Discrete Event Simulation of a Call Centre

Course Project for IE603: Discrete Event System Simulation

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INTRODUCTION

PROBLEM DESCRIPTION

A pharmaceutical company wants to set up a call center in India. People with chronic kidney disease undergo a treatment called peritoneal dialysis. The company supplies the machine and chemicals for doing dialysis at home and answers any questions or complaints about the machine and the supply of chemicals. Retention of patients for a long duration of time is very important for the success of the company as the treatment lasts for at least 7 months.

People in India speak many different languages so a multilingual call center is needed to answer the patients' queries. The patients will be allowed to choose a language from Hindi, Bengali, Marathi, Kannada, Telugu, Tamil and English.

How many employees should be hired for the call center and what should be their language composition so as to reduce the average waiting time as well as reduce employee idle time?

DATA AVAILABLE

The call center will be operational from 6 AM to 10 PM. The peak period is from 8 AM to 12 AM and 3 PM to 7 PM, that is, 8 hours in a day. The average number of calls per month is 22300 out of which ¾-th come during the peak period. The average interarrival time between calls is 0.857 minutes during the peak period. Equivalently, the call arrival rate is 70 calls per hour. Call durations last for an average of 7 minutes and have a standard deviation of 4 minutes. Updating records and writing email after the call takes an average of 1 minute. The percentage distribution of the patients according to language is also known:

Table 1: Linguistic distribution of patients

Language	**Percentage**
Hindi	43 %
Bengali	9 %
Marathi	8 %
Kannada	6 %
Malayalam	3 %
Telugu	6 %
Tamil	7 %
English	18 %

SIMULATION MODEL AND ASSUMPTIONS

We have assumed that the interarrival times are exponentially distributed with mean 0.857 minutes and the call durations are normal distributed with 7 minutes and standard deviation 4 minutes. The time required for updating records and writing email is assumed to be exponentially distributed with mean 1 minute.

The simulation model consists of eight separate queues for calls of each language. In case there is more than one available employee to take a call, the call is taken by the employee which has the least active time. Also, an employee speaking multiple languages takes calls in the order of their arrival and does not give preference to calls according to language.

We also define the acceptable values of average waiting time and maximum waiting time as 1.5 minutes and 15 minutes, respectively.

STATIC ANALYSIS

ANALYSIS WITHOUT SIMULATION

It takes an average of 8 minutes for an employee to answer a call, update records and write an email. Therefore, in 1 hour each employee can receive an average of 60/8 = 7.5 calls. In the peak time period the call arrival rate is 70 calls per hour. So, we would need 70/7.5 = 9.33 employees to take calls during the peak period. The linguistic distribution of the employees is taken same as the linguistic distribution of the patients.

Table 2 shows the calculation number of employees required for each language:

Table 2: Employees as per static analysis

Sl. No.	Language	Percentage	Calculated no. of employees	Rounding off
1	Hindi	43 %	4.01	4
2	Bengali	9 %	0.83	1
3	Marathi	8 %	0.74	1
4	Kannada	6 %	0.56	1
5	Malayalam	3 %	0.28	1
6	Telugu	6 %	0.56	1
7	Tamil	7 %	0.65	1
8	English	18 %	1.67	2
	TOTAL	**100 %**	**9.33**	**12**

SIMULATION

The following results were obtained when the simulation was run over a time period of 15000 minutes with the employees calculated in Table 2:

Table 3: Simulation Results: Waiting Time and Queue Length

Language	Avg Waiting Time (minutes)	Max Waiting Time (minutes)	Std Dev Waiting Time (minutes)	Avg Calls Waiting	Std Dev Calls Waiting
Hindi	434.3749708	848.0245046	262.9544793	216.6537003	128.7135134
Bengali	26.00248141	185.254473	29.93671973	2.683456081	3.415529855
Marathi	31.04086962	244.7567129	44.44351455	2.948882614	4.65081612
Kannada	6.292796762	51.09498061	8.763508828	0.416108194	0.844450664
Malayalam	1.9559888	23.82899698	4.187664853	0.068850806	0.287187204
Telugu	5.216435774	67.47864963	8.59200405	0.358543019	0.836913015
Tamil	10.81081465	120.7239814	15.87529022	0.842966613	1.596911386
English	12.04919736	87.78237898	15.61986903	2.471333256	3.539185001

