1) A flexible manufacturing system is being planned. It has a ladder layout as pictured in Figure 1 and uses a rail guided vehicle system to move parts between stations in the layout. All workparts are loaded into the system at station 1, moved to one of three processing stations (2, 3, or 4), and then brought back to station 1 for unloading. Once loaded onto its RGV, each workpart stays onboard the vehicle throughout its time in the FMS. Load and unload times at station 1 are each 1.0 min. Processing times at other stations are: 5.0 min at station 2, 7.0 min at station 3, and 9.0 min at station 4. Hourly production of parts through the system is: 7 parts through station 2, 6 parts through station 3, and 5 parts through station 4.

a. Develop the from-to Chart for trips and distances
b. Develop the network diagram for this data
c. Determine the number of rail guided vehicles that are needed to meet the requirements of the flexible manufacturing system, if vehicle speed = 60 m/min and the anticipated traffic factor = 0.85. Assume reliability = 100%.

Solution: (a) First develop the distances from the FMS layout.
Distance from 1 to 2: 10 + 10 + 10 = 30 m
Distance from 2 to 1: 5 + 10 + 5 = 20 m
Distance from 1 to 3: 10 + 20 + 10 = 40 m
Distance from 3 to 1: 5 + 20 + 5 = 30 m
Distance from 1 to 4: 10 + 30 + 10 = 50 m
Distance from 4 to 1: 5 + 30 + 5 = 40 m

From-To chart:

<table>
<thead>
<tr>
<th>From:</th>
<th>To:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0/0</td>
<td>7/30</td>
<td>6/40</td>
<td>5/50</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>7/20</td>
<td>0/0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>6/30</td>
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<td>0/0</td>
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</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5/40</td>
<td>-</td>
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<td>0/0</td>
</tr>
</tbody>
</table>
(b) Network diagram:

(c) \( L_d = \frac{7(30+20) + 6(40+30) + 5(50+40)}{7+6+5} = \frac{1220}{18} = 67.7 \text{ m} \quad L_e = 0 \)

Average handling and processing time = \( 1.0 + \frac{7(5,0) + 6(7,0) + 5(9,0)}{7+6+5} + 1.0 = 8.78 \text{ min} \)

\( T_c = 8.78 + \frac{67.7}{60} + \frac{0}{60} = 9.91 \text{ min} \)

\( R_{dv} = \frac{60(0.85)}{9.91} = 5.15 \text{ pc/hr per vehicle} \quad n_c = \frac{7+6+5}{5.15} = 18/5.15 = 3.5 \rightarrow 4 \text{ vehicles} \)

2) An AGVS will be used to satisfy material flows indicated in the from-to Chart in the table below, which shows deliveries per hour between stations (above the slash) and distances in meters between stations (below the slash). Moves indicated by "L" are trips in which the vehicle is loaded, while "E" indicates moves in which the vehicle is empty. It is assumed that availability = 0.90, traffic factor = 0.85, and efficiency = 1.0. Speed of an AGV = 0.9 m/s. If load handling time per delivery cycle = 1.0 min, determine the number of vehicles needed to satisfy the indicated deliveries per hour? Assume that availability = 0.90.

<table>
<thead>
<tr>
<th>To</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>From:</td>
<td>1</td>
<td>0/0</td>
<td>9L/90</td>
<td>7L/120</td>
</tr>
<tr>
<td>2</td>
<td>5E/90</td>
<td>0/0</td>
<td>0/NA</td>
<td>4L/80</td>
</tr>
<tr>
<td>3</td>
<td>7E/120</td>
<td>0/NA</td>
<td>0/0</td>
<td>0/NA</td>
</tr>
<tr>
<td>4</td>
<td>9E/75</td>
<td>0/NA</td>
<td>0/NA</td>
<td>0/0</td>
</tr>
</tbody>
</table>

Solution: \( v_c = 0.9 \text{ m/s}(60 \text{ s/min}) = 54 \text{ m/min} \)

