Excellent
10

Queuing Model For

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As a group, we went to Moe's Southwest Grill in Glen Cove to conduct a queuing model simulation based on their services. Prior to conducting the simulation, Vittorio spoke to the Manager, Manuel Segarra, about the cost of salary paid to the employees per hour and also busiest hours of business.

He stated:

- "11:45 AM – 2:30 PM" are the busiest hours throughout the week
- "Each employee is paid an hourly rate of $10 per hour."
- Part time employees may be hired during the busiest hours stated above

We started collecting data from 11AM and ended the collection process at 4PM:

- Hassan watched the door and counted how many people walked in
- Padma recorded the exact time customers came in and walked out the door
- Vittorio used the stop watch feature on his phone to calculate how long each customer waited in the queue and served by the servers
- Daisy wrote all the timings of the customer's queue and service.

Due to the shortage of our team members and only one member had a stop watch, we were not able to collect data for ALL the customers; however, we were able to do our best and collected most of the customers that walked in. Padma and Vittorio stayed for the entire session while Daisy and Hassan left after the first 2 hours. Between 2 and 3 PM Vittorio and Padma took a lunch break and reviewed some of the data collected.

Brief Overview of the Data Collected

11AM – 12PM

- 40 Customers walked in, out of which we have collected data for 36 customers
- The average time for each customer was 2.86 Minutes

12PM - 1PM

- 91 Customers walked in, out of which we have collected data for 63 customers
- The average time for each customer was 6.26 Minutes

1PM - 2PM

- 74 Customers walked in, out of which we have collected data for 31 customers
- The average time for each customer was 3.74 Minutes

2PM – 3PM

- Lunch Break, reviewed the data already collected

3PM - 4PM

- 33 Customers walked in, out of which we have collected data for 25 customers
- The average time for each customer was 3.63 Minute

Data Recorded for 11AM – 12PM

11-12PM					
Customer	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
1	0:03	1:35	98	1.63	1
2	0:01	1:40	101	1.68	1
3	0:01	2:20	141	2.35	2
4	2:00	0:29	149	2.48	2
5	2:08	0:55	183	3.05	2
6	1:45	2:00	225	3.75	2
7	0:03	1:24	87	1.45	2
8	0:27	1:24	111	1.85	2
9	0:03	0:48	51	0.85	2
10	0:11	2:05	136	2.27	1
11	0:04	2:02	126	2.10	2
12	0:29	1:31	120	2.00	2
13	1:39	2:10	229	3.82	2
14	1:12	1:36	168	2.80	2
15	0:50	2:31	201	3.35	2
16	0:01	0:59	60	1.00	1
17	0:01	0:53	54	0.90	1
18	0:01	1:42	103	1.72	2
19	0:19	1:32	111	1.85	2
20	0:02	1:46	108	1.80	3
21	0:23	1:32	115	1.92	3
22	0:04	2:30	154	2.57	3
23	0:38	3:30	248	4.13	3
24	2:05	2:08	253	4.22	3
25	0:01	1:23	84	1.40	2
26	0:01	1:58	119	1.98	2
27	0:18	1:48	126	2.10	2
28	0:50	1:50	160	2.67	3
29	1:10	4:25	335	5.58	3
30	1:36	2:04	220	3.67	3
31	1:23	2:08	211	3.52	3
32	2:07	2:38	285	4.75	3
33	2:09	3:03	312	5.20	3
34	3:45	1:40	325	5.42	3
35	3:30	1:52	322	5.37	3
36	3:54	2:00	354	5.90	3
Mean:	**0:58**	**1:53**	**171.81**	**2.86**	**2.25**

Mean Results = (Sum of each column) / (36)

	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
Mean:	**0:58**	**1:53**	**171.81**	**2.86**	**2.25**
Lambda	**= Mean Arrival Rate for customers coming into the queueing system**				
	=Expected number of arrivals per unit time				
	= 36 customers in 60 minutes				
	= 0.6 customers in one minute				
1/Mu	**= Expected service time for each customers**				
	= 2.86 minutes per each customer (average time)				
Mu	**= Mean Service Rate**				
	= Expected number of service completions per unit time				
	= 1/2.86 0.35 services per minute				

