Vehicle Based Systems

END4650 – Material Handling Systems

Mehmet Güray Güler

Industrial Engineering Department

Yıldız Technical University

Analysis of Material Handling Systems

- Charting techniques are helpful for visualizing the movement of materials
- Quantitative models are useful for
  - analyzing material flow rates,
  - delivery cycle times, and
  - other aspects of performance.
- We will discuss
  - Charting Techniques
  - Analysis of Vehicle Based Techniques
  - Conveyor Analysis

Charting Techniques in Material Handling

<u>From-to-Charts:</u>

- Organized for possible material flows in both directions between the load/unload stations in the layout.
- Can be used to represent parameters of the material flow problem like
  - *the number of deliveries or flow rates* between locations in the layout, and
  - <u>travel distances </u>between from-to locations.

Charting Techniques in Material Handling

From-to-Charts:

- left-hand column lists origination points (loading stations) from which trips are made,
- the horizontal row at the top of the chart lists destination points (unload stations).

From-To Chart

	To	1	2	3	4	5
From	1	0	9/50	5/120	6/205	0
	2	0	0	0	0	9/80
	3	0	0	0	2/85	3/170
	4	0	0	0	0	8/85
	5	0	0	0	0	0

Charting Techniques in Material Handling

From-to-Charts:

- On the left of slash mark:
  - flow rates, loads/hr
- On the right of slash mark
  - Travel distances, meters

From-To Chart

	To	1	2	3	4	5
From	1	0	9/50	5/120	6/205	0
	2	0	0	0	0	9/80
	3	0	0	0	2/85	3/170
	4	0	0	0	0	8/85
	5	0	0	0	0	0

Charting Techniques in Material Handling

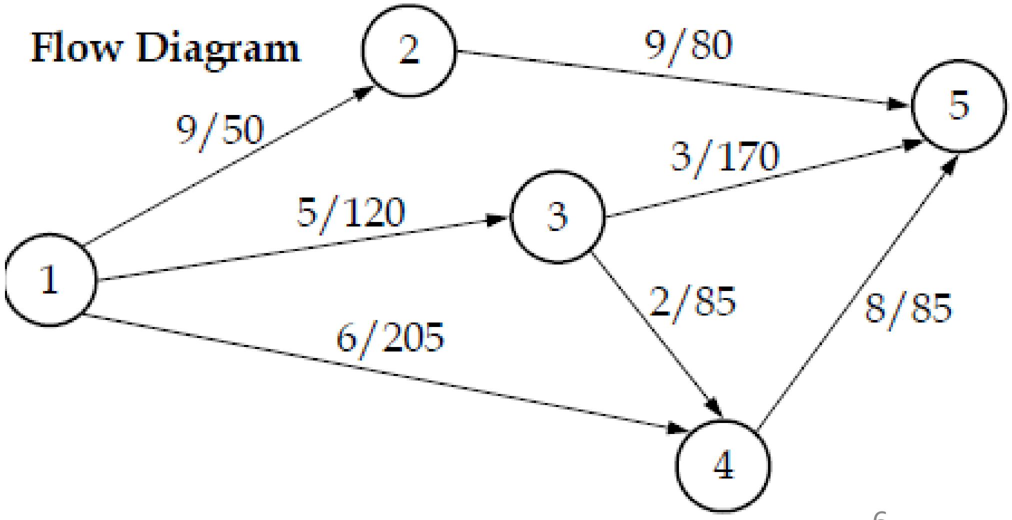
Flow Diagram:

- used to visualize
  - the movement of materials
  - the corresponding origination and destination points of the moves.
- The nodes might represent
  - production departments between which parts are moved or
  - load and unload stations in a facility.

From-To Chart

	To	1	2	3	4	5
From	1	0	9/50	5/120	6/205	0
	2	0	0	0	0	9/80
	3	0	0	0	2/85	3/170
	4	0	0	0	0	8/85
	5	0	0	0	0	0

Flow Diagram



Analysis of Vehicle-Based Systems

Equipment used in such systems include

- industrial trucks (both hand trucks and powered trucks),
- automated guided vehicles,
- monorails and other rail guided vehicles,
- certain types of conveyor systems (e.g. in-floor towline conveyors),
- certain Crane operations

Analysis of Vehicle-Based Systems

- We assume that the vehicle operates at a constant velocity throughout its operation
- ignore effects of acceleration, deceleration, and other speed diff.
- The time for a typical delivery cycle in the operation of a vehicle-based transport system consists of:
  - loading at the pickup station
  - travel time to the drop-off station
  - unloading at the drop-off station
  - empty travel time of the vehicle between deliveries

Analysis of Vehicle-Based Systems

The total cycle time per delivery per vehicle is given by

$$T_c = T_L + \frac{L_d}{v_c} + T_U + \frac{L_e}{v_c}$$

where T_c = delivery cycle time (min/del)

T_L = time to load at load station (min)

L_d = distance the vehicle travels between load and unload stations (m)

v_c = carrier velocity traveling loaded (m/min)

T_U = time to unload at unload station (min)

L_e = distance the vehicle travels empty until the start of the next delivery cycle (m)

Analysis of Vehicle-Based Systems

- The cycle time, *Tc* , is an <u>ideal value</u>,
- Because it ignores any time loss due to
  - reliability problems,
  - traffic congestion,
  - and other factors that may slow down a delivery.
- In addition, not all delivery cycles are the same.
- Originations and destinations may be different from one delivery to the next, which will effect the L_d and L_e terms.

Analysis of Vehicle-Based Systems

- **AT**: the available time (min/hr) per vehicle.
- AT accounts for the possible time losses due to
  - availability (A),
  - traffic congestion (Tf)
  - efficiency of manual drivers in the case of manually operated trucks (E)
    - $AT = (60)\,(A)\,(T_f)\,(E)$
- For Ex. ***AT=45*** min means,
  - the vehicle is available for 45min in an hour

$AT = (60)\ (A)\ (T_f)\ (E)$

Availability (*A*)

- The proportion of the total shift time that the vehicle is operational,
  - i.e. not broken down or not being repaired.
- The reliability of the vehicles

Traffic Factor (T_f)

- To deal with the time losses due to traffic congestion
- Sources of inefficiency accounted for by T_f :
  - waiting at intersections,
  - blocking of vehicles (as in an AGVS), and
  - waiting in a queue at load/unload stations.

