Modeling and Simulation Project Report

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Description of The Project:

We built a simple bank simulation in order to find the optimum employee count to maximize the profit of the bank & more importantly decrease the amount of waiting time inside the bank for customers.

System Components:

1. Agents
2. Queues
3. Schedules
4. Resources
5. Resource Pools
6. Exits
7. Decision Blocks
8. Delays
9. Seize Blocks
10. Release Blocks
11. Time Measurement Blocks
12. Custom Distributions

Relations:

1. We have a queue for every service offered.
2. Every agent has its own schedule set.
3. We have 2 exits in order to count customers who timeout.
4. Customers, Tellers, ATMs are our agents.
5. ATM service, Teller Service, Special Case Service are being offered.
6. ATMs, Tellers, specialCaseTellers have ResourcePools which provide services being offered.
7. Time spent in queues are being measured via time measurement components.
8. Customers who wait too long in queues and hence those who leave the bank are measured via time measurement components.
9. Time spent in the bank is being measured via time measurement components.
10. Since our system is a Bank every agent in our system is set via

    Schedules.ServicePools work between 9am-17pm.Giving a break at noon.

    Customers are allowed to enter the system between 9am-16.45pm.

Input and Output Parameters:

1. **Input Parameters**

   1.1. Shift Time Intervals.

   1.2. The count of working teller employees.

   1.3. The count of working special case teller employees.

   1.4. The count of ATM's in the bank.

   1.5. Custom distributions for services of tellers,sCaseTellers,ATMs.

2. **Output Parameters**

   2.1. Average waiting times in queues

   2.2. Average time spent in the bank

   2.3. Count of timeouts of queues.

b.Answers to the questions asked in the project document.

1. We have calculated our mean values with several replications with different seed values as follow:

   Data of Teller Service:

The Number of Teller:1						The Number of Teller:2			
	mean	t.out	s.work				mean	t.out	s.work
1	25,2	22087	7979			1	23	14164	15714
2	25,09	22002	7929			2	23,02	13937	15739
3	25,13	22111	7907			3	22,87	14147	15778
4	25,12	22085	7956			4	23,28	14282	15829
5	25,05	22079	7992			5	22,82	13805	15923
avg:	25,118	22072,8	7952,6			avg:	22,998	14067	15796,6

The Number of Teller:3						The Number of Teller:4			
	mean	t.out	s.work				mean	t.out	s.work
1	18,89	6555	23165			1	8,28	1314	28444
2	18,64	6719	23146			2	9,01	1813	28015
3	18,18	6681	23348			3	8,61	1648	28353
4	18,63	6638	23351			4	8,55	1645	28301
5	18,84	6745	23054			5	8,86	1671	28470
avg:	18,636	6667,6	23212,8			avg:	8,662	1618,2	28316,6

The Number of Teller:5						The Number of Teller:6			
	mean	t.out	s.work				mean	t.out	s.work
1	2,07	300	29648			1	0,57	104	29726
2	1,96	309	29407			2	0,64	126	29875
3	1,93	332	29416			3	0,58	146	29709
4	2,24	362	29535			4	0,63	107	29826
5	2,23	400	29671			5	0,62	122	29915
avg:	2,086	340,6	29535,4			avg:	0,608	121	29810,2

1,05	172	29821	2,07
0,34	105	29953	0,97
0,12	92	30049	0,55
0,04	65	29832	0,27

Data of ATM service:

The Number of ATM:1			
	mean	t.out	s.work
1	11,62	13692	13668
2	11,65	13820	13682
3	11,67	13780	13509
4	11,64	13900	13733
5	11,74	14058	13594
avg:	11,664	13850	13637,2

The Number of ATM:2			
	mean	t.out	s.work
1	6,76	2812	24856
2	6,8	2852	24597
3	6,49	2544	25005
4	6,84	2754	24681
5	6,9	2904	24819
avg:	6,758	2773,2	24791,6

The Number of ATM:3			
	mean	t.out	s.work
1	1,31	169	27544
2	1,19	104	27340
3	1,31	92	27375
4	1,29	107	27434
5	1,23	99	27403
avg:	1,266	114,2	27419,2

