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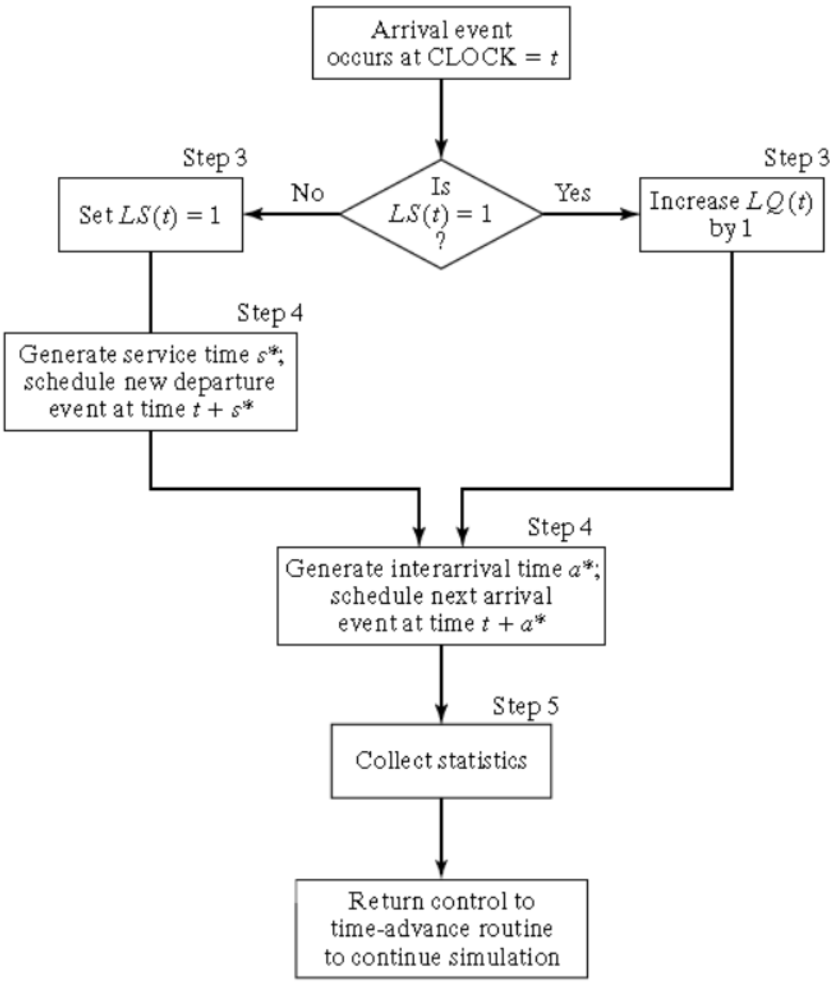
Example 3: Single-Channel Queue

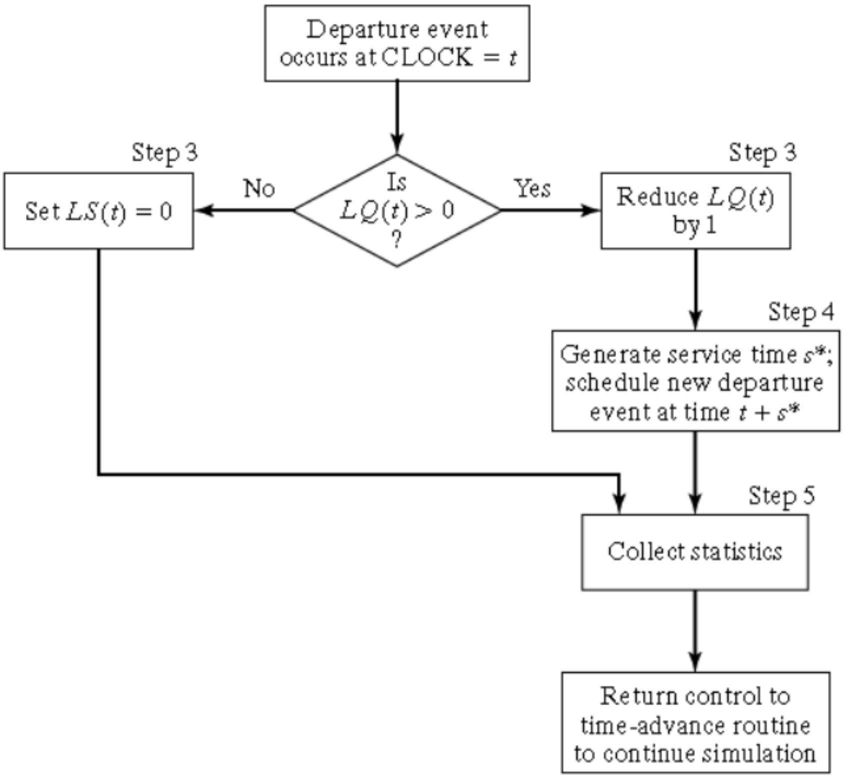
Consider the grocery store with one checkout counter that is simulated in Example 5 from the Simulation Examples in a Spreadsheet chapter by an ad hoc method. The system consists of those customers in the waiting line plus the one (if any) checking out. A stopping time of 60 minutes is set for this example.