Lambda (λ) = 36 Customers / 60 minutes = 0.6 Customers per minute

Of Servers = 3

Cost of Servers = $10 per Hour

Assumed Cost of waiting = $15 per Hour

QM Model Results

Waiting Lines Results

(untitled) Solution					
Parameter	Value	Parameter	Value	Seconds	Seconds * 60
M/M/s		Average server utilization	.57		
Arrival rate(lambda)	.6	Average number in the queue(Lq)	.43		
Service rate(mu)	.35	Average number in the system(Ls)	2.14		
Number of servers	3	Average time in the queue(Wq)	.71	42.52	2551.5
Server cost $/time	10	Average time in the system(Ws)	3.57	213.95	12837.21
Waiting cost $/time	15	Cost (Labor + # waiting*wait cost)	36.38		
		Cost (Labor + # in system*wait cost)	62.09		

Sensitivity to num servers

(untitled) Solution						
	1	2	3	4	5	6
Average server utilization		.86	.57	.43	.34	.29
Average number in the queue(Lq)		4.75	.43	.08	.02	.0
Average number in the system(Ls)		6.46	2.14	1.8	1.73	1.72
Average time in the queue(Wq)		7.91	.71	.14	.03	.01
Average time in the system(Ws)		10.77	3.57	3	2.89	2.86

From the results of the QM Model, the average total cost comes out to $62.09 with customers waiting .71 minutes in the Queue. If Manuel decides to add an additional server to maximize profit, the average time of waiting in queue is lowered to .14 minutes, however he will have to pay $ 10 to an additional employee. Since we noticed that it wasn't too busy, we would suggest Manuel to keep the current amount of servers at 3.

	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
MEAN	**2:26**	**3:49**	**375.33**	**6.26**	**3.222222222**
Lambda	**= Mean Arrival Rate for customers coming into the queueing system**				
	=Expected number of arrivals per unit time				
	= 63 customers in 60 minutes				
	= 1.05	**customers in one minute**			
1/Mu	**= Expected service time for each customers**				
	= 6.26 minutes per each customer (average time)				
Mu	**= Mean Service Rate**				
	= Expected number of service completions per unit time				
	= 1/6.26	**= 0.16**	**services per minute**		

Lambda (λ) = 63 Customers / 60 minutes = 1.05 Customers per minute

Of Servers = 4

Cost of Servers = $10 per Hour

Assumed Cost of waiting = $15 per Hour

QM Model Results

Waiting Lines Results

(untitled) Solution

Parameter	Value	Parameter	Value	Seconds	Seconds * 60
M/M/s		Average server utilization	.94		
Arrival rate(lambda)	1.05	Average number in the queue(Lq)	12.3		
Service rate(mu)	.16	Average number in the system(Ls)	18.86		
Number of servers	7	Average time in the queue(Wq)	11.71	702.66	42159.76
Server cost $/time	10	Average time in the system(Ws)	17.96	1077.66	64659.76
Waiting cost $/time	15	Cost (Labor + # waiting*wait cost)	254.45		
		Cost (Labor + # in system*wait cost)	352.89		

Sensitivity to num servers

(untitled) Solution

	5	6	7	8	9	10	11
Average server utilization			.94	.82	.73	.66	.6
Average number in the queue(Lq)			12.3	2.29	.79	.31	.12
Average number in the system(Ls)			18.86	8.86	7.35	6.87	6.69
Average time in the queue(Wq)			11.71	2.19	.75	.29	.12
Average time in the system(Ws)			17.96	8.44	7	6.54	6.37

When we first entered the data, QM software stated that the product of the service rate and the # of servers must be greater than the arrival rate. Through trial and error we were able to come up with 7 servers needed to satisfy the problem. From the results of the QM, The average total cost comes out to $352.99 with customers waiting 11.71 minutes in the Queue. If Manuel decides to add an additional 4 server to maximize profit, the average time of waiting in queue is lowered to 2.19 minutes. We noticed this hour to be very busy and customers were upset to wait a long time in the queue. This is a drastic difference in which we would highly suggest Manuel to have 8 employees during this hour; it would lead to paying an additional $40 for the 4 more employees, but customers will be served faster, resulting in an increase in profit.

