Chapter 16—Simulation

MULTIPLE CHOICE

1. A simulation model uses the mathematical expressions and logical relationships of the
   a. real system.
   b. computer model.
   c. performance measures.
   d. estimated inferences.

   ANS: A PTS: 1 TOP: Introduction

2. Values for the probabilistic inputs to a simulation
   a. are selected by the decision maker.
   b. are controlled by the decision maker.
   c. are randomly generated based on historical information.
   d. are calculated by fixed mathematical formulas.

   ANS: C PTS: 1 TOP: Introduction

3. A quantity that is difficult to measure with certainty is called a
   a. risk analysis.
   b. project determinant.
   c. probabilistic input.
   d. profit/loss process.

   ANS: C PTS: 1 TOP: Risk analysis

4. A value for probabilistic input from a discrete probability distribution
   a. is the value given by the RAND() function.
   b. is given by matching the probabilistic input with an interval of random numbers.
   c. is between 0 and 1.
   d. must be non-negative.

   ANS: B PTS: 1 TOP: Simulation approach

5. The number of units expected to be sold is uniformly distributed between 300 and 500. If r is a random number between 0 and 1, then the proper expression for sales is
   a. $200(r)$
   b. $r + 300$
   c. $300 + 500(r)$
   d. $300 + r(200)$

   ANS: D PTS: 1 TOP: Simulation approach

6. When events occur at discrete points in time
   a. a simulation clock is required.
   b. the simulation advances to the next event.
   c. the model is a discrete-event simulation.
   d. All of the alternatives are correct.

   ANS: D PTS: 1 TOP: Discrete-event simulation

7. If customer 2 has a service time of 1.6, and if customer 3 has an interarrival time of 1.1 and a service time of 2.3, when will customer 3's service be completed?
   a. 5.0
   b. 3.9
   c. 3.4
   d. There is not enough information to answer.

   ANS: D PTS: 1 TOP: Waiting line simulation

8. Common features of simulations--generating values from probability distributions, maintaining records, recording data and summarizing results--led to the development of
   a. Excel and Lotus.
   b. BASIC, FORTRAN, PASCAL, and C.
   c. GPSS, SIMSCRIPT, SLAM, and Arena
   d. LINGO and The Management Scientist

   ANS: C PTS: 1 TOP: Computer implementation

9. In order to verify a simulation model
   a. compare results from several simulation languages.
   b. be sure that the procedures for calculations are logically correct.
   c. confirm that the model accurately represents the real system.
   d. run the model long enough to overcome initial start-up results.

   ANS: B PTS: 1 TOP: Verification and validation

10. Simulation
    a. does not guarantee optimality.
    b. is flexible and does not require the assumptions of theoretical models.
    c. allows testing of the system without affecting the real system.
    d. All of the alternatives are correct.

    ANS: D PTS: 1 TOP: Advantages and disadvantages

11. A simulation model used in situations where the state of the system at one point in time does not affect the state of the system at future points in time is called a
    a. dynamic simulation model.
    b. static simulation model.
    c. steady-state simulation model.
    d. discrete-event simulation model.

    ANS: B PTS: 1 TOP: Static simulation models

12. The process of determining that the computer procedure that performs the simulation calculations is logically correct is called
    a. implementation.
    b. validation.
    c. verification.
    d. repetition.

    ANS: C PTS: 1 TOP: Other simulation issues

13. Numerical values that appear in the mathematical relationships of a model and are considered known and remain constant over all trials of a simulation are
    a. parameters.
    b. probabilistic input.

c. controllable input.
d. events.

ANS: A PTS: 1 TOP: Other simulation issues

14. Which of the following statements is incorrect regarding the disadvantages of simulation?
a. Each simulation run only provides a sample of how the real system will operate.
b. The summary of the simulation data only provides estimates about the real system.
c. The process of developing a simulation model of a complex system can be time-consuming.
d. The larger the number of probabilistic inputs a system has, the less likely a simulation will provide the best approach for studying the system.

ANS: D PTS: 1 TOP: Advantages and disadvantages of using simulation

15. Which of the following statements is incorrect regarding the advantages of simulation?
a. Simulation is relatively easy to explain and understand.
b. Simulation guarantees an optimal solution.
c. Simulation models are flexible.
d. A simulation model provides a convenient experimental laboratory for the real system.

