Transit

BUS FACILITIES

Dwell Time

Inputs

<table>
<thead>
<tr>
<th>Bus type:</th>
<th>Conventional (rigid body)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of available doors or channels:</td>
<td>Nd := 2</td>
</tr>
<tr>
<td>Location of doors or channels:</td>
<td>Front</td>
</tr>
<tr>
<td>Number of seats:</td>
<td>Sn := 42</td>
</tr>
<tr>
<td>Door opening and closing time:</td>
<td>$t_{oc} := 4\text{ s}$</td>
</tr>
<tr>
<td>Boarding time per passenger:</td>
<td>$t_b := 3\text{ s}$</td>
</tr>
<tr>
<td>Alighting time per passenger:</td>
<td>$t_a := 2\text{ s}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stop number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alighting passengers</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>14</td>
<td>6</td>
<td>16</td>
<td>19</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Boarding passengers</td>
<td>20</td>
<td>16</td>
<td>11</td>
<td>12</td>
<td>16</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Variables used in this section and not defined in HCM

Data: input table of the Dwell Time section
Stops: total number of stops

Number of stops

The number of stops is calculated as the number of columns (with data) of the input table of the Dwell Time section (Data).

Stops := cols (Data)

Function to determine if standees are present or not

This function returns a vector of $n$ elements, where each of the elements corresponds to a different bus stop. Each element is 1 if standees are present in that specific stop or 0 if not.

The number of passengers in a specific stop is calculated as the number of passengers that arrives in the bus + boarding passengers - alighting passenger ($\text{Passengers} + \text{Data}_2,m - \text{Data}_1,m$).

If the resulting number of passengers is greater than the number of seats ($Sn$) of the bus, a 1 is assigned for that stop, otherwise a 0 is assigned.

$$\text{Standees}(n) := \begin{align*}
\text{Passengers} & \leftarrow 0 \\
\text{for } m & \in 0..n - 1 \\
\text{Passengers} & \leftarrow \text{Passengers} + \text{Data}_{2,m} - \text{Data}_{1,m} \\
X_m & \leftarrow 1 \text{ if } \text{Passengers} > \text{Sn} \\
X_m & \leftarrow 0 \text{ otherwise} \\
X & 
\end{align*}$$
Function to determine the number of standees and seated passengers

This function returns a matrix of two rows and \( n \) columns, where each column corresponds to a different stop. The first row gives the number of seated passengers in every stop and the second row gives the number of standees.

The total number of passengers in a specific stop is calculated as the number of passengers that arrives in the bus + boarding passengers - alighting passenger (Total + Data_{2,m} - Data_{1,m}).

If the total number of passengers is less than or equal to the number of seats (Total \( \leq \) Sn), the number of passengers is assigned to the first row (Seated vector) and 0 to the second row (Standees vector).

If the total number of passengers is greater than the number of seats, the number of seats is assigned to the first row (Seated vector) and the difference between the number of passengers and the number of seats is assigned to the second row (Standees vector).

\[
\text{SeatedStandees}(n) := \begin{cases} 
\text{Total} & \leftarrow 0 \\
\text{for} & m \in 0..n - 1 \\
\text{Total} & \leftarrow \text{Total} + \text{Data}_{2,m} - \text{Data}_{1,m} \\
\text{if} & \text{Total} \leq \text{Sn} \\
\text{Seated}_m & \leftarrow \text{Total} \\
\text{Standees}_m & \leftarrow 0 \\
\text{otherwise} \\
\text{Seated}_m & \leftarrow \text{Sn} \\
\text{Standees}_m & \leftarrow \text{Total} - \text{Sn} \\
\text{stack}(\text{Seated}^T, \text{Standees}^T) 
\end{cases}
\]

Boarding time (see Page 27-9)

This function determines the boarding time for each of the stops. If no standees are present (\( \text{Standees}(\text{Stops})_m = 0 \)) in a given stop, the boarding time for that stop is calculated as the number of boarding passengers times the boarding time per passenger (Data_{2,m} \cdot t_b). Otherwise, 0.5 s is added to the boarding time per passenger (Data_{2,m} \cdot (t_b + 0.5\sec)).

\[
\text{BoardingTime}(n) := \begin{cases} 
\text{Boarding}_m & \leftarrow 0 \text{ for} \ m \in 0..n - 1 \\
\text{Boarding}_m & \leftarrow \text{Data}_{2,m} \cdot t_b \text{ if } \text{Standees}(\text{Stops})_m = 0 \\
\text{Boarding}_m & \leftarrow \text{Data}_{2,m} \cdot (t_b + 0.5\sec) \text{ otherwise} 
\end{cases}
\]

Alighting time

This function determines the alighting time for each of the stops. It is computed as the number of alighting passengers times the alighting time per passenger (Data_{1,m} \cdot t_a).

\[
\text{AlightingTime}(n) := \begin{cases} 
\text{Alighting}_m & \leftarrow 0 \text{ for} \ m \in 0..n - 1 \\
\text{Alighting}_m & \leftarrow \text{Data}_{1,m} \cdot t_a 
\end{cases}
\]
Dwell time (see Equation 27-2)

