COMMERCE MENTORSHIP PROGRAM

MIDTERM REVIEW SESSION

COMM 204

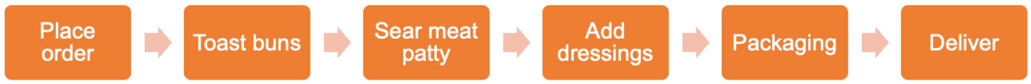
PREPARED BY

SANG NGUYEN

TABLE OF CONTENTS

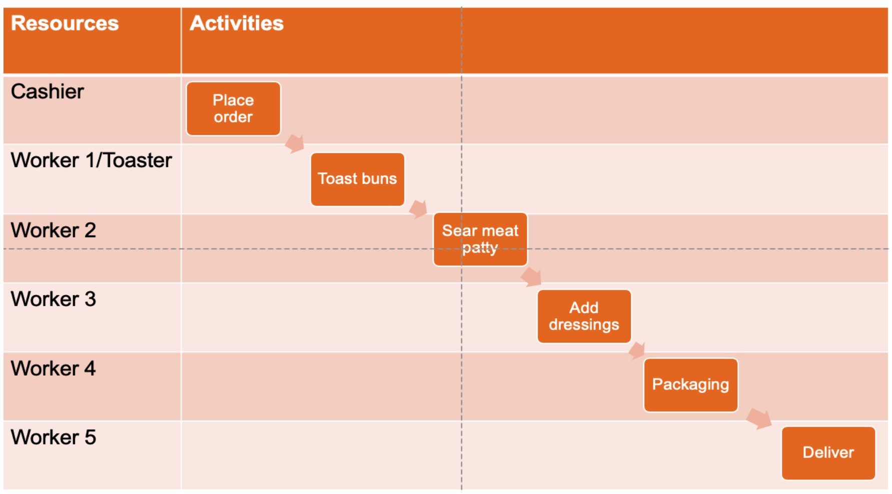
FLOWCHARTS, CAPACITY RATE, BOTTLENECK ANALYSIS

Linear Flow Chart:

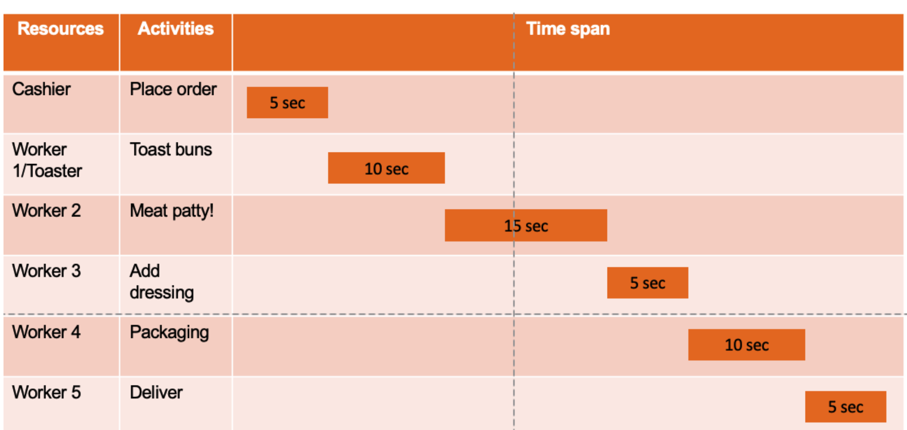


Cashier	Worker 1 /Toaster	Worker 2	Worker 3	Worker 4	Worker 5
5 sec	10 sec	15 sec	5 sec	10 sec	5 sec

Swim Lane Flow Diagram:



Gantt Chart



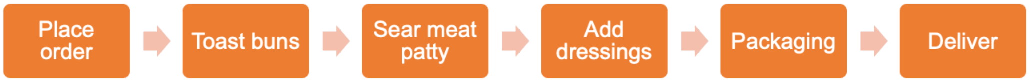
Key terms:

- **Activity:**
  - A step in the process
- **Resources:**
  - The performer of the activity
- **Flow unit:**
  - The basic unit of analysis in any given scenario (customer, sandwich, phone calls, etc.)
- **Theoretical Flow Time/Flow Time:**
  - The amount of time a flow unit spends in a business process from beginning to end.
    - If there is more than one path through the process, the flow time is equivalent to the length of the longest path.
    - The theoretical flow time ignores the possibility of waiting; so it is the lowest possible flow time
- **Unit load**
  - Total amount of time that a resource needs to process a flow unit
- **Capacity rate**
  - Maximum output rate at which units can flow through a resource or process
  - Capacity rate of the process = The capacity rate of the bottleneck
- **Bottleneck:**
  - Resource/activity with the slowest capacity rate in a process
  - Determines the capacity rate of a process

CAPACITY RATE & BOTTLENECK ANALYSIS

1. *Increasing the Capacity Rate of a **Process**:*
- by **increasing the capacity rate of the bottleneck activity**
- Increasing the capacity of NON-bottleneck resources does NOT increase the capacity rate of the process
- 2 ways to increase the Capacity Rate of a Process:
  - Increase the Resource Pool (adding more worker/machine in that activity)
    - Capacity rate of 1 worker: 100 unit/hr
    - Capacity rate of 2 workers = 100*2 = 200 unit/hr
    - Note: Increasing the capacity rate does not decrease the Unit Load of that activity
  - Reduce Unit Load
    - I.e. Reducing the amount of time to process an activity

2. *Bottleneck Characteristics*
- The bottleneck is fully utilized while other resources are not utilized
- Shortening non-bottleneck tasks decreases flow time but **does not affect capacity rate of the whole process**



Resource	Cashier	Worker 1/Toaster	Worker 2	Worker 3	Worker 4	Worker 5
Flow time	5 sec	10 sec	15 sec	5 sec	10 sec	5 sec
Capacity Rate	720/hour	360/hour	240/hour	720/hour	360/hour	720/hour

Pro tip: Make sure the time units are consistent!

Foolproof Capacity Rate Calculations:

1 / Flow Time = Capacity rate corresponding to the time unit
Cashier Example: 1 / 5 sec = $\frac{1}{5}$ burger/second
-> $\frac{1}{5}$ * 60 * 60 = 720 burger/hour

PRACTICE QUESTION 1: FLOW CHART, CAPACITY RATE, BOTTLENECK ANALYSIS

Colonel Sandy wants to improve efficiency at his newest restaurant - Kennedy Fried Chicky at the UBC location. Because he is old, he could only give you a Linear Flow Chart of the restaurant's operations. Please calculate the following:

Place order → Toast buns → Sear meat patty → Add dressings → Packaging → Deliver

Resource	Cashier	Worker 1/Toaster	Worker 2	Worker 3	Worker 4	Worker 5
Flow time	12 sec	16 sec	15 sec	12 sec	12 sec	5 sec

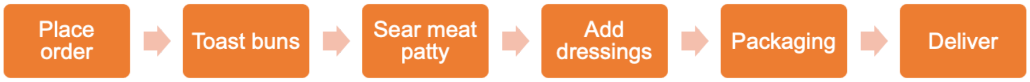
a) The flow time of Colonel's operation.
b) The flowtime of the bottleneck activity.
c) Capacity rate of worker 4
d) The capacity rate of the process
e) For this question only: If Colonel Sandy wanted to increase the rate at which orders are processed, what would he do? Suppose he added one more worker/resource to this activity, what is the new capacity rate of this activity? New bottleneck? New flow time?
f) For this question only: Suppose Colonel Sandy decided to replace Worker 2. The new worker is not only funny but he also flips patty faster. He can sear the patty in 8 seconds. Who is the new bottleneck?
g) Colonel claimed that by investing in one more toaster, customers would not have to wait as long as they used to. Please explain why he is correct/incorrect.

