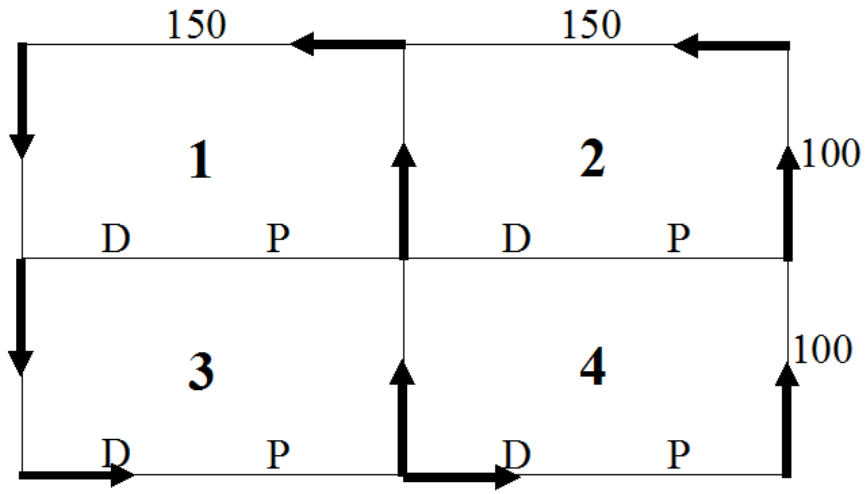
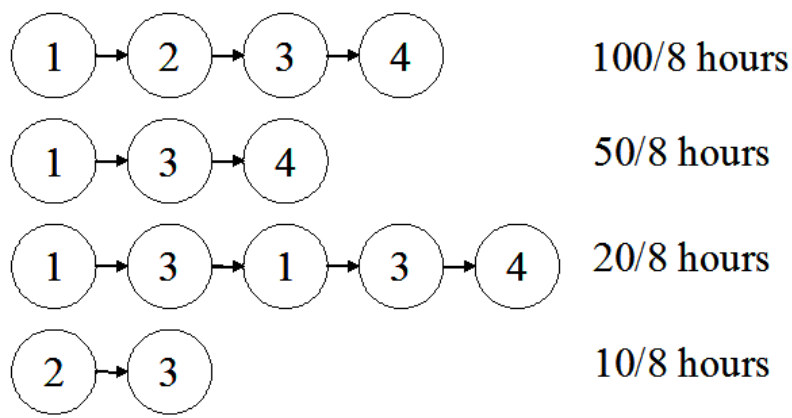
Motivation





- How will you estimate the number of AGVs needed to transport this flow?

Problem Statement

- How will you estimate the number of AGVs needed to transport this flow?
- At any given time, what is the AGV doing?
  1. traveling loaded
  2. traveling unloaded
  3. loading or unloading
  4. sitting idle
- Any easy? Any hard?
- We will develop a way to estimate the first three.

Easy Components: Loaded Travel and P/D Time

- How will we estimate the loaded travel time?
- Travel Time = Distance/Velocity
- Total Travel Time = $\sum_i \sum_i F(i,j) * D(P_i, D_j)/V$
- How will we estimate the load/unload time?
- Total P/D Time = $2(\sum_i \sum_j F(i,j)) * t_{p/d})$
- How will we estimate the unloaded travel time? ...difficult!

Difficult Component: Unloaded Travel

- Why is this difficult to estimate?
  - not sure which vehicle will come get load
  - not sure where vehicle is coming from
  - may have to wait for vehicle if want to optimize (i.e., minimize empty travel)
- We will use two different models to estimate the unloaded travel time:
  1. Maxwell & Muckstadt (Best Case)[a]
  2. Egbelu's Model 4 (Expected Case)[b]

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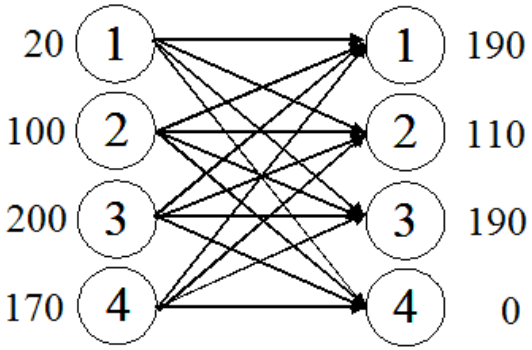
[a] Maxwell, W. L. and J. A. Muckstadt, "Design of Automatic Guided Vehicle Systems," *IIE Transactions*, **14**, 2, 114-124 (1982).

[b] Egbelu, P. J., "The Use of Non-Simulation Approaches in Estimating Vehicle Requirements in an Automated Guided Vehicle Based Transport System," *Material Flow*, **4**, pp. 17–32 (1987).

Maxwell & Muckstadt's Model

- Model based on "best-case scenario."
- Best Case: Vehicles wait to be dispatched to minimize empty travel.
- Will serve as a lower bound on the amount of empty travel (i.e., mandatory empty travel).

Station	Flow In	Flow Out
1	20	190
2	100	110
3	200	190
4	170	0



- Solve with Transportation Problem

Egbelu's Model 4

- Model based on "expected-case scenario."
- Expected Case: Assumes that an empty vehicle will come from any of the stations based on how often an empty vehicle is generated there . . . FCFS dispatching.
- Estimate g_{ij} = expected number of unloaded trips from i to j.
- $g_{ij} =$
  (exp. # of pickups at j) $\left(\dfrac{\text{exp. \# of drops at } i}{\text{tot number of dropoffs in system}}\right)$
- Illustrate with example . . .

The Answer

- Number of Vehicles = (Total Working Time per Day)/(Total Time Available per AGV per Day).
  - Total Working Time per Day = Loaded Travel Time + Unloaded Travel Time + P/D Time
  - Must round up the result and ensure utilization is not greater than upper limit (e.g., 85%).
  - Can correct Total Time Available per AGV per Day for charging time, maintenance, expected blocking time, efficiency, etc., as supported by data.
- Each model for Unloaded Travel Time may yield a different number of AGVs needed ...

Discussion

- Answer will typically fall somewhere between the LB and the expected number of vehicles.
- There are better analytical models, but more complicated to compute.
- Only way to be sure, is to simulate since analytical models do not consider (except to assume values *a priori*):
  - dispatching rules
  - blocking
  - idle times
  - congestion
  - breakdowns
  - etc.