If the number of available doors is greater than or equal to 2 \( (Nd \geq 2) \), the dwell time is calculated as the maximum between the boarding time and alighting time plus the door opening and closing time \( (\max(\text{BoardingTime}(\text{Stops}_m), \text{AlightingTime}(\text{Stops}_m)) + t_{oc}) \). Otherwise the dwell time is computed as the boarding time plus the alighting time plus the door opening and closing time \( (\text{BoardingTime}(\text{Stops}_m) + \text{AlightingTime}(\text{Stops}_m) + t_{oc}) \).

\[
\text{DwellTime}(n) := \begin{cases} 
\text{Dwell}_m &\text{for } m \in 0..n-1 \\
\text{Dwell}_m \leftarrow \max(\text{BoardingTime}(\text{Stops}_m), \text{AlightingTime}(\text{Stops}_m)) + t_{oc} &\text{if } Nd \geq 2 \\
\text{Dwell}_m \leftarrow \text{BoardingTime}(\text{Stops}_m) + \text{AlightingTime}(\text{Stops}_m) + t_{oc} &\text{otherwise}
\end{cases}
\]

Results table

The stop number is added as a header of the columns \( (\text{Data}^T)^{D_T} \). Units are removed, dividing by 1 second.

\[
\text{Results} := \text{stack}(\text{Data}^T)^{D_T}, \text{SeatedStandees}(\text{Stops}), \text{BoardingTime}(\text{Stops})^T \cdot \frac{1}{s}, \text{AlightingTime}(\text{Stops})^T \cdot \frac{1}{s}, \text{DwellTime}(\text{Stops})
\]

Results

<table>
<thead>
<tr>
<th>Stop number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seated</td>
<td>20</td>
<td>36</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>26</td>
<td>11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Standees</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Boarding time (s)</td>
<td>60</td>
<td>48</td>
<td>38.5</td>
<td>42</td>
<td>56</td>
<td>28</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Alighting time (s)</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>28</td>
<td>12</td>
<td>32</td>
<td>38</td>
<td>30</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Dwell time (s)</td>
<td>64</td>
<td>52</td>
<td>42.5</td>
<td>46</td>
<td>60</td>
<td>32</td>
<td>36</td>
<td>42</td>
<td>34</td>
<td>26</td>
</tr>
</tbody>
</table>

Bus Vehicle Capacity

Units definition

Definition of new units used in this section. In this case the units for liters are used, but any other units could be used.

\[ \text{veh} := \frac{L}{L}, \text{pc} := \frac{L}{L}, \text{ln} := \frac{L}{L}, \text{stops} := \frac{L}{L}, \text{p} := \frac{L}{L}, \text{buses} := \frac{L}{L} \]
**Inputs**

**Type of facilities:**
- Exclusive Urban Street

**Number of lanes:**
- N := 3

**Signalized intersections:**
- Si := 4

**Effective green time per signal cycle:**
- gC := 0.45

**Cycle length:**
- C := 90 s

**Buses per hour that will use the street:**
- Bh := 40

**Automobiles per hour that will use the street:**
- Ah := 1200

**Loading areas per stop:**
- La := 2

**Location of loading areas:**
- On-Line

**Bus stop location:**
- Near-side

**Bus lane type:**
- Type 1

**Conditions of stops:**
- Stops every block

**Type of arrivals:**

**Base saturation flow rate:**
- \( s_0 := 1900 \text{ pc/hr/ln} \)

**Bus blockage factor:**
- \( f_{bb} := 0.84 \)

**Area factor:**
- \( f_a := 0.9 \)

**Clearance time:**
- \( t_c := 10 \text{ s} \)

**Failure rate:**
- \( Fr := 7.5\% \)

**Coefficient of variation of dwell times:**
- \( c_v := 60\% \)

---

### Stop number

<table>
<thead>
<tr>
<th>Stop number</th>
<th>Dwell time (s)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curb lane right-turn auto volume (veh/h)</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Curb lane through auto volume (veh/h)</td>
<td>350</td>
<td>200</td>
<td>100</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Conflicting ped volume (p/h)</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>( f_{Rob} )</td>
<td>100</td>
<td>300</td>
<td>500</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>( f_{HV} )</td>
<td>0.948</td>
<td>0.898</td>
<td>0.883</td>
<td>0.908</td>
<td></td>
</tr>
<tr>
<td>Bus lane vehicle capacity (buses/h)*</td>
<td>34</td>
<td>34</td>
<td>36</td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* input the bus lane vehicle capacity when the stops conditions are alternating 2-block stops or alternating 3-block stops.

