From personal to mass transit

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My 43 years in transportation

- Transit network planning - VIPS
- Taxi fleet management - Taxi80
- VP, Marketing director Volvo Bus Corp.
- Multi-discipline PRT research - Chalmers
- Road traffic research – KTH Royal Inst of Tech
- 5 PRT patents
- VP, Advanced Transit Association

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Outline

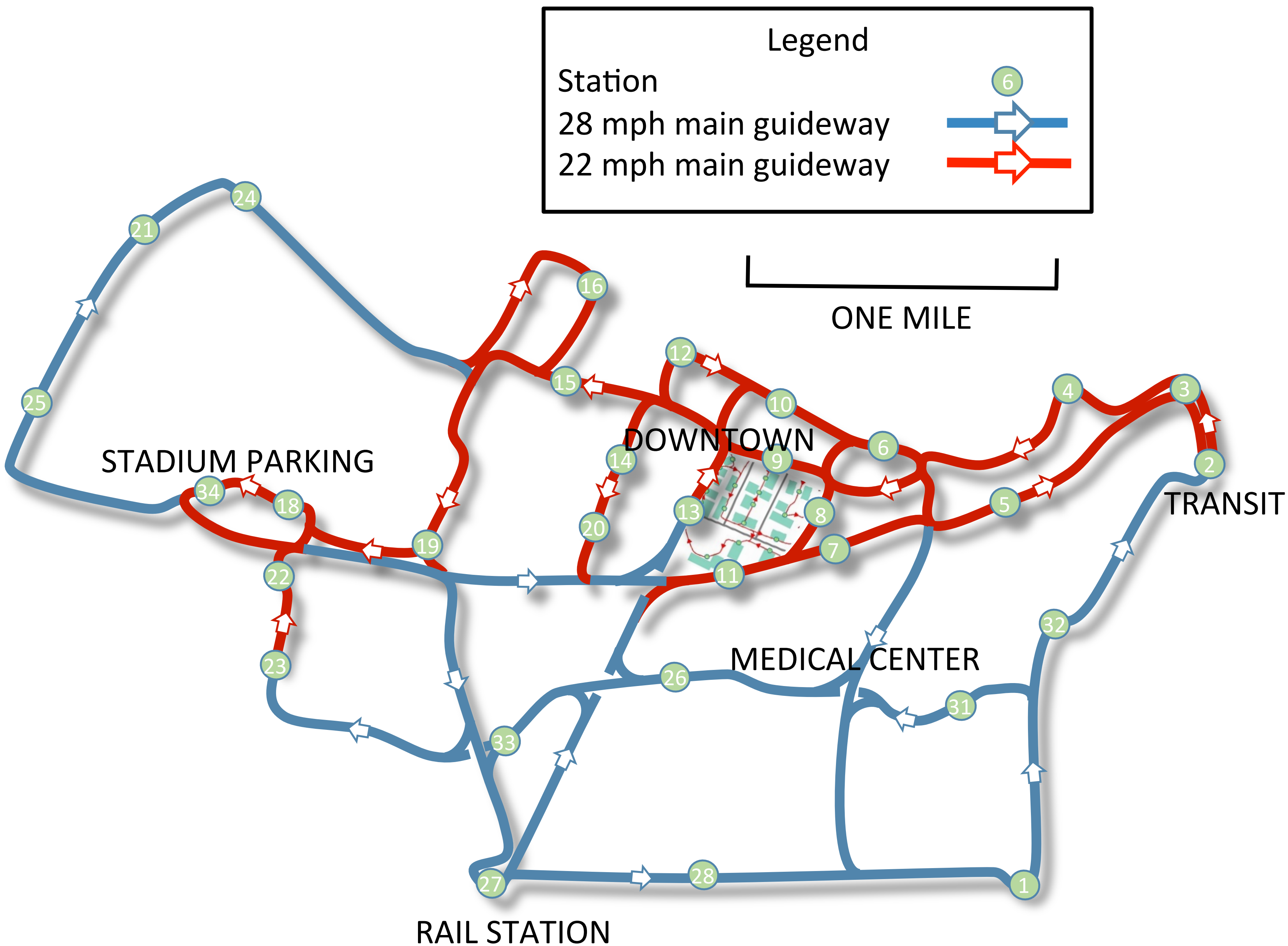
- Stretching the capacity of ATNs
- Advanced ride-sharing strategies
- Vehicle coupling and decoupling
- Simulation modeling