Table 4: Simulation Results: Employee Utilization

Employee No.	Language	Utilization (%)
0	Hindi	99.936806
1	Hindi	99.934105
2	Hindi	99.930763
3	Hindi	99.904878
4	Bengali	85.724724
5	Marathi	80.919704
6	Kannada	54.450016
7	Malayalam	29.713263
8	Telugu	56.188909
9	Tamil	66.049699
10	English	84.365695
11	English	84.351054

Observations:

The simulation shows that the number of employees calculated using static analysis are not sufficient to provide satisfactory service to the patients. The average and maximum waiting times for all languages are extremely high.

SIMULATION WITH UNILINGUAL AND MULTILINGUAL EMPLOYEES

UNILINGUAL EMPLOYEES

We will now increase the number of employees speaking each language in Table 2. Now, the total number of employees is 26. The simulation is run over a time period of 15000 minutes.

Table 5: Unilingual Employees

Language	**Number of Employees**
Hindi	7
Bengali	3
Marathi	3
Kannada	2
Malayalam	2
Telugu	3
Tamil	3
English	4
TOTAL	**26**

The simulation results are as follows:

Table 6: Simulation Results: Waiting Time and Queue Length

Language	**Avg Waiting Time (minutes)**	**Max Waiting Time (minutes)**	**Std Dev Waiting Time (minutes)**	**Avg Calls Waiting**	**Std Dev Calls Waiting**
Hindi	0.330587	11.16489	1.033914	0.167894	0.647262
Bengali	0.174283	10.07978	0.924441	0.018032	0.163813
Marathi	0.065432	7.060851	0.515506	0.00605	0.085682
Kannada	0.519393	12.49724	1.676729	0.036184	0.219297
Malayalam	0.195962	12.81935	1.192303	0.006676	0.110074
Telugu	0.060455	8.288531	0.496681	0.004175	0.069703
Tamil	0.071149	5.84963	0.505263	0.005943	0.084842
English	0.307279	11.84737	1.125943	0.063238	0.342166

Table 7: Simulation Results: Employee Utilization

Employee No.	**Languages**	**Utilization (%)**
0	Hindi	60.65343
1	Hindi	60.65492

2	Hindi	60.6412
3	Hindi	60.68617
4	Hindi	60.68255
5	Hindi	60.64743
6	Hindi	60.66207
7	Bengali	28.49881
8	Bengali	28.51771
9	Bengali	28.52032
10	Marathi	25.63263
11	Marathi	25.59383
12	Marathi	25.61128
13	Kannada	29.13926
14	Kannada	29.09412
15	Malayalam	14.25473
16	Malayalam	14.1986
17	Telugu	19.10273
18	Telugu	19.07074
19	Telugu	19.06478
20	Tamil	23.0406
21	Tamil	23.02054
22	Tamil	23.04513
23	English	43.25303
24	English	43.25521
25	English	43.30554
26	English	43.27563

Observations:

There is a significant improvement in the waiting times and queue lengths as compared to Table 3. The average and maximum waiting times for all languages are now under acceptable limits. The drawback of this configuration is that many employees are underutilized.

BILINGUAL EMPLOYEES

We will now consider employees that can speak two languages in the simulation model. We have tried to group languages in such a way that finding a person which speaks those languages is not too unlikely.