Data Recorded for 1PM – 2PM

1-2PM					
Customer	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
1	0:01	4:18	259	4.32	4
2	0:11	4:08	259	4.32	4
3	0:02	4:02	244	4.07	4
4	0:03	3:47	230	3.83	4
5	0:39	4:13	292	4.87	4
6	2:28	3:25	353	5.88	4
7	0:10	3:48	238	3.97	3
8	1:35	2:22	237	3.95	3
9	0:01	1:08	69	1.15	3
10	0:22	2:45	187	3.12	3
11	0:43	2:35	198	3.30	3
12	2:56	2:28	324	5.40	3
13	1:51	3:03	294	4.90	3
14	1:21	1:44	185	3.08	3
15	0:55	2:47	222	3.70	3
16	1:02	3:56	298	4.97	3
17	1:48	3:54	342	5.70	3
18	0:05	4:09	254	4.23	3
19	0:50	3:42	272	4.53	3
20	0:01	1:08	69	1.15	3
21	0:02	2:27	149	2.48	3
22	0:46	2:15	181	3.02	3
23	0:47	2:11	178	2.97	3
24	1:10	1:49	179	2.98	1
25	0:02	2:10	132	2.20	1
26	0:56	2:35	211	3.52	2
27	0:30	2:17	167	2.78	2
28	0:14	3:22	216	3.60	2
29	2:12	2:23	275	4.58	2
30	1:32	2:25	237	3.95	2
31	1:01	2:17	198	3.30	2
MEAN	**0:50**	**2:53**	**224.16**	**3.74**	**2.870967742**

Mean Results = (Sum of each column) / (31)

	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
MEAN	**0:50**	**2:53**	**224.16**	**3.74**	**2.870967742**
Lambda	**= Mean Arrival Rate for customers coming into the queueing system**				
	=Expected number of arrivals per unit time				
	= 31 customers in 60 minutes				
	= 0.52	**customers in one minute**			
1/Mu	**= Expected service time for each customers**				
	= 3.74 minutes per each customer (average time)				
Mu	**= Mean Service Rate**				
	= Expected number of service completions per unit time				
	= 1/3.74	**= 0.27**	**services per minute**		

Lambda (λ) = 31 Customers / 60 minutes = 0.52 Customers per minute

Of Servers = 3

Cost of Servers = $10 per Hour

Assumed Cost of waiting = $15 per Hour

QM Model Results

Waiting Lines Results

(untitled) Solution

Parameter	Value	Parameter	Value	Seconds	Seconds * 60
M/M/s		Average server utilization	.64		
Arrival rate(lambda)	.52	Average number in the queue(Lq)	.72		
Service rate(mu)	.27	Average number in the system(Ls)	2.63		
Number of servers	3	Average time in the queue(Wq)	1.38	82.98	4978.78
Server cost $/time	10	Average time in the system(Ws)	5.09	305.2	18312.11
Waiting cost $/time	15	Cost (Labor + # waiting*wait cost)	40.73		
		Cost (Labor + # in system*wait cost)	69.45		

Sensitivity to num servers

(untitled) Solution

	1	2	3	4	5	6
Average server utilization		.96	.64	.48	.38	.32
Average number in the queue(Lq)		21.05	.72	.14	.03	.01
Average number in the system(Ls)		22.97	2.63	2.06	1.95	1.92
Average time in the queue(Wq)		40.72	1.38	.27	.06	.01
Average time in the system(Ws)		44.42	5.09	3.98	3.76	3.72

From the results of the QM, The average total cost comes out to $69.45 with customers waiting 1.38 minutes in the Queue. If Manuel decides to add an additional server to maximize profit, the average time of waiting in queue is lowered to .27 minutes. We noticed the queue in the first half hour was too busy but the second half hour was slow. We would suggest Manuel to have only 3 servers from 1PM – 1:30 PM and have 2 servers from 1:30PM – 2PM because during the last thirty minutes of the hour, the workers had only a few customers to deal with.

Data Recorded for 3PM – 4PM

3-4PM					
Customer	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
1	0:01	2:47	168	2.80	2
2	0:18	2:29	167	2.78	2
3	1:22	1:48	190	3.17	2
4	0:42	1:47	149	2.48	2
5	0:01	2:02	123	2.05	1
6	0:02	1:32	94	1.57	1
7	0:01	2:55	176	2.93	1
8	0:01	0:58	59	0.98	2
9	0:02	1:18	80	1.33	3
10	0:02	1:26	88	1.47	2
11	0:01	2:50	171	2.85	3
12	0:01	2:46	167	2.78	3
13	1:05	1:41	166	2.77	3
14	1:35	2:06	221	3.68	3
15	0:05	4:36	281	4.68	2
16	2:24	3:24	348	5.80	2
17	2:46	3:45	391	6.52	2
18	3:21	3:58	439	7.32	2
19	3:27	4:11	458	7.63	3
20	5:35	5:55	690	11.50	3
21	0:31	2:44	195	3.25	3
22	0:01	2:12	133	2.22	1
23	0:01	1:11	72	1.20	2
24	0:01	3:12	193	3.22	1
25	0:37	3:04	221	3.68	1
MEAN	**0:57**	**2:39**	**217.60**	**3.63**	**2.08**

