QMB 612 – Fall 2023: Critical Thinking Project 4

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Rules

This is a take-home project. The rules are as follows:

I This is to be your own work. You may not consult with anyone, except the Professor, regarding these problems.

II You may not consult any references other than your text, your class notes from this course, material on the course's Blackboard site and your assignments.

III Show all work leading to your answers in a clear and organized fashion. Show your Excel calculations explicitly. No Work means No Credit. Do not copy and paste values and lose the formulas.

IV This Project is due by 8:00 PM on Thursday, December 14, 2023. All work must be submitted electronically on Canvas in the Assignments area, including a photo of this signature page with your Signature.

V Part of the grade is on Excel calculations/work and the other part on the managerial report. The last page gives you the breakdown. Remember to write the report to the recipient identified in the description below. It should not read like an assignment, but like a managerial report. In particular, the story you are telling should flow naturally and seamless.

VI I, _____, certify that, by submitting this cover page, I completed all work according to rules I–IV, and that I did not copy nor use anyone else's ideas or work to complete this project. I also certify that I will not share this project or my work on this project with anyone else now or in the future.

Signature _____

To Do or Not to Do

You work for an engineering company that operates an equipment repair business for local domestic manufacturers. The repair jobs arrive randomly at a rate of three jobs per 8-hour day. The company's repair facility is a single channel system operated by a repair technician. The service time varies with a mean repair time of 2 hours and a standard deviation of 1.5 hours. The company's cost of repair is $28 per hour. In the economic analysis of the waiting line system, you discovered that it costs $35 of customer waiting time during the repair process.

1. What are the arrival rate and service rates per hour? (**1 point**)
2. Show the operating characteristics including the cost per hour. (**3 point**)
3. The company is considering purchasing a computer-based equipment repair system that would enable a constant repair time of 2 hours. Because of the computer based system, the company's cost of the new operation would be $32 per hour.

(a) The company's director of operations said no to the request for the new system because the cost of hourly cost is $4 higher and the mean repair time is the same. Do you agree? Show your work for credit. (**5 point**)

(b) What effect will the new system have on the waiting line characteristics of the repair service? (**4 point**)

(c) Does paying for the computer based system to reduce variation in service time make economic sense? Furthermore, how much will the new system save the company during a 40 hour work week? (**5 point**)

Priya Printing

Bhavya runs the Priya Printing Press, a firm that prints affordable college and high textbooks to local schools here in South Florida. Priya has a 800 toll-free telephone number that teachers, professors and librarians can call when thinking about adopting new books, or review copies of new materials, and also to place orders. Currently, Priya has two extension lines to the number which are manned by two representatives who answer the phone inquiries. Calls occurring when both representatives are busy on the phone receive a busy signal, and there is no waiting allowed in the system. Each representative can accommodate an average of 12 calls per hour. The mean arrival rate is 20 calls per hour. Assume the calls follow Poisson arrival distribution and the service rate is exponentially distributed.

1. How many extension lines should be used if the company wants to handle 90% of the calls immediately? (**4 point**)
2. What is the average number of extension lines that will be if your recommendation above is used? (**4 point**)
3. What percentage of calls receive a busy signal for the current telephone system with two extension lines? (**4 point**)

Brodsky's Solutions

Jack owns and operates Brodsky's Solutions, a small but thriving consulting business in downtown Tampa. He has 6 UT graduates as part of his team. The employees all use a fancy copy and fax machine to run the business in addition to their individual computers. On average, the time between an employee's arrivals to use the copy and fax machine is 40 minutes, and each employee spends an average of 5 minutes using the machine. Assume the employee arrivals follow a Poisson distribution and the service times are exponentially distributed.

1. Determine the following (**2.5 points**):
   (a) The probability that the machine is idle.
   (b) The average number of employees waiting in line for the machine.
   (c) The average number of employees at the machine.
   (d) The average time an employee spends waiting for the machine.

(e) The average time an employee spends at the machine.

2. During an 8-hour work day, how many minutes does an employee spend at the machine? How much of that time is spent waiting in line? (**4 points**)

3. Recall that Jack's business is thriving. Should he consider buying an additional machine? Explain your reasoning clearly. You can use reasonable assumptions to help you answer this question. (**3.5**)

Trepani's Superstore

The Trepani Department store is having a Christmas sale (which will actually start December 20), and plans to send out an eight-page advertisement for it. This advertisement must be mailed out at least 10 days before December 20 to be effective, but various tasks must be done and decisions made first. The department managers decide which items on stock to put on sale, and buyers decide what merchandise should be brought in for the sale. Then a management committee decides which items to put in the advertisement and sets their sale prices. The art department prepares pictures of the sale items and a writer provides copy describing them. Then the final design of the advertisement, integrating words and pictures, is put together.