THROUGHPUT RATE & UTILIZATION RATE

- **Throughput rate/flow rate:**
    - Actual output rate of the process. Depends on input rate & capacity rate:
        - If Input Rate < Capacity Rate: Throughput Rate = Input Rate
            - E.g: You can expect faster service at Tims @ Sauder at 6pm
        - If Input Rate > Capacity Rate: Throughput Rate = Capacity Rate
            - E.g: Tims @ Sauder at 11am.....
- **Utilization Rate = Throughput rate / Capacity Rate <= 100%**

PRACTICE QUESTION 2: THROUGHPUT RATE & UTILIZATION

Revisitting the last question, suppose students arrive at KFC @ Sauder at 6pm only to buy its famous Chicken Sandwich with a rate of 250 students/hour. However, at 9am, students only arrive at 200 students/hour. Calculate the Throughput rate and the Utilization rate of the process at 6pm and 9am.



Resource	Cashier	Worker 1/Toaster	Worker 2	Worker 3	Worker 4	Worker 5
Flow time	12 sec	16 sec	15 sec	12 sec	12 sec	5 sec
Capacity Rate	300/hour	225/hour	240/hour	300/hour	300/hour	720/hour

INVENTORY BUILDUP DIAGRAM

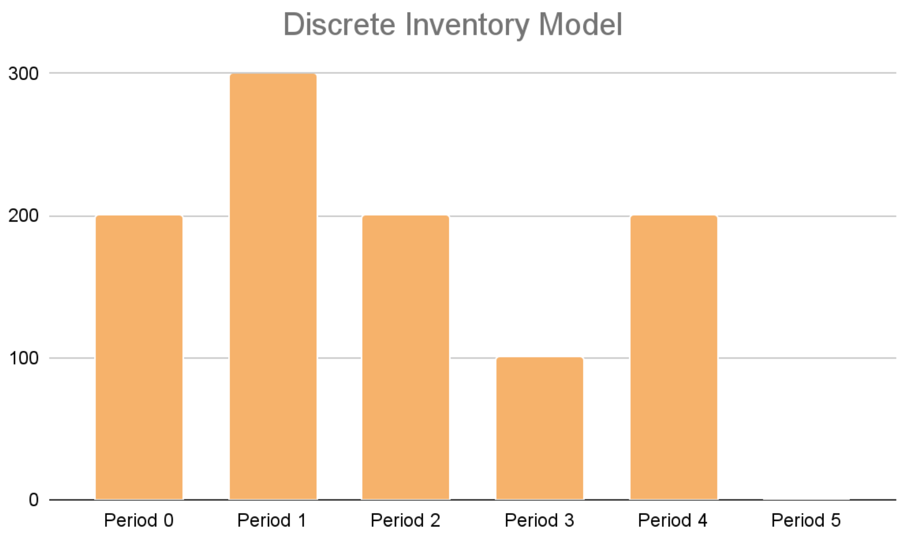
Review of related Key Terms:

	Production Process	**Service Process**
Flow unit	Materials	Customers
Input Rate	Raw materials arrival rate	Customer arrival rate
Capacity rate	Maximum output rate	Maximum service completion rate
Throughput rate	Finished goods output rate	Actual service completion rate
Flow Time	Time required to turn material to products	Time that a customer is being served
Inventory	Amount of WIP	Numbers of customers being served

Discrete Input Assumption:

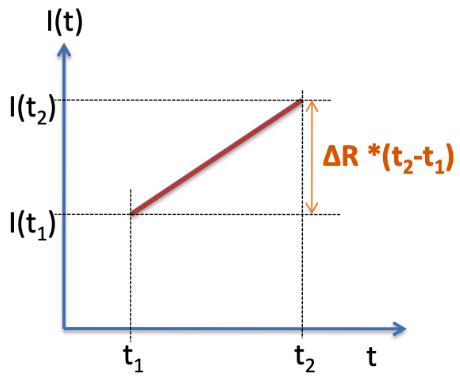
Period	**Input**	**Capacity**	**Output**	**Inventory**
0	0	0	0	**200**
1	400	300	300	200+400-300= **300**
2	200	300	300	300+200-300= **200**
3	300	400	400	200+300-400= **100**
4	500	400	400	100+500-400= **200**
5	100	400	300	**0**

Avg Inventory = Sum of Inventory / # Periods = (200 + 300 + 200 + 100 + 200) / 5 = 200