Table 8: Bilingual Employees

Languages	**Number of Employees**
Hindi, Bengali	8
English, Malayalam	5
Marathi, Kannada	4
Telugu, Tamil	4

TOTAL	**21**

The total number of employees is 21. The simulation is run over a time period of 15000 minutes. Following are the results:

Table 9: Simulation Results: Waiting Time and Queue Length

Language	Avg Waiting Time (minutes)	Max Waiting Time (minutes)	Std Dev Waiting Time (minutes)	Avg Calls Waiting	Std Dev Calls Waiting
Hindi	0.360888	10.39374	1.037247	0.182393	0.677762
Bengali	0.355657	7.07486	0.984496	0.037723	0.220543
Marathi	0.114562	7.50746	0.642738	0.010509	0.118376
Kannada	0.118647	6.123332	0.648124	0.008582	0.100341
Malayalam	0.076914	5.221215	0.445052	0.002554	0.051023
Telugu	0.125991	7.649175	0.675227	0.009164	0.110188
Tamil	0.101076	7.775097	0.596854	0.008214	0.103955
English	0.097879	7.50992	0.563969	0.020248	0.180895

Table 10: Simulation Results: Employee Utilization

Employee No.	Languages	Utilization (%)
0	Hindi, Bengali	63.67021
1	Hindi, Bengali	63.7169
2	Hindi, Bengali	63.66452
3	Hindi, Bengali	63.66853
4	Hindi, Bengali	63.66923
5	Hindi, Bengali	63.66629
6	Hindi, Bengali	63.69968
7	Hindi, Bengali	63.67015
8	English, Malayalam	40.00186
9	English, Malayalam	40.00436
10	English, Malayalam	40.00632
11	English, Malayalam	40.00187
12	English, Malayalam	40.02049
13	Marathi, Kannada	34.3208
14	Marathi, Kannada	34.29238
15	Marathi, Kannada	34.28926
16	Marathi, Kannada	34.32844
17	Telugu, Tamil	31.94815
18	Telugu, Tamil	31.92977
19	Telugu, Tamil	31.89518
20	Telugu, Tamil	31.93974

Observations:

Acceptable results are achieved with a lesser number of employees. The minimum utilization of employees has also improved.

MULTILINGUAL EMPLOYEES

Since Hindi and English are common languages in India, there can be further improvements in waiting time and employee utilization if all employees can speak at least one of Hindi and English. We consider the following employee configuration:

Table 11: Multilingual Employees

Languages	**Number of Employees**
English, Bengali, Hindi	5
Malayalam, Tamil, Telugu, English	5
Marathi, Kannada, English, Hindi	5
TOTAL	**15**

The simulation is run over 15000 minutes.

Table 12: Simulation Results: Waiting Time and Queue Length

Languages	**Avg Waiting Time (minutes)**	**Max Waiting Time (minutes)**	**Std Dev Waiting Time (minutes)**	**Avg Calls Waiting**	**Std Dev Calls Waiting**
Hindi	0.327513	8.568345	1.007015	0.165503	0.639109
Bengali	0.613618	9.734871	1.375233	0.065412	0.296563
Marathi	0.676381	9.460246	1.503871	0.065338	0.292291
Kannada	0.746622	10.13917	1.557739	0.049675	0.246776
Malayalam	0.353252	5.393697	0.875463	0.011704	0.112114
Telugu	0.386159	7.041649	0.975239	0.027495	0.181428
Tamil	0.358279	6.641073	0.94923	0.029833	0.187672
English	0.061565	4.972502	0.349031	0.01331	0.138108

Table 13: Simulation Results: Employee Utilization

Employee No.	**Languages**	**Utilization (%)**
0	English, Bengali, Hindi	68.50827
1	English, Bengali, Hindi	68.49981
2	English, Bengali, Hindi	68.49126
3	English, Bengali, Hindi	68.49447
4	English, Bengali, Hindi	68.49539

5	Malayalam, Telugu, Tamil, English	61.17313
6	Malayalam, Telugu, Tamil, English	61.18592
7	Malayalam, Telugu, Tamil, English	61.16462
8	Malayalam, Telugu, Tamil, English	61.16844
9	Malayalam, Telugu, Tamil, English	61.18872
10	Marathi, Kannada, English, Hindi	68.51683
11	Marathi, Kannada, English, Hindi	68.5164
12	Marathi, Kannada, English, Hindi	68.50745
13	Marathi, Kannada, English, Hindi	68.49951
14	Marathi, Kannada, English, Hindi	68.49938

Observations:

The average and maximum waiting times are under acceptable limits with a much lesser number of employees. Employee utilization has improved greatly. All employees are being utilized more that 60%.