$AT = (60)\ (A)\ (T_f)\ (E)$

- If there is no blocking of vehicles then $T_f = 1$.
- T_f decreases as blocking increases.
- Blocking, waiting at intersections, and waiting in line at load/unload stations are effected by <u>the number of vehicles in the system</u>.
  - If there is only one vehicle in the system,
    - no blocking should occur, and
    - the traffic factor will be 1.0.
  - For systems with many vehicles,
    - there will be more instances of blocking and congestion and
    - the traffic factor will take a lower value.
- Typical values of traffic factor for an AGV system range in 0.85 and 1.00.

$AT = (60)\ (A)\ (T_f)\ (E)$

Efficiency (*E*)

- Not only traffic congestion,
  - the operators
- Defined as
  - the actual work rate of the human operator
    - relative to work rate expected
    - under standard or normal performance.

Analysis of Vehicle-Based Systems

- The total number of vehicles needed to satisfy a specified total delivery schedule (R_f) in the system can be estimated by
  - first calculating the **total workload** required
  - then dividing by the **available time per vehicle**.
- What is workload?
  - the total amount of work,
  - expressed in terms of time,
  - must be accomplished by the material transport system in 1 hour.

Analysis of Vehicle-Based Systems

- **WL:** the total work load(min/hr)
- **R_f**: the specified flow rate of total deliveries per hour (del/hr).

$$WL = R_f T_C$$

- *For example*
  - *if we need total 150 deliveries in an hour (Rf = 150 del)*
  - *a delivery cycle time is 3 min/del (Tc = 3 min/del)*
  - *then the total work load is 450 min/hour*

Analysis of Vehicle-Based Systems

- $\boldsymbol{R_{dv}}$:the rate of deliveries per vehicle (del/hr)

$$R_{dv} = \frac{AT}{T_C}$$

- For example
  - AT = 45 min
  - T_c = 3 min/delivery
  - R_{dv} = 15 delivery
- R_f => Total (needed) flow
- R_{dv} => Flow by a vehicle

Analysis of Vehicle-Based Systems

- **n_c**: The number vehicles [*note that n_c must be an integer*]