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### Variables used in this section and not defined in HCM

- **Ah:** automobiles per hour that will use the street
- **Arrivals:** defines the type of arrivals; 1 for random, 2 for typical, 3 for platooned
- **Bh:** buses per hour that will use the street
- **Data2:** input table of the Bus Vehicle Capacity section
- **Facilities:** defines the type of facilities; 1 for Exclusive Urban Street, 2 for Mixed Traffic
- **Fr:** failure rate
La: loading areas per stop
LaneType: bus lane type; 1 for Type 1, 2 for Type 2, 3 for Type 3
LoadingArea: location of loading areas; 1 for On-line, 2 for Off-line
StopCondition: defines the condition of the stops; 1 for Stops every block, 2 for Alternating 2-block stops, 3 for Alternating 3-block stops.
StopLocation: bus stop location; 1 for near-side, 2 for midblock, 3 for far-side
Stops2: total number of stops

Number of stops
The number of stops is calculated as the number of columns (with data) of the input table of the Bus Vehicle Capacity section (Data2).

Stops2 := cols(Data2)

Curb-lane volume at critical bus stop
The curb-lane volume at critical bus stop is computed as the summation of the curb lane right-turn auto volume plus the curb lane through auto volume plus the buses per hour that will use the street (Data2,m + Data2,m + Bh)

\[ V_c(n) := \begin{cases} 
  for \ m \in 0..n-1 \\
  V_m \leftarrow Data2,m + Data2,m + Bh \\
  V 
\end{cases} \]

Volume of adjacent lanes (see Example 4, Page 27-41)
If the type of facilities is Exclusive Urban Street (Facilities = 1) or the bus stop location is Near Side (StopCondition = 1), the volume of adjacent lanes is 0. Otherwise the volume of adjacent lanes is computed as the substraction of Automobiles per hour that will use the street (Ah) less the curb lane right-turn auto volume (Data2,m) and less the curb lane through auto volume (Data2,m), and the result divided by the number of lanes less the curb lane (N - 1).

\[ V_a(n) := \begin{cases} 
  for \ m \in 0..n-1 \\
  V_m \leftarrow 0 \ if \ (Facilities = 1 \lor \ StopCondition = 1) \\
  V_m \leftarrow Ah - Data2,m,2 - Data2,m,3 \\
  \frac{N-1}{N-1} \ otherwise 
\end{cases} \]

Volume of right turns at specific intersection
The volume of right turns is taken from the second row of the input table of the Bus Vehicle Capacity section (Data2).

\[ V_r(n) := \begin{cases} 
  for \ m \in 0..n-1 \\
  V_m \leftarrow Data2,m \\
  V 
\end{cases} \]
Proportion of right turn volume

The proportion of right turn volume is computed as the division of the curb lane right-turn auto volume divided by curb-lane volume at critical bus stop

\[
\text{P}_{RT}(n) := \begin{cases} 
\text{P}_{\text{RT}} & \text{for } m \in 0..n - 1 \\
\text{Data}_{2,m}^{2} & \text{V}_{c}^{c}(\text{Stops2})_{m} \\
\text{P}_{\text{RT}} & \text{otherwise}
\end{cases}
\]

Right-turn saturation adjustment factor (see Example 2, Page 27-39)

\[
\text{f}_{RT}(n) := \begin{cases} 
\text{f}_{RT} & \text{for } m \in 0..n - 1 \\
1 - 0.15 \cdot \text{P}_{RT}(\text{Stops2})_{m} & \text{otherwise}
\end{cases}
\]

Capacity of right turns at specific intersection (see Example 2, Page 27-39)

The units of \(s_0\) are removed.

\[
\text{c}_{r}(n) := \begin{cases} 
\text{c} & \text{for } m \in 0..n - 1 \\
\text{Data}_{6,m}^{2} & \text{\cdot Data}_{5,m}^{2} \\
\text{fa} \cdot \text{f}_{RT}(\text{Stops2})_{m} & \text{otherwise}
\end{cases}
\]

Capacity of adjacent lane (see Example 4, Page 27-41)

If the type of facilities is Exclusive Urban Street (Facilities = 1) or the bus stop location is Near Side (StopCondition = 1), the capacity of adjacent lanes is 0. The units of \(s_0\) are removed.

\[
\text{c}_{a}(n) := \begin{cases} 
\text{c} & \text{for } m \in 0..n - 1 \\
0 & \text{Facilities = 1 \lor StopCondition = 1} \\
\text{Data}_{6,m}^{2} & \text{\cdot Data}_{5,m}^{2} \\
f_{a} \cdot \text{f}_{RT}(\text{Stops2})_{m} & \text{otherwise}
\end{cases}
\]

Number of alternating skip stops in sequence

\(N_s\) is 1 for stops every block (StopCondition = 1), 2 for alternating 2-block stops (StopCondition = 2) and 3 for alternating 3-block (StopCondition = 3).

\[
N_s := \begin{cases} 
1 & \text{if } \text{StopCondition} = 1 \\
2 & \text{if } \text{StopCondition} = 2 \\
3 & \text{if } \text{StopCondition} = 3
\end{cases}
\]
Adjustment factor for ability to fully utilize bus stops in a skip-stop operation  
*(see Definition of Variables of Equation 27-8)*