OUTPUT AND SENSITIVITY ANALYSIS

AVERAGE WAITING TIME VS. NUMBER OF UNILINGUAL EMPLOYEES

Figure 1 and 2 show the plots between the average waiting time and the number of unilingual employees for different languages.

Figure 1: Average Waiting Time vs. No. of Unilingual Employees

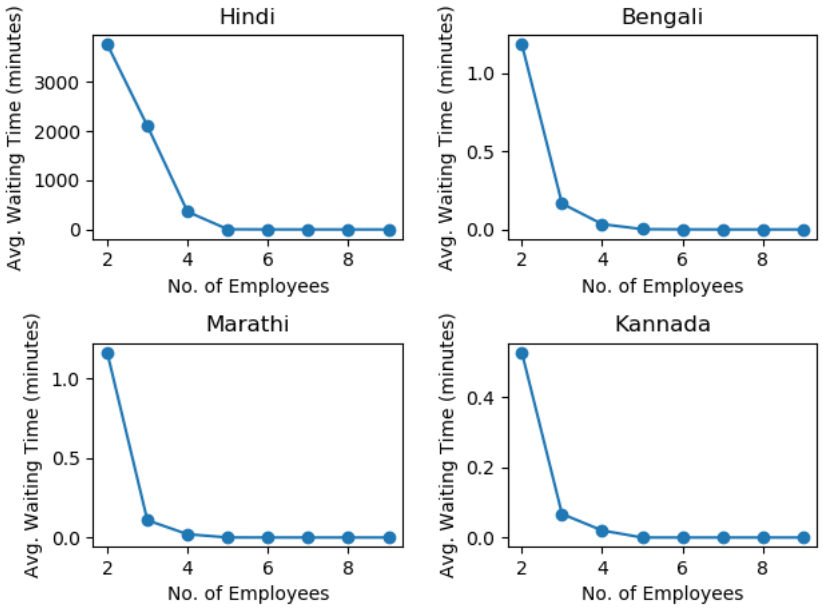
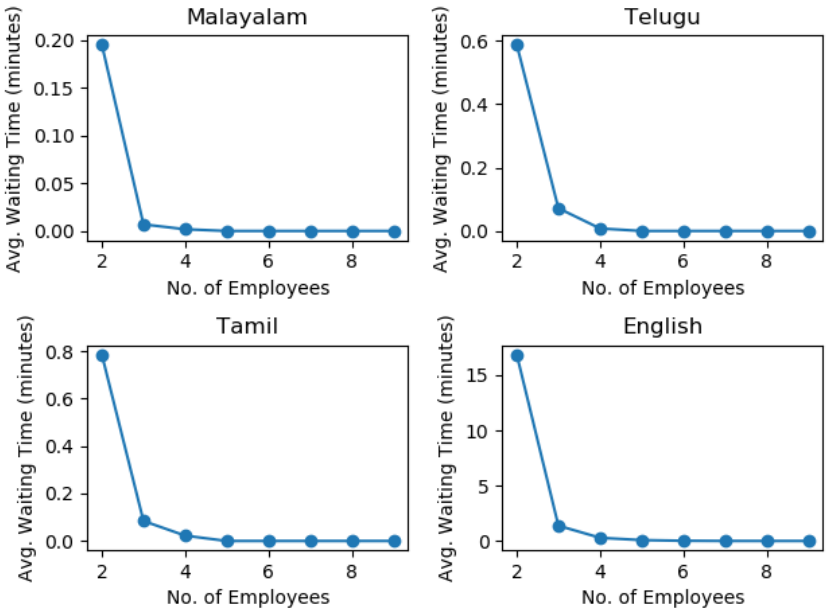


Figure 2: Average Waiting Time vs. No. of Unilingual Employees



EFFECT OF INTERARRIVAL TIME ON WAITING TIME AND UTILIZATION (MULTILINGUAL EMPLOYEES)

Figures 3 and 4 show the effect of changing the average interarrival time on the average waiting time and average utilization with the multilingual employee configuration of Table 11.