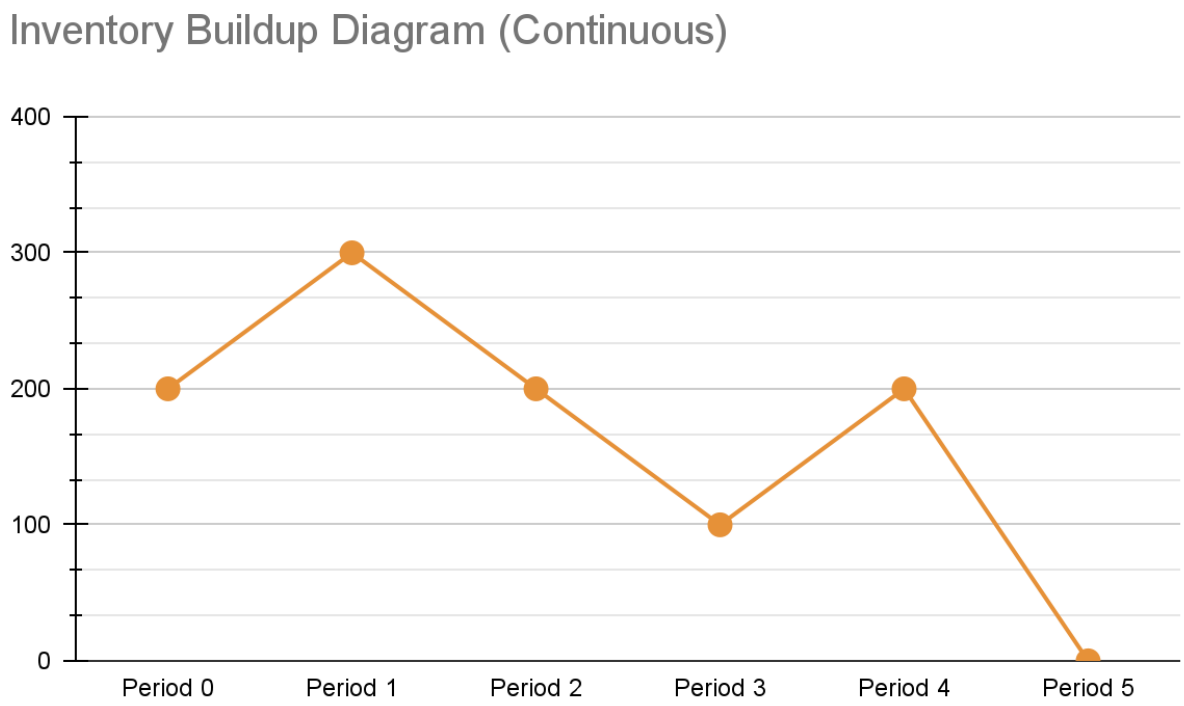


Continuous Assumption (Easier to calculate!)

- **Instantaneous Flow Rate:**
  - $R_i(t)$ = Input rate at time t
  - $R_o(t)$ = Output rate at time t
  - $\Delta R(t) = R_i(t) - R_o(t)$ = Instantaneous Inventory Accumulation at time t **= the slope**
- **Inventory Level**
  - $I(t)$ = The number of units within the process boundaries at time t
- **Finding Inventory at a given time**
  - Suppose (t_1, t_2) denotes an interval of time starting at t_1 and ending at t_2
  - Finding Inventory at t_2:
    - $I(t_2) = I(t_1) + \Delta R \cdot (t_2 - t_1)$
- Avg Inv = (Starting Inv + Ending Inv)/2



Continuous Assumption (cont.):



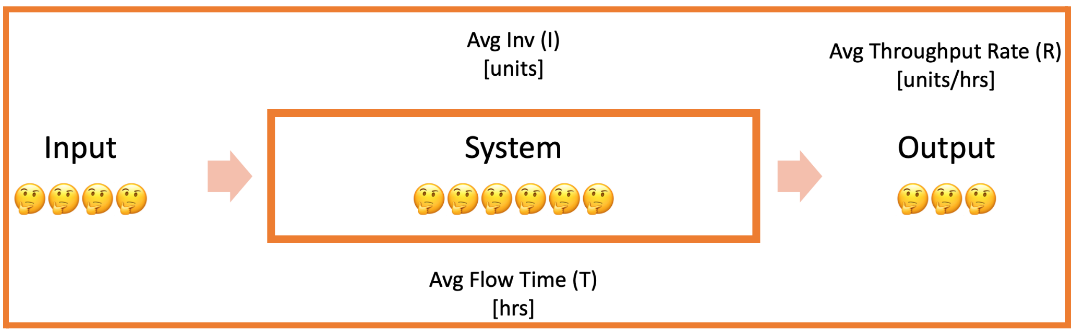
- **Average inventory = Area under curve / # of periods**
  - Avg Inv = ((200+300)/2 + 2*(300+100)/2 + (100+200)/2 + 200/2) / 5 = 180