K is 0.5 for random arrivals (Arrivals = 1), 0.75 for typical arrivals (Arrivals = 2) and 1 for platooned arrivals (Arrivals = 3)

\[
K := \begin{cases} 
0.5 & \text{if } \text{Arrivals} = 1 \\
0.75 & \text{if } \text{Arrivals} = 2 \\
1 & \text{if } \text{Arrivals} = 3 
\end{cases}
\]

Adjacent-lane impedance factor *(see Equation 27-9)*

If the type of facilities is Exclusive Urban Street (Facilities = 1) or the bus stop location is Near Side (StopCondition = 1), \(a\) is 0.

\[
a(n) := \begin{cases} 
a_{m} \leftarrow 0 & \text{if } (\text{Facilities} = 1 \lor \text{StopCondition} = 1) \\
a_{m} \leftarrow 1 - 0.8 \left( \frac{V_{a}(\text{Stops2})_{m}}{c_{a}(\text{Stops2})_{m}} \right)^{3} & \text{otherwise} 
\end{cases}
\]

Capacity adjustment factor for skip-operations *(see Equation 27-8)*

If the type of facilities is Exclusive Urban Street (Facilities = 1) or the bus stop location is Near Side (StopCondition = 1), \(f_{k}\) is 0.

\[
f_{k}(n) := \begin{cases} 
f_{k_{m}} \leftarrow 0 & \text{if } (\text{Facilities} = 1 \lor \text{StopCondition} = 1) \\
f_{k_{m}} \leftarrow 1 + K_a(\text{ Stops2})_{m} \left( \frac{N_{s} - 1}{N_{s}} \right) & \text{otherwise} 
\end{cases}
\]

Bus stop location factors *(see Exhibit 27-15)*

A matrix with the values of Exhibit 27-15 is created.

\[
f_{I} := \begin{pmatrix} 1 & 0.9 & 0 \\
0.9 & 0.7 & 0 \\
0.8 & 0.5 & 0 
\end{pmatrix}
\]

Mixed-traffic adjustment factor *(see Equation 27-16)*

If the type of facilities is Exclusive Urban Street (Facilities = 1), \(f_{m}\) is 0.

If the type of facilities is Mixed Traffic (Facilities = 2), \(f_{m}\) is computed with the Equation 27-16. \(f_{I}\) depends on the bus stop location and on the bus lane type (\(f_{I_{\text{StopLocation} = 1, \text{LaneType} = 1}}\)). The stop location (Near-side, Midblock, or Far-side) defines the row and the bus lane type (Type 1, 2, or 3) defines the column in Exhibit 27-15.
Right-turn adjustment factor (see Equation 27-7)

If the type of facilities is Mixed Traffic (Facilities = 2), \( f_r \) is 0.

If the type of facilities is Exclusive Urban Street (Facilities = 1), \( f_r \) is computed with the Equation 27-7. \( f_I \) depends on the bus stop location and on the bus lane type (\( f_{\text{StopLocation-1,LaneType-1}} \)).

The stop location (Near-side, Midblock, or Far-side) defines the row and the bus lane type (Type 1, 2, or 3) defines the column in Exhibit 27-15.

Values of percent failure associated with \( Z_a \) (see Exhibit 27-11)

\[
\begin{array}{c|c}
\text{FailureRate} & Z_a \\
\hline
1 & 2.33 \\
2.5 & 1.96 \\
5 & 1.645 \\
7.5 & 1.44 \\
10 & 1.28 \\
15 & 1.04 \\
20 & 0.84 \\
25 & 0.675 \\
30 & 0.525 \\
50 & 0 \\
\end{array}
\]

Maximum number of buses per berth per hour (see Equation 27-5)

\( B_{bb} \) is calculated for \( n \) stops.

\( Z_a \) of the equation is computed as a linear interpolation of \( Fr \) (given failure rate) on the vectors of FailureRate and \( Z_a \) defined above \( \text{interp} \{ \text{FailureRate}, Z_a, Fr \} \). The units of \( t_c \) are removed.

\[
B_{bb}(n) := \begin{cases} 
\text{for } m \in 0..n - 1 \\
B_{bb} & \left[ \frac{\text{3600 gC}}{t_c/s + gC \cdot \text{Data2}_{1,m} + \text{interp} \{ \text{FailureRate}, Z_a, Fr \} \cdot c_v \cdot \text{Data2}_{1,m}} \right]
\end{cases}
\]
Number of effective loading areas \( N_{eb} \) (see Exhibit 27-12)

A matrix with the values of No. of Cumulative Effective Loading Areas of Exhibit 27-12 is created. The first column corresponds to On-Line Loading Areas and the second column corresponds to Off-Line Loading Areas:

\[
\begin{bmatrix}
1.00 & 1.00 \\
1.85 & 1.85 \\
2.45 & 2.60 \\
2.65 & 3.25 \\
2.70 & 3.75 \\
\end{bmatrix}
\]

\( \text{NEB} := \begin{bmatrix}
1.00 \\
1.85 \\
2.45 \\
2.65 \\
2.70 \\
\end{bmatrix} \)

The value of \( N_{eb} \) depends on the number of loading areas per stop, \( La \), and depends on the location of loading areas, \( \text{LoadingArea} \).

\[ N_{eb} := \text{NEB}_{La-1, \text{LoadingArea}-1} \]

Bus lane vehicle capacity (see Equation 27-10 and Equation 27-11)

If the type of facilities is Exclusive Urban Street (\( \text{Facilities} = 1 \)), B is computed with the Equation 27-10.

