Example 5: The Dump-Truck Problem

Six dump trucks are used to haul coal from the entrance of a small mine to the railroad. Each truck is loaded by one of two loaders. After a 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 loaders queue.

System state:

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, …., 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

1: Distribution of loading Time for the Dump trucks

|  |  |  |  |
| --- | --- | --- | --- |
| Loading Time | Probability | Cumulative probability | Random number Interval |
| 5 | 0.30 | 0.30 |  |
| 10 | 0.50 | 0.80 |  |
| 15 | 0.20 | 1.00 |  |

2: Distribution of Weighing time for the Dump trucks

|  |  |  |  |
| --- | --- | --- | --- |
| Weighing Time | Probability | Cumulative probability | Random number Interval |
| 12 | 0.70 | 0.70 |  |
| 16 | 0.30 | 1.00 |  |
|  |  |  |  |

3: Distribution of Travel Time for the Dump trucks

|  |  |  |  |
| --- | --- | --- | --- |
| Travel Time | Probability | Cumulative probability | Random number Interval |
| 40 | 0.40 | 0.40 |  |
| 60 | 0.30 | 0.70 |  |
| 80 | 0.20 | 0.90 |  |
| 100 | 0.10 | 1.00 |  |

Lists

Loader queue, all trucks waiting to being loading, ordered on a first-come-first-served basis;

Weigh queue, all trucks waiting to be weighed, 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.

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 | 10 | 5 | 5 | 10 | 15 | 10 | 10 |
| Weighing time | 12 | 12 | 12 | 16 | 12 | 16 |  |
| Travel time | 60 | 100 | 40 | 40 | 80 |  |  |

Generate simulation table for dump-truck operation.

Using the **loading times, weighing times, and travel times provided**, let's simulate the system for **6 trucks** (DT1 to DT6). We'll assume two loaders and one scale, following the first-come-first-serve rule.

**Step-by-Step Simulation Table**

| **Clock (t)** | **LQ(t)** | **L(t)** | **WQ(t)** | **W(t)** | **Loader Queue** | **Weigh Queue** | **FEL** | **B\_L** | **B\_S** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **0** | 4 | 2 | 0 | 1 | DT3, DT4, DT5, DT6 | — | (EL,10,DT1), (EL,5,DT2), (EW,12,DT1) | 0 | 0 |
| **5** | 3 | 2 | 0 | 1 | DT4, DT5, DT6 | — | (EL,10,DT1), (EW,12,DT2), (EL,15,DT3) | 5 | 0 |
| **10** | 2 | 2 | 1 | 1 | DT5, DT6 | DT1 | (EW,12,DT2), (EL,15,DT3), (EL,20,DT4) | 10 | 5 |
| **12** | 2 | 2 | 0 | 1 | DT5, DT6 | DT2 | (EL,15,DT3), (EL,20,DT4), (EW,24,DT1) | 15 | 10 |
| **15** | 1 | 2 | 0 | 1 | DT6 | DT2 | (EL,20,DT4), (EW,24,DT1), (EL,25,DT5) | 20 | 15 |
| **20** | 0 | 2 | 0 | 1 | — | DT2 | (EW,24,DT1), (EL,25,DT5), (EL,30,DT6) | 25 | 20 |
| **24** | 0 | 2 | 0 | 1 | — | DT1 | (EW,28,DT2), (EL,30,DT6) | 30 | 24 |
| **28** | 0 | 1 | 0 | 1 | — | DT3 | (EL,30,DT6), (EW,40,DT3) | 35 | 28 |
| **30** | 0 | 0 | 0 | 1 | — | DT6 | (EW,40,DT3), (EW,50,DT5) | 40 | 30 |
| **40** | 0 | 0 | 0 | 0 | — | — | (EW,50,DT5), (EW,60,DT6) | 40 | 36 |
| **50** | 0 | 0 | 0 | 0 | — | — | (EW,60,DT6) | 40 | 48 |
| **60** | 0 | 0 | 0 | 0 | — | — | — | 40 | 60 |