LITTLE'S LAW

Establishes a relationship between average inventory, average throughput rate, and average flow time:

$$I = R * T$$

Average Inventory (I): Average number of units or customers in the system
Average Throughput Rate (R): The average actual output rate
Average Flow Time (T): The average for a unit to move through the system



***Depending on the situation, the decision-maker can adjust 2 measures to influence the third measure**

E.g. Adjusting flow time by either decreasing inventory or increasing throughput rate (T = I / R)

Example 1:

Suppose you want to network with every student in Sauder but you could not find the total number of undergrad students. You only knew that on average, there are 600 undergrads in Sauder who graduate every year. A degree normally takes 4 years to complete. How many undergrads are there to network with?

R = 600 / year
T = 4 years
I = 600 * 4 = 2400 students at Sauder

Example 2:

On average, there are 500 travelers waiting in the line at the airport. Suppose on average each person has to wait 2 hours to be processed. How many travelers are being processed in an hour?

I = 500 (travelers)
T = 2 (hours)
R = I / T = 250 (travelers / hour)

PRACTICE QUESTION 3: THROUGHPUT RATE, UTILIZATION & INVENTORY BUILDUP DIAGRAM, LITTLE'S LAW

Every Monday morning, the Tim Hornet line at UBC Sauder offers a special type of fresh coffee that comes from the UBC farm. The counter opens at 10 am. However, customers start lining up at 9:30 am. Customers show up at a rate of 20 customers/hr until 10:30 am and then at a rate of 15/hr until 11:30am. The counter can serve at a rate of 10/hr, and the counter works until all customers served.

a. Draw a graph of the number of customers waiting in the line. Start the graph at 9:30 am and show the number of waiting customers until the line is empty again. Using the inventory build-up diagram, calculate the average number of customers in line.

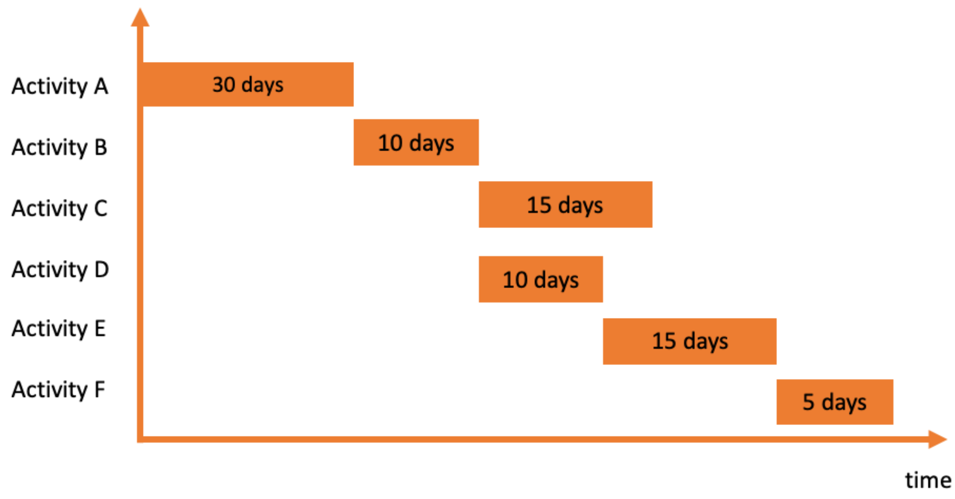
b. How long does an average person spend in the line? (Hint: Little's Law)