ANS: B PTS: 1 TOP: Advantages and disadvantages of using simulation

16. The word *uniform* in the term *uniform random numbers* means
a. all the numbers have the same number of digits.
b. if one number is, say, 10 units above the mean, the next number will be 10 units below the mean.
c. all the numbers are odd or all are even.
d. each number has an equal probability of being drawn.

ANS: D PTS: 1
TOP: Random numbers and generating probabilistic input values

17. A table of uniformly distributed random numbers should be read
a. from left to right.
b. from top to bottom.
c. diagonally, starting from the top left corner and moving to the bottom right.
d. in any consistent sequence.

ANS: D PTS: 1
TOP: Random numbers and generating probabilistic input values

18. The process of generating probabilistic inputs and computing the value of the output is called
a. simulation.
b. verification.
c. validation.
d. implementation.

ANS: A PTS: 1 TOP: Simulation

19. A graphical tool that helps describe the logic of the simulation model is a
a. Gantt chart
b. histogram
c. flowchart
d. stem-and-leaf display

ANS: C PTS: 1 TOP: Simulation

TRUE/FALSE

1. Simulation is an excellent technique to use when a situation is too complicated to use standard analytical procedures.

   ANS: T PTS: 1 TOP: Introduction

2. Simulation is a trial-and-error approach to problem solving.

   ANS: T PTS: 1 TOP: Introduction

3. The degree of risk is associated with the probability or magnitude of loss.

   ANS: T PTS: 1 TOP: Simulation approach

4. To use Excel to generate a normally distributed random variable, you must know the mean and standard deviation of the distribution and have a random number between 0 and 1.

   ANS: T PTS: 1 TOP: Simulation approach

5. Trials of a simulation show what would happen when values of the probabilistic input change.

   ANS: T PTS: 1 TOP: Simulation approach

6. In a Monte Carlo simulation, each simulation trial is dependent upon the result of a previous trial.

   ANS: F PTS: 1 TOP: Monte Carlo simulation

7. Verification is the process of ensuring that the simulation model provides an accurate representation of the real system.

   ANS: F PTS: 1 TOP: Verification and validation

8. In comparing different policies using simulation, one should use the same set of random numbers whenever possible.

   ANS: T PTS: 1 TOP: Waiting line simulation

9. Validation determines that the computer procedure is operating as it is intended to operate.

   ANS: F PTS: 1 TOP: Verification and validation

10. A discrete-event simulation reviews the status of the system periodically, whether or not an event occurs.

    ANS: T PTS: 1 TOP: Waiting line simulation

11. A static simulation model is used in situations where the state of the system affects how the system changes or evolves over time.

    ANS: F PTS: 1 TOP: Waiting line simulation

12. For any waiting line system, (Average number of units in waiting line) = (Total waiting time) divided by (Total time of simulation).

    ANS: T PTS: 1 TOP: Waiting line simulation

13. The parameters of a simulation model are the controllable inputs.

    ANS: F PTS: 1 TOP: Controllable inputs

14. Using simulation to perform risk analysis is like playing out many what-if scenarios by randomly generating values for the probabilistic inputs.

    ANS: T PTS: 1 TOP: Risk analysis

15. Computer-generated random numbers are normally distributed over the interval from 0 to 1.

    ANS: F PTS: 1
    TOP: Random numbers and generating probabilistic input values

16. Computer-generated random numbers are not technically random.

    ANS: T PTS: 1
    TOP: Random numbers and generating probabilistic input values

17. Simulation is an optimization technique.

    ANS: F PTS: 1 TOP: Introduction

18. Simulation models that must take into account how the system changes or evolves over time are referred to as dynamic simulation models.

    ANS: T PTS: 1 TOP: Waiting line simulation

19. Computer-generated random numbers are normally distributed.

    ANS: F PTS: 1
    TOP: Random numbers and generating probabilistic input values

20. Each simulation run provides only a sample of how the real system will operate.

    ANS: T PTS: 1 TOP: Advantages and disadvantages of using simulation

21. One disadvantage of simulation is that it is limited in the variety of probability distributions that can be used in modeling a system.

    ANS: F PTS: 1 TOP: Simulation

22. A simulation model provides a convenient experimental laboratory for the real system.

    ANS: T PTS: 1 TOP: Advantages and disadvantages of using simulation

23. Simulation allows the user to specify certain desired results (for example, profit or service level values), and then the necessary model parameters and operating policies are determined.