A mailing list for the advertisement is compiled from several sources, depending on the items put on sale. Then the mailing labels are printed. After the advertisement itself is printed, labels are attached, and the finished product, sorted by zip code, is taken to the post office.

Of course, all these operations take time. Unfortunately, it is already November 30 (**Pretend you got the CTP during last week's class.)**, so only 20 days are available for the whole operation, including delivery. There is some concern whether the advertisements can be gotten out in time, and so estimates are made for the number of days needed for each task, based on past experience. These times are listed in Table 1.

Task	*Description*	*Time in Days*	*Preceding Tasks*
A	Choose items (department managers)	3	None
B	Choose items (buyers)	2	None
C	Choose and price items for ad	2	A,B
D	Prepare art	4	C
E	Prepare copy	3	C
F	Design advertisement	2	D,E
G	Compile mailing list	3	C
H	Print labels	1	G
I	Print advertisement	5	F
J	Affix labels	2	H,I
K	Deliver advertisements	10	J

Table 1: Trepani's timeline for Christmas Sale.

Alyssa is currently in her first year running the store entirely, and would like to know if it is possible to get the advertisements out in time for the sale. Initially, she has you to perform the following tasks to help in project.

TO DO OR NOT TO DO

1.1

Refer excel sheet-Q-1.1

Arrival rate (per hour) = 3/8 = 0.375 repair jobs/hour

Service rate (per hour)=1/2 =0.5 hours.

Standard deviation (given) = 1.5 hours

Appropriate Queuing model to be applied for this scenario is Singler server model with general service time (M/G/1).

1.2 Operating Characteristics

Operating Characteristics	
Average number of customers waiting in the system (L)	2.50 Customers
Average number customers in the queue for repair (Lq)	1.75 Customers
Average waiting time in the Queue (Wq)	4.68 hours
Average time in the system (W)	6.68 hours
Utilization (U)	0.75 (75%)
Total cost per hour*	$192.06

Cost of repair(per hour)=	$28
Cost of customer waiting (per hour)=	$35
Total Cost per hour=	$192.06
(Cost of waiting*Wq)+ cost of repair	

1.3 *Refer excel sheet: Q-1-1.3*

Since the company is now considering a constant repair, we will examine this using the queuing method of single server constant service time (M/D/1).

Operating Characteristics	
Average number of customers waiting in the system (L)	1.87 Customers
Average number customers in the queue for repair (Lq)	1.12 Customers
Average waiting time in the Queue (Wq)	3 hours
Average time in the system (W)	5 hours
Utilization (U)	0.75 (75%)
Total cost per hour* (Excel for calculation)	$137.00

1.3a

Estimating the total cost using the new computer -based system.

Cost of repair(per hour)=	$32
Cost of customer waiting (per hour)=	$35
Total Cost per hour=	$137.00
(Cost of waiting*Wq)+ cost of repair	

Total cost per hour =**$137.00 per hour.**

Total cost reduction with new system = $192-$137 =$55 per hour.

No, I do not agree with the company's director of operations and would recommend the request for new system though it increases the cost of repair by $4, it drastically reduces the total cost per hour by $55 (due to the reduction in wait times bought by new system).

1.3b

Wait time characteristics	**Old system**	**New system**
Average waiting time in the Queue (Wq)	4.68 hours	3 hours
Average time in the system (W)	6.68 hours	5 hours

The new system drastically reduces the average waiting time in queue and average wait time in system by 1.68 hours, which means company can now serve a greater number of customers at a lesser cost.

1.3c

The reduction in variation of service time-constant service time makes greater economic sense, since it reduces the total cost for the company and also the waiting line parameters.

Total cost reduction with new system(per hour) = Total cost old system -Total cost new system

=$192-$137

=$55 per hour.

Savings on total cost for a 40-hour work week = 55*40 =$2200.

Hence, the new computer-based system would save the company an amount of $2200 for a 40 hour work week.

Q-2 PRIYA PRINTING

Multi-server queuing model is appropriate for this scenario (M/M/s)

Q2.1

Company looks at handling 90% of their calls immediately, which means it wants to keep only 10% of their customers waiting.

When we solve for no.of servers giving us a Pw-probability (using below formula) that a customer must wait for service of close to 10%, we can find the right number of servers needed for serving 90% of calls immediately.

$$P_w = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \frac{c\mu}{c\mu-\lambda} P_0 = \text{probability customer must wait for service}$$

Refer to excel sheet: Q-2.1

Arrival rate =	20	Mean Arrival Rate
Service rate =	12	Calls taken by each representative per hour
c =	4	No of representatives/lines managing the calls
Po =	0.217075	
Pw =	0.11964	11.96%

The closest we could go to this requirement is with a c value of 4, serving 88.03% of customers with 4 representatives.

