

Waiting Line Simulation

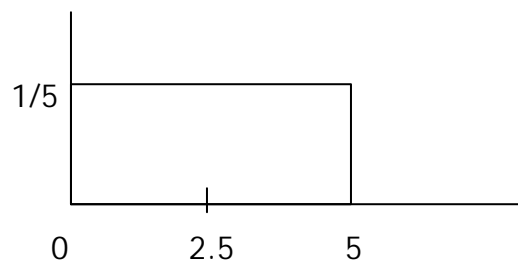
Hammondsport Savings Bank will open several new branch banks during the coming year. Each new branch is designed to have one automated teller machine (ATM). A concern is that during busy periods several customers may have to wait to use the ATM. This concern has led the bank to undertake a study of the ATM waiting line system. The bank's vice president wants to determine whether one ATM will be sufficient. The bank has established service guidelines for its ATM system stating that the average customer waiting time for an ATM should be one minute or less.

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

1

Customer inter-arrival times:

uniformly distributed between 0 and 5 minutes



EXCEL:

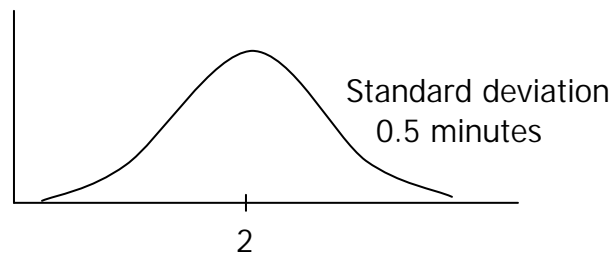
$$= 0 + \text{RAND}() * (5-0)$$

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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Customer service times:

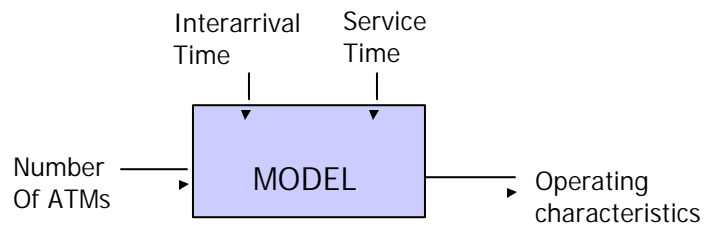
normally distributed with a mean of 2 minutes and a standard deviation of 0.5 minutes



EXCEL:
= NORMINV(RAND(),2,0.5)