ANS: F PTS: 1 TOP: Inventory simulation

SHORT ANSWER

1. Simulation is to be used to study customer waiting patterns at several branches of an organization. Acknowledging that arrivals and service times follow different distributions over the branches, of what use is the development of a general simulation model?

   ANS:
   Answer not provided.

   PTS: 1 TOP: Advantages and disadvantages

2. Why would one want to use a general purpose programming language rather than a spreadsheet to develop a simulation?

   ANS:
   Answer not provided.

   PTS: 1 TOP: Computer implementation

3. How are both analysts and managers involved in the validation process?

   ANS:
   Answer not provided.

   PTS: 1 TOP: Verification and validation

4. How can historical information be used to create discrete probability distributions?

   ANS:
   Answer not provided.

   PTS: 1 TOP: Simulation approach

5. Why is a flowchart useful in simulation?

   ANS:
   Answer not provided.

   PTS: 1 TOP: Simulation approach

6. Explain the difference between verification and validation as they relate to a simulation model.

   ANS:
   Answer not provided.

   PTS: 1 TOP: Simulation approach

PROBLEM

1. For the past 50 days, daily sales of laundry detergent in a large grocery store have been recorded (to the nearest 10).

Units Sold	Number of Times
30	8
40	12
50	15
60	10
70	5

a. Determine the relative frequency for each number of units sold.
b. Suppose that the following random numbers were obtained using Excel:

.12 .96 .53 .80 .95 .10 .40 .45 .77 .29

Use these random numbers to simulate 10 days of sales.

ANS:

a.

Units Sold	Relative Frequency	Cumulative Frequency	Interval of Random Numbers
30	.12	.12	0.00 but less than 0.12
40	.24	.36	0.12 but less than 0.36
50	.32	.68	0.36 but less than 0.68
60	.26	.94	0.68 but less than 0.94
70	.06	1.00	0.94 but less than 1.00

b.

Random Number	Units Sold
.12	40
.96	70
.53	50
.80	60
.95	70
.10	30
.40	50
.45	50
.77	60
.29	40

PTS: 1 TOP: Simulation approach: discrete-event

2. The drying rate in an industrial process is dependent on many factors and varies according to the following distribution.

Minutes	Relative Frequency
3	.14
4	.30
5	.27
6	.18
7	.11

a. Compute the mean drying time.
b. Using these random numbers, simulate the drying time for 12 processes.

.33 .09 .19 .81 .12 .88 .53 .95 .77 .61 .91 .47

c. What is the average drying time for the 10 processes you simulated?

ANS:

a. 4.82

b.

Random Number	Drying Time
.33	4
.09	3
.19	4
.81	6
.12	3
.88	6
.53	5
.95	7
.77	6
.61	5
.91	7
.47	5

c. The average is 5.083

PTS: 1 TOP: Simulation approach: discrete-event

3. Greenfields is a mail order seed and plant business. The size of orders is uniformly distributed over the interval from $25 to $80. Use the following random numbers to generate the size of 10 orders.

.41 .99 .07 .05 .38 .77 .19 .12 .58 .60

ANS:

Random Number	Order Size
0.41	47.55
0.99	79.45
0.07	28.85
0.05	27.75
0.38	45.90
0.77	67.35
0.19	35.45
0.12	31.60
0.58	56.90
0.60	58.00

PTS: 1 TOP: Simulation approach: uniform distribution

4. The time required to set up lighting for a portrait studio is uniformly distributed between 12 and 20 minutes. Use the following random numbers to generate the setup time for 10 customers.

.27 .53 .06 .92 .16 .74 .06 .29 .82 .23

ANS:

Random Number	Time
0.27	14.16
0.53	16.24
0.06	12.48
0.92	19.36
0.16	13.28
0.74	17.92
0.06	12.48
0.29	14.32
0.82	18.56
0.23	13.84

PTS: 1 TOP: Simulation approach: uniform distribution

5. Estimates of the financial information for a new product show the following information:

Units Sold	Probability
600	.35
800	.45
1000	.20

Fixed cost	$8,000
Variable cost	$6 / unit
Revenue	$22 / unit

Use the random numbers .51, .97, .58, .22, and .16 to simulate five trials. What is the net profit for each trial?