If the type of facilities is Mixed Traffic, the value of B is computed using the Equation 27-10, if the bus stops every block (\( \text{StopCondition} = 1 \)), otherwise B is computed with the Equation 27-11.

\[
B(n) := \begin{cases} 
\text{if } \text{Facilities} = 1 & \frac{\text{BB}_m}{\text{StopCondition} = 1} \\
\text{otherwise} & \text{otherwise} \\
\text{if } \text{StopCondition} = 2 & \text{otherwise} \\
\text{otherwise} & \text{otherwise} \\
\text{if } \text{StopCondition} = 3 & \text{otherwise} \\
\end{cases}
\]

\[
\begin{align*}
\text{for } m & \in 0..n - 1 & \text{if } \text{Facilities} = 1 \\
\text{BB}_m & \leftarrow \text{B}_{bb}(\text{Stops2})_m \cdot N_{eb} \cdot f_1(\text{Stops2})_m \\
\end{align*}
\]

\[
\begin{align*}
\text{otherwise} & \text{for } m \in 0..n - 1 & \text{if } \text{StopCondition} = 1 \\
\text{BB}_m & \leftarrow \text{B}_{bb}(\text{Stops2})_m \cdot N_{eb} \cdot f_1(\text{Stops2})_m \\
\end{align*}
\]

\[
\begin{align*}
\text{otherwise} & \text{if } \text{StopCondition} = 2 \\
\text{for } m & \in 0..n - 1 \\
\text{Route}_1 & \leftarrow \text{Data}_{7,m}^{2,m} \\
\text{for } m & \in 1..n - 1 \\
\text{Route}_2 & \leftarrow \text{Data}_{7,m}^{2,m+1} \\
\text{for } m & \in 0..n - 1 \\
\text{BB}_m & \leftarrow f_k(\text{Stops2})_m \left( \min(\text{Route}_1) + \min(\text{Route}_2) \right) \\
\end{align*}
\]

\[
\begin{align*}
\text{otherwise} & \text{if } \text{StopCondition} = 3 \\
\text{for } m & \in 0..n - 1 \\
\text{Route}_1 & \leftarrow \text{Data}_{7,m}^{2,m} \\
\end{align*}
\]

9
for \( m = 1, 4 \ldots n - 1 \)

\[
\text{Route}_2^m \leftarrow \text{Data}_2^m, m \frac{3}{2m+1}
\]

for \( m = 2, 5 \ldots n - 1 \)

\[
\text{Route}_3^m \leftarrow \text{Data}_2^m, m \frac{3}{2m+2}
\]

for \( m = 0 \ldots n - 1 \)

\[
\text{BB}_m \leftarrow f_k(\text{Stops}_2)_m \left( \min(\text{Route}_1) + \min(\text{Route}_2) + \min(\text{Route}_3) \right)
\]

**Results table**

The results are rounded to the nearest integer.

All the functions all called using the total number of stops (\( \text{Stops}_2 \)) as an argument.

\[
\text{Results} := \text{stack} \left( \text{Data}_2^T, \text{P}_\text{RT}(\text{Stops}_2)^T, f_{\text{RT}}(\text{Stops}_2)^T, \left( \text{Data}_2^T \right)^T, \left( \text{Data}_2^T \right)^T, \left( \text{round}(c_r(\text{Stops}_2), 0) \right)^T, \left( \text{round}(c_r(\text{Stops}_2), 0) \right)^T \right)
\]