We recommend that Priya Printing should have 4 representatives to handle calls in order to serve 88.03% (close to 90%) of customers immediately.

Q2.2

Refer to excel sheet: Q-2.2

As per the above recommendation, no. of servers would be 4 and when we run the model with 4 servers, below is the output.

Average server utilization(r)	**0.41667**
Average number of customers in the queue(L_q)	**0.0732**
Average number of customers in the system(L)	**1.73986**
Average waiting time in the queue(W_q)	**0.00366**
Average time in the system(W)	**0.08699**
Probability (% of time) system is empty (P_0)	**0.18593**

The average server utilization of the model r = 41.67%

Hence, the average number of extension lines that will be busy when 4 servers are employed= 4* 41.67%

= 1.66 = **2 servers.**

Q.2.3

Refer to excel sheet:Q-2.3

Since, current telephone system is having two representatives to serve the calls-the percentage of calls receiving a busy signal (waiting to be served) would be equal to the value of Pw when c = 2.

$$P_w = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c \frac{c\mu}{c\mu-\lambda} P_0 = \text{probability customer must wait for service}$$

Arrival rate =	20	Mean Arrival Rate
Service rate =	12	Calls taken by each representative per hour
c =	2	No of representatives/lines managing the calls
Po =	0.080717	
Pw =	0.672646	67.26%

Thus, the percentage of calls receiving a busy signal for the current telephone system would be **67.2%.**

Q-3

BRODSKY SOLUTIONS

Refer to excel sheet:Q-3.1

Single-server with finite calling population is the appropriate queuing model for this scenario.

3.1

Arrival Rate = 60/40 = 1.5/hour

Service Rate = 60/5 = 12/hour

N = 6

3.1a Probability that machine is idle (P0) = 38.9%

3.1b The average number of employees waiting in line for the machine (Lq) = 0.5 (approximately 1) employee.

3.1c The average number of employees at the machine =>(L) = 1.11 (approximately 1) employee.

3.1d The average time an employee spends waiting for the machine (Wq) = 0.069 hours.

3.1e The average time an employee spends at the machine => (W) = 0.15 hours.

3.2

Amount of time an employee spends at the machine, during an 8-hour workday = 0.15* 8 = 1.2 hours

Number of minutes an employee spends at the machine, during an 8-hour workday = 1.2*60 = **72 minutes**

Amount of time employee spends waiting in the line, during an 8-hour workday = 0.069*8 = 0.55 hours

No. of minutes an employee spends waiting in the line, during an 8-hour workday = 0.55 * 60=**33 minutes**

3.3

When Jack considers buying an additional machine, the service would be reduced to half.

We can run the queuing analysis with new service rate and existing arrival rate to analyze if Jack's decision to buy an additional machine is profitable or not.

Refer to excel sheet: Q-3.3

Arrival rate = 60/40 = 1.5

Service rate = 60/2.5 (1/2 of 5) = 24

N = 6

Operating Characteristics	**1 Machine**	**2 Machines**
Average number of customers waiting in the system (L)	1.11 employees	0.47 employees
Average number customers in the queue for repair (Lq)	0.50 employees	0.12 employees
Average waiting time in the Queue (Wq)	0.069 hours	0.015 hours
Average time in the system (W)	0.15 hours	0.05 hours
Utilization (U)	0.610 (61%)	0.345 (34.5%)

Assuming the employees' arrival rate is going to be the same and that new machine will reduce the amount of time employee spend with the machine (service) will reduce to half:

- It is seen that the new machine reduces the amount of time customers spend waiting in line by 0.054 hours, that is by 3.24 minutes and time spent at the machine is reduced by 0.1 hours that is by 6 minutes.
- The average number of employee waiting in queue comes down by 0.38 employees and employees waiting in the system is reduced to 0.64 employees which is less than 1 employee and means almost no waiting.
- However, the utilization rate comes down by 26%.

Refer to Excel Q.3-3b

Since, Jack's business is thriving when tested the model for 15 employees assuming he would be having more graduates joining him, the operating characteristics look as shown below:

Operating Characteristics	**2 Machines and 15 employees**
Average number of customers waiting in the system (L)	2.4 employees
Average number customers in the queue for repair (Lq)	1.61 employees
Average waiting time in the Queue (Wq)	0.08 hours
Average time in the system (W)	0.12 hours
Utilization (U)	0.78 (78%)

- It is observed that even when Jack's team expands to 15 it is seen that buying an additional is not very profitable since the time spent by employees and also number of employees went up as per above analysis.

- Also, in the first analysis with 1 machine, we could see that the utilization is only 61% and hence we have more than one reason to say that it is recommended that Jack should not buy an additional machine-which would come with an extra cost.