=> Mass capacity with small vehicles on demand

A challenging application

- Dense urban area in California
- Very large employers
- Severe highway congestion
- Encouraging non-car modes
- Transfers to ATN from Train and LRT
- Connecting buildings

Contract with PRT Consulting Ltd


Legend
Station
28 mph main guideway
22 mph main guideway
ONE MILE
STADIUM PARKING
DOWNTOWN
TRANSIT
MEDICAL CENTER
RAIL STATION
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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22
23
24
25
26
27
28
31
32
33
34


Legend
Station
51
28 mph main guideway
22 mph main guideway
22 mph feeder guideway
(with slowing at stations)
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
500 Feet

Tentative design

- 50 stations
- 48 kms (30 miles) guideway (6 % double)
- 54 intersections (4 bi-level)
- Speeds 36 and 45 kph (22-28 mph)
- Headway 3 secs (as certified)
- 910 vehicles with 6-seats

Morning peak hour demand

- 30 % of trips from 3 transfer stations
- 400 passengers from a single train
- 50 destinations
- How much can you handle?

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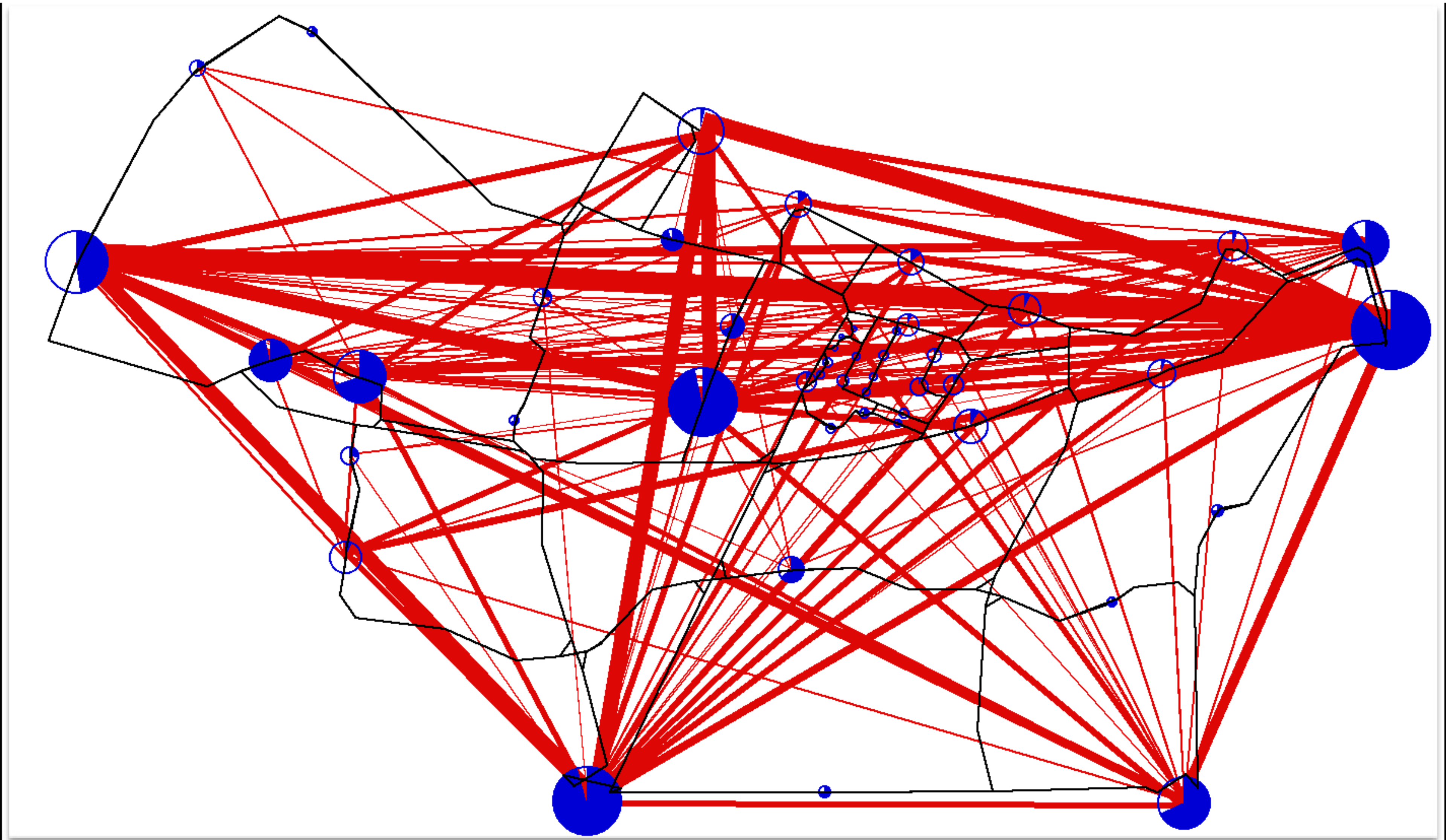
Train / PRT station

