Solutions Manual

# Module D: Simulation

1a. Using the first 15 random numbers from the first row of Table D.5, the average interarrival time is 2.33.

|  |  |  |
| --- | --- | --- |
| *Car* | *Random Number* | *Interarrival Time* |
| 1 | 56 | 2 |
| 2 | 74 | 3 |
| 3 | 93 | 4 |
| 4 | 83 | 3 |
| 5 | 39 | 2 |
| 6 | 69 | 3 |
| 7 | 6 | 1 |
| 8 | 44 | 2 |
| 9 | 81 | 3 |
| 10 | 70 | 3 |
| 11 | 50 | 2 |
| 12 | 11 | 1 |
| 13 | 28 | 2 |
| 14 | 29 | 2 |
| 15 | 26 | 2 |

1b. Using the first 30 random numbers from the second row of Table D.5, the average interarrival time is 2.

|  |  |  |  |
| --- | --- | --- | --- |
| *Car* | *Random Number* | *Interarrival Time* | *Cumulative Time* |
| 1 | 14 | 1 | 1 |
| 2 | 19 | 1 | 2 |
| 3 | 58 | 2 | 4 |
| 4 | 13 | 1 | 5 |
| 5 | 22 | 1 | 6 |
| 6 | 49 | 2 | 8 |
| 7 | 68 | 3 | 11 |
| 8 | 9 | 1 | 12 |
| 9 | 35 | 2 | 14 |
| 10 | 10 | 1 | 15 |
| 11 | 84 | 3 | 18 |
| 12 | 36 | 2 | 20 |
| 13 | 79 | 3 | 23 |
| 14 | 77 | 3 | 26 |
| 15 | 31 | 2 | 28 |
| 16 | 95 | 4 | 32 |

1c. This is a very small sample, but the averages should be approximately equal.

Cognitive Domain: Comprehension

Difficulty Level: Easy

2a. Average waiting time is 1.2 minutes, average service time is 2 minutes, and average total time is 3.2 minutes.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Car* | *Interarrival* | *Service* | *Arrive* | *Start* | *Finish* | *Wait* | *Service + Wait* |
| 1 | 2 | 1 | 2 | 2 | 3 | 0 | 1 |
| 2 | 3 | 1 | 5 | 5 | 6 | 0 | 1 |
| 3 | 4 | 2 | 9 | 9 | 11 | 0 | 2 |
| 4 | 3 | 1 | 12 | 12 | 13 | 0 | 1 |
| 5 | 2 | 2 | 14 | 14 | 16 | 0 | 2 |
| 6 | 3 | 2 | 17 | 17 | 19 | 0 | 2 |
| 7 | 1 | 3 | 18 | 19 | 22 | 1 | 4 |
| 8 | 2 | 1 | 20 | 22 | 23 | 2 | 3 |
| 9 | 3 | 2 | 23 | 23 | 25 | 0 | 2 |
| 10 | 3 | 1 | 26 | 26 | 27 | 0 | 1 |
| 11 | 2 | 4 | 28 | 28 | 32 | 0 | 4 |
| 12 | 1 | 2 | 29 | 32 | 34 | 3 | 5 |
| 13 | 2 | 3 | 31 | 34 | 37 | 3 | 6 |
| 14 | 2 | 3 | 33 | 37 | 40 | 4 | 7 |
| 15 | 2 | 2 | 35 | 40 | 42 | 5 | 7 |

2b. Six out of 15 cars wait in the queue. The probability is 40%.

Cognitive Domain: Analysis

Difficulty Level: Medium

3a. 

3b. Using the first 48 random numbers from the first two rows of Table D.5, the average time between calls is 3.79.

3c. This is a small sample, so the simulated values should be different from the computed values in 3a.