<table>
<thead>
<tr>
<th>Results</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop number ( P_\text{RT} )</td>
<td>0.795</td>
<td>0.588</td>
<td>0.417</td>
<td>0.769</td>
</tr>
<tr>
<td>Right-turn saturation adjustment factor, ( f_{\text{RT}} )</td>
<td>0.881</td>
<td>0.912</td>
<td>0.938</td>
<td>0.885</td>
</tr>
<tr>
<td>Pedestrian adjustment factor for right-turn movements, ( f_{\text{RPB}} )</td>
<td>0.948</td>
<td>0.898</td>
<td>0.883</td>
<td>0.908</td>
</tr>
<tr>
<td>Heavy-vehicle factor, ( f_{HV} )</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Right-turn lane capacity, ( c_r ) (veh/h)</td>
<td>540</td>
<td>529</td>
<td>535</td>
<td>519</td>
</tr>
<tr>
<td>Curb lane capacity, ( c_c ) (veh/h)</td>
<td>540</td>
<td>529</td>
<td>535</td>
<td>519</td>
</tr>
<tr>
<td>Adjacent lane capacity, ( c_a ) (veh/h)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Right-turn lane volume, ( v_r ) (veh/h)</td>
<td>350</td>
<td>200</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>Curb lane volume, ( v_c ) (veh/h)</td>
<td>440</td>
<td>340</td>
<td>240</td>
<td>390</td>
</tr>
<tr>
<td>Adjacent lane volume, ( v_a ) (veh/h)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Right-turn adjustment factor, ( f_r )</td>
<td>0.351</td>
<td>0.622</td>
<td>0.813</td>
<td>0.422</td>
</tr>
<tr>
<td>Mixed-traffic adjustment factor, ( f_m )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Capacity adjustment factor for skip-stop operations, ( f_k )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum number of buses per berth per hour, ( B_{bb} ) (buses/h)</td>
<td>33</td>
<td>29</td>
<td>26</td>
<td>45</td>
</tr>
<tr>
<td>Bus lane capacity, ( B ) (buses/h)</td>
<td>21</td>
<td>33</td>
<td>39</td>
<td>35</td>
</tr>
</tbody>
</table>
Bus Person Capacity

**Inputs**

- Number of seats: \(Sn := 43\)
- Number of buses that not allow standees: \(Nbns := 10\)
- Number of buses that allow standees: \(Nbys := 30\)
- Load factor: \(Lf := 1.5\)
- Peak-hour factor: \(PHF := 0.75\)

**Bus person capacity (see Example 5 Page 27-42)**

The function \(\text{ceil}\) returns the smallest integer greater than the value computed.

\[
P := \text{ceil}[(Nbns \cdot Sn) + (Nbys \cdot Sn \cdot Lf) \cdot PHF]
\]

**Results**

- Bus person capacity: \(P = 1774\ p\)

Average Speed of Buses

**Inputs**

- Block length: \(Bl := 400\ ft\)
- Volume in adjacent lane: \(v := 400\ \text{veh/hr}\)
- Vehicular capacity of adjacent lane: \(c := 985\ \text{veh/hr}\)
- Volume of buses in bus lane: \(v_b := 40\ \text{buses/hr}\)
- Bus vehicle capacity: \(c_b := 48\ \text{buses/hr}\)
- Bus running time losses: \(t_{r1} := 3.8\ \text{min/mi}\)
- Bus-bus interference adjustment factor: \(f_b := 1\)

**Variables used in this section and not defined in HCM**

- \(Bl\): block length
- \(Data\): input table of the Bus Vehicle Capacity section
- \(StopCondition\): defines the condition of the stops; 1 for Stops every block, 2 for Alternating 2-block stops, 3 for Alternating 3-block stops.
Stops frequency

The stops frequency depends if the bus stops every block \( \text{StopCondition} = 1 \), every 2 blocks \( \text{StopCondition} = 2 \) or every 3 blocks \( \text{StopCondition} = 3 \)

\[
\text{SF} := \begin{cases} 
N \leftarrow 1 & \text{if StopCondition = 1} \\
N \leftarrow 2 & \text{if StopCondition = 2} \\
N \leftarrow 3 & \text{if StopCondition = 3} \\
1 & N \text{ Bl}
\end{cases}
\]

Average dwell time

\[
\text{AvgDwellTime} := \text{mean}\left(\left[\left(\text{Data}\right)^T\right]\right)
\]

Estimated base bus running time (see Exhibit 27-18)

A vector is created with the headers of the columns of Exhibit 27-18.

\[
\text{StopsPerMi} := \begin{pmatrix} 2 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 12 \end{pmatrix}
\]

A vector with the dwell times shown in the first column of Exhibit 27-18 is created.

\[
\text{DwellTime} := \begin{pmatrix} 10 \\ 20 \\ 30 \\ 40 \\ 50 \\ 60 \end{pmatrix}
\]

A matrix with the values of the estimated base bus running time given in Exhibit 27-18 is created.

\[
\text{tr0} := \begin{pmatrix} 2.4 & 3.27 & 3.77 & 4.3 & 4.88 & 5.53 & 6.23 & 7 & 8.75 \\
2.73 & 3.93 & 4.6 & 5.3 & 6.04 & 6.87 & 7.73 & 8.67 & 10.75 \\
3.07 & 4.6 & 5.43 & 6.3 & 7.2 & 8.2 & 9.21 & 10.33 & 12.75 \\
3.4 & 5.27 & 6.26 & 7.3 & 8.35 & 9.53 & 10.71 & 12 & 14.75 \\
3.74 & 5.92 & 7.08 & 8.3 & 9.52 & 10.88 & 12.21 & 13.67 & 16.75 \\
4.07 & 6.58 & 7.9 & 9.3 & 10.67 & 12.21 & 13.7 & 15.33 & 18.75 \end{pmatrix}
\]
A new row of Exhibit 27-18 is created using a linear interpolation. This new row corresponds to the average dwell time.

\[
\text{NewRow} := \begin{cases} 
\text{for } m \in [0..8] \\
\text{Newrow}_m & \leftarrow \text{interp}\left(DwellTime, tr_0^{(m)}, \text{AvgDwellTime}\right) 
\end{cases}
\]

\(t_{r0}\) is computed using a linear interpolation of the stop frequency (SF) in the vector stops per mi and the new row of Exhibit 27-18 calculated above. The units of the stop frequency (SF) are removed, multiplying by 1 mile.