- Length of train = 64 podcars

Morning peak demand pattern



Personal Rapid Transit

- Network can handle 910 vehicles
- …with 3 second headways
- Average 1.5 passengers per vehicle
- Can only carry 3,200 pph
- 2.6 minutes average wait

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Ride-matching at departure

- System knows requests from station
- First passenger determines destination
- Destination posted on or over vehicle
- Vehicle assigned when enough load (5 of 6)
- …or after max holding (1 min)

Ride-sharing morning

- 7 % of relations have 60 % of all trips
- Apply in relations with >1 party per minute
- 49 % of passengers matched
- Average load 1.5 –> 3.4 passengers
- 3,200 –> 9,900 passengers carried
- 4.4 minutes waiting

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Sharing to 2 destinations

- First acceptable 2nd destination (<20 % detour)
- 28 % of departures serve 2 destinations
- 49 –> 57 % of passengers matched
- Vehicle load 3.4 –> 4.4
- 9,900 –> 11,600 passengers carried
- 4.4 –> 3.9 mins waiting

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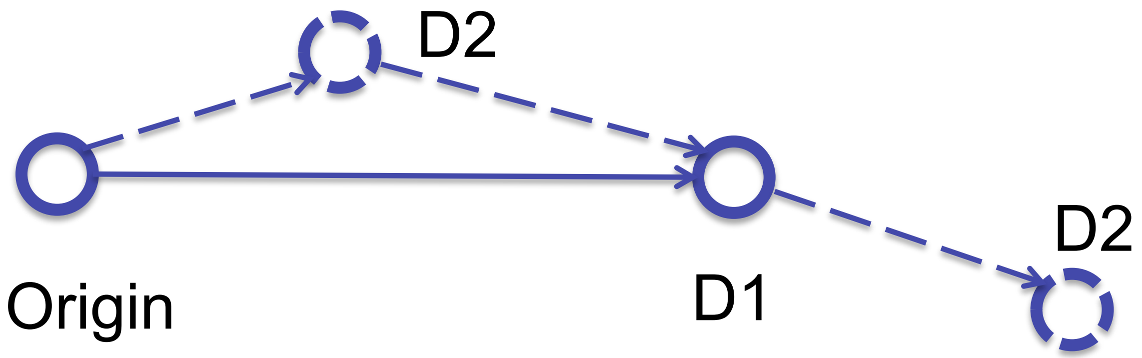
Second destination before or after