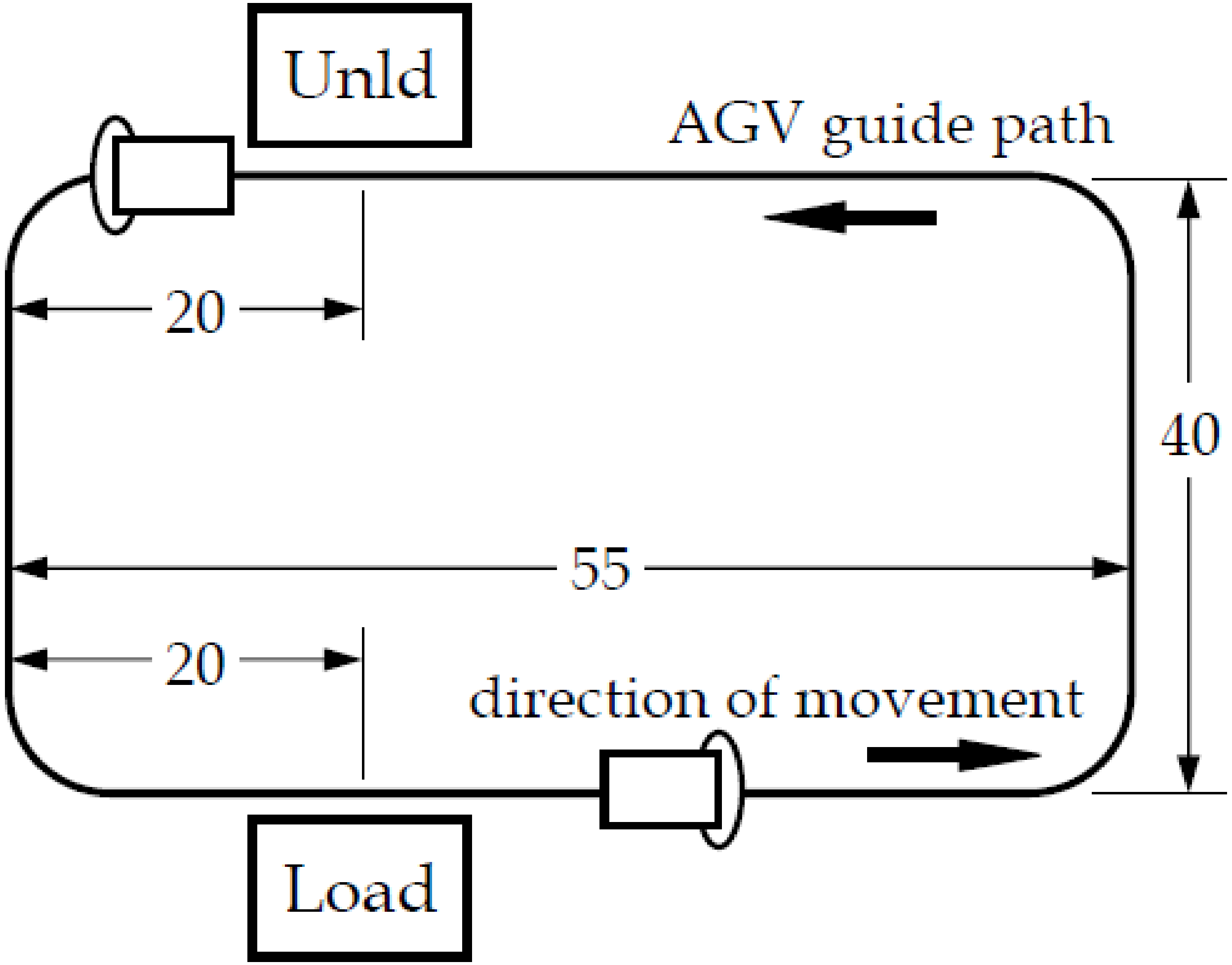
$$\boldsymbol{n_c = \frac{WL}{AT}}$$

- Then

$$n_c = \frac{R_f T_c}{R_{dv} T_c} = \frac{R_f}{R_{dv}}$$

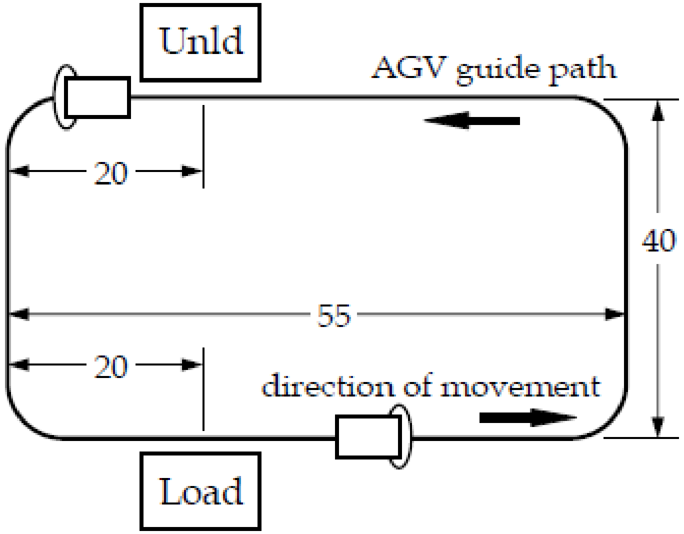
Analysis of Vehicle-Based Systems

- Given the AGVS layout.
- Vehicles travel counterclockwise around the loop to deliver loads from the load station to the unload station.
- Loading and unloading times are 0.75 and 0.50 min, respectively.
- A total of 40 del/hr must be completed by the AGVS.
- Vehicle velocity is 50 m/min,
- A = 0.95, T_f = 0.95, and E = 1.00.
- Determine how many vehicles are required to satify demand



Analysis of Vehicle-Based Systems

Example 10.1 p314 (cont)
We start with calculating T_c which in turn requires the determination of L_d and L_e. Following the direction of movement starting from the Load station, we observe that the distance the AGV travels equals (55 − 20) + 40 + (55 − 20) = 110. Similary the distance from the Unload station to the Load station equals 20 + 40 + 20 = 80.



$$R_f = 40\,\text{del/hr}$$

$$T_c = 0.75 + \frac{110}{50} + 0.5 + \frac{80}{50} = 5.05\,\text{min/del}$$

$$AT = 60 \cdot 0.95 \cdot 0.95 \cdot 1.00 = 54.15\,\text{min} \qquad R_{dv} = \frac{54.15}{5.05} = 10.72\,\text{del/hr}$$

Analysis of Vehicle-Based Systems

Example 10.1 p314 (cont)
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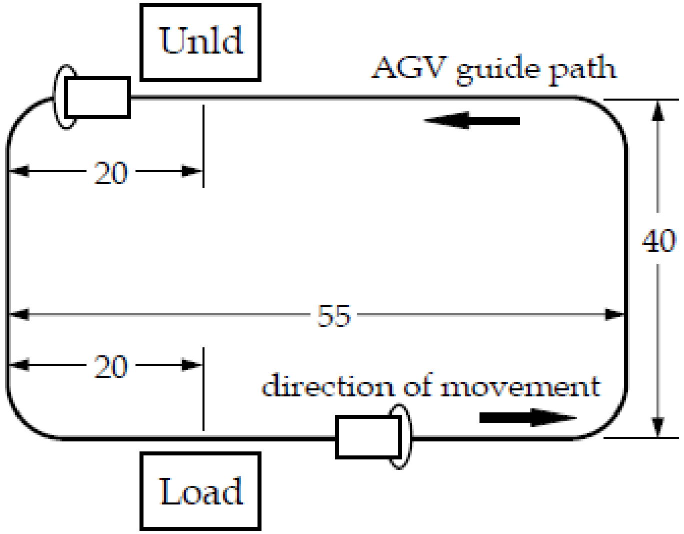


$$R_f = 40\,\text{del/hr}$$

$$T_c = 0.75 + \frac{110}{50} + 0.5 + \frac{80}{50} = 5.05\,\text{min/del}$$

$$AT = 60 \cdot 0.95 \cdot 0.95 \cdot 1.00 = 54.15\,\text{min} \qquad R_{dv} = \frac{54.15}{5.05} = 10.72\,\text{del/hr}$$