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

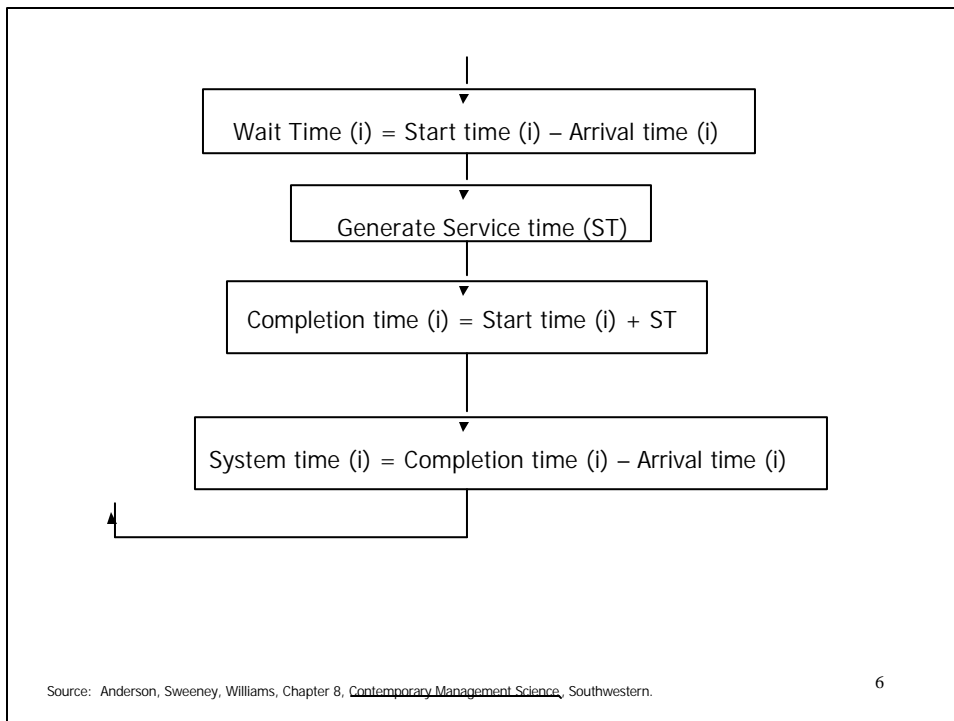
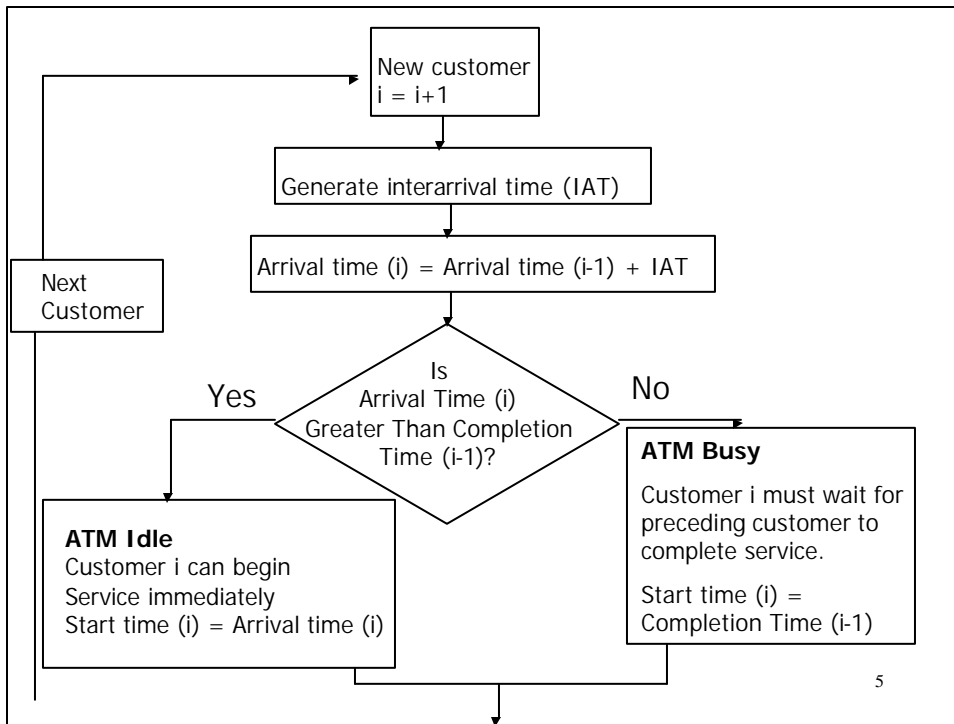
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IAT = inter-arrival time generated
Arrival time = time at which customer arrives
Start time = time at which customer starts service
Wait time = waiting time for customer
ST = service time generated
Completion time = time at which customer completes service
System time = system time for customer (waiting time + service time)

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

	Interarrival	Arrival	Service	Waiting	Service	Completion	Time
Customer	Time	Time	Start Time	Time	Time	Time	in System
1	2.6						
2	0.2						
3	3.9						
4	1.4						
5	4.6						
6	0.4						
7	0.6						
8	2.8						
9	2.3						
10	1.9						

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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	A	B	C	D	E	F	G	H
1	Hammondsport Savings Bank with One ATM							
2								
3	Interarrival Times (Uniform Distribution)							
4	Smallest Value	0						
5	Largest Value	5						
6								
7	Service Times (Normal Distribution)							
8	Mean	2						
9	Standard Dev	0.5						
10								
11								
12	Simulation							
13								
14		Interarrival	Arrival	Service	Waiting	Service	Completion	Time
15	Customer	Time	Time	Start Time	Time	Time	Time	in System
16	1	0.1	0.1	0.1	0.0	1.0	1.1	1.0
17	2	1.7	1.8	1.8	0.0	2.1	3.9	2.1
18	3	0.8	2.6	3.9	1.3	1.9	5.8	3.2

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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	A	B	C	D	E	F	G
1017		Summary Statistics					
1018		Number Waiting			526		
1019		Probability of Waiting			0.5844		
1020		Average Waiting Time			1.26		
1021		Maximum Waiting Time			9.5		
1022		Utilization of ATM			0.7761		
1023		Number Waiting > 1 Min			379		
1024		Probability of Waiting > 1 Min			0.4211		

Source: Anderson, Sweeney, Williams, Chapter 8, *Contemporary Management Science*, Southwestern.