Mean Results = (Sum of each column) / (25)

	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
MEAN	**0:57**	**2:39**	**217.60**	**3.63**	**2.08**
Lambda	**= Mean Arrival Rate for customers coming into the queueing system**				
	=Expected number of arrivals per unit time				
	= 25 customers in 60 minutes				
	= 0.42	**customers in one minute**			
1/Mu	**= Expected service time for each customers**				
	= 3.63 minutes per each customer (average time)				
Mu	**= Mean Service Rate**				
	= Expected number of service completions per unit time				
	= 1/3.63	**= 0.28**	**services per minute**		

Lambda (λ) = 25 Customers / 60 minutes = 0.42 Customers per minute

Of Servers = 3

Cost of Servers = $10 per Hour

Assumed Cost of waiting = $15 per Hour

QM Model Results

Waiting Lines Results

(untitled) Solution

Parameter	Value	Parameter	Value	Seconds	Seconds * 60
M/M/s		Average server utilization	.5		
Arrival rate(lambda)	.42	Average number in the queue(Lq)	.24		
Service rate(mu)	.28	Average number in the system(Ls)	1.74		
Number of servers	3	Average time in the queue(Wq)	.56	33.83	2030.08
Server cost $/time	10	Average time in the system(Ws)	4.14	248.12	14887.22
Waiting cost $/time	15	Cost (Labor + # waiting*wait cost)	33.55		
		Cost (Labor + # in system*wait cost)	56.05		

Sensitivity to num servers

(untitled) Solution

	1	2	3	4	5	6
Average server utilization		.75	.5	.38	.3	.25
Average number in the queue(Lq)		1.93	.24	.04	.01	.0
Average number in the system(Ls)		3.43	1.74	1.54	1.51	1.5
Average time in the queue(Wq)		4.59	.56	.11	.02	.0
Average time in the system(Ws)		8.16	4.14	3.68	3.59	3.58

From the results of the QM, The average total cost comes out to $58.05 with customers waiting .56 minutes in the Queue. If Manuel decides to add an additional server to maximize profit, the average time of waiting in queue is lowered to .11 minutes. We noticed this hour to be very slow with 2 customers coming in every 10 minutes. We also noticed that servers would take their lunch break during this time right next to us. I would highly suggest Manuel to only have 2 servers instead of 3 based on how many customers came in during this hour.

Overall Data Recorded for 11AM – 4PM

OVERVIEW	TIME	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
	11-12 PM	0:58	1:53	171.81	2.86	2.25
	12-1 PM	2:26	3:49	375.3333333	6.26	3.222222222
	1-2 PM	0:50	2:53	224.1612903	3.74	2.87
	3-4 PM	0:57	2:39	217.6	3.63	2.08
	TOTAL AVERAGE	**0.05**	**0.12**	**247.23**	**4.12**	**2.61**

Mean Results = (Sum of each column) / (4)

		Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
	TOTAL AVERAGE	**0.05**	**0.12**	**247.23**	**4.12**	**2.61**
Lambda	**= Mean Arrival Rate for customers coming into the queueing system**					
	=Expected number of arrivals per unit time					
	=39 Customers in Total Average / 60 Minutes					
	= 0.65 customers in one minute					
1/Mu	**= Expected service time for each customers**					
	= 4.12 minutes per each customer (average time)					
Mu	**= Mean Service Rate**					
	= Expected number of service completions per unit time					
	= 1/4.12 =0.24 services per minute					

Of Servers = 3

Cost of Servers = $10 per Hour

Assumed Cost of waiting = $15 per Hour

QM Model Results

Waiting Lines Results

(untitled) Solution					
Parameter	Value	Parameter	Value	Seconds	Seconds * 60
M/M/s		Average server utilization	.9		
Arrival rate(lambda)	.65	Average number in the queue(Lq)	7.63		
Service rate(mu)	.24	Average number in the system(Ls)	10.34		
Number of servers	3	Average time in the queue(Wq)	11.74	704.55	42272.99
Server cost $/time	10	Average time in the system(Ws)	15.91	954.55	57272.99
Waiting cost $/time	15	Cost (Labor + # waiting*wait cost)	144.49		
		Cost (Labor + # in system*wait cost)	185.11		