ANS:

Trial	1	2	3	4	5
Random Number	0.51	0.97	0.58	0.22	0.16
Units sold	800	1000	800	600	600
Revenue	17600	22000	17600	13200	13200
Variable cost	4800	6000	4800	3600	3600
Fixed cost	8000	8000	8000	8000	8000
Net Profit	4800	8000	4800	1600	1600

PTS: 1 TOP: Simulation approach: profit

6. Seventy-five percent of calls arriving at a help line can be handled by the person who answers the phone, but the remaining 25% of them will need to be referred to someone else. Assume that every call requires one minute of attention by the person who answers the phone (either to answer the question or to figure out how the referral should be handled). Calls that are referred need an additional amount of time, as given in the table below.

Time Required	Probability
3 minutes	.25
5 minutes	.35
10 minutes	.40

Callers are served on a first come, first served basis, and are put on hold until the line is free. Use the random numbers to simulate what happens to 10 callers. (Use the random numbers in order - from left to right, first row first - as you need them.) What percentage of your callers needs to be referred? Of those who had to be referred, what is the average referral time?

.82 .39 .16 .79 .56 .62 .13 .04 .42 .81
.85 .32 .64 .90 .73 .02 .76 .03 .86 .67

ANS:

Call	RN	Referred?	RN	Time
1	0.82	yes	0.39	5
2	0.16	no		
3	0.79	yes	0.56	5
4	0.62	no		
5	0.13	no		
6	0.04	no		
7	0.42	no		
8	0.81	yes	0.85	10
9	0.85	yes	0.32	5
10	0.64	no		

40% of the callers were referred. The average referral time was 6.25 minutes.

PTS: 1 TOP: Simulation approach: two events

7. An airline reservation system first asks customers whether they want to schedule a domestic or an international flight. Sixty-five percent of the reservations are for domestic flights. The time distribution of advance sales is also important, and it is given below.

Domestic Flights		
Make Reservations	Rel. Freq.	RN Range
Less than 1 week in advance	.25	
1 week to 2 months in advance	.35	
Over 2 months in advance	.40	

International Flights		
Make Reservations	Rel. Freq.	RN Range
Less than 1 week in advance	.12	
1 week to 2 months in advance	.35	
2 months to 6 months in advance	.40	
Over 6 months In advance	.13	

Flight Type	Rel. Freq.	RN Range
Domestic	.65	
International	.35	

a. Place the appropriate random number ranges in the tables above.
b. Set up and perform a simulation for three customers. Determine whether they want a domestic or international flight, and how far in advance the reservation is being made. Use random numbers from this list: .632 .715 .998 .671 .744 .021

ANS:

a.

Domestic Flights		
Make Reservations	Rel. Freq.	RN Range
Less than 1 week in advance	.25	.00 to < .25
1 week to 2 months	.35	.25 to < .60

International Flights		
Make Reservations	Rel. Freq.	RN Range
Less than 1 week in advance	.12	.00 to < .12
1 week to 2 months	.35	.12 to < .47

in advance		
Over 2 months In advance	.40	.6 to < 1.00

in advance		
2 months to 6 months in advance	.40	.47 to < .87
Over 6 months In advance	.13	.87 to < 1.00

Flight Type	Rel. Freq.	RN Range
Domestic	.65	.00 to < .65
International	.35	.65 to < 1.00

b.