Cognitive Domain: Analysis

Difficulty Level: Medium

4a.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Day* | *Order Receipt* | *Beginning Inventory* | *Random Number* | *Simulated Demand* | *Ending Inventory* | *Backorder* | *Order Placed* | *Random Number* | *Simulated Lead Time* |
| 1 |  | 8 | 56 | 2 | 6 | 0 | NO |  |  |
| 2 |  | 6 | 14 | 1 | 5 | 0 | YES | 49 | 2 |
| 3 |  | 5 | 82 | 3 | 2 | 0 | NO |  |  |
| 4 |  | 2 | 96 | 5 | -3 | 3 | NO |  |  |
| 5 | 15 | 12 | 67 | 3 | 9 | 0 | NO |  |  |
| 6 |  | 9 | 83 | 3 | 6 | 0 | NO |  |  |
| 7 |  | 6 | 83 | 3 | 3 | 0 | YES | 60 | 2 |
| 8 |  | 3 | 2 | 0 | 3 | 0 | NO |  |  |
| 9 |  | 3 | 4 | 0 | 3 | 0 | NO |  |  |
| 10 | 15 | 18 | 53 | 2 | 16 | 0 | NO |  |  |
| 11 |  | 16 | 57 | 2 | 14 | 0 | NO |  |  |
| 12 |  | 14 | 8 | 0 | 14 | 0 | NO |  |  |
| 13 |  | 14 | 42 | 2 | 12 | 0 | NO |  |  |
| 14 |  | 12 | 95 | 5 | 7 | 0 | NO |  |  |
| 15 |  | 7 | 32 | 2 | 5 | 0 | YES | 48 | 2 |
| 16 |  | 5 | 14 | 1 | 4 | 0 | NO |  |  |
| 17 |  | 4 | 53 | 2 | 2 | 0 | NO |  |  |
| 18 | 15 | 17 | 74 | 3 | 14 | 0 | NO |  |  |
| 19 |  | 14 | 19 | 1 | 13 | 0 | NO |  |  |
| 20 |  | 13 | 15 | 1 | 12 | 0 | NO |  |  |

4b.

Cognitive Domain: Analysis

Difficulty Level: Hard

5a.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Day* | *Random Number* | *Break downs* | *Random Number* | *Repair Time* | *Random Number* | *Repair Time* | *Random Number* | *Repair Time* | *Random Number* | *Repair Time* |
| 1 | 56 | 2 | 74 | 2 | 19 |  |  |  |  |  |
| 2 | 14 | 0 |  |  |  |  |  |  |  |  |
| 3 | 82 | 3 | 15 | 1 | 25 | 1 | 87 | 2 |  |  |
| 4 | 96 | 4 | 64 | 2 | 18 | 1 | 61 | 2 | 54 | 1 |
| 5 | 67 | 2 | 62 | 2 | 22 | 1 |  |  |  |  |
| 6 | 83 | 3 | 69 | 2 | 94 | 3 | 8 | 1 |  |  |
| 7 | 83 | 3 | 99 | 3 | 78 | 2 | 34 | 1 |  |  |
| 8 | 2 | 0 |  |  |  |  |  |  |  |  |
| 9 | 4 | 0 |  |  |  |  |  |  |  |  |
| 10 | 53 | 2 | 93 | 3 | 58 | 1 |  |  |  |  |
| 11 | 57 | 2 | 43 | 1 | 11 | 1 |  |  |  |  |
| 12 | 8 | 0 |  |  |  |  |  |  |  |  |
| 13 | 42 | 1 | 99 | 3 |  |  |  |  |  |  |
| 14 | 95 | 4 | 69 | 2 | 12 | 1 | 12 | 1 | 31 | 1 |
| 15 | 32 | 1 | 33 | 1 |  |  |  |  |  |  |

5b. Average repair time is 1.62 hours, and the average weekly repair cost is $280.