Calculate either way

$$n_c = \frac{40 \cdot 5.05}{54.15} = 3.73 \rightarrow 4\ \text{vehicles}$$

$$n_c = \frac{40}{10.72} = 3.73 \rightarrow 4\ \text{vehicles}$$

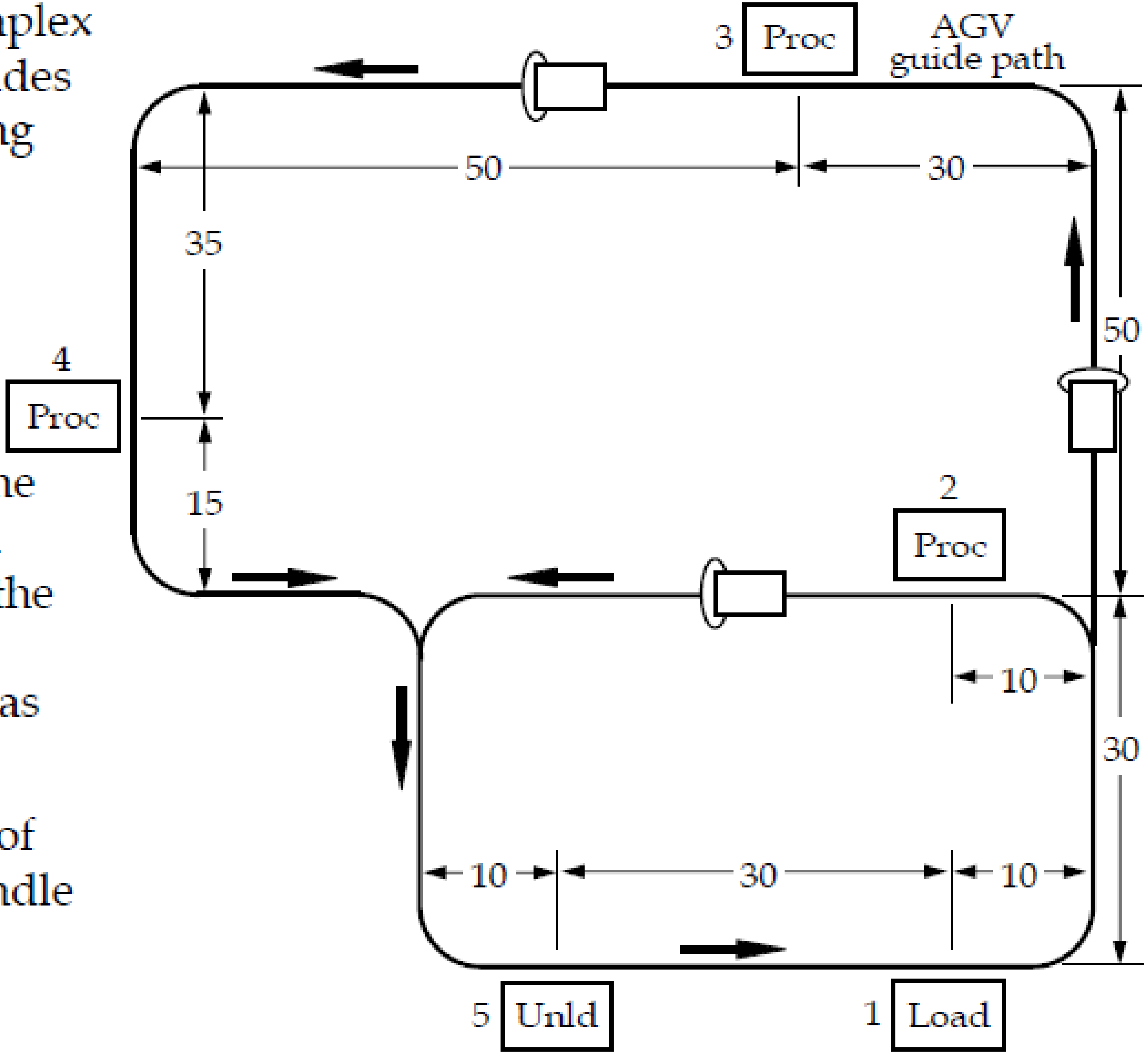
Note that 3.73 is rounded up to the next integer.

Example 10.2 p315

Consider this more complex layout. The AGVS includes load station 1, processing stations 2, 3, and 4, and unload station 5. Load and unload times are 0.5 min.

The flow rates and the distances are given in the from-to chart presented before and repeated in the next page. The vehicle specifications are same as the previous example.

Determine the number of vehicles required to handle the workload.



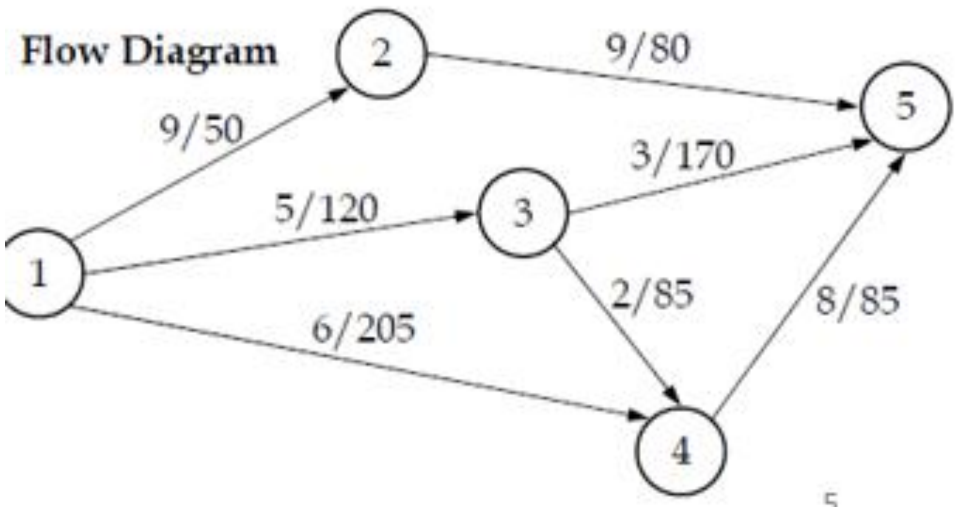
From-To Chart

	To	1	2	3	4	5
From	1	0	9/50	5/120	6/205	0
	2	0	0	0	0	9/80
	3	0	0	0	2/85	3/170
	4	0	0	0	0	8/85
	5	0	0	0	0	0

