T.C.
MARMARA UNIVERSITY
FACULTY OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE ENGINEERING

IE381/3081 - Modeling and Discrete Simulation

2019-2020 Fall

Tugay SARICI - 150119829
Oğuzhan BÖLÜKBAŞ – 150114022

- 07.12.2018 –

BARBER SHOP SIMULATION

In this Project, we have built a barber shop to simulate. We have two expert barbers and two barber apprentices to help them. Barbers cut hairs, beards and wash heads and apprentices blow-dry. System's time unit is minute based, and queueing system of the simulation is FIFO.

The Scenario: Firstly, customers come to the barber shop and they tell the receptionist what they want and get a number. If the part they want (haircut, beard cut, both or blow-dry) has an idle attendant then they go to directly this part of the saloon otherwise they wait in the lobby ("waiting" queue).

The two hairdressers are Ahmet and Mehmet. Ahmet is more experienced than Mehmet. Thus, customers prefer Mehmet if there is not queue for him. If there is, they go to the Ahmet. Even though Mehmet is more experienced, he is slower than Ahmet. In the blow-dry part, there are two apprentices for the first simulation and three for the second simulation.

Uncontrollable Input Parameters of the System: Arrival patterns of customers, number of customers that get service from Ahmet & Mehmet.

Interarrival Time (Minute)	Probability	Cumulative Probability
3	0.03	0.03
4	0.04	0.07
5	0.04	0.11
6	0.07	0.18
7	0.06	0.24
8	0.05	0.29
9	0.09	0.38
10	0.14	0.52
11	0.11	0.63
12	0.16	0.79
13	0.07	0.86
14	0.08	0.94
15	0.06	1.00

Table 1: Customers' Interarrival Times

Number of customers that get service from Ahmet/Mehmet varies with the occupations of them and the occupations varies depending on the service times which is randomly determined.

Cumulative Probability	Service Time (Ahmet)
0.05	8
0.15	12
0.25	16
0.5	25
0.7	29
0.85	33
0.95	38
1.0	42

Table 2: Ahmet's Service Time

Cumulative Probability	Service Time (Mehmet)
0.05	10
0.15	15
0.25	20
0.5	30
0.7	35
0.85	40
0.95	45
1.0	50

Table 3: Mehmet's Service Time

Cumulative Probability	Service Time (Apprentices)
0.1	4
0.25	4
0.4	6
0.6	6
0.75	7
0.85	7
0.95	8
1.0	8

Table 4: Apprentices' Service Times

Decision Input Parameters of the System: Number of hairdressers and apprentices

Output Parameters of the System: Number of customers waiting in the lobby, customers' average time spent in the system, utilizations of Ahmet, Mehmet, and apprentices.

After Running the System: Our system results for original model are as follows:

Seed values (n)	***Output 1 (Y_{n1})***	***Output 2 (Y_{n2})***	***Output 3 (Y_{n3})***	***Mean Value (Y_n)***
Seed value:1	(Y_{11}) = 25.441	(Y_{12}) = 27.52	(Y_{13}) = 5.653	(Y_1) = 19.538
Seed value:3	(Y_{21}) = 24.59	(Y_{22}) = 26.117	(Y_{23}) = 5.59	(Y_2) = 18.766
Seed value:5	(Y_{31}) = 25.787	(Y_{32}) = 27.659	(Y_{33}) = 5.792	(Y_3) = 19.746
Seed value:9	(Y_{41}) = 23.541	(Y_{42}) = 28.43	(Y_{43}) = 5.876	(Y_4) = 19.282
Seed value:12	(Y_{51}) = 24.256	(Y_{52}) = 29.426	(Y_{53}) = 5.998	(Y_5) = 19.893

Table 5: Total service times of the first experiment

Mean	**19.445**
Standard Deviation	**0.443724**
Variance	**0.196891**
Intervals (CI: 95%)	**19.455 ±0.55**
Standard Error	**0.198439**
Replication Estimation (H=0, z=1.96)	**53**

Table 6: Results of the first experiment

Count, N: 5
Sum, Σx: 97.225
Mean, x̄: 19.445
Variance, s^2: 0.196891

Steps

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

$$s^2 = \frac{\Sigma(x_i - \bar{x})^2}{N - 1}$$

$$= \frac{(19.538 - 19.445)^2 + ... + (19.893 - 19.445)^2}{5 - 1}$$

$$= \frac{0.787564}{4}$$

$$= 0.196891$$

$$s = \sqrt{0.196891}$$

$$= 0.4437240133236$$

Confidence Level	Margin of Error	Error Bar
95%, $1.960 s_{\bar{x}}$	19.445 ±0.389 (±2.00%)	

95% confidence intervals for the mean (of output parameters):

$Y \pm t_{\frac{\alpha}{2},n-1} \frac{S}{\sqrt{n}}$ *1-α = 0.05* $\alpha/2 = 0.025$

$$19.445 \pm 2.77645 \frac{0.443}{\sqrt{5}} = 19.455 \pm 0.55$$

- For - → 18.905
- For + → 20.005

The total number of replications needed to estimate mean output parameters :

CI = 90% *1-α = 0.1* $\alpha/2 = 0.05$ $Z_{0.05} = 1.64$

$$R \geq \left(\frac{Z_{0.05}\, S_0}{\varepsilon}\right)^2 = \frac{(1.64)^2 * (0.443)^2}{0.1^2} = 52.783$$

At least 53 replications are needed.

