**Chapter 3 Exercises**

1. (a) Using the event-scheduling approach, continue the (manual) checkout-counter simulation in Example 3.3, Table 3.1. Use the same interarrival and service times that were previously generated and used in Example 2.1. When the last interarrival time is used, continue the simulation (allowing no new arrivals) until the system is empty. Compare the results obtained here to those obtained in Example 2.1. The results should be identical

|  |  |  |  |
| --- | --- | --- | --- |
| Customer | Interarrival Time (Minutes) | Arrival Time | Service Time (Minutes) |
|
|
| 1 |  | 0 | 3 |
| 2 | 4 | 4 | 1 |
| 3 | 3 | 7 | 3 |
| 4 | 8 | 15 | 3 |
| 5 | 1 | 16 | 4 |
| 6 | 4 | 20 | 4 |
| 7 | 1 | 21 | 3 |
| 8 | 8 | 29 | 3 |
| 9 | 7 | 36 | 3 |
| 10 | 8 | 44 | 2 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CLOCK | System State | | Future Event List | Comments | Cumulative Statistics | |
| **LQ(t)** | **LS(t)** | **B** | **MQ** |
| 0 | 0 | 1 | (D,3), (A,4) | C1 arrival | 1 | 0 |
| 3 | 0 | 0 | (A,4) | C1 departure | 0 | 0 |
| 4 | 0 | 1 | (D,5) | C2 arrival | 1 | 0 |
| 5 | 0 | 0 |  | C2 departure | 0 | 0 |
| 7 | 0 | 1 | (A,7),(D,10) | C3 arrival | 1 | 0 |
| 10 | 0 | 0 |  | C3 departure | 0 | 0 |
| 15 | 0 | 1 | (a,15), (d,18) | C4 arrival | 1 | 1 |
| 16 | 1 | 1 | (a,16),(d,18) | C5 arrival | 1 | 2 |
| 18 | 0 | 1 | (d,20) | C5 started | 1 | 2 |
| 20 | 1 | 0 | (d,20),(a,20) | C6 arrival | 2 | 3 |
| 21 | 0 | 1 | (d,24),(a,21) | C6 started | 2 | 3 |
| 24 | 0 | 1 | (d,27) | C7 started | 1 | 3 |
| 27 | 0 | 0 |  | C7 departed | 1 | 3 |
| 29 | 0 | 1 | (a,29),(d,32) | C8 arrived | 1 | 3 |
| 32 | 0 | 0 |  | C8 departed | 0 | 3 |
| 36 | 0 | 1 | (a,36),(d,39) | C9 started | 1 | 3 |
| 39 | 0 | 0 |  | C9 departed | 0 | 3 |
| 44 | 0 | 1 | (a,44),(d,46) | C10 started | 0 | 3 |
| 45 | 0 | 0 |  | C10 departed | 0 | 3 |

(b) Do Exercise 1(a) again, adding the mode l components necessary to estimate mean

response time and proportion of customers who spend 4 or more minutes in the system. [Hint: See Example 3.4, Table 3.2]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CLOCK | System State | | Future Event List | Response time |  | Cumulative Statistics | |
| **LQ(t)** | **LS(t)** | **Wait >5 mins** | **B** | **MQ** |
| 0 | 0 | 1 | (D,3), (A,4), (E,20) | 3 |  | 1 | 0 |
| 3 | 0 | 0 | (A,4), (E,20) |  |  | 0 | 0 |
| 4 | 0 | 1 | (D,5),(E,20) | 1 |  | 1 | 0 |
| 5 | 0 | 0 | (E,20) |  |  | 0 | 0 |
| 7 | 0 | 1 | (A,7),(D,10),(E,20) | 3 |  | 1 | 0 |
| 10 | 0 | 0 | (E,60) |  |  | 0 | 0 |
| 15 | 0 | 1 | (a,15), (d,18),(e,20) | 3 |  | 1 | 1 |
| 16 | 1 | 1 | (a,16),(d,18)(e,20) |  |  | 1 | 2 |
| 18 | 0 | 1 | (a,16),(d,20)(e,20) | 6 |  | 2 | 3 |
| 20 | 0 | 1 | (a,20),(d,20),(e,20) |  |  | 2 | 3 |
| 21 | 0 | 1 | (d,24),(a,21) |  |  | 2 | 3 |
| 24 | 0 | 1 | (d,27) | 8 | yes | 1 | 3 |
| 27 | 0 | 0 |  |  |  | 1 | 3 |
| 29 | 0 | 1 | (a,29),(d,32) | 3 |  | 1 | 3 |
| 32 | 0 | 0 |  |  |  | 0 | 3 |
| 36 | 0 | 1 | (a,36),(d,39) | 3 |  | 1 | 3 |
| 39 | 0 | 0 |  |  |  | 0 | 3 |
| 44 | 0 | 1 | (a,44),(d,46) | 2 |  | 0 | 3 |
| 45 | 0 | 0 |  |  |  | 0 | 3 |