**Explanation of the Table**

1. **Clock 0**:
   * Two loaders (DT1 and DT2) begin loading. Remaining trucks (DT3–DT6) wait in the loader queue.
   * DT1 starts weighing after being loaded because the scale is free.
2. **Clock 5**:
   * DT2 finishes loading and begins weighing. DT3 starts loading.
3. **Clock 10**:
   * DT1 finishes weighing and enters the travel stage. DT4 begins loading.
4. **Clock 12**:
   * DT2 finishes weighing and enters the travel stage. DT1 enters the weigh queue.
5. **Clock 15**:
   * DT3 finishes loading and enters the weigh queue. DT5 begins loading.
6. **Clock 20**:
   * DT4 finishes loading. DT6 begins loading.
7. **Clock 24**:
   * DT1 finishes weighing and enters travel. DT2 enters the weigh queue.
8. **Clock 28**:
   * DT3 begins weighing. The loaders are idle temporarily.
9. **Clock 30**:
   * DT6 finishes loading and begins weighing after DT3.
10. **Clock 40**:
    * DT3 finishes weighing and enters travel. DT5 begins weighing.
11. **Clock 50**:
    * DT5 finishes weighing and enters travel. DT6 is the last truck being weighed.
12. **Clock 60**:
    * Simulation ends with all trucks finished weighing and traveling.

**Cumulative Busy Times**

* **Busy Time for Loaders (BLB\_LBL​)**:
  + Loader 1 and 2 handled trucks sequentially for a total of **40 minutes**.
* **Busy Time for Scale (BSB\_SBS​)**:
  + The scale was busy weighing trucks for **60 minutes**.

| **Truck** | **Loading Time (min)** | **Weighing Time (min)** | **Travel Time (min)** | **EL (End Loading)** | **EW (End Weighing)** | **FEL (Future Event List)** |
| --- | --- | --- | --- | --- | --- | --- |
| **DT1** | 10 | 12 | 60 | 0+10=100 + 10 = 100+10=10 | 10+12=2210 + 12 = 2210+12=22 | (EL,10,DT1),(EW,22,DT1)(EL,10,DT1), (EW,22,DT1)(EL,10,DT1),(EW,22,DT1) |
| **DT2** | 5 | 12 | 100 | 0+5=50 + 5 = 50+5=5 | 5+12=175 + 12 = 175+12=17 | (EL,5,DT2),(EW,17,DT2)(EL,5,DT2), (EW,17,DT2)(EL,5,DT2),(EW,17,DT2) |
| **DT3** | 5 | 12 | 40 | 0+5=50 + 5 = 50+5=5 | 5+12=175 + 12 = 175+12=17 | (EL,5,DT3),(EW,17,DT3)(EL,5,DT3), (EW,17,DT3)(EL,5,DT3),(EW,17,DT3) |
| **DT4** | 10 | 16 | 40 | 0+10=100 + 10 = 100+10=10 | 10+16=2610 + 16 = 2610+16=26 | (EL,10,DT4),(EW,26,DT4)(EL,10,DT4), (EW,26,DT4)(EL,10,DT4),(EW,26,DT4) |
| **DT5** | 15 | 12 | 80 | 0+15=150 + 15 = 150+15=15 | 15+12=2715 + 12 = 2715+12=27 | (EL,15,DT5),(EW,27,DT5)(EL,15,DT5), (EW,27,DT5)(EL,15,DT5),(EW,27,DT5) |
| **DT6** | 10 | 16 | — | 0+10=100 + 10 = 100+10=10 | 10+16=2610 + 16 = 2610+16=26 | (EL,10,DT6),(EW,26,DT6)(EL,10,DT6), (EW,26,DT6)(EL,10,DT6),(EW,26,DT6) |

**Explanation of Columns**

1. **Loading Time**: Provided as given for each truck.
2. **Weighing Time**: Provided as given for each truck.
3. **Travel Time**: Provided as given, but missing for DT6.
4. **EL (End Loading)**:
   * Calculated as the start time of loading (assumed to be t=0t = 0t=0 for all trucks initially) plus the loading time.
   * EL=Start Time+Loading TimeEL = \text{Start Time} + \text{Loading Time}EL=Start Time+Loading Time.
5. **EW (End Weighing)**:
   * Calculated as the ELELEL time plus the weighing time.
   * EW=EL+Weighing TimeEW = EL + \text{Weighing Time}EW=EL+Weighing Time.
6. **FEL (Future Event List)**:
   * Lists the events **(EL, t, Truck ID)** and **(EW, t, Truck ID)** for each truck, showing when loading and weighing are scheduled to complete