95% prediction intervals for the output parameters:

$$Y \pm t_{\frac{\alpha}{2},n-1} S \sqrt{1+\frac{1}{n}} \quad ||| \quad t_{\frac{\alpha}{2},n-1} = 2.77645 \quad ||| \quad S = 0.443 \quad ||| \quad 1+\frac{1}{n} = 1.095$$

$$19.445 \pm 2.77645 * 0.443 * \sqrt{1.095} = 19.445 \pm 1.34681$$

- For + → 20.79181
- For - → 18.09819

After Changing the System: Now, Ahmet is also more experienced than Mehmet, customers prefers firstly Ahmet than Mehmet. Our system results for new model are as follows:

Seed values (n)	***Output 1 (Y_{n1})***	***Output 2 (Y_{n2})***	***Output 3 (Y_{n3})***	***Mean Value (Y_n)***
Seed value:1	$(Y_{11}) = 23.076$	$(Y_{12}) = 29.836$	$(Y_{13}) = 5.563$	$(Y_1) = 19.492$
Seed value:3	$(Y_{21}) = 21.760$	$(Y_{22}) = 30.100$	$(Y_{23}) = 5.590$	$(Y_2) = 19.150$
Seed value:5	$(Y_{31}) = 23.405$	$(Y_{32}) = 29.808$	$(Y_{33}) = 5.792$	$(Y_3) = 19.669$
Seed value:9	$(Y_{41}) = 23.593$	$(Y_{42}) = 28.102$	$(Y_{43}) = 5.876$	$(Y_4) = 19.190$
Seed value:12	$(Y_{51}) = 24.319$	$(Y_{52}) = 29.464$	$(Y_{53}) = 5.998$	$(Y_5) = 19.927$

Table 7: Total service times of second experiment

Mean	**19.4856**
Standard Deviation	**0.32731**
Variance	**0.196891**
Intervals (CI: 95%)	**19.455 ±0.4064**
Standard Error	**0.14637**
Replication Estimation (H=0, z=1.96)	**23**

Table 8: Results of the second experiment

Count, N: 5
Sum, Σx: 97.428
Mean, x̄: 19.4856
Variance, s^2: 0.1071293

Steps

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

$$s^2 = \frac{\Sigma(x_i - \bar{x})^2}{N - 1}$$

$$= \frac{(19.492 - 19.4856)^2 + \ldots + (19.927 - 19.4856)^2}{5 - 1}$$

$$= \frac{0.4285172}{4}$$

$$= 0.1071293$$

$$s = \sqrt{0.1071293}$$

$$= 0.32730612582107$$

Confidence Level	Margin of Error	Error Bar
95%, 1.960$s_{\bar{x}}$	19.4856 ±0.287 (±1.47%)	

95% confidence intervals for the mean (of output parameters):

$Y \pm t_{\frac{\alpha}{2},n-1}\frac{S}{\sqrt{n}}$ *1-α = 0.05* $\alpha/2 = 0.025$

$$19.4856 \pm 2.77645\,\frac{0.32730}{\sqrt{5}} = 19.455 \pm 0.4064$$

- For - → 19.0486
- For + → 19. 8614

The total number of replications needed to estimate mean output parameters:

CI = 90% *1-α = 0.1* $\alpha/2 = 0.05$ *$Z_{0.05}$ = 1.64*

R$\geq (\frac{Z_{0.05}\,S_0}{\varepsilon})^{2}$ = $\frac{(1.64)^2*(0.3273)^2}{0.1^2}$*= 28.812*

At least 23 replications are needed.

95% prediction intervals for the output parameters:

$$Y \pm t_{\frac{\alpha}{2},n-1}S\sqrt{1+\frac{1}{n}} \quad ||| \quad t_{\frac{\alpha}{2},n-1} = 2.77645 \;|||\; S = 0.3273 \;|||\; 1+\frac{1}{n} = 1.095$$

$$19.4856 \pm 2.77645 * 0.3273 * \sqrt{1.095} = 19.445 \pm 0.9509$$

- For - → 18.4941
- For + → 20.3959

The additional replications needed to reduce the half-width of the confidence interval by 10% for the differences of the estimated values of the performance parameters:

CI = 80% *1-α = 0.2* $\alpha/2 = 0.1$ *$Z_{0.1}$ = 1.28*

R$\geq (\frac{Z_{0.1}\,S_0}{\varepsilon})^{2}$ = $\frac{(1.28)^2*(0.3273)^2}{0.1^2}$*= 17.551*

At least 18 replications are needed.