Figure 3: Avg. Waiting Time (minutes) vs. Avg. Interarrival Time

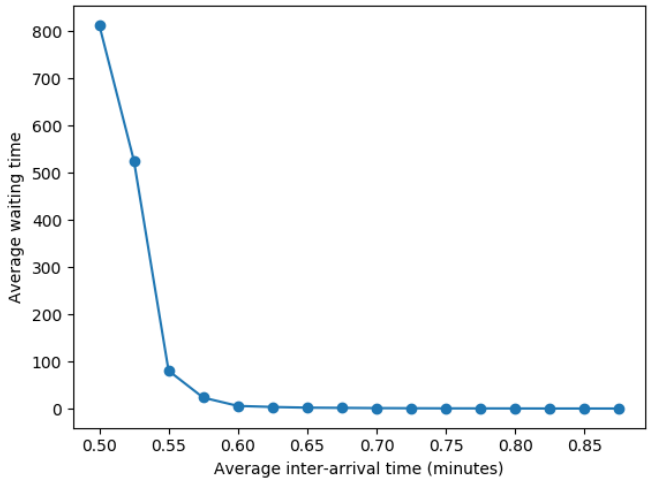
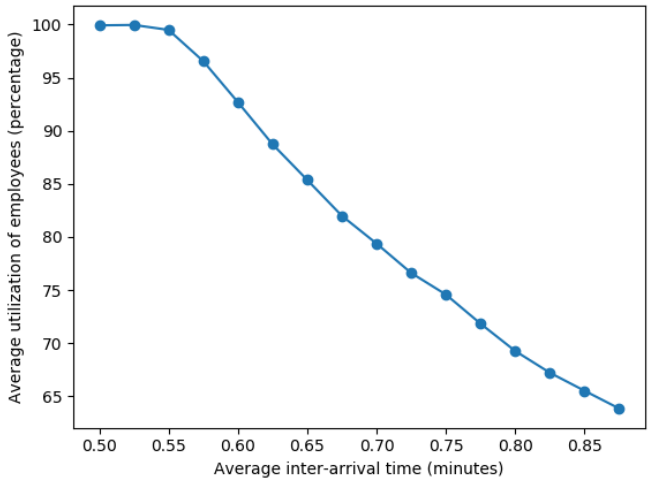


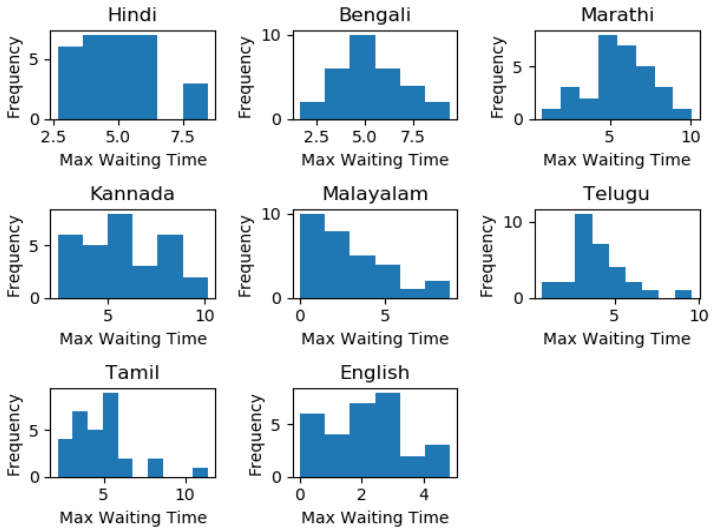
Figure 4: Avg. Waiting Time (minutes) vs. Avg. Interarrival Time



HISTOGRAMS OF MAXIMUM WAITING TIMES (MULTILINGUAL EMPLOYEES)

Following are the histograms of maximum waiting times obtained by simulating 30 peak cycles. The employee configuration of Table 11 is assumed.