\(t_{r0} := \text{interp}(\text{StopsPerMi, NewRow, SF-mi})\)

**Skip stop speed adjustment factor (see Equation 27-15)**

If the bus stops every block (StopCondition = 1), \(f_s\) is 1. Otherwise, \(f_s\) is computed using the Equation 27-15.

\[
f_s := \begin{cases} 
1 & \text{if } \text{StopCondition} = 1 \\
1 - \frac{\text{Bl}}{\text{StopCondition} \cdot \text{Bl}} \left( \frac{v}{c} \right)^2 \frac{v_b}{c_b} & \text{otherwise}
\end{cases}
\]

**Bus travel speed (see Equation 27-14)**

To compute \(S_t\), the units of \(t_{r0}\) and \(t_{r1}\) are removed, multiplying by 1 mi/min. Then, the units of mi/hr are added to the final value of \(S_t\).

\[
S_t := \frac{60}{t_{r0} \text{ mi/min} + t_{r1} \text{ mi/min}} \cdot f_s \cdot f_b \cdot \frac{\text{mi}}{\text{hr}}
\]

**Results**

Stop frequency: \(SF = 13.2 \ \text{stops/mi}\)

Base bus running time: \(t_{r0} = 14.477 \ \text{min/mi}\)

Skip-stop speed adjustment factor: \(f_s = 1\)

Bus travel speed: \(S_t = 3.3 \ \text{mi/hr}\)
LIGHT RAIL AND STREETCAR FACILITIES

Inputs

General Inputs

Number of cars per train: \( C_t := 1 \)
Block length \( B_l := 450 \text{ft} \)
Peak-hour loading service standard: \( \text{PHL} := 1.5 \frac{D}{\text{ft}} \)

Dwell Time Inputs

Dwell time: \( t_d := 35 \text{s} \)
Number of channels per door for moving passengers: \( N_{cd} := 0 \)
Door opening and closing time: \( t_{oc} := 0 \text{s} \)
Alighting passengers per rail through busiest door: \( P_d := 0 \text{p} \)
Type of car entry:
Flow classification: Level
Mainly Boarding

Minimum Headways Inputs

Effective green time per signal cycle: \( g_C := 0.5 \)
Maximum cycle length in line's on-street section: \( C_{\text{max}} := 90 \text{s} \)
Clearance time between successive trains: \( t_c := 27.7 \text{s} \)
Failure rate: \( F_r := 25\% \)
Coefficient of variation of dwell times: \( c_v := 40\% \)
Time to cover single-track section: \( t_{\text{st}} := 0 \text{s} \)
Length of single-track section: \( L_{\text{st}} := 0 \text{ft} \)
Train length: \( L := 0 \text{ft} \)
Car length: \( L_c := 90 \text{ft} \)
Number of stations on single-track section: \( N_s := 0 \)
Maximum speed reached: \( S_{\text{max}} := 0 \frac{\text{ft}}{\text{s}} \)
Deceleration rate: \( d_s := 0 \frac{\text{ft}}{\text{s}^2} \)
Initial acceleration: \( a_s := 3 \frac{\text{ft}}{\text{s}^2} \)
Jerk-limiting time: \( t_{jl} := 0 \text{s} \)
Operator and braking system reaction time: \( t_{br} := 0 \text{s} \)
Speed margin: \( \text{SM} := 0 \)
Operating margin time: \( t_{om} := 0 \text{s} \)
Minimum block-signaled section train headway: \( h_{bs} := 0 \text{s} \)

**Light Rail and Streetcar Capacity Inputs**

Analysis section length: \( L_{as} := 0 \text{mi} \)
Free-flow speed of train: \( S_f := 0 \text{ mi/hr} \)
Number of stops or stations in analysis section: \( N := 0 \)

---

**Variables used in this section and not defined in HCM**

*CarEntry*: defines the type of car entry; 1 for level, 2 for steps  
*DwellTime*: defines if the dwell time is known or unknown; 1 for known, 2 for unknown  
*Flow*: defines the flow classification; 1 for Mainly boarding, 2 for Mainly alighting, 3 for Mixed flow  
*Fr*: failure rate

**Passenger Flow Time (see Exhibit 27-23)**

A matrix with the values of \( t_{pf} \) given in Exhibit 27-23 is created.

\[
\begin{bmatrix}
2.0 & 1.5 & 2.5 \\
3.2 & 3.7 & 5.2
\end{bmatrix}
\]

**Dwell time (see Equation 27-19)**

If the dwell time is known (\( DwellTime = 1 \)), the actual value of \( t_d \) is used. Otherwise \( t_d \) is computed using the Equation 27-19.

