

Tutorial 4 Simulation by Hand

Question 1

Susan runs a pizza restaurant and each day she needs to decide how many orders of pizza ingredients to purchase from the wholesaler. The number of pizza sales each day is between 1 to 7, and the frequency distribution of pizza sales (X) is obtained using sales from previous 100 days:

Pizza Sales (X)	1	2	3	4	5	6	7
Number of days	5	12	16	25	20	16	6

In this question, you will design a SIMULATION BY HAND experiment over 10 days (i.e. 10 trials). The random numbers from 00-99 have already been generated in List 1 shown on the next page.

1. Calculate the cumulative probability based on historical data, assign the corresponding 2-digit random numbers and then fill in the following form.

Pizza Sales	Probability	Cumulative Probability	Random Number Assignment
1	0.05	0.05	01-05
2	0.12	0.17	06-17
3	0.16	0.33	18-33
4	0.25	0.58	34-58
5	0.20	0.78	59-78
6	0.16	0.94	79-94
7	0.06	1.00	95-00
Total	1		

2. Using simulation by hand, run a simulation with 10 trials/days to determine the number of pizza sales per day. Start from the top of random number List 1. What is the average pizza sales based on the simulation results?

10 Simulation trials; # of pizza sales per day

Day	Random Number	# of pizza sales
1	21	3
2	85	6
3	71	5
4	48	4
5	39	4
6	31	3
7	35	4
8	12	2
9	73	5
10	41	4

Average # of pizza sales: $(3+6+5+4+4+3+4+2+5+4)/10 = 4$

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3. Using an analytical technique, what is the theoretical average sales (or expected sales) per day?

Theoretical average sales (or expected sales) per day:

$$1*0.05+2*0.12+3*0.16+4*0.25+5*0.2+6*0.16+7*0.06 = 4.15$$

4. Suppose Susan orders 5 pizza ingredients on each day and makes all the ingredients into pizza at the beginning of the day (i.e., Pizza supply is fixed at 5 each day). Each pizza is sold for \$10, and unsold pizza will be donated to local charity and receive \$0. The cost of each pizza is \$5. How would you calculate the average profit over the 10-day period simulated in question 2?
Notes: Unsold pizza will bring \$0 revenue. In days of pizza shortages, customers will just switch to other pizza stores for purchasing pizza.

Day	Random Number	# of pizza sales	Cost	Revenue	Profit
1	21	3	25	30	5
2	85	6	25	50	25
3	71	5	25	50	25
4	48	4	25	40	15
5	39	4	25	40	15
6	31	3	25	30	5
7	35	4	25	40	15
8	12	2	25	20	-5
9	73	5	25	50	25
10	41	4	25	40	15

$$\text{Average Profit: } (5+25+25+15+15+5+15+(-5)+25+15)/10 = \$14$$

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Question 2

(a)

Data for Service Time			
Service Time (Minutes)	Probability (Frequency)	Cumulative Probability	Random Number Interval
0	0.00	0.00	(impossible)
1.0	0.25	0.25	01 to 25
2.0	0.20	0.45	26 to 45
3.0	0.40	0.85	46 to 85
4.0	0.15	1.00	86 to 00

Data for Customer Arrivals			
Time between Successive Customer Arrivals	Probability (Frequency)	Cumulative Probability	Random Number Interval
0	0.10	0.10	01 to 10
1.0	0.35	0.45	11 to 45
2.0	0.25	0.70	46 to 70
3.0	0.15	0.85	71 to 85
4.0	0.10	0.95	86 to 95
5.0	0.05	1.00	96 to 00

(b)

Customer Number	Random Number	Interval To Arrival	Time of Arrival	Random Number	Service Time	Start Service	End Service	Wait Time	Idle Time
1	50	2	9:02	52	3	9:02	9:05	0	2
2	28	1	9:03	37	2	9:05	9:07	2	0
3	68	2	9:05	82	3	9:07	9:10	2	0
4	36	1	9:06	69	3	9:10	9:13	4	0
5	90	4	9:10	98	4	9:13	9:17	3	0
6	62	2	9:12	96	4	9:17	9:21	5	0
7	27	1	9:13	33	2	9:21	9:23	8	0
8	50	2	9:15	50	3	9:23	9:26	8	0
9	18	1	9:16	88	4	9:26	9:30	10	0
10	36	1	9:17	90	4	9:30	9:34	13	0
11	61	2	9:19	50	3	9:34	9:37	15	0
12	21	1	9:20	27	2	9:37	9:39	17	0
13	46	2	9:22	45	2	9:39	9:41	17	0
14	01	0	9:22	81	3	9:41	9:44	19	0
15	14	1	9:23	66	3	9:44	9:47	21	0

(c) The drive-in window clearly does not meet the manager's criteria for an average wait time of 2 minutes. As a matter of fact, we can observe an increasing queue buildup after only a few customer simulations.