- We need to find the total cycle time per delivery Tc

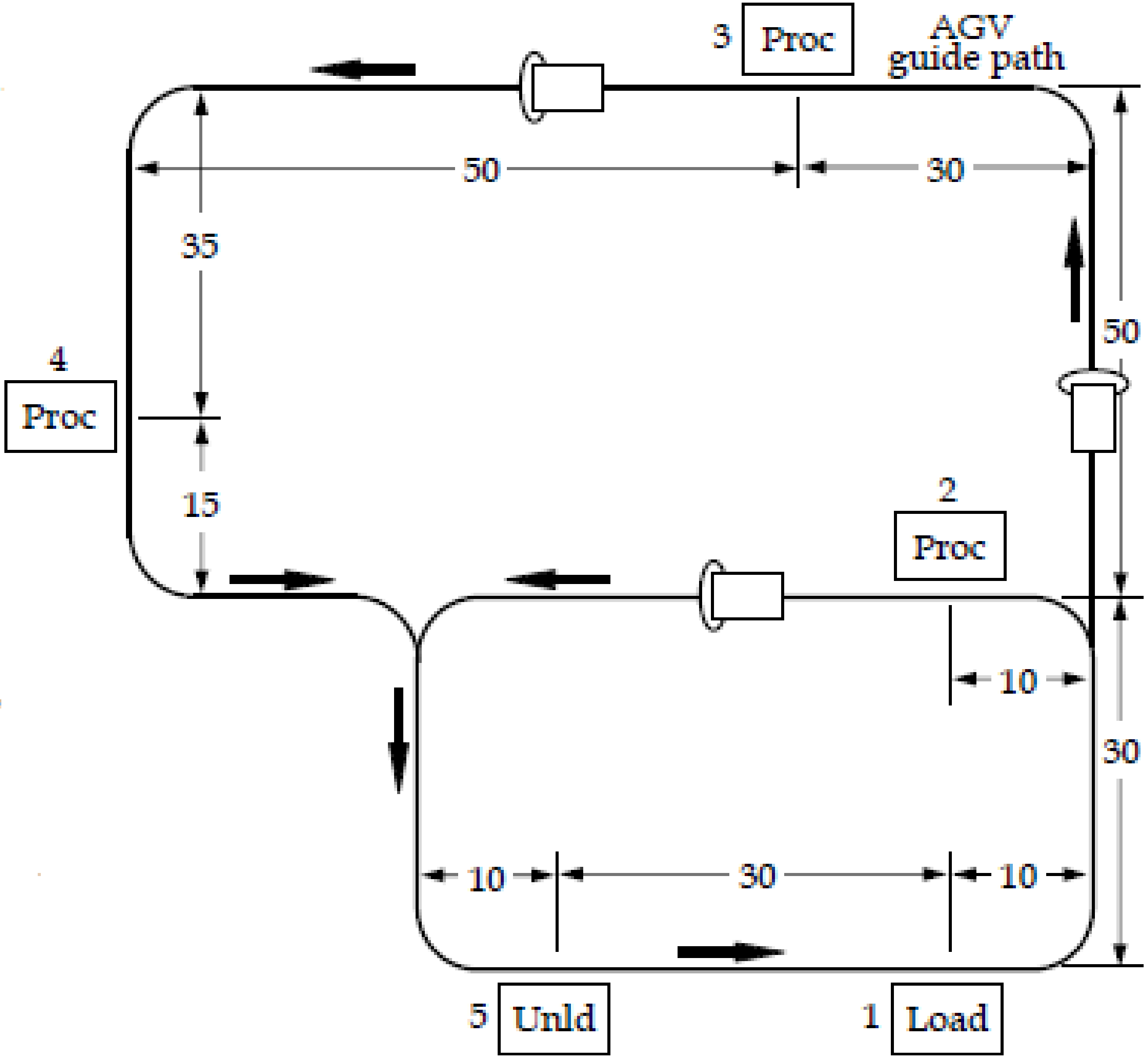
$$T_c = T_L + \frac{L_d}{v_c} + T_U + \frac{L_e}{v_c}$$

- We need L_d, the loaded travel distance with weighted average:



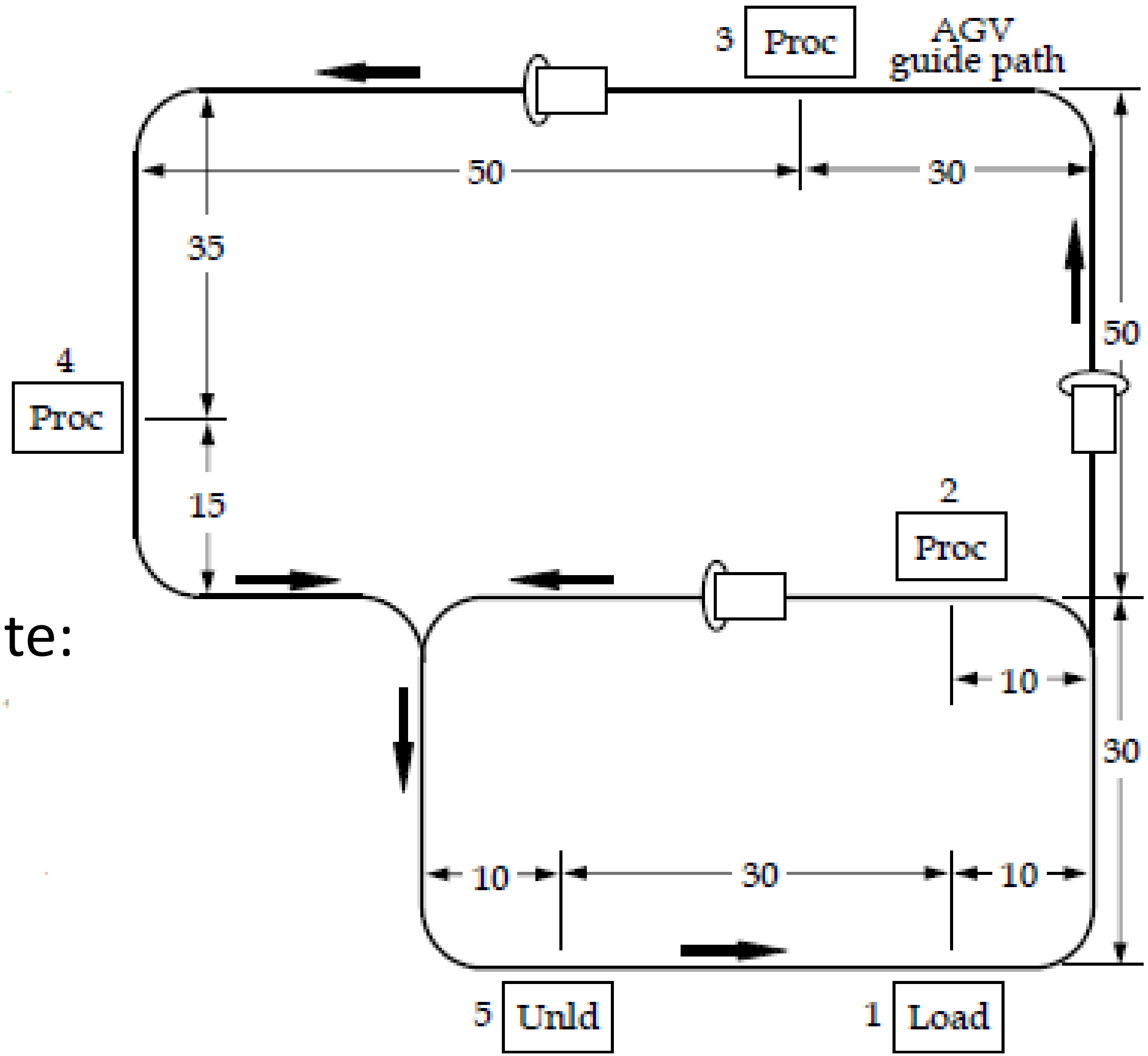
$$L_d = \frac{9 \cdot 50 + 5 \cdot 120 + 6 \cdot 205 + 9 \cdot 80 + 2 \cdot 85 + 3 \cdot 170 + 8 \cdot 85}{9 + 5 + 6 + 9 + 2 + 3 + 8} = 103$$