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	A	B	C	D
3	Interarrival Times (Uniform Distribution)			
4	Smallest Value	0		
5	Largest Value	5		

	A	B
13		
14		Interarrival
15	Customer	Time
16	1	=B\$4+RAND()*(\$B\$5-\$B\$4)
17	2	=B\$4+RAND()*(\$B\$5-\$B\$4)

	C	D	E
13			
14	Arrival	Service	Waiting
15	Time	Start Time	Time
16	=B16	=C16	=D16-C16
17	=C16+B17	=IF(C17>G16,C17,G16)	=D17-C17

Source: Anderson, Sweeney, Williams, Chapter 8, *Contemporary Management Science*, Southwestern.

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	A	B	C	D
7	Service Times (Normal Distribution)			
8	Mean	2		
9	Standard Dev	0.5		

	F
13	
14	Service
15	Time
16	=NORMINV(RAND(),\$B\$8,\$B\$9)
17	=NORMINV(RAND(),\$B\$8,\$B\$9)

	G	H
13		
14	Completion	Time
15	Time	in System
16	=D16+F16	=G16-C16
17	=D17+F17	=G17-C17

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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Interarrival Time
=B\$4+RAND()*(\$B\$5-\$B\$4)
=B\$4+RAND()*(\$B\$5-\$B\$4)

Arrival Time	Service Start Time
=B16	=C16
=C16+B17	=IF(C17>G16,C17,G16)

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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Two ATM Simulation

	A	B	C	D	E	F	G	H	I	J	
1	Hammondsport Savings Bank with Two ATMs										
2											
3	Interarrival Times (Uniform Distribution)										
4	Smallest Value	0									
5	Largest Value	5									
6											
7	Service Times (Normal Distribution)										
8	Mean	2									
9	Standard Dev	0.5									
10											
11											
12	Simulation										
13											
14		Interarrival	Arrival	Service	Waiting	Service	Completion	Time	Time Available		
15	Customer	Time	Time	Start Time	Time	Time	Time	in System	ATM 1	ATM 2	
16	1	0.3	0.3	0.3	0.0	2.5	2.8	2.5	2.8	0.0	
17	2	2.2	2.5	2.5	0.0	2.5	5.0	2.5	2.8	5.0	

Source: Anderson, Sweeney, Williams, Chapter 8, *Contemporary Management Science*, Southwestern.

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	A	B	C
14		Interarrival	Arrival
15	Customer	Time	Time
16	1	=B\$4+RAND()*(\$B\$5-\$B\$4)	=B16
17	2	=B\$4+RAND()*(\$B\$5-\$B\$4)	=C16+B17

	D	E
14	Service	Waiting
15	Start Time	Time
16	=C16	=D16-C16
17	=IF(C17<=MIN(I16,J16),MIN(I16,J16),C17)	=D17-C17

	F	G	H
14	Service	Completion	Time
15	Time	Time	in System
16	=NORMINV(RAND(),\$B\$8,\$B\$9)	=D16+F16	=G16-C16
17	=NORMINV(RAND(),\$B\$8,\$B\$9)	=D17+F17	=G17-C17

Source: Anderson, Sweeney, Williams, Chapter 8, *Contemporary Management Science*, Southwestern.

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	I	J
14	Time Available	
15	ATM 1	ATM 2
16	=G16	0
17	=IF(I16=MIN(I16,J16),G17,I16)	=IF(J16=MIN(I16,J16),G17,J16)
18	=IF(I17=MIN(I17,J17),G18,I17)	=IF(J17=MIN(I17,J17),G18,J17)

Source: Anderson, Sweeney, Williams, Chapter 8, Contemporary Management Science, Southwestern.

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