Sensitivity to num servers

(untitled) Solution							
	1	2	3	4	5	6	7
Average server utilization			.9	.68	.54	.45	.39
Average number in the queue(Lq)			7.63	.83	.2	.05	.01
Average number in the system(Ls)			10.34	3.53	2.91	2.76	2.72
Average time in the queue(Wq)			11.74	1.27	.31	.08	.02
Average time in the system(Ws)			15.91	5.44	4.48	4.25	4.19

From the results of the QM, The average total cost comes out to $185.11 with customers waiting 11.74 minutes in the Queue. If Manuel decides to add an additional server to maximize profit, the average time of waiting in queue is lowered to 1.27 minutes. This is based on the overall data collected; however we wouldn't rely on these results based on the data we collected per hour.

Our best suggestion to Manuel would be to definitely have no less than 7 servers during the 12PM – 1PM hour. By seeing how busy it was and how upset some customers were while standing in the queue waiting to start their order, we suggest 8 servers to keep the customers satisfied, minimize the time in queue and system, and to increase profit. We also suggest Manuel to have only 2 servers during the 3PM – 4PM hour based on the amount of customers that walked in and how employees were not being productive while they waited for a customer to come in.

Data Recorded for 12PM – 1PM

12-1PM					
Customer	Time Out Que, in Min and Sec	Time Out Server, in Min and Sec	Total Time in System in Sec	Total Time in System Min	# Of Servers
1	3:34	2:35	369	6.15	4
2	3:25	2:46	371	6.18	4
3	3:49	2:43	392	6.53	4
4	4:17	2:01	378	6.30	4
5	4:20	2:37	417	6.95	4
6	4:21	2:44	425	7.08	4
7	4:23	3:40	483	8.05	4
8	0:01	2:45	166	2.77	4
9	0:22	1:45	127	2.12	4
10	0:35	1:54	149	2.48	4
11	0:43	2:14	177	2.95	4
12	1:55	2:42	277	4.62	4
13	2:00	2:25	265	4.42	4
14	2:05	3:13	318	5.30	4
15	2:10	3:42	352	5.87	4
16	2:50	4:02	412	6.87	4
17	3:15	4:21	456	7.60	4
18	3:15	4:24	459	7.65	4
19	3:25	4:35	480	8.00	4
20	3:37	5:01	518	8.63	4
21	3:42	5:07	529	8.82	3
22	3:51	5:44	575	9.58	3
23	3:52	6:02	594	9.90	3
24	4:02	6:18	620	10.33	3
25	4:07	6:36	643	10.72	3
26	4:22	4:54	556	9.27	3
27	4:28	5:51	619	10.32	3
28	4:25	6:02	627	10.45	3
29	4:29	6:18	647	10.78	3
30	4:32	6:36	668	11.13	3
31	4:30	4:54	564	9.40	3
32	4:37	5:51	628	10.47	3
33	4:38	4:16	534	8.90	3
34	4:37	6:50	687	11.45	3
35	4:40	7:20	720	12.00	3
36	4:42	7:47	749	12.48	3
37	4:45	8:51	816	13.60	3
38	4:38	9:12	830	13.83	3
39	0:01	2:44	165	2.75	2
40	0:53	3:13	246	4.10	2
41	1:15	3:11	266	4.43	2
42	0:01	2:40	161	2.68	2
43	0:01	2:07	128	2.13	2
44	0:20	1:53	133	2.22	2
45	0:01	2:11	132	2.20	3
46	0:33	2:20	173	2.88	3
47	1:01	2:02	183	3.05	3
48	1:51	2:28	259	4.32	3
49	2:00	2:52	292	4.87	3
50	0:30	3:10	220	3.67	3
51	0:01	2:38	159	2.65	3
52	0:30	3:09	219	3.65	3
53	0:01	1:59	120	2.00	3
54	0:22	2:46	188	3.13	3
55	0:55	2:34	209	3.48	3
56	0:33	2:58	211	3.52	3
57	1:23	2:45	248	4.13	3
58	2:31	3:10	341	5.68	3
59	1:41	2:29	250	4.17	3
60	2:05	2:38	283	4.72	3
61	0:59	2:32	211	3.52	3
62	0:37	2:01	158	2.63	3
63	0:01	1:33	94	1.57	3
MEAN	**2:26**	**3:49**	**375.33**	**6.26**	**3.222222222**

Mean Results = (Sum of each column) / (63)