Planning under uncertainty

Use of waiting line models

- In service systems, waiting time is an important operational measure that determines the service quality
- When uncertainty makes capacity requirement estimation difficult
  - use queueing theory fundamentals
- To analyse the impact of alternative capacity choices
- on important operational measures such as queue length, waiting time and utilisation of resources

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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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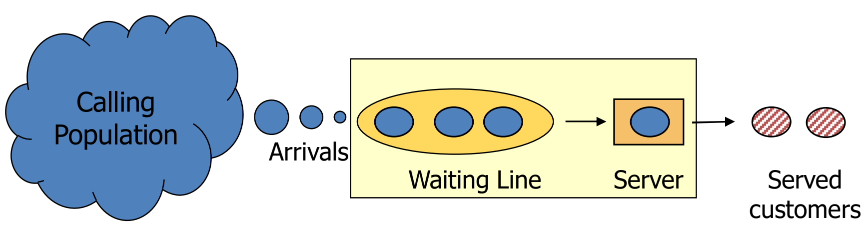
Components of Queuing System



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Customer Arrivals

- Finite population: limited-size customer pool that will use the service and, at times, form a line
  - When a customer leaves his/her position as a member of the population, the size of the user group is reduced by one.
- Infinite population: population large enough so that the population size caused by subtractions or additions to the population does not significantly affect the system probabilities

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Distribution of Arrivals

- Arrival rate: the number of units arriving per period
  - Constant arrival distribution: periodic, with exactly the same time between successive arrivals
- Variable (random) arrival distributions: arrival probabilities described statistically
  - Exponential distribution – inter-arrival times
  - Or Poisson distribution – arrival rates

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Distributions

- Exponential distribution: when arrivals at a service facility occur in a purely random fashion
  - The probability function is

$$f(t) = \lambda e^{-\lambda t}$$

- Poisson distribution: where one is interested in the number of arrivals during some time period *T*
  - The probability function is

$$P_T(n) = \frac{(\lambda T)^n e^{-\lambda T}}{n!}$$

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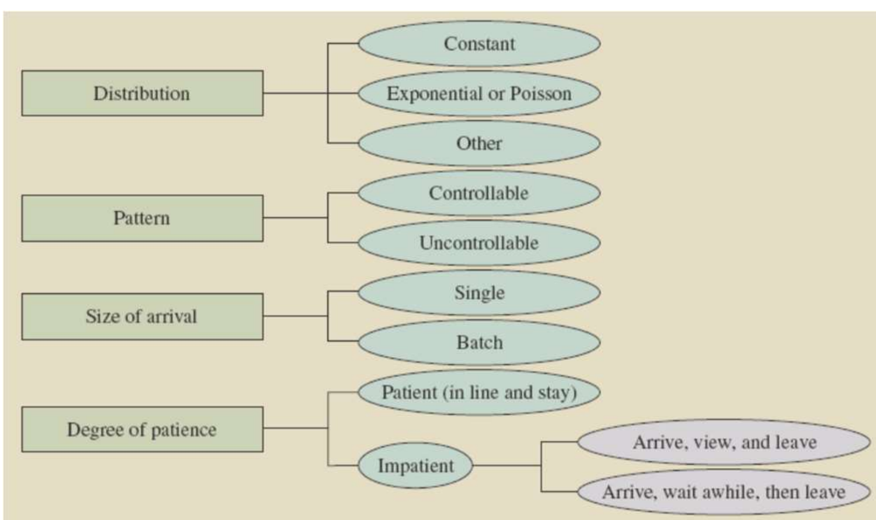
Customer Arrivals in Queues



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Other Arrival Characteristics

- Arrival patterns
- Size of arrival units
- Degree of patience
  - —Balking
  - —Reneging

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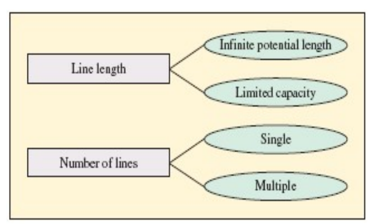
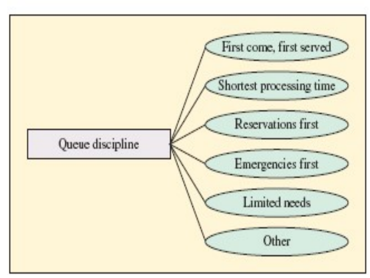
The Queuing System