Figure 5: Histograms of Maximum Waiting Times



EFFECT OF ADDING AND REMOVING EMPLOYEES ON AVERAGE WAITING TIME (MULTILINGUAL EMPLOYEES)

The following table shows the percentage decrease in the average waiting times of different languages when one or more employees are added to the employee configuration of Table 11:

Table 14: Percentage decrease in average waiting times when employees are added

Employee Languages	No. of employees added	Hindi	Bengali	Marathi	Kannada	Malayalam	Telugu	Tamil	English
English, Bengali, Hindi	1	56.27419	53.25587	38.53652	39.23648	17.07809	-6.24498	13.01719	65.46016
English, Bengali, Hindi	2	77.59598	74.75935	58.48709	59.78604	41.01088	27.51307	32.11274	83.77439
Malayalam, Telugu, Tamil, English	1	-5.94829	7.883775	8.66688	19.52559	63.18056	62.94622	71.23653	67.79745
Malayalam, Telugu, Tamil, English	2	17.39209	8.410377	24.9707	30.22647	94.16939	87.31612	88.70222	93.28415
Marathi, Kannada, English, Hindi	1	33.21761	26.25616	57.09488	42.37697	20.35619	-8.06978	8.422525	26.83151
Marathi, Kannada, English, Hindi	2	80.066	55.34029	80.92676	81.28633	39.95654	19.83808	26.66676	81.12676
Hindi, Marathi, English	1	50.00861	31.70817	57.68136	41.97844	45.35166	-2.62901	15.48773	61.53538
English, Tamil, Telugu	1	4.761545	5.240633	8.869185	22.53533	60.75363	61.6162	70.12659	63.44018
Hindi, Bengali	1	46.18807	43.96522	38.91028	46.17378	22.93739	-10.2986	2.76288	35.74057
Marathi, Kannada	1	34.41849	29.52552	57.83338	60.10656	24.13639	-0.96508	23.3378	60.62852
Tamil, Telugu	1	15.60429	4.001143	17.99554	22.10925	58.12688	67.57837	66.45494	47.34649
English, Malayalam	1	7.802037	3.835544	22.67731	16.48349	71.77105	43.07048	44.62505	69.75063
Hindi	1	60.07055	38.67119	30.57021	45.78176	15.77998	-2.2691	11.40618	71.16536
English	1	17.7942	10.56222	14.96008	35.83155	53.53643	33.87898	29.06104	73.17704

Similarly, Table 15 shows the percentage increase in waiting times when one or more employees are removed from the configuration of Table 11.

Table 15: Percentage increase in waiting times when one or more employees are removed

Employee Languages	No. of employees removed	Hindi	Bengali	Marathi	Kannada	Malayalam	Telugu	Tamil	English
English, Bengali, Hindi	1	215.466	210.8092	80.45008	73.32393	-4.88597	8.103821	19.96244	108.0174
English, Bengali, Hindi	2	499.6067	442.2605	209.052	165.7154	-12.3344	29.61272	10.64322	213.0224
Malayalam, Telugu, Tamil, English	1	32.23923	24.70573	1.616699	-12.9895	55.80822	107.0936	103.4802	80.43754
Malayalam, Telugu, Tamil, English	2	136.6819	85.91256	49.95185	39.55706	393.8172	536.7442	475.8958	422.7269
Marathi, Kannada, English, Hindi	1	122.9983	52.70867	92.27107	91.19068	16.70003	34.32974	9.778633	26.85921
Marathi, Kannada, English, Hindi	2	595.8677	276.845	427.0922	358.4319	-25.0919	27.5955	19.14316	261.0972

SIMULATION WITH A REALISTIC MIX OF EMPLOYEES

The multilingual employee configurations considered in the previous sections are not very realistic. In real life, it would be very hard for a company to hire call center employees if it is too specific about the languages they speak. Also, finding employees which are fluent in multiple languages is also difficult.