Cognitive Domain: Analysis

Difficulty Level: Medium

6a. Random numbers were generated in Excel using the RANDBETWEEN(0,100) function.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Day* | *Rand #* | *Ship Arrivals* | *Rand #* | *Unload Capacity* | *Ships Not Unloaded* | *Cumulative Carryover* |
| 1 | 67 | 3 | 32 | 1 | 2 | 2 |
| 2 | 30 | 2 | 99 | 4 | 0 | 0 |
| 3 | 31 | 2 | 40 | 2 | 0 | 0 |
| 4 | 14 | 1 | 35 | 1 | 0 | 0 |
| 5 | 100 | 5 | 46 | 2 | 3 | 3 |
| 6 | 65 | 3 | 99 | 4 | 2 | 2 |
| 7 | 97 | 5 | 93 | 4 | 1 | 3 |
| 8 | 34 | 2 | 68 | 2 | 0 | 3 |
| 9 | 96 | 5 | 76 | 3 | 2 | 5 |
| 10 | 86 | 4 | 77 | 3 | 1 | 6 |
| 11 | 80 | 4 | 0 | 1 | 3 | 9 |
| 12 | 14 | 1 | 54 | 2 | 0 | 8 |
| 13 | 16 | 1 | 88 | 3 | 0 | 6 |
| 14 | 26 | 1 | 2 | 1 | 0 | 6 |
| 15 | 73 | 3 | 79 | 3 | 0 | 6 |
| 16 | 88 | 4 | 77 | 3 | 1 | 7 |
| 17 | 64 | 3 | 52 | 2 | 1 | 8 |
| 18 | 55 | 3 | 77 | 3 | 0 | 8 |
| 19 | 77 | 3 | 10 | 1 | 2 | 10 |
| 20 | 20 | 1 | 23 | 1 | 0 | 10 |

6b. The average number of ship arrivals is 2.8 per day. The average number of ships unloaded is 2.3 per day. On average, 0.9 arriving ships are not unloaded each day.

Cognitive Domain: Analysis

Difficulty Level: Hard

7a. Random numbers were generated using Excel’s RANDBETWEEN function.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Day* | *Rand #* | *Patient Arrivals* | *Rand #* | *Rand #* | *Rand #* | *Rand #* | *Rand #* | *Rand #* | *Rand #* | *Highest Rand #* | *Number of Doctors* |
| 1 | 3 | 0 |  |  |  |  |  |  |  | 0 | 0 |
| 2 | 20 | 2 | 66 | 73 |  |  |  |  |  | 73 | 4 |
| 3 | 35 | 3 | 23 | 19 | 90 |  |  |  |  | 90 | 4 |
| 4 | 25 | 2 | 28 | 46 |  |  |  |  |  | 46 | 2 |
| 5 | 29 | 2 | 66 | 57 |  |  |  |  |  | 66 | 2 |
| 6 | 78 | 5 | 78 | 30 | 2 | 17 | 31 |  |  | 78 | 4 |
| 7 | 16 | 2 | 54 | 96 |  |  |  |  |  | 96 | 4 |
| 8 | 72 | 4 | 83 | 47 | 80 | 52 |  |  |  | 83 | 4 |
| 9 | 75 | 5 | 81 | 20 | 89 | 36 | 15 |  |  | 89 | 4 |
| 10 | 61 | 4 | 88 | 68 | 59 | 0 |  |  |  | 88 | 4 |
| 11 | 32 | 3 | 59 | 72 | 11 |  |  |  |  | 72 | 4 |
| 12 | 14 | 1 | 18 |  |  |  |  |  |  | 18 | 1 |
| 13 | 15 | 2 | 14 | 12 |  |  |  |  |  | 14 | 1 |
| 14 | 94 | 6 | 29 | 65 | 27 | 96 | 35 | 42 |  | 96 | 4 |
| 15 | 49 | 3 | 68 | 39 | 79 |  |  |  |  | 79 | 4 |

7b. The average number of patient arrivals each night is 2.65. Using just the maximum injury as an indicator, there are 3.2 doctors needed each night, with a maximum of four on several nights. If each patient needs multiple doctors and the doctors are not allowed to switch from one patient to the next, then the maximum number of doctors needed on nights is 14, and the average number needed is 6.87.