Route 1 → 2 → 1: \( T_c = 1.0 + (90 + 90)/54 = 4.33 \text{ min} \), 5 deliveries.
Route 1 → 3 → 1: \( T_c = 1.0 + (120 + 120)/54 = 5.44 \text{ min} \), 7 deliveries.
Route 1 → 4 → 1: \( T_c = 1.0 + (75 + 75)/54 = 3.78 \text{ min} \), 5 deliveries.
Route 2 → 4 → 1*: \( T_c = 1.0 + (80 + 75)/54 = 3.87 \text{ min} \), 4 deliveries.
Route 1 → 2*: \( T_c = 1.0 + 90/54 = 2.67 \text{ min} \), 4 deliveries.

* Assumes vehicles on route 1 → 2 are used to make deliveries on route 2 → 4 → 1.

Average \( T_c = \frac{5(4.33) + 7(5.44) + 5(3.78) + 4(3.87) + 4(2.67)}{25} = 4.192 \text{ min/delivery cycle} \)

\( R_{dv} = \frac{60(0.85)}{4.192} = 12.166 \text{ deliveries/hr per vehicle} \)

Including effect of availability factor, \( R_{dv} = 12.166(0.90) = 10.95 \text{ deliveries/hr per vehicle} \)

\( n_c = 25/10.95 = 2.28 \rightarrow 3 \text{ vehicles} \)
**Alternative solution:** Total time (workload, WL) to make all deliveries, neglecting traffic factor:

\[ WL = (25)4.192 = 104.8 \text{ min} \]

Time available per vehicle per hour, \( AT = 60(0.90)(0.85)(1.0) = 45.9 \text{ min} \)

\[ n_c = \frac{104.8}{45.9} = 2.28 \rightarrow 3 \text{ vehicles} \]

3) An automated guided vehicle system is being proposed to deliver parts between 40 workstations in a factory. Loads must be moved from each station about once every hour; thus, the delivery rate = 40 loads per hour. Average travel distance loaded is estimated to be 250 ft and travel distance empty is estimated to be 300 ft. Vehicles move at a speed = 200 ft/min. Total handling time per delivery = 1.5 min (load = 0.75 min and unload = 0.75 min). Traffic factor \( F_t \) becomes increasingly significant as the number of vehicles \( n_c \) increases; this can be modeled as:

\[ F_t = 1.0 - 0.05(n_c - 1) \quad \text{for } n_c \text{ = Integer > 0} \]

Determine the minimum number of vehicles needed in the factory to meet the flow rate requirement. Assume that availability = 1.0 and worker efficiency = 1.0.

**Solution:**

\[ T_c = 1.5 + \frac{250 + 300}{200} = 4.25 \text{ min/cycle} \]

\[ R_{dv} = \frac{60(1.0 - 0.05(n_c - 1))}{4.25} = \frac{60(1.05 - 0.05n_c)}{4.25} = 14.824 - 0.706 n_c \text{ deliveries/hr per vehicle} \]

\[ n_c = \frac{40}{14.824 - 0.706n_c} \]

\[ n_c (14.824 - 0.706 n_c) = 40 \]

\[ 14.824 n_c - 0.706 n_c^2 = 40 \]

\[ 0.706 n_c^2 - 14.824 n_c + 40 = 0 \]

Use quadratic equation to find roots:

\[ n_c = \frac{-(-14.824) \pm \sqrt{(14.824^2 - 4(0.706)(40))}}{2(0.706)} = 17.82 \text{ or } 3.18 \rightarrow \text{Use } n_c = 4 \text{ vehicles} \]

**Check:**

\[ F_t = 1.0 - 0.05(4 - 1) = 1.0 - 0.15 = 0.85 \]

\[ R_{dv} = \frac{60(0.85)}{4.25} = 12 \text{ deliveries/hr per vehicle,} \quad n_c = 40/12 = 3.33 \rightarrow \text{Use } n = 4 \text{ vehicles} \]