SIMULATION RESULTS

We simulate the model with following employee configuration, which is based on our guess of what a realistic mix of employees would look like in India:

Table 16: Realistic mix of employees

Languages	Number of Employees
Hindi	4
Hindi, Bengali	3
Hindi, Marathi	3
Kannada	2
Malayalam	1
Malayalam, English	1
Telugu, Kannada	1
Telugu	2
Tamil, English	1
Tamil	2
English	2
TOTAL	**22**

The simulation is run for a time period of 15000 minutes. The results are as follows:

Table 17: Simulation Results: Realistic Mix of Employees: Waiting Time and Queue Length

Language	Avg Waiting Time (minutes)	Max Waiting Time (minutes)	Std Dev Waiting Time (minutes)	Avg Calls Waiting	Std Dev Calls Waiting
Hindi	0.127001	9.038095	0.619142	0.064474	0.408247
Bengali	0.838103	11.8721	1.814185	0.089509	0.347738
Marathi	0.856937	10.86213	1.728379	0.078096	0.313502
Kannada	0.097548	8.81011	0.637459	0.006932	0.095672
Malayalam	0.478735	12.7921	1.646454	0.016851	0.146473
Telugu	0.15024	7.808052	0.866106	0.010377	0.128982
Tamil	0.23027	9.145105	0.963606	0.019389	0.153364
English	0.390242	10.55831	1.263151	0.08078	0.386833

Table 18: Simulation Results: Realistic Mix of Employees: Employee Utilization

Employee No.	Languages	Utilization (%)

0	Hindi	59.36078
1	Hindi	59.36602
2	Hindi	59.34607
3	Hindi	59.38063
4	Bengali, Hindi	59.3394
5	Bengali, Hindi	59.3339
6	Bengali, Hindi	59.35324
7	Marathi, Hindi	59.34906
8	Marathi, Hindi	59.356
9	Marathi, Hindi	59.34125
10	Kannada	23.43638
11	Kannada	23.47373
12	Malayalam	23.88492
13	Malayalam, English	46.16574
14	Telugu, Kannada	23.48197
15	Telugu	23.32588
16	Telugu	23.29223
17	Tamil, English	46.13262
18	Tamil	33.06015
19	Tamil	33.12374
20	English	46.15847
21	English	46.15337

SIMULATION WITH TWO RANDOM EMPLOYEES LEAVING THE COMPANY

In this section, we will consider a simulation model with employee configuration same as Table 16. However, at the beginning of the simulation two random employees are chosen and removed. The simulation is run for 15000 minutes. We obtain the following results:

Table 19: Simulation Results: Waiting Time and Queue Length

	Avg Waiting Time (minutes)	**Max Waiting Time (minutes)**	**Std Dev Waiting Time (minutes)**	**Avg Calls Waiting**	**Std Dev Calls Waiting**
Hindi	0.207666	7.89086	0.763695	0.104428	0.49586
Bengali	1.047927	10.76783	1.901938	0.105002	0.378854
Marathi	2.289287	25.06787	3.573232	0.213819	0.573917
Kannada	0.094379	9.528057	0.651594	0.006701	0.0912
Malayalam	0.592957	13.00396	1.814458	0.020358	0.156245
Telugu	0.059925	7.299593	0.449847	0.004367	0.067814
Tamil	0.734138	17.11779	2.115606	0.060297	0.300525
English	1.334573	17.0747	2.619282	0.274566	0.725023

Table 20: Simulation Results: Employee Utilization

Employee No.	Languages	Utilization (%)
0	Hindi	64.32035
1	Hindi	64.29792
2	Hindi	64.27582
3	Hindi	64.29748
4	Bengali, Hindi	64.30224
5	Bengali, Hindi	64.27763
6	Bengali, Hindi	64.27008
7	Marathi, Hindi	64.30962
8	Marathi, Hindi	64.32202
9	Kannada	24.2074
10	Kannada	24.21921
11	Malayalam	24.9864
12	Malayalam, English	58.75257
13	Telugu, Kannada	24.22047
14	Telugu	24.20722
15	Telugu	24.18972
16	Tamil	34.07895
17	Tamil	34.03326
18	English	58.69372
19	English	58.69475

SIMULATION MODEL WITH RENEGING

The simulation model considered in the previous sections assumes that the patient will wait as long as he/she is not served. In reality, a person is likely to hang up the call after waiting for some time. In our problem, the people calling are kidney patients for whom getting their queries answered is very important. So, they are likely to wait for more time on the phone than other people. Our guess is that the patients wait for at least 7 minutes before hanging up.

We assume that the time after which a patient hangs up is 7 minutes plus an exponential random variable with mean 2.