The model has the following components:

System state	(*LQ(t)*, *LS(t)*), where *LQ(t)* is the number of customers in the waiting line, and *LS(t)* is the number being served (0 or 1) at time *t*.
Entities	The server and customers are not explicitly modelled except in terms of the state variables.
Events	Arrival (A), departure (D), and stopping event (E) are scheduled to occur at time 60.
Event notices	(A, *t*), representing an arrival event to occur at future time *t*; (D, *t*), representing a customer departure at future time *t*; (E, 60), representing the simulation stop event at future time 60.
Activities	Interarrival time, defined in Table 1; Service time, defined in Table 2
Delay	Customer time spent in waiting line.



Execution of the arrival event.



Execution of the departure event.

(Table-I) Distribution of time between inter-arrival

Time B/W Arrivals (M)	**Probability**	**Commutative Probability**	**Random Digit Assign**
1	0.125	0.125	001-125
2	0.125	0.250	126-250
3	0.125	0.375	251-375
4	0.125	0.500	376-500
5	0.125	0.625	501-625
6	0.125	0.750	626-750
7	0.125	0.875	751-875
8	0.125	1.000	876-000

(Table-2) Service Time Distribution

Service Time (M)	**Probability**	**Commutative Probability**	**Random Digit Assign**
1	0.10	0.10	01-10
2	0.20	0.30	11-30
3	0.30	0.60	31-60
4	0.25	0.85	61-85
5	0.10	0.95	86-95
6	0.05	1.00	96-00

	Cumulative System state				statistics	
CLOCK	***LQ(t)***	***LS(t)***	**Future event list**	**Comment**	***B***	***MQ***

Example 4: The Checkout-Counter Simulation, Continued. Suppose that, in the simulation of the checkout counter in Example 3, the simulation analyst desires to estimate the mean response time and mean proportion of customers who spend five or more minutes in the system. A response time is the length of time a customer spends in the system. In order to estimate these customer averages, it is necessary to expand the model in Example 3 to represent the individual customers explicitly. In addition, to be able to compute an individual customer's response time when that customer departs, it will be necessary to know that customer's arrival time. Therefore, a customer entity with arrival time as an attribute will be added to the list of model components in

Example 3. These customer entities will be stored in a list to be called "CHECKOUT LINE"; they will be called *C*1, *C*2, *C*3, . . . Finally, the event notices on the FEL will be expanded to indicate which customer is affected. For example, (D,4, *C*1) means that customer *C*1 will depart at time 4. The additional model components are the following:

Entities	(*Ci, t*), representing customer *Ci* who arrived at time *t*.
Event notices	(A, *t, Ci*), the arrival of customer *Ci* at future time *t*; (D, *t, Cj*), the departure of customer *Cj* at future time *t*, Set "CHECKOUT LINE," the set of all customers currently at the checkout counter (being served or waiting to be served), ordered by time of arrival.
Activities	Interarrival time, defined in Table 1; Service time, defined in Table 2

Three new cumulative statistics will be collected: *S*, the sum of customer response times for all customers who have departed by the current time; *F*, the total number of customers who spend 5 or more minutes at the checkout counter; and ND, the total number of departures up to the current simulation time. These three cumulative statistics will be updated whenever the departure event occurs; the logic for collecting these statistics will be incorporated into Step 5 of the departure event in Figure 2.

(Table-1) interracial distribution of cars

Time b/w Arrivals	Prob	C. Prob	RDA
1	0.25	0.25	01-25
2	0.40	0.65	26-65
3	0.20	0.85	66-85
4	0.15	1.00	86-00

(Table-2) Service distribution of Able

Service Time	Prob	C. Prob	RDA
2	0.30	0.30	01-30
3	0.28	0.58	31-58
4	0.25	0.83	59-83
5	0.17	1.00	84-00

(Table-3) Service distribution of Baker

Service Time	Prob	C. Prob	RDA
3	0.35	0.35	01-35
4	0.25	0.60	36-60
5	0.20	0.80	61-80
6	0.20	1.00	81-00

	Cumulative System state				**statistics**		
CLOCK	***LQ(t)***	***LS(t)***	**CHECKOUT LINE**	**Future event list**	***S***	***ND***	***F***

Example 5: The Dump-Truck Problem

Six dump trucks are used to haul coal from the entrance of a small mine to the railroad. The following figure provides a schematic of the dump truck operation. Each truck is loaded by one of two loaders. After