- How about L_e?
- We need more info!
- Consider the following scheduling rules:
- (1) vehicles delivering raw workparts from station 1 to stations 2, 3, and 4 must return empty to station 5;
- (2) vehicles picking up finished parts at stations 2, 3, and 4 for delivery to station 5 must travel empty from station 1.



From-To Chart

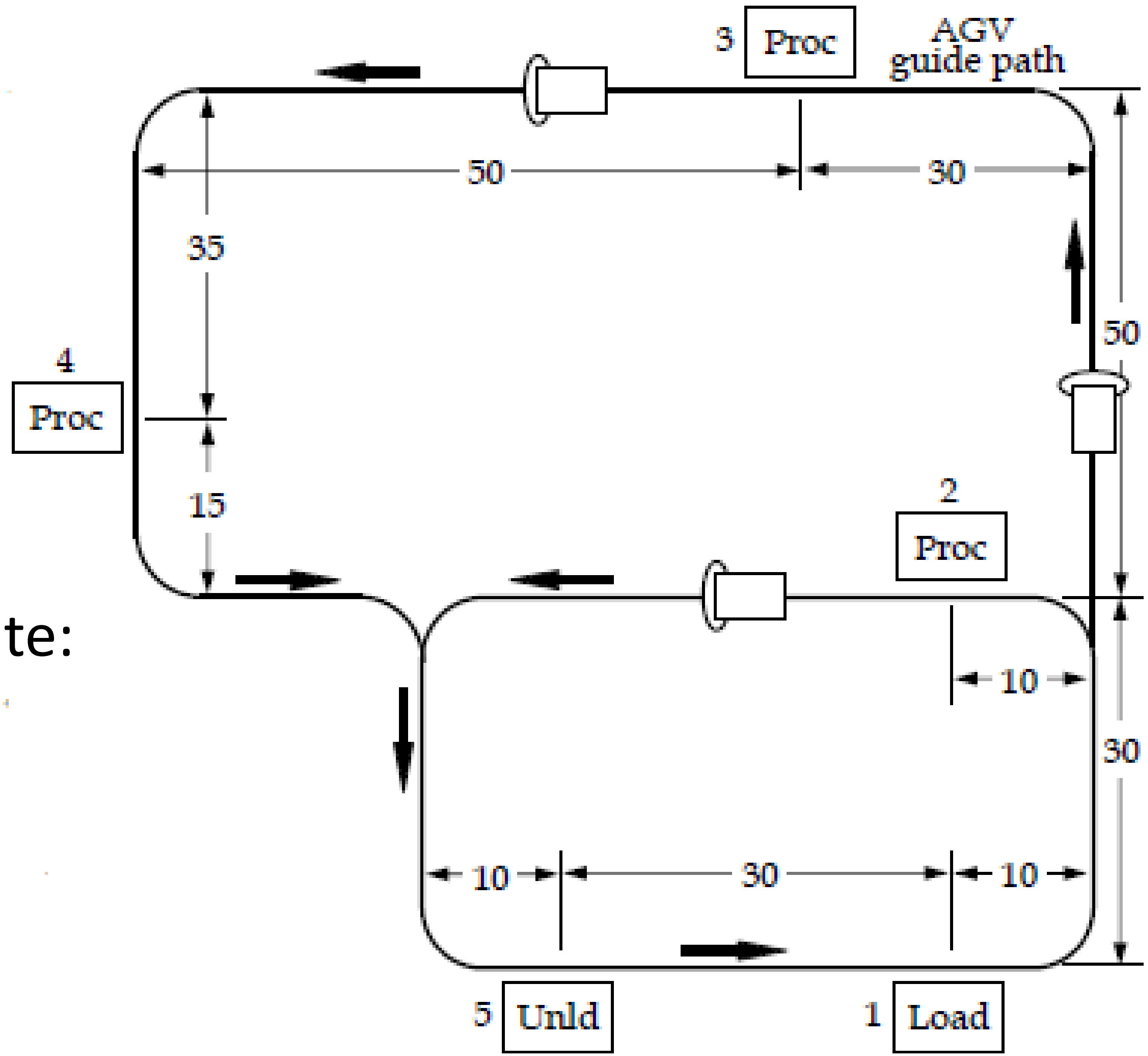
To	1	2	3	4	5
From 1	0	9/50	5/120	6/205	0
2	0	0	0	0	9/80
3	0	0	0	2/85	3/170
4	0	0	0	0	8/85
5	0	0	0	0	0



- From-To:
  - 1-2
- Flow Rate:
  - 9
- Rule
  - 1
- Empty Route:
  - 2-5-1
- Distance:
  - 80+30