PROJECT MANAGEMENT: GANTT CHART, CRITICAL PATH ANALYSIS

The process of producing an album:

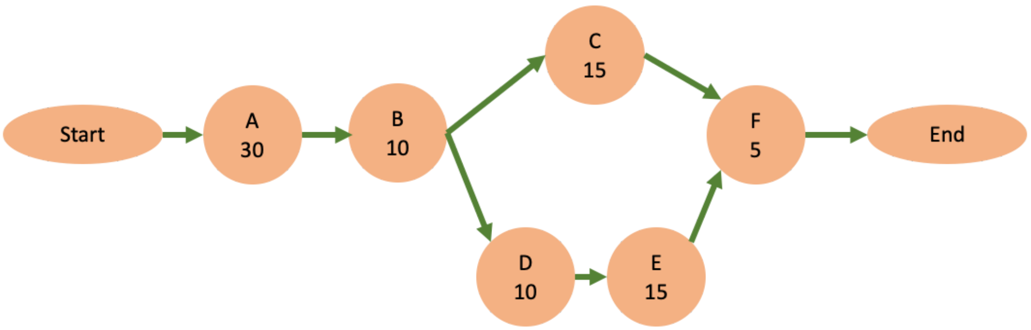
Activities	Times	Precedence
A. Making the beat	30 days	None
B. Contacting artists	10 days	A
C. Studio session	15 days	B
D. Mixing	10 days	B
E. Mastering	15 days	D
F. Publishing	5 days	C, E

Corresponding Gantt Chart:



Project duration: 30 + 10 + 10 + 15 + 5 = 70 days

Corresponding Critical Path Diagram



Critical path method:

- Identify all paths between the start node and the end node (Enumeration Method)
  - For each path, add the activity times for all activities on that path
  - Find the maximum path time
    - This path is called the critical path
    - This is the time required to finish the project

Example:

- Path 1: ABCF: 30 + 10 + 15 + 5 = 60 days
- Path 2: ABDEF: 30 + 10 + 10 + 15 + 5 = 70 days **(Critical path)**

PRACTICE QUESTION 4: CRITICAL PATH ANALYSIS

Colonel Sandy, a famous public figure behind the AFC fast-food chain. Colonel Sandy wants to open a new location near UBC Sauder to offer undergrads the best chicken sandwich ever. He does not know anything about critical path, but he wants to know the duration of the construction process of the restaurant. The only thing he had was this chart below. Please help Colonel Sandy to figure the critical path & duration of the process.

Node	Activity	Time (days)	Precedence
A	Planning	20	None
B	Purchasing location	60	A
C	Excavation	100	A
D	Purchasing Materials	30	B
E	Building the frame	20	C,D
F	Assembly	10	E
G	Painting walls	20	F
H	Interior placements	10	F
I	Decorations	30	G,H

COSTING, CRASHING ACTIVITIES

- Activity times are dependant on costs
    - Can be reduced at a cost (by adding resources)
    - Partial crashing with proportional cost is allowed
- **Crashing:** refers to reducing the time it takes to complete the activity
- **Crash time:** the minimum possible time to complete an activity (smaller than the normal time)
    - Easier if we include crashable time i.e. the amount of time we can reduce
- **Crash cost:** the cost associated with the crash time (in place of the normal cost)
    - Easier to calculate if we include cost/crashable day

Steps to Crash:

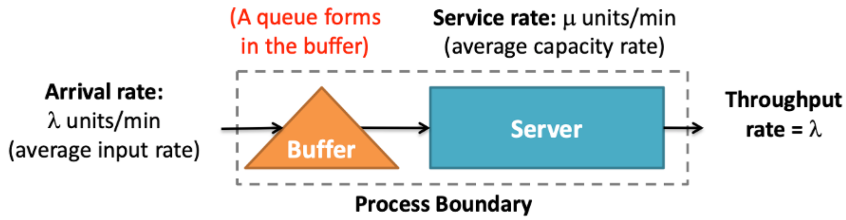
- Always look at the critical path and only crash critical path's activities
- Prioritize the activity that has the lowest cost/day
- Update your critical path as you go

PRACTICE QUESTION 5: COSTING, CRASHING ACTIVITIES (continued from last question)

After knowing the time needed to complete the construction process. Colonel Sandy was furious because he wanted to complete in 6 months. With the information given below, please Colonel Sandy to help reduce the project completion to 175 days.