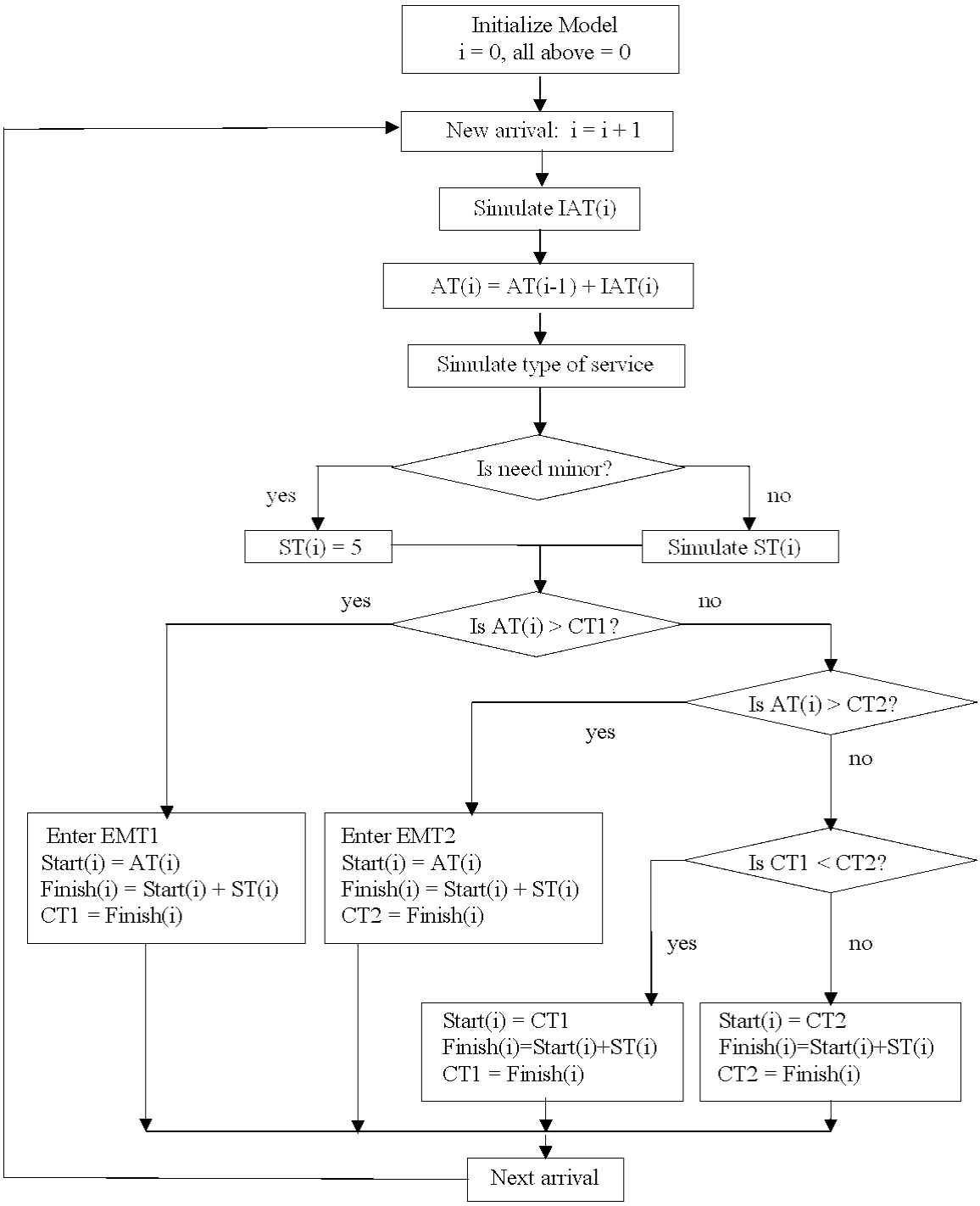
Observation	RN	Flight Type	RN	Booking
1	.632	Domestic	.715	Over 2 months
2	.998	International	.671	2 to 6 months
3	.774	International	.021	Less than 1 week

PTS: 1 TOP: Simulation approach: two events

8. On a visit to an amusement park you pass someone who has just ridden a roller coaster and asks you for directions to the First Aid Station. Realizing that traffic at the First Aid Station would be something to study with simulation, you gather some information. Two EMTs staff the station, and patients wait and go to the first one available. People coming there can be divided into two groups: those who need something minor (e.g. Tylenol, a band-aid) or those who need more help. Assume those in the first group constitute 25% of the patients and take 5 minutes to have their problem solved. Those in the second group need an uncertain amount of time, as given by a probability distribution. Develop a flowchart for this simulation problem.

ANS:

Let i = patient counter
AT(i) = arrival time
IAT(i) = interarrival time
Start(i) = time patient i begins service
ST(i) = service time
Finish(i) = time patient leaves
CT1 = time that EMT 1 completes current service
CT2 = time that EMT 2 completes current service



PTS: 1 TOP: Simulation flowchart

9. Using the spreadsheet below, give the cell address which would have the formula shown.

Cell Formula	Belongs in Cell
=VLOOKUP(B18,$B$10:$C$12,2)	
=VLOOKUP(D23,$F$11:$G$14,2)	
=K19*($I$16-I19)	
=VLOOKUP(H27,$B$10:$C$12,2)	
=AVERAGE(L18:L27)	