When loading, the truck immediately moves to the scale to be weighed as soon as possible. Both the loaders and the scale have a first-come-first-served waiting line (or queue) for trucks. Travel time from a loader to the scale is considered negligible. After being weighed, a truck begins a travel time (during which time the truck unloads) and then afterward returns to the loader queue. The distributions of loading time, weighing time, and travel time are given in Tables 3, 4, and 5, respectively. These activity times are generated in exactly the same manner as service times in Section 1.5, Example 2 from the Simulation Examples in a Spreadsheet chapter, using the cumulative probabilities to divide the unit interval into subintervals whose lengths correspond to the probabilities of each individual value. A random number is drawn, and the interval it falls into determines the next random activity time. The purpose of the simulation is to estimate the loader and scale utilization percentage of time busy). The model has the following components:

System state	[*LQ(t)*, *L(t)*, *WQ(t)*, *W(t)*], where *LQ(t)* = number of trucks in loader queue; *L(t)* = number of trucks (0, 1, or 2) being loaded *WQ(t)* = number of trucks in weigh queue; *W(t)* = number of trucks (0 or 1) being weighed, all at simulation time *t*.
Entities	The six dump trucks ($DT1, \ldots, DT6$).
Event notices	((*ALQ*, *t*, *DTi*), *DTi* arrives at loader queue (*ALQ*) at time *t*; (*EL*, *t*, *DTi*), *DTi* ends loading (*EL*) at time *t*; (*EW*, *t*, *DTi*), *DTi* ends weighing (*EW*) at time *t*.

(Table-1) Distribution of Loading Time

Loading Time	Prob	C. Prob	RD Interval
5	0.30	0.30	$0.0 \le R \le 0.30$
10	0.50	0.80	$0.3 < R \le 0.80$
15	0.20	1.00	$0.8 < R \le 1.00$

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(Table-2) Weighing distribution of Able

Weighing Time	Prob	C. Prob	RDA
12	0.70	0.70	$0.0 \le R \le 0.70$
16	0.30	1.00	$0.3 < R \le 1.00$

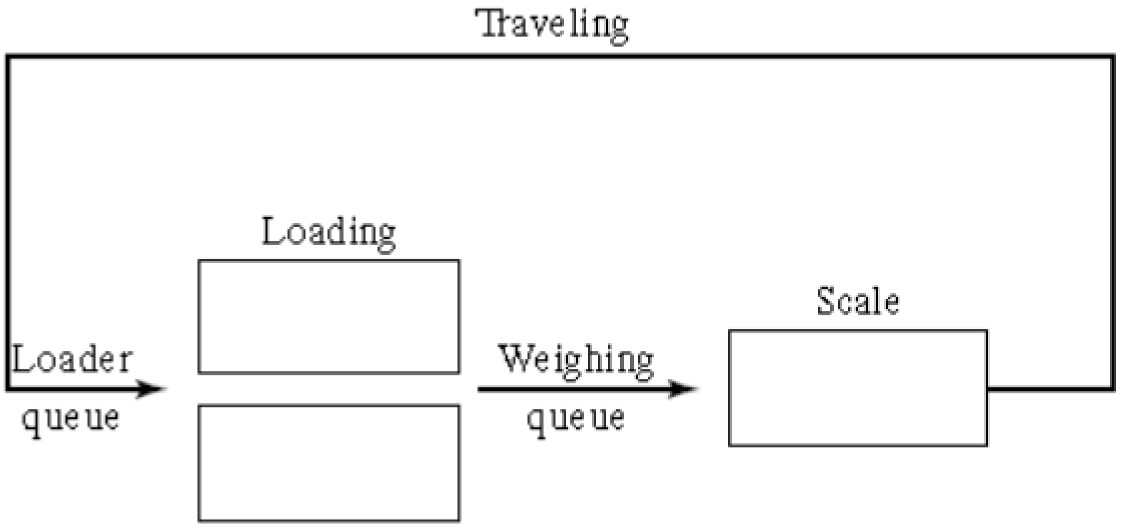
(Table-3) Distribution of Travel Time for Trucks

Service Time	Prob	C. Prob	RDA
3	0.35	0.35	01-35
4	0.25	0.60	36-60
5	0.20	0.80	61-80
6	0.20	1.00	81-00

Lists	The loader queue includes all trucks waiting to begin loading, which are ordered on a first-come, first-served basis. The weigh queue includes all trucks waiting to be weighed, which are ordered on a first-come, first-served basis.
Activities	Loading time, weighing time, and travel time.
Delays	Delay at loader queue and delay at scale.

The simulation table is given in Table 6. To initialize the table's first row, we assume that, at time 0, five trucks are at the loaders and one is at the scale. For simplicity, we take the (randomly generated) activity times from the following list as needed:

Loading Time	Weighing Time	Travel Time
10	12	60
5	12	100
5	12	40
10	16	40
15	12	80
10	16	
10		



CLOCK	System state				Loader queue	Weigh queue	Future event list	Cumulative statistics	
t	$LQ(t)$	$L(t)$	$WQ(t)$	$W(t)$				BL	BS