From-To Chart

	To 1	2	3	4	5
From 1	0	9/50	5/120	6/205	0
2	0	0	0	0	9/80
3	0	0	0	2/85	3/170
4	0	0	0	0	8/85
5	0	0	0	0	0

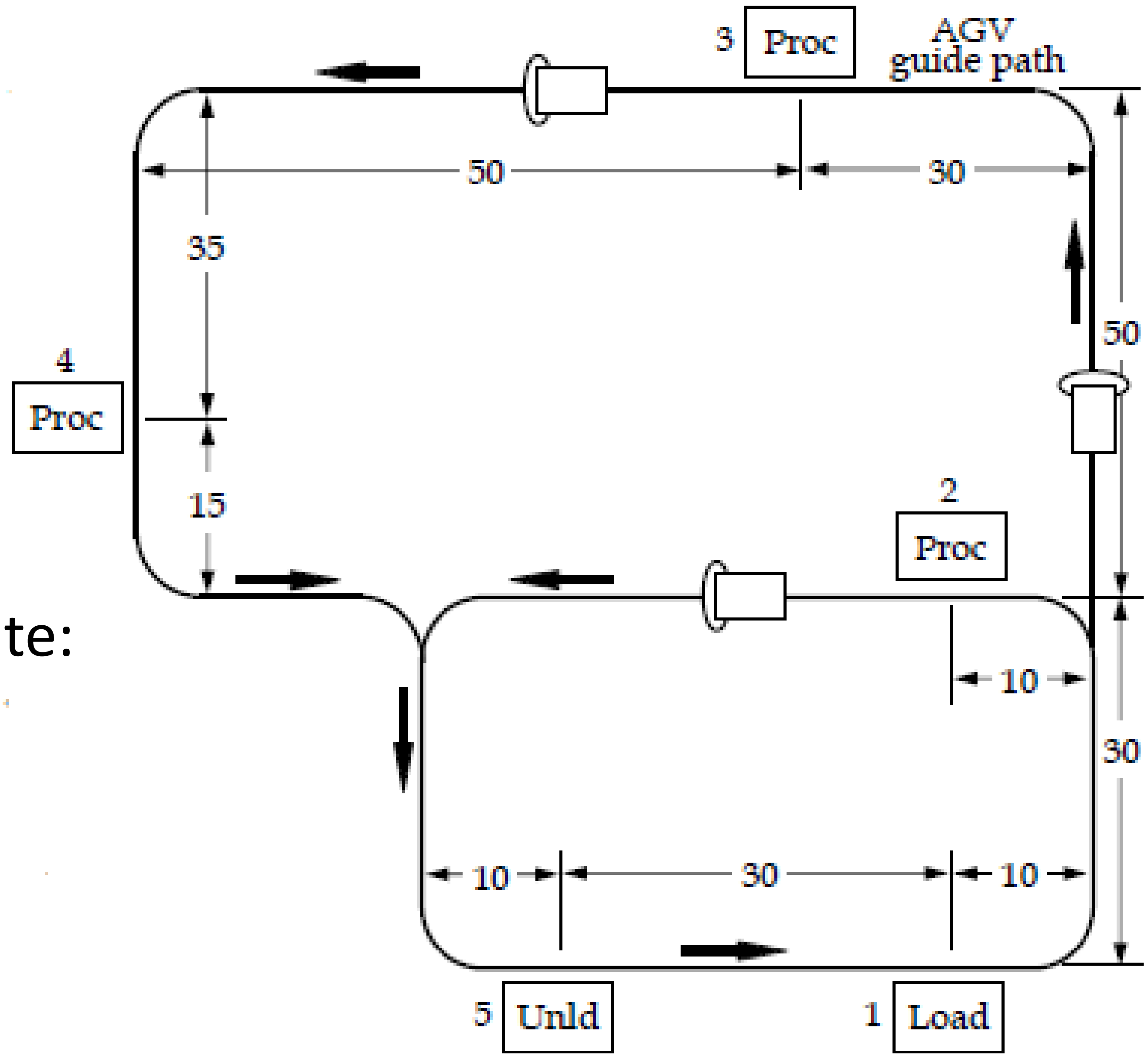


- From-To:
  - 1-3
- Flow Rate:
  - 5
- Rule
  - 1
- Empty Route:
  - 3-5-1
- Distance:
  - 170+30