	A	B	C	D	E	F	G	H	I	J	K	L
1	Argosy Incorporated											
2	New Product Simulation											
3		Argosy is making a new product and is uncertain about two events: the cost of the product,										
4		and the demand for the product. Argosy will use simulation to see the affect of varying										
5		the selling price. Demand depends on price. Cost will not affect selling price.										
6												
7												
8		**Distribution of Cost**				**Distribution of Demand**						
9		MinProb	Cost			When price is $20			When price is $25			
10		0	8			MinProb	Demand		MinProb	Demand		
11		0.35	10			0	5000		0	5000		
12		0.75	15			0.2	8000		0.3	8000		
13						0.55	10000		0.75	10000		
14						0.85	18000		0.9	18000		
15												
16	For selling price of		20				For selling price of		25			
17	Trial	RN	Unit cost	RN	Demand	Profit	Trial	RN	Unit cost	RN	Demand	Profit
18	1	0.8474	15	0.9559	18000	90000	1	0.7241	10	0.6481	8000	120000
19	2	0.4034	10	0.1144	5000	50000	2	0.8654	15	0.7253	8000	80000
20	3	0.2712	8	0.5127	8000	96000	3	0.0732	8	0.5681	8000	136000
21	4	0.7370	10	0.0627	5000	50000	4	0.5631	10	0.9745	18000	270000
22	5	0.4245	10	0.9173	18000	180000	5	0.6018	10	0.5556	8000	120000
23	6	0.1009	8	0.6462	10000	120000	6	0.1099	8	0.0987	5000	85000
24	7	0.2879	8	0.3423	8000	96000	7	0.6103	10	0.1906	5000	75000
25	8	0.3713	10	0.8377	10000	100000	8	0.2107	8	0.4779	8000	136000
26	9	0.2440	8	0.7518	10000	120000	9	0.0298	8	0.3279	8000	136000
27	10	0.6109	10	0.5009	8000	80000	10	0.2886	8	0.7981	10000	170000
28				Average Profit is		98200				Average Profit is		132800
29												

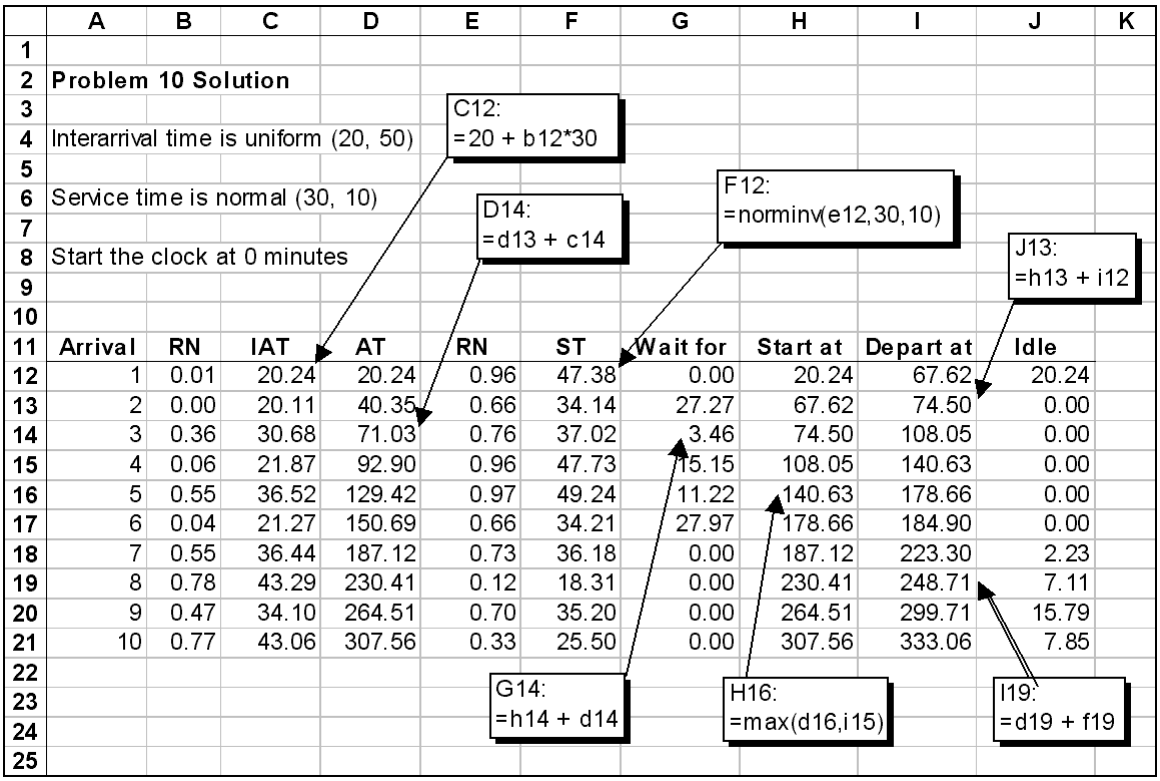
ANS:

Cell Formula	Belongs in Cell
=VLOOKUP(B18,$B$10:$C$12,2)	C18
=VLOOKUP(D23,$F$11:$G$14,2)	E23
=K19*($I$16-I19)	L19
=VLOOKUP(H27,$B$10:$C$12,2)	I27
=AVERAGE(L18:L27)	L28

PTS: 1 TOP: Simulation with Excel

10. Arrivals to a truck repair facility have an interarrival time that is uniformly distributed between 20 and 50 minutes. Service times are normally distributed with mean 30 minutes and standard deviation 10 minutes. Develop a spreadsheet model to simulate the arrival of 100 trucks. Collect information on the time the repair facility is idle and on the average waiting time for trucks.

ANS:
Representative formulas for cell references are shown in comments.



	A	B	C	D	E	F	G	H	I	J
11	Arrival	RN	IAT	AT	RN	ST	Wait for	Start at	Depart at	Idle
12	1	0.01	20.24	20.24	0.96	47.38	0.00	20.24	67.62	20.24
13	2	0.00	20.11	40.35	0.66	34.14	27.27	67.62	74.50	0.00
14	3	0.36	30.68	71.03	0.76	37.02	3.46	74.50	108.05	0.00
15	4	0.06	21.87	92.90	0.96	47.73	15.15	108.05	140.63	0.00
16	5	0.55	36.52	129.42	0.97	49.24	11.22	140.63	178.66	0.00
17	6	0.04	21.27	150.69	0.66	34.21	27.97	178.66	184.90	0.00
18	7	0.55	36.44	187.12	0.73	36.18	0.00	187.12	223.30	2.23
19	8	0.78	43.29	230.41	0.12	18.31	0.00	230.41	248.71	7.11
20	9	0.47	34.10	264.51	0.70	35.20	0.00	264.51	299.71	15.79
21	10	0.77	43.06	307.56	0.33	25.50	0.00	307.56	333.06	7.85

PTS: 1 TOP: Spreadsheet simulation, uniform and normal distributions

11. As the owner of a rent-a-car agency you have determined the following statistics:

Potential Rentals Daily	Probability	Rental Duration	Probability
0	.10	1 day	.50
1	.15	2 day	.30
2	.20	3 days	.15
3	.30	4 days	.05
4	.25		

The gross profit is $40 per car per day rented. When there is demand for a car when none is available there is a goodwill loss of $80 and the rental is lost. Each day a car is unused costs you $5 per car. Your firm initially has 4 cars.

a. Conduct a 10-day simulation of this business using Row #1 below for demand and Row #2 below for rental length.

Row #1:	63	88	55	46	55	69	13	17	36	81
Row #2:	59	09	57	87	07	92	29	28	64	36

b. If your firm can obtain another car for $200 for 10 days, should you take the extra car?

ANS:

a. 10-day profit is $885

b. 10-day profit is $970. Take the extra car.

PTS: 1 TOP: Simulation approach: two events

12. Susan Winslow has two alternative routes to travel from her home in Olport to her office in Lewisburg. She can travel on Freeway 5 to Freeway 57 or on Freeway 55 to Freeway 91. The time distributions are as follows:

Freeway 5		Freeway 57		Freeway 55		Freeway 91	
Time	Relative Frequency	Time	Relative Frequency	Time	Relative Frequency	Time	Relative Frequency
5	.30	4	.10	6	.20	3	.30
6	.20	5	.20	7	.20	4	.35
7	.40	6	.35	8	.40	5	.20
8	.10	7	.20	9	.20	6	.15
		8	.15				

Do a five-day simulation of each of the two combinations of routes using the random numbers below. Based on this simulation, which routes should Susan take if her objective is to minimize her total travel time?

Freeway 5	63	88	55	46	55
Freeway 57	59	09	57	87	07
Freeway 55	71	95	83	44	34
Freeway 91	51	79	09	67	15

ANS:
Freeways 5-57 have 62 minutes; Freeways 55-91 have 61 minutes; Select 55-91.

PTS: 1 TOP: Simulation approach: multiple events

13. Three airlines compete on the route between New York and Los Angeles. Stanton Marketing has performed an analysis of first class business travelers to determine their airline choice. Stanton has modeled this choice as a Markov process and has determined the following transition probabilities.