The \( t_{pf} \) value depends on the type of car entry (\( \text{CarEntry} \)) and the flow classification (\( \text{Flow} \)).

\[
t_d := \begin{cases} 
  t_d & \text{if } DwellTime = 1 \\
  P_d \cdot t_{pf} \cdot \text{CarEntry} - 1, \text{Flow} - 1 \cdot N_{cd} + t_{oc} & \text{if } DwellTime = 2
\end{cases}
\]

**Number of doors available in peak hour (see Equation 27-20)**

Units of seconds are added to 3600, in order to make the equation units compatible.

\[
D := \frac{3600 \cdot D_c \cdot N_c}{h_s}
\]
Passenger volume through busiest door during peak 15 min (see Equation 27-21)

\[ P_d := \frac{R_d \cdot P}{D \cdot PHF} \]

Minimum on-street section train headway (see Equation 27-23)

If more than one-car train can occupy a block or stop at the same time without blocking other vehicles (\(Bl \geq 2L_c\)), the traffic signal cycle time component of the equation is not considered (\(2C_{\text{max}}\)).

\[
h_{\text{os}} := \begin{cases} 
    \frac{t_c + gC \cdot t_d + \text{interp}(\text{FailureRate}, Z_{a'}, Fr) \cdot \frac{c_v}{100\%} \cdot t_d}{gC} & \text{if } Bl \geq 2L_c \cdot C_t \\
    \max \left[ \frac{t_c + gC \cdot t_d + \text{interp}(\text{FailureRate}, Z_{a'}, Fr) \cdot \frac{c_v}{100\%} \cdot t_d}{gC}, 2C_{\text{max}} \right] & \text{otherwise}
\end{cases}
\]

The headway is rounded to an even interval of 1h. The smallest integer greater than result of the division of \(h_{\text{os}}\) by 60 is taken (\(\text{ceil}\left(\frac{h_{\text{os}}}{60}\right)\)) and multiplied by 60 (1h).

\[ h_{\text{os}} := \text{ceil}\left(\frac{h_{\text{os}}}{60}\right) \cdot 60 \]

Time to cover single-track section (see Equation 27-24)

\[
t_{\text{st}} := SM \left[ \left( \frac{N_s + 1}{2} \right) \left( \frac{3S_{\text{max}}}{d_s} + t_{\text{jl}} + t_{\text{br}} \right) + \frac{L_{\text{st}} + L}{s_{\text{max}}} \right] + N_s \cdot t_d + t_{\text{om}}
\]

Minimum single-track section train headway (see Equation 27-25)

\[ h_{\text{st}} := 2 \cdot t_{\text{st}} \]

Minimum train headway (see Equation 27-22)

\[ h_{\text{min}} := \max(h_{\text{os}}, h_{\text{bs}}, h_{\text{st}}) \]

Maximum number of trains per hour (see Equation 27-26)

The units of seconds is added to 3600 in order to make the equation units compatible.

\[ T := \frac{3600s}{h_{\text{min}}} \]
Maximum single-track capacity in passengers per peak-hour direction (see Example 7 Page 27-45)

If the bus person capacity is not input above (P = 0), P is computed using the equation shown on the Example 7, page 27-45, step 4.

\[
P := \begin{cases} 
\text{ceil} \left( \frac{3600s}{h_{\text{min}}} \cdot C_t \cdot L_c \cdot PHL \cdot PHF \right) & \text{if } P = 0 \\
& \text{P otherwise}
\end{cases}
\]

Running time (see Equation 27-29)

\[
t_r := \frac{L_{\text{as}}}{S_f}
\]

Acceleration and deceleration time (see Equation 27-30)

\[
t_a := \frac{3S_f}{d_s} + t_{\text{jl}} + t_{\text{br}}
\]

Total travel time (see Equation 27-31)

\[
t_t := t_r + (N - 1) \cdot (t_d + t_a)
\]

Average travel speed (see Equation 27-32)

\[
S_t := \frac{L_{\text{as}}}{t_t}
\]

Results

Dwell Time: \( t_d = 0 \text{s} \)

Number of doors available in peak hour: \( D = 120 \)

Passenger volume through busiest door: \( P_d = 0 \text{p} \)

Minimum on-street section train headway: \( h_{\text{os}} = 60 \text{s} \)

Minimum single-track section train headway: \( h_{\text{st}} = 0 \text{s} \)

Time to cover single-track section: \( t_{\text{st}} = 0 \text{s} \)

Maximum number of trains per hour: \( T = 60 \)

Maximum person capacity: \( P = 6075 \text{p} \)

Running time: \( t_r = 0 \text{s} \)

Acceleration and deceleration time: \( t_a = 0 \text{s} \)

Total travel time: \( t_t = 0 \text{s} \)

Average travel speed: \( S_t = 0 \text{ mi/hr} \)