SIMULATION RESULTS FOR MULTILINGUAL EMPLOYEES

We take the multilingual employee configuration of Table 11 and run the simulation over a time period of 15000 minutes. Following are the results obtained:

Table 21: Simulation with Reneging: Waiting Time, Queue Length and Calls Reneged

	Avg Waiting Time (minutes)	**Max Waiting Time (minutes)**	**Std Dev Waiting Time (minutes)**	**Avg Calls Waiting**	**Std Dev Calls Waiting**	**Calls Reneged**
Hindi	0.285192	8.401626	0.895092	0.143889	0.587979	1
Bengali	0.568986	9.465184	1.283968	0.056975	0.257577	1
Marathi	0.725809	10.22284	1.536607	0.069823	0.299318	5
Kannada	0.656319	8.880989	1.41634	0.047342	0.234923	4
Malayalam	0.400136	7.984798	1.006716	0.014005	0.125175	0
Telugu	0.453091	7.19676	1.16638	0.031837	0.199861	1
Tamil	0.370699	7.506557	1.010389	0.028519	0.183557	1
English	0.061228	7.947291	0.426696	0.013025	0.152933	1

Total number of calls generated = 17568

Table 22: Simulation with Reneging: Employee Utilization

Employee No.	**Languages**	**Utilization**
0	English, Bengali, Hindi	67.63446
1	English, Bengali, Hindi	67.63797
2	English, Bengali, Hindi	67.62761
3	English, Bengali, Hindi	67.63014
4	English, Bengali, Hindi	67.6179
5	Malayalam, Telugu, Tamil, English	60.127
6	Malayalam, Telugu, Tamil, English	60.17554

7	Malayalam, Telugu, Tamil, English	60.14969
8	Malayalam, Telugu, Tamil, English	60.1667
9	Malayalam, Telugu, Tamil, English	60.13631
10	Marathi, Kannada, English, Hindi	67.66022
11	Marathi, Kannada, English, Hindi	67.65602
12	Marathi, Kannada, English, Hindi	67.66739
13	Marathi, Kannada, English, Hindi	67.66234
14	Marathi, Kannada, English, Hindi	67.62965

We observe that a total of 14 calls were lost out of 17568 which is quite less.

CALLS RENEGED VS. AVERAGE INTERARRIVAL TIME

The following figure shows the effect of average interarrival time between calls on the total number of calls reneged. The employee configuration is assumed to be the same as Table 11 and each simulation run is done for 15000 minutes.

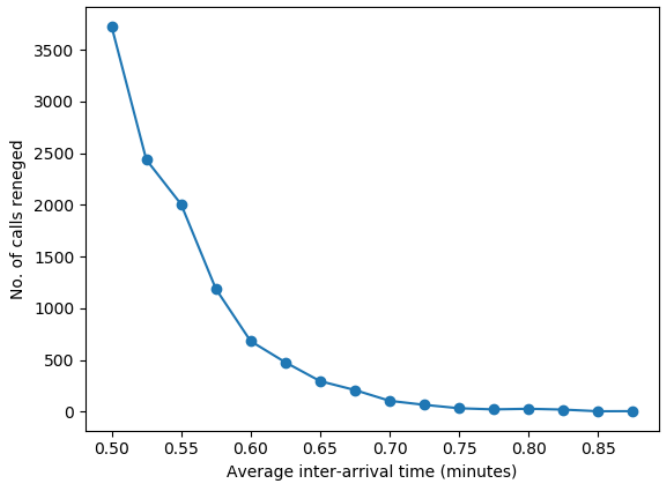


Figure 6: Effect of interarrival time on the total number of calls reneged

SUMMARY OF KEY LEARNINGS

- Simply relying on static analysis may lead to inefficient system, it is good have analysis backed by simulations
- Human resource is one of the most expensive resource, by some smart allocation of human resource and backing the effects by simulation we can reduce the cost.

REFERENCES

- Manish Kumar, Jyoti Bhat, “Discrete Event Monte-Carlo Simulation of Business Process for Capacity Planning: A Case Study”, Pacific Asia Conference on Information Systems (PACIS) Proceedings, 2009