Confidence Intervals & Prediction Intervals for Varying Teller Number:

N. Teller	Normal System Wait avg.		Confidence min	max	Prediction min	max			-3,6959	28,08928			9
			min	max	min	max			0,511977	2,881056			5
1	25,29		19,66912	30,91088	14,55565	36,02435			0,881581	3,965757			60
2	23,408		18,73497	28,08103	13,13818	33,67782			52,11221	7			2,306004
3	20,13		16,27411	23,98589	10,20529	30,05471			819,5806	110,0906			3,965757
4	12,36		9,091008	15,62899	2,64824	22,07176							
5	3,75		0,701649	6,798351	-5,88973	13,38973							
6	1,05		-2,21899	4,318992	-8,66176	10,76176							
7	0,34		-3,51589	4,195892	-9,58471	10,26471							
8	0,12		-4,55303	4,793033	-10,1498	10,38982							
9	0,04		-5,58088	5,660881	-10,6944	10,77435							

N. ATM	Normal System Wait avg.		Confidence min	max	Prediction min	max			-1,43293	8,986993			8
			min	max	min	max			0,436937	2,206425			4,5
1	11,67		7,347845	15,99215	3,70034	19,63966			0,641897	2,831678			42
2	6,92		3,416273	10,42373	-0,63715	14,47715			10,75497	6			2,364624
3	1,32		-1,50951	4,149515	-5,94915	8,589154			86,23765	48,11039			2,831678
4	0,3		-2,12305	2,723051	-6,82079	7,420789							
5	0,07		-2,35305	2,493051	-7,05079	7,190789							
6	0,02		-2,80951	2,849515	-7,24915	7,289154							
7	0,01		-3,49373	3,513727	-7,54715	7,567153							
8	0,0006		-4,32155	4,322755	-7,96906	7,97026							

Confidence Interval(CI) for 4Tellers and 3 ATM's:

ATMs: mean: 1,258667 n: 45 std:0,058876 t.value:2,015368 min:1,240978 max:1,27635

Tellers: mean: 9,968667 n:45 std:0,388848 t.value:2,015368 min:9,851844 max:10,08549

Replications:

1. **Number of replications needed for ATM's is 5;**
   1,23 1,18 are the first 2 values which gave us 0,107566(half interval range).We continued our with our replications till we faced 4. %7,3 5.%21 shrinks in intervals. Therefore we say it's 5.
2. **Number of replications needed for Tellers is 9.**
   We followed the same procedure with tellers.

Prediction Interval for 4Tellers and 3ATM's:

ATMs:min: 1,138699 max:1,378634

Tellers: min: 9,176336 max:10,761

Changed System Design

We took out our sCaseTeller part of the system and distributed the workload of sCaseTellers to normal tellers.Our new system had pretty much the same statistics in ATM service but tellerService time drastically changed.

Our new CI's data is as followed: mean: 19,14711 n:45 std:0,2054 t.value:2,015368 min:19,0854 max:19,20882

Our new teller service distribution data is as followed:

The Number of Teller:1	mean	t.out	s.work
1	25,11	24136	5674
2	24,81	24397	5639
3	25,2	24429	5526
4	24,97	24117	5716
5	25,07	24002	5733
avg:	25,032	24216,2	5657,6

The Number of Teller:2	mean	t.out	s.work
1	23,72	18542	11359
2	23,82	18622	11278
3	23,69	18363	11420
4	23,62	18489	11365
5	23,89	18978	11210
avg:	23,748	18598,8	11326,4

The Number of Teller:3	mean	t.out	s.work
1	21,61	12804	16965
2	21,75	13158	16672
3	21,76	13216	16816
4	21,97	13402	16667
5	21,94	13278	16706
avg:	21,806	13171,6	16765,2

The Number of Teller:4	mean	t.out	s.work
1	18,61	7751	22175
2	19	8266	21765
3	19,18	8211	21844
4	18,77	8106	21808
5	18,97	8197	21705
avg:	18,906	8106,2	21859,4

The Number of Teller:5	mean	t.out	s.work
1	12,97	3615	26282
2	13,1	3486	26391
3	13,17	3720	26150
4	13,53	3571	26344
5	13,68	3712	26238
avg:	13,29	3620,8	26281