	Next Airline		
Last Airline	A	B	C
A	.50	.30	.20
B	.30	.45	.25
C	.10	.35	.55

a. Show the random number assignments that can be used to simulate the first class business traveler's next airline when her last airline is A, B, and C.
b. Assume the traveler used airline C last. Simulate which airline the traveler will be using over her next 25 flights. What percent of her flights are on each of the three airlines? Use the following random numbers, going from left to right, top to bottom.

71	95	83	44	34
49	88	56	05	39
75	12	03	59	29
77	76	57	15	53
37	46	85	24	53

ANS:

a.

A Last		B Last		C Last	
	RNs		RNs		RNs
A Next	00 - 49	A Next	00 - 29	A Next	00 - 09
B Next	50 - 79	B Next	30 - 74	B Next	10 - 44
C Next	80 - 99	C Next	75 - 99	C Next	45 - 99

b. 20% of flights on Airline A
48% of flights on Airline B
32% of flights on Airline C

PTS: 1 TOP: Dynamic simulation models

14. Attendees at the National Management Science Society (NMSS) Conference register by first standing in line to pay their fees. They then proceed to a designated line based on the first letter of their last name to collect their conference materials.

At the conference, it is planned to have three different parallel lines for the collection of materials: one each for people whose last names begin with A-H, I-Q, and R-Z respectively.

During each minute of the morning registration period it is anticipated that attendees will arrive to pay their fees according to the following distribution:

Number of Arrivals	Probability
0	.30
1	.30
2	.30
3	.10

The time to pay one's fees is either one minute or two minutes depending upon whether one uses a check or credit card. The probability of a one-minute time is .60.

After paying his fees, an attendee then goes to the correct line for the conference materials. At this year's conference 35% of the attendees have last names beginning with A-H, 36% with last names beginning with I-Q, and 29% with last names beginning with R-Z. The time required to pick up conference materials is fixed at 2 minutes.

a. Simulate the waiting line for the first 10 minutes of the morning registration that begins at 8:00 AM. Use the following random numbers to generate:

Number of arrivals in any given minute: 71, 95, 83, 44, 34, 49, 88, 56, 05, 39
Registration fee service time: 51, 79, 09, 67, 15, 58, 04, 78, 30, 56
First letter of the last name: 15, 08, 19, 45, 76, 42, 38, 47, 82, 37

b. What is the average size of the waiting line to pay fees (not including the person being served), and the average customer waiting time to pay fees based on this simulation?

ANS:
a.

ARRIVALS			FEE PAY				CONFERENCE MATERIAL			
Time	RN	# Q	I	Wait	Begin	RN	Time	End	RN	Name	Wait	Begin	End

8:00 71 2 0 1 0 8:00 51 1 8:01 15 A-H 0
8:01 8:03
2 1 8:01 79 2 8:03 08 A-H
0 8:03 8:05
8:01 95 3 1 3 2 8:03 09 1 8:04 19 A-H 1
8:05 8:07
4 3 8:04 67 2 8:06 45 I-Q
0 8:06 8:08
5 5 8:06 15 1 8:07 76R-Z 0
8:07 8:09
8:02 83 2 3 6 5 8:07 58 1 8:08 42 I-Q
0 8:08 8:10
7 6 8:08 04 1 8:09 38 I-Q
1 8:10 8:12
8:03 44 1 5 8 6 8:09 78 2 8:11 47 I-Q
1 8:12 8:14
8:04 34 1 5 9 7 8:11 30 1 8:12 82 R-Z
0 8:12 8:14
8:05 49 1 5 10 7 8:12 56 1 8:13 37 I-Q
1 8:14 8:16
8:06 88 2 6 11 7 8:13 75 2 8:15 49 I-Q
1 8:16 8:18
12 9 8:15 75 2 8:17 43 I-Q
1 8:18 8:20
8:07 56 1 7 13 10 8:17 05 1 8:18 37 I-Q
2 8:20 8:22
8:08 05 0 7
8:09 39 1 6 14 9 8:18 49 1 8:19 11
A-H 0 8:19 8:21
8:10 6 ---------------------------- Simulation Over ---------------------
10 **14** **51** **77** **19**

b. Avg. Number in Fee Wait Line = 51/10 = 5.1 people
Avg. Fee Wait Time = 77/14 = 5.5 minutes

PTS: 1