Cognitive Domain: Analysis

Difficulty Level: Hard

8. Random numbers were generated using Excel’s RANDBETWEEN function.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Week* | *Rand #* | *Demand* | *Rand #* | *Lead Time* | *Beg Inv* | *End Inv* | *Order ?* | *Lost Sales* |
| 1 | 60 | 5 | 36 | 2 | 8 | 3 | YES |  |
| 2 | 71 | 6 |  |  | 3 | 0 | NO | 3 |
| 3 | 13 | 3 |  |  | 0 | 0 | NO | 3 |
| 4 | 70 | 6 |  |  | 20 | 14 | NO |  |
| 5 | 30 | 4 |  |  | 14 | 10 | NO |  |
| 6 | 7 | 2 |  |  | 10 | 8 | NO |  |
| 7 | 90 | 8 | 11 | 1 | 8 | 0 | YES |  |
| 8 | 52 | 5 |  |  | 0 | 0 | NO | 5 |
| 9 | 21 | 3 |  |  | 20 | 17 | NO |  |
| 10 | 59 | 5 |  |  | 17 | 12 | NO |  |

Champion places two orders at a cost of $140. Champion loses 11 sales at a cost of $2,200. The total holding cost of inventory is $1,280. The total inventory management cost is $3,620.

Cognitive Domain: Analysis

Difficulty Level: Medium

9a.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Call* | *Rand #* | *Call Interarrival* | *Arrival Time* | *Rand #* | *Tom Time* | *Rand #* | *Harry Time* | *In Queue* | *Tom Ready* | *Harry Ready* |
| 1 | 25 | 1 | 1 | 60 | 2 |  |  |  | 3 |  |
| 2 | 10 | 1 | 2 |  |  | 65 | 4 |  |  | 6 |
| 3 | 42 | 1 | 3 | 0 | 1 | 56 | 3 |  | 4 |  |
| 4 | 99 | 4 | 7 |  |  | 91 | 5 |  |  | 12 |
| 5 | 87 | 3 | 10 | 18 | 1 |  |  |  | 11 |  |
| 6 | 10 | 1 | 11 | 27 | 1 |  |  |  | 12 |  |
| 7 | 47 | 2 | 13 |  |  | 69 | 4 |  |  | 17 |
| 8 | 56 | 2 | 15 | 40 | 2 |  |  |  | 17 |  |
| 9 | 54 | 2 | 17 | 21 | 1 |  |  |  | 18 |  |
| 10 | 21 | 1 | 18 | 27 | 1 |  |  |  | 19 |  |
| 11 | 80 | 3 | 21 |  |  | 46 | 3 |  |  | 24 |
| 12 | 27 | 1 | 22 | 36 | 1 |  |  |  | 23 |  |
| 13 | 94 | 3 | 25 |  |  | 46 | 3 |  |  | 28 |
| 14 | 46 | 2 | 27 | 13 | 1 |  |  |  | 28 |  |
| 15 | 58 | 2 | 29 | 94 | 4 |  |  |  | 33 |  |
| 16 | 38 | 1 | 30 |  |  | 7 | 3 |  |  | 33 |
| 17 | 97 | 4 | 34 | 73 | 2 |  |  |  | 36 |  |
| 18 | 33 | 1 | 35 |  |  | 47 | 3 |  |  | 38 |
| 19 | 68 | 2 | 37 | 45 | 2 |  |  |  | 39 |  |
| 20 | 75 | 2 | 39 |  |  | 31 | 3 |  |  | 42 |

9b. There is no customer waiting in this simulation. Customers are in the system only for actual call time, which averages 2.5 minutes. Tom averages 1.58 minutes per call, while Harry averages 3.44 minutes per call.

Cognitive Domain: Analysis

Difficulty Level: Hard

10. Numbers were generated using Excel’s RANDBETWEEN function.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Trial* | *Rand #* | *Failure Time* | *Rand #* | *Repair Time* |
| 1 | 65 | 1,100 | 76 | 15 |
| 2 | 89 | 1,300 | 22 | 10 |
| 3 | 68 | 1,100 | 32 | 10 |
| 4 | 98 | 1,600 | 2 | 5 |
| 5 | 91 | 1,400 | 23 | 10 |
| 6 | 56 | 1,100 | 95 | 20 |
| 7 | 47 | 1,000 | 6 | 5 |
| 8 | 22 | 900 | 50 | 10 |
| 9 | 40 | 1,000 | 21 | 10 |
| 10 | 70 | 1,200 | 35 | 10 |

The average repair time was 10.5 minutes, and total repair labor cost was a paltry $70. The loss due to down time was $1,750. The total cost of bearing failure was $1,820. The average time between repairs was 1,170 hours.

Cognitive Domain: Analysis

Difficulty Level: Medium