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Question 3

(a)

Time Between Generator Breakdown at Three Hills Power				
Time Between Recorded Machine Failures (Hours)	Number of Times Observed	Probability	Cumulative Probability	Random Number Assignment
0.5	5	0.05	0.05	01 to 05
1.0	6	0.06	0.11	06 to 11
1.5	16	0.16	0.27	12 to 27
2.0	33	0.33	0.6	28 to 60
2.5	21	0.21	0.81	61 to 81
3.0	19	0.19	1	82 to 00
Total	100	1		

Repair time required with two-person crews			
Repair Time Required (Hours)	Probability (Frequency)	Cumulative Probability	Random Number Assignment
0.5	0.28	0.28	01-28
1	0.52	0.8	29-80
1.5	0.2	1	81-00
Total	1		

Breakdown Number	Random Number	Time Between Breakdown (Hours)	Time of Breakdown	Time Repair-Person is Free to Begin This Repair	Random Number	Repair Time Required (Hours)	Time Repair Ends	No. Hours Machine Down
1	69	2.5	02:30	02:30	37	1	03:30	1
2	84	3	05:30	05:30	77	1	06:30	1
3	12	1.5	07:00	07:00	13	0.5	07:30	0.5
4	94	3	10:00	10:00	10	0.5	10:30	0.5
5	51	2	12:00	12:00	02	0.5	12:30	0.5
6	36	2	14:00	14:00	18	0.5	14:30	0.5
7	17	1.5	15:30	15:30	31	1	16:30	1
8	02	0.5	16:00	16:30	19	0.5	17:00	1
9	15	1.5	17:30	17:30	32	1	18:30	1
10	29	2	19:30	19:30	85	1.5	21:00	1.5
11	16	1.5	21:00	21:00	31	1	22:00	1
12	52	2	23:00	23:00	94	1.5	00:30	1.5
13	56	2	01:00	01:00	81	1.5	02:30	1.5
14	43	2	03:00	03:00	43	1	04:00	1
15	26	1.5	04:30	04:30	31	1	05:30	1
							Total	14.5

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- (b) Cost of labor hours
= 29.5 hours (00:00 hours on day 1 to 05:30 hours on day 2, 24 + 5.5 hours) X \$60/
hour (\$30 X 2) = \$1,770

Cost of machine downtime = 14.5 hours X \$75/ hour = \$1,087.5

Total maintenance cost = \$1,770 + \$1,087.5 = \$2,857.5

- (c) It is cheaper to hire the second worker each shift. Total cost with only one
repairperson was \$4,320.

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Question 4

(a)

Arrival Distribution	Probability	Cumulative Probability	Random Number Assignment
20 minutes early	0.2	0.2	01-20
10 minutes early	0.1	0.3	21-30
On time	0.4	0.7	31-70
10 minutes late	0.25	0.95	71-95
20 minutes late	0.05	1	96-00

Examination Time Distribution	Probability	Cumulative Probability	Random Number Assignment
20% faster than expected	0.15	0.15	01-15
In expected time	0.5	0.65	16-65
20% later than expected	0.25	0.9	66-90
40% later than expected	0.1	1	91-00

Patient	Random Number	Arrival Time (a.m.)	Random Number	Examination Length (Minutes)	Time In (a.m.)	Time Patient Leaves
Adams	60	9:30	80	18	9:30	9:48
Brown	08	9:25	45	20	9:48	10:08
Clark	19	9:55	86	18	10:08	10:26
Dannon	29	10:20	99	14	10:26	10:40
Edwards	36	10:45	02	24	10:45	11:09
Foster	72	11:25	34	15	11:25	11:40
Gray	30	11:20	87	24	11:40	12:04 p.m.
Harris	27	11:35	08	12	12:04 p.m.	12:16 p.m.

- (b) Dr. Coleman is 6 minutes late so he cannot make his flight. Since in this simulation, Patient Foster is late (11:25 a.m. arrive, 10 minutes late) and Dr. Coleman underestimated Gray's examination length (underestimated 4 minutes), Dr. Coleman cannot follow his flight schedule.