Avg response time= 38/10=3.8 , 90% of the customers spend less than 5 min sin the queue.

(c) Comment on the relative merits of manual versus computerized simulations. (a) Using the Name entities, attributes, activities, events, and state variables for the following systems:

In the manual simulation we check every step and then verify the results whereas in the computerized we write formulae for everything and the values may change for every run. For smaller simulations manually are optimal.

Q 4 Prepare a table in the manner of Table 3.2, until the CLOCK reaches time 15, using the interarrival and service times given below in the order shown. The stopping event will be time 30.

Interarrival times: 1 5 6 3 8

Service times: 3 5 4 1 5

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CLOCK | System State | | Checkout Line | FEL | Cumulative Statistics | |
| **LQ(t)** | **LS(t)** | **S** | **ND** |
| 0 | 0 | 1 | (C1,0) | (A,1,C2), (D,3,C1), (E,30) | 0 | 0 |
| 1 | 1 | 1 | (C1,0), (C2,1) | (D,3,C1), (A,6,C3), (E,30) | 0 | 0 |
| 3 | 0 | 1 | (C2,1) | (A,6,C3), (D,8,C2), (E,30) | 3 | 1 |
| 6 | 1 | 1 | (C2,1), (C3,6) | (D,8,C2), (A,12,C4), (E,30) | 3 | 1 |
| 8 | 0 | 1 | (C3,6) | (A,12,C4), (D,12,C3), (E,30) | 10 | 2 |
| 12 | 0 | 1 | (C4,12) | (D,13,C4), (A,15,C5), (E,30) | 16 | 3 |
| 13 | 0 | 0 | ( ) | (A,15,C5), (E,30) | 17 | 4 |
| 15 | 0 | 1 | (C5, 15) | (D,20,C5), (A,23,C6), (E,30) | 17 | 4 |

Q.7 Redo Example 2.6 ( the able – baker call center problem) by manual simulation using event simulation approach

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CLOCK | System State | | Checkout Line | FEL | Cumulative Statistics | | |
| **LQ(t)** | **LS(t)** | **S** | **ND** | **F** |
| 0 | 0 | 1 | (c1,0) | (a,1,c2)(d,4,c1)(e,60) | 0 | 0 | 0 |
| 1 | 1 | 1 | (c1,0)(c2,1) | (a,2,c3) (d,4,c1)(e,60) | 0 | 0 | 0 |
| 2 | 2 | 1 | (c1,0)(c2,1)(c3,2) | (d,4,c1)(a,8,c4)(e,60) | 0 | 0 | 0 |
| 4 | 1 | 1 | (c2,1)(c3,2) | (d,6,c2),(a,8,c4)(d,1,c3)(e,60) | 4 | 1 | 0 |
| 6 | 0 | 1 | (c3,2) | (a,8,c4),(d,11,c3),(3,60) | 9 | 2 | 1 |
| 8 | 1 | 1 | (c3,2)(c4,8) | (d,11,c3)(a,11,c5)(e,60) | 9 | 2 | 1 |
| 11 | 1 | 1 | (c4,8)(c5,11) | (d,15,c4)(a,18,c6)(e,60) | 18 | 3 | 2 |
| 15 | 0 | 1 | (c5,11) | (d,16c5)(a,18,c6)(e,60) | 25 | 4 | 3 |
| 16 | 0 | 0 |  | (a,18,c6),(e,60) | 30 | 5 | 4 |
| 18 | 0 | 1 | (c6,18) | (d,23,c6), (a,23,c7) (e,60) | 30 | 5 | 4 |
| 23 | 0 | 1 | (c7,23) | (a,25,c8)(d,27,c7)(e,60) | 35 | 6 | 5 |