The Number of Teller:6	mean	t.out	s.work
1	6,24	1168	28733
2	6,31	1242	28585
3	6,62	1156	28634
4	6,41	1325	28585
5	6,56	1264	28782
avg:	6,428	1231	28663,8

Difference between new system and old:

The Number of Teller:1	mean	t.out	s.work
1	0,09	-2049	2305
2	0,28	-2395	2290
3	-0,07	-2318	2381
4	0,15	-2032	2240
5	-0,02	-1923	2259
avg:	0,086	-2143,4	2295

The Number of Teller:2	mean	t.out	s.work
1	-0,72	-4378	4355
2	-0,8	-4685	4461
3	-0,82	-4216	4358
4	-0,34	-4207	4464
5	-1,07	-5173	4713
avg:	-0,75	-4531,8	4470,2

The Number of Teller:3	mean	t.out	s.work
1	-2,72	-6249	6200
2	-3,11	-6439	6474
3	-3,58	-6535	6532
4	-3,34	-6764	6684
5	-3,1	-6533	6348
avg:	-3,17	-6504	6447,6

The Number of Teller:4	mean	t.out	s.work
1	-10,33	-6437	6269
2	-9,99	-6453	6250
3	-10,57	-6563	6509
4	-10,22	-6461	6493
5	-10,11	-6526	6765
avg:	-10,244	-6488	6457,2

The Number of Teller:5	mean	t.out	s.work
1	-10,9	-3315	3366
2	-11,14	-3177	3016
3	-11,24	-3388	3266
4	-11,29	-3209	3191
5	-11,45	-3312	3433
avg:	-11,204	-3280,2	3254,4

The Number of Teller:6	mean	t.out	s.work
1	-5,67	-1064	993
2	-5,67	-1116	1290
3	-6,04	-1010	1075
4	-5,78	-1218	1241
5	-5,94	-1142	1133
avg:	-5,82	-1110	1146,4

Confidence Intervals & Prediction Intervals for Varying Teller Number:

N. Teller	Wait avg.	Without Special Case	Confidence min	Confidence max	Prediction min	Prediction max				
								-3,64617	30,77306	9
1	24,96		21,70044	28,21956	18,73512	31,18488		0,296897	1,670732	5
2	23,82		21,11009	26,52991	17,8645	29,7755		0,955646	2,299754	60
3	22,08		19,84396	24,31604	16,32463	27,83537		150,8209	7	2,306004
4	18,69		16,7943	20,5857	13,05812	24,32188		797,6719	37,02207	2,299754
5	13,21		11,44225	14,97775	7,619892	18,80011				
6	6,5		4,604302	8,395698	0,868123	12,13188				
7	2,35		0,113957	4,586043	-3,40537	8,105368				
8	0,9		-1,80991	3,609905	-5,0555	6,855498				
9	0,37		-2,88956	3,629565	-5,85488	6,594881				

CI & PI Interval Difference between old and new system:

N. Teller	Wait avg.	Without Special Case	Confidence min	Confidence max	Prediction min	Prediction max				
								-3,64617	30,77306	9
1	24,96		21,70044	28,21956	18,73512	31,18488		0,296897	1,670732	5
2	23,82		21,11009	26,52991	17,8645	29,7755		0,955646	2,299754	60
3	22,08		19,84396	24,31604	16,32463	27,83537		150,8209	7	2,306004
4	18,69		16,7943	20,5857	13,05812	24,32188		797,6719	37,02207	2,299754
5	13,21		11,44225	14,97775	7,619892	18,80011				
6	6,5		4,604302	8,395698	0,868123	12,13188				
7	2,35		0,113957	4,586043	-3,40537	8,105368				
8	0,9		-1,80991	3,609905	-5,0555	6,855498				
9	0,37		-2,88956	3,629565	-5,85488	6,594881				

Additional replications needed to reduce the half-width of the confidence interval by 10%: We followed the same procedure we used previously on this one also. After 4 iterations we had %11 shrink in interval.

References:

https://mimoza.marmara.edu.tr/~mujdat.soyturk/courses/ie3081_2021_Fall
https://towardsdatascience.com/