From-To Chart

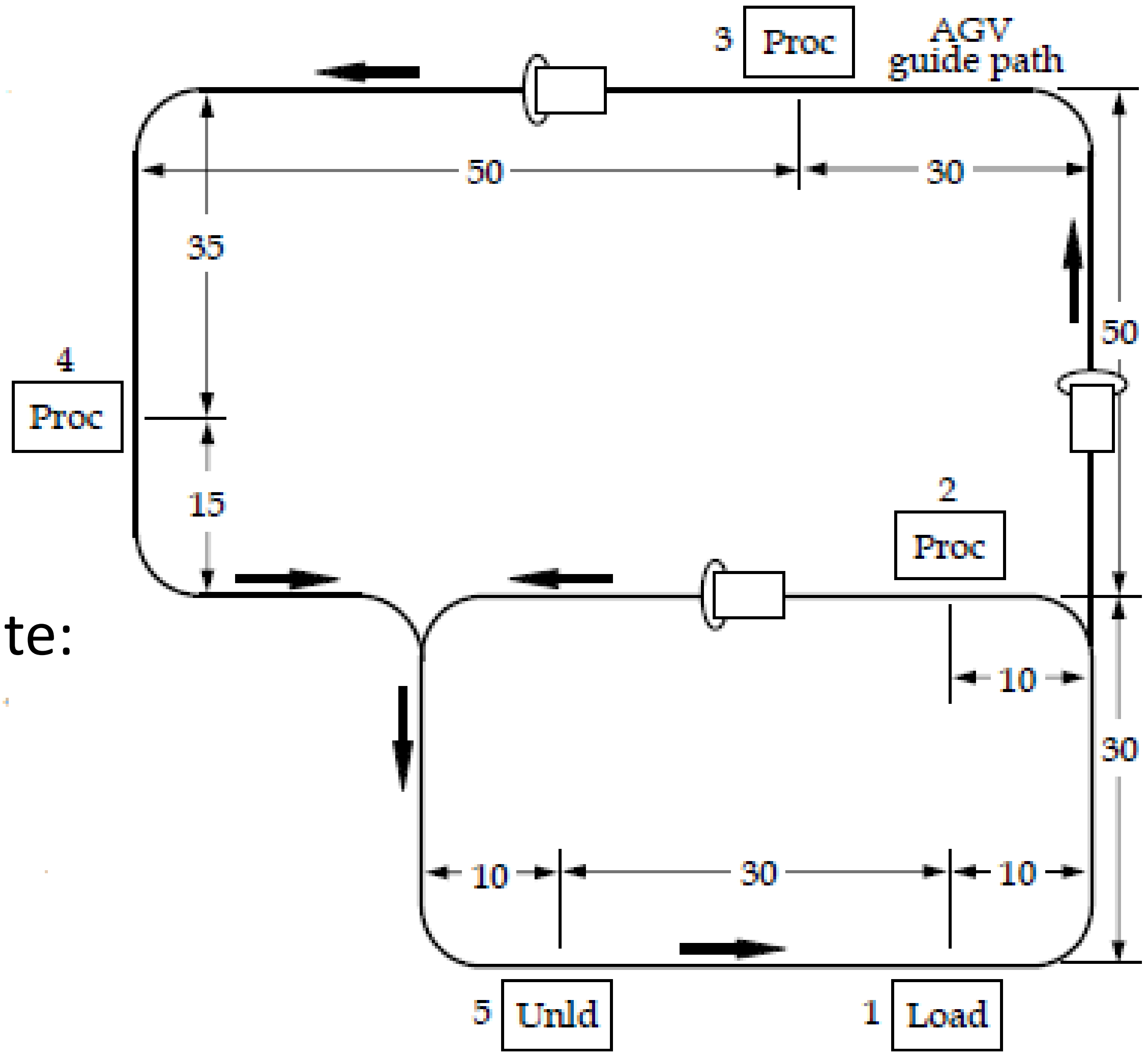
	To	1	2	3	4	5
From	1	0	9/50	5/120	6/205	0
	2	0	0	0	0	9/80
	3	0	0	0	2/85	3/170
	4	0	0	0	0	8/85
	5	0	0	0	0	0

- From-To:
  - 1-4
- Flow Rate:
  - 6
- Rule
  - 1
- Empty Route:
  - 4-5-1
- Distance:
  - 85+30



From-To Chart

	To 1	2	3	4	5
From 1	0	9/50	5/120	6/205	0
2	0	0	0	0	9/80
3	0	0	0	2/85	3/170
4	0	0	0	0	8/85
5	0	0	0	0	0



- From-To:
  - 2-5
- Flow Rate:
  - 9
- Rule
  - 2
- Empty Route:
  - 1-2+5-1
- Distance:
  - 50+30

Analysis of Vehicle-Based Systems

From-To	Flow Rate	Rule	Empty Route	Distance
1-2	9	(1)	2-5-1	80+30
1-3	5	(1)	3-5-1	170+30
1-4	6	(1)	4-5-1	85+30
2-5	9	(2)	1-2 + 5-1	50+30
3-4	2	(2)	1-3 + 4-5-1	120+85+30
3-5	3	(2)	1-3 + 5-1	120+30
4-5	8	(2)	1-4 + 5-1	205+30

Analysis of Vehicle-Based Systems – Corrected

- $\mathrm{L_e} = \frac{9 \cdot 110+5 \cdot 200+6 \cdot 115+9 \cdot 80+2 \cdot 230+3 \cdot 150+8 \cdot 235}{9+5+6+9+2+3+8} = 147.6$
- $T_\mathrm{c} = 0.75 + \frac{103.8}{50} + 0.5 + \frac{147.6}{50} = 6.3.$
- Recall that AT = 54.15 and needed flow rate is 40. So:
- $n_\mathrm{c} = (42 \cdot 6.3)$ / 54.15 = 4.88 hence we need 5 vehicles.

Analysis of Vehicle-Based Systems

- Exercise
- Now suppose that the vehicles operate according to the following scheduling rule in order to minimize the distances the vehicles travel empty:
- Vehicles delivering raw workparts from station 1 to stations 2, 3, and 4 must pick up finished parts at these respective stations for delivery to station 5. This means
  - (i) after delivering a raw part to a station from station 1, the vehicle will not travel empty back to 5 and then to 1,
  - (ii) in order to transport a finished part from stations 2, 3, or 4 to another station the vehicle does not need to travel empty from station 1.

Example

- The From-To chart below shows the number of loads moved per hour and the distances in meters between departments in a particular factory.
- The needed flow rate is 165 units.
- Fork lift trucks are used to transport materials between departments. They move at an average speed of 80 m/min (loaded) and 100 m/min(empty).
- Load handling time per delivery is 1.5 min and unloading time per delivery is 1 min.
- Traffic factor F becomes increasingly significant as the number of vehicles, n_c, increases and can be modeled as follows:

$$F = 1.0 - 0.01 \times (n_c - 1) \quad \text{for } n_c = \text{positive integer}$$

From\To	A	B	C	D	E
A	0	25/80	25/120	20/100	0
B	0	0	15/60	10/90	0
C	0	0	0	0	40/60
D	0	0	0	0	30/40
E	0	0	0	0	0

Example

- Use availability factor=95% and worker efficiency=100%. The required total flow per hour is 165.

a. (5 points) Draw the flow chart for this table.

b. (15 points) Determine the number of trucks. Assume that, for simplicity, the distance that the trucks travel empty (L_e) is <u>equal to</u> their loaded distance (L_d).

Hint: the solution for $ax^2 + bx + c = 0$ *is given by*

$$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Solution…

- $L_d = 165$
- $T_c = 4.19$
- $WL = 4.19 \times 165 = 691.5$
- n_C can be 14 or 87.