

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			
2			
3			
4			
5			
6			
7			
Total			

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

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List 1 – Random numbers to determine the number of pizza sales. Start from the top of the list. There may be more random numbers than you need.

21
85
71
48
39
31
35
12
73
41
31
97
78
94
66
74
90
95
29
72

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Question 2

The manager of a bank in North Carolina, is attempting to determine how many tellers are needed at the drive-in window during peak times. As a general policy, the manager wishes to offer service such that average customer waiting time does not exceed 2 minutes.

Data for Service Time	
Service Time (Minutes)	Probability (Frequency)
0	0
1.0	0.25
2.0	0.2
3.0	0.4
4.0	0.15

Data for Customer Arrivals	
Time between Successive Customer Arrivals	Probability (Frequency)
0	0.10
1.0	0.35
2.0	0.25
3.0	0.15
4.0	0.10
5.0	0.05

List 2 – Random numbers to determine the time of customer arrival. Start from the top of the list. There may be more random numbers than you need.

50
28
68
36
90
62
27
50
18
36
61
21
46
01
14
81
87
72
80
46

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List 3 – Random numbers to determine the service time. Start from the top of the list. There may be more random numbers than you need.

52
37
82
69
98
96
33
50
88
90
50
27
45
81
66
74
30
59
67
60

- (a) Calculate the cumulative probability based on above data tables (Service Time & Customer Arrivals), assign the corresponding 2-digit random numbers and then fill in the following two forms.

Data for Service Time			
Service Time (Minutes)	Probability (Frequency)	Cumulative Probability	Random Number Assignment
0	0.00		
1.0	0.25		
2.0	0.20		
3.0	0.40		
4.0	0.15		

Data for Customer Arrivals			
Time between Successive Customer Arrivals	Probability (Frequency)	Cumulative Probability	Random Number Assignment
0	0.10		
1.0	0.35		
2.0	0.25		
3.0	0.15		
4.0	0.10		
5.0	0.05		

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- (b) Assume the bank will open at 9:00 am and there is only one teller available, fill in the following form to design a SIMULATION BY HAND experiment over 15 customers (i.e. 15 trials).

Customer Number	Random Number	Interval To Arrival	Time of Arrival	Random Number	Service Time	Start Service	End Service	Wait Time	Idle Time

- (c) Given the existing service level, does the drive-in window meet this criterion?

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Question 3

The Three Hills Power Company provides electricity to a large metropolitan area through a series of almost 200 hydroelectric generators. Management recognizes that even a well-maintained generator will have periodic failures or breakdowns. As expensive as the maintenance staff salaries are, breakdown expenses are even higher. For each hour that one of its generators is down, Three Hills loses approximately \$75. Stephanie Robbins is the Three Hills Power Company management analyst assigned to simulate maintenance costs. Robbins identifies two important maintenance system components. First, the time between successive generator breakdowns varies historically from as little as 0.5 hour to as much as 3 hours. For the past 100 breakdowns, she tabulates the frequency of various times between machine failures:

Time Between Generator Breakdown at Three Hills Power		
Time Between Recorded Machine Failures (Hours)	Number of Times Observed	Probability
0.5	5	0.05
1.0	6	0.06
1.5	16	0.16
2.0	33	0.33
2.5	21	0.21
3.0	19	0.19
Total	100	1

The simulation of 15 generator breakdowns and the repair times required when one repairperson was on duty per shift. The total simulated maintenance cost of the previous system was \$4,320. Robbins would now like to examine the relative cost-effectiveness of adding one more repairing worker per shift. Each new repairperson would be paid \$30 per hour, the same rate as the first is paid. Robbins makes one vital assumption as she begins—that repair times with two repairing workers will be exactly one-half the times required with only one repairperson on duty per shift. In the following table, she performs a statistical analysis of past repair times:

Repair time required with two-person crews	
Repair Time Required (Hours)	Probability
0.5	0.28
1	0.52
1.5	0.2
Total	1

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List 4 – Random numbers to determine the time between breakdowns. Start from the top of the list. There may be more random numbers than you need.

69
84
12
94
51
36
17
02
15
29
16
52
56
43
26
22
08
62
40
67

List 5 – Random numbers to determine the required time of generator repair. Start from the top of the list. There may be more random numbers than you need.

37
77
13
10
02
18
31
19
32
85
31
94
81
43
31
58
33
51
29
11

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- (a) Assume the first day begins at midnight (00:00 hours), fill in the following three tables to design a SIMULATION BY HAND proposed maintenance system change over a 15-generator breakdown period. Select the random numbers needed for time between breakdowns from List 4. Select random numbers for generator repair times from List 5.

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		
1.0	6	0.06		
1.5	16	0.16		
2.0	33	0.33		
2.5	21	0.21		
3.0	19	0.19		
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		
1	0.52		
1.5	0.2		
Total			

[illegible]

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- (b) Calculate the cost of labor hours and cost of machine downtime. Measure the simulated total maintenance cost.
- (c) Should Three Hills add a second repairperson each shift?

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Question 4

Dr. Mark Coleman is a dentist who owns his dental clinic. Coleman tries hard to schedule appointments so that patients do not have to wait beyond their appointment time. His October-20th schedule is shown in the following table.

Patient Name	Scheduled Appointment Time	Expected Time Needed
Adams	9:30 a.m.	15
Brown	9:45 a.m.	20
Clark	10:15 a.m.	15
Dannon	10:30 a.m.	10
Edwards	10:45 a.m.	30
Foster	11:15 a.m.	15
Gray	11:30 a.m.	20
Harris	11:45 a.m.	15

Unfortunately, not every patient arrives exactly on schedule, and expected times to examine patients are just that—expected. Some examinations take longer than expected, and some take less time.

Greenberg's experience dictates the following:

- (a) 20% of the patients will be 20 minutes early.
- (b) 10% of the patients will be 10 minutes early.
- (c) 40% of the patients will be on time.
- (d) 25% of the patients will be 10 minutes late.
- (e) 5% of the patients will be 20 minutes late.

He further estimates that

- (a) 15% of the time he will finish in 20% less time than expected.
- (b) 50% of the time he will finish in the expected time.
- (c) 25% of the time he will finish in 20% more time than expected.
- (d) 10% of the time he will finish in 40% more time than expected.

List 6 – Random numbers to determine the patients' arrival time. Start from the top of the list. There may be more random numbers than you need.

60
08
19
29
36
72
30
27
50
64

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List 7 – Random numbers to determine the examination time. Start from the top of the list. There may be more random numbers than you need.

80
45
86
99
02
34
87
08
86
84

- (a) Assume that Dr. Coleman is ready to start his workday at 9:30 a.m. and that patients are treated in order of their scheduled exam, fill in the following forms to design a SIMULATION BY HAND.

Arrival Distribution	Probability	Cumulative Probability	Random Number Assignment

Examination Time Distribution	Probability	Cumulative Probability	Random Number Assignment

Patient	Random Number	Arrival Time (a.m.)	Random Number	Examination Length (Minutes)	Time In (a.m.)	Time Patient Leaves

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- (b) Dr. Coleman has to leave at 12:10 p.m. on October 20 to catch a flight to a dental convention in New York, otherwise he will miss his flight. Will he be able to make the flight? Comment on this simulation and explain what factor contributes to this situation? *(Hint: did patient(s) arrive on time? Is the estimated examination time accurate?)*