Node	Activity	Time (days)	Precedence	Cost	Crash time	Crash Cost
A	Planning	20	None	300	15	450
B	Purchasing location	60	A	2,100	50	2,140
C	Excavation	100	A	4,000	75	4,500
D	Purchasing Materials	30	B	2,850	20	3,000
E	Building the frame	20	C,D	500	Cannot be crashed	
F	Assembly	10	E	200		
G	Painting walls	20	F	400		
H	Interior placements	10	F	600		
I	Decorations	30	G,H	1,350		

VARIABILITY IN THE PROCESS: P-K FORMULA



Variables	
λ (units/time)	Average arrival rate (input rate)
1/λ	Average customer inter-arrival time
μ (units/time)	Average service rate (capacity rate)
1/μ	Average service time
p = λ/μ	Single Server Queue: Server Utilization System is stable whenever λ < μ, i.e., ρ < 100%
p = λ/cμ	Multiple Server Queue: Server Utilization

G/G/1 Queue $I_q \cong \frac{\rho^2}{1-\rho} \times \frac{C_a^2 + C_s^2}{2}$	
I_q	Average Queue Length
ρ	Server Utilization
$C_a = \sigma_a/E_a$	Coefficient of Variation of inter-arrival time (std dev/mean)
$C_s = \sigma_s/E_s$	Coefficient of Variation of service time (std dev/mean)

P-K FORMULAS		
G/G/1	$I_q \cong \frac{\rho^2}{1-\rho} \times \frac{C_a^2 + C_s^2}{2}$	Inter-arrival times and service times are **generally distributed**. 1 server in queue.
M/M/1	$I_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu-\lambda)}$	Inter-arrival times and service times are **exponentially distributed.** 1 server in queue
M/D/1	$I_q = \frac{\rho^2}{1-\rho} \times \frac{1}{2} = \frac{\lambda^2}{2\mu(\mu-\lambda)}$	Inter-arrival times are **exponentially distributed**. Service times are **deterministic.** 1 server in queue.
G/G/c	$I_q = \frac{\rho^{\sqrt{2(c+1)}}}{1-\rho} \times \frac{C_a^2 + C_s^2}{2}$	Inter-arrival times and service times are **generally distributed**. There are c servers.

Performance Measures		
I_q	Average Queue Length	$I_q = \lambda * T_q$
I_s	Average # of customers being served	$I_s = \lambda * T_s = \lambda / \mu$
$I = I_s + I_q$	Average # of customers in the process	$I = \lambda * T$
T_q	Average waiting time in queue	$T_q = I_q / \lambda$
T_s	Average service time (server)	$T_s = 1/\mu$
$T = T_s + T_q$	Average Flow Time in the process	$T = I / \lambda$

VARIABILITY IN THE PROCESS: P-K FORMULA

- M/M/1 queue characteristics
  - For deterministic inter-arrival/service time: mean = std dev

- G/G/c queue characteristics
  - Compared to G/G/1 queue: All other things being equal, if the number of servers c increases, then Iq decreases

PRACTICE QUESTION 6: P-K FORMULA

A) Professor Getman holds office hours every day to answer students' questions. Students arrive at an average rate of 50 per hour. Professor Getman can process students at an average rate of 60 per hour. What is the average number of students waiting outside Professor Getman's office, and how long do they wait on average?
* Assume the inter-arrival and service times are exponentially distributed

B) Customers arrive at rate 4/hour, and mean service time is 10 minutes
   - Assume that standard deviation of inter-arrival times equals 5 minutes, and the standard deviation of service time equals 3 minutes
   - What is the average size of the queue? What is the average time that a flow unit spends in the queue
   - Assume the inter-arrival time and service times are generally distributed

C) Customers arrive at a rate 4/hour. Assume inter-arrival times follow an exponential distribution. Service times, on the other hand, are exactly 10 minutes.
   - What is the average size of the queue? What is the average time that a flow unit spends in the queue? Time in the process?