- Length
- Infinite potential length
- Limited line capacity
- Number of lines
- Queue discipline: a priority rule or set of rules for determining the order of service to customers in a waiting line





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Service Time Distribution

- Constant
  - Service provided by automation
- Variable
  - Service provided by humans
  - Described using exponential distribution

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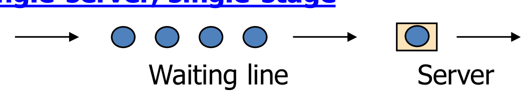
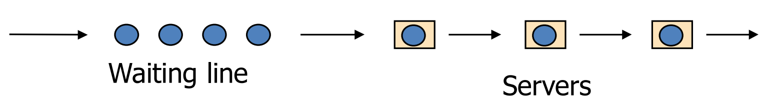
Single-Channel Structures

Single-server, single-stage



Single-server, multiple stages



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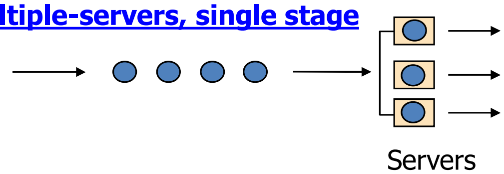
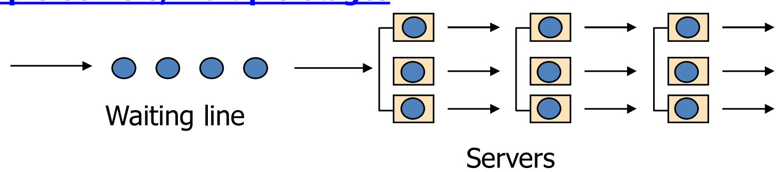
Multi-Channel Structures

Multiple-servers, single stage



Multiple-servers, multiple-stages



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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) $L_q = \dfrac{\lambda^2}{\mu(\mu - \lambda)}$

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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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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 : Western National Bank

- Western National Bank is considering opening a drive through window for customer service. Management estimates that customers will arrive at the rate of 15 per hour. The teller who will staff the window can service customers at the rate of one every three minutes.

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Example : Western National Bank

- Part 1 Assuming Poisson arrivals and exponential service, find
  - Utilization of the teller
  - Average number in line
  - Average number in system
  - Average waiting time in line
  - Average waiting time in system, including service

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Solution

$$\rho = \frac{\lambda}{\mu} = \frac{15}{20} = 0.75 = 75 \text{ percent}$$

$$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{(15)^2}{20(20-15)} = 2.25 \text{ customers}$$

$$L_s = \frac{\lambda}{\mu-\lambda} = \frac{15}{20-15} = 3 \text{ customers}$$

$$\mathrm{W_q} = \frac{L_q}{\lambda} = \frac{2.25}{15} = 0.15 \text{ hours or 9 minutes}$$

$$\mathrm{W_s} = \frac{L_s}{\lambda} = \frac{3}{15} = 0.2 \text{ hour or 12 minutes}$$

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No More Than Three Cars

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

at $n = 0$, $P_0 = (1 - 15/20)$	$(15/20)^0 = 0.250$		
at $n = 1$, $P_1 = (1/4)$	$(15/20)^1 = 0.188$		
at $n = 2$, $P_2 = (1/4)$	$(15/20)^2 = 0.141$		
at $n = 3$, $P_3 = (1/4)$	$(15/20)^3 = \underline{0.105}$		
	0.684	or	68.5 percent

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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

- Arrival rate at the bank: λ = 15 per hour
- Service rate at the teller: μ = 20 per hour
- Utilisation of teller facility: $\rho = \frac{\lambda}{\mu} = \frac{15}{20} = 0.75$
- Probability of at most three customers in the system = $\sum_{n=0}^{n=3} P_n$
- Using equation 10.10, we compute P_n for values of n = 0 to 3
  $P_0 = (1-\rho) = 0.25$; $P_1 = 0.25*0.75^1 = 0.1875$;
  $P_2 = 0.25*0.75^2 = 0.1406$; $P_3 = 0.25*0.75^3 = 0.1055$.
- Probability of at most 3 customers =
  0.25 + 0.1875 + 0.1406 + 0.1055 = 0.6836

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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: $W_q = \frac{L_q}{\lambda} = \frac{2.25}{15} = 0.15\,Hr = 9 \text{ min}$

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

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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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