- Detours within 20 %

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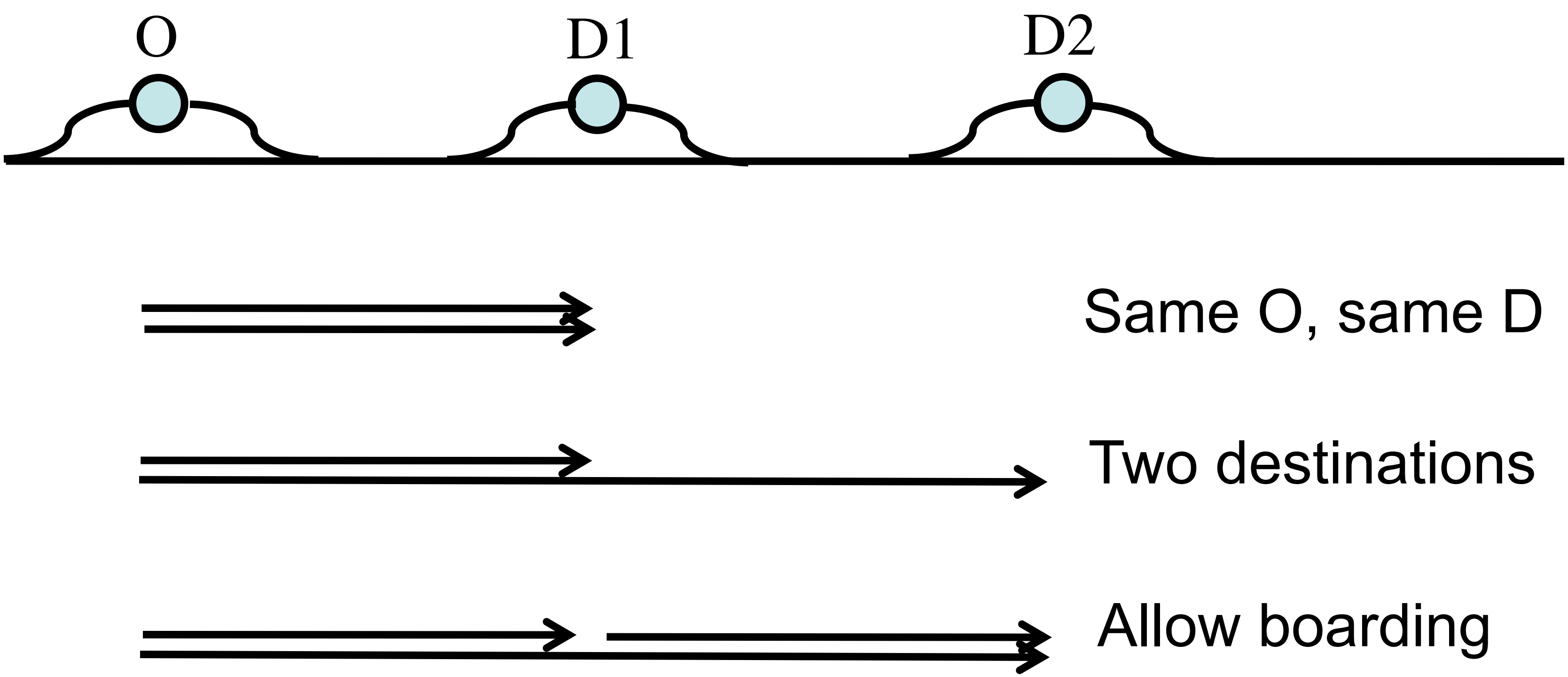
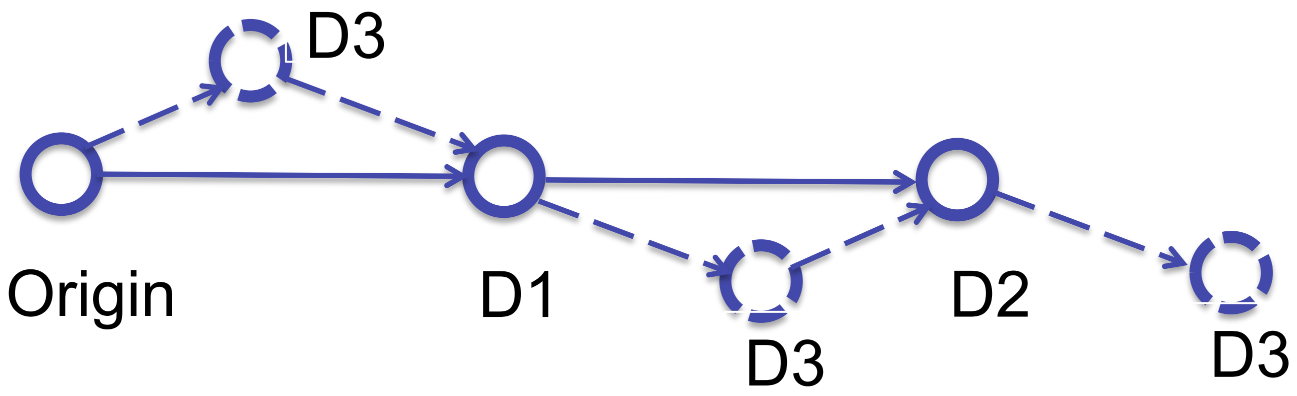
Allow boarding to same destination

- When stopped to drop off
- Waiting passengers to same destination
- Destination sign over vehicle

Ride-sharing patterns



Adding a third destination



- Before, between or after

Sharing to 3 destinations

- 8 % of departures for 3 stops
- Vehicle load 4.4 –> 4.5
- 11,600 –> 11,800 passengers carried
- 3.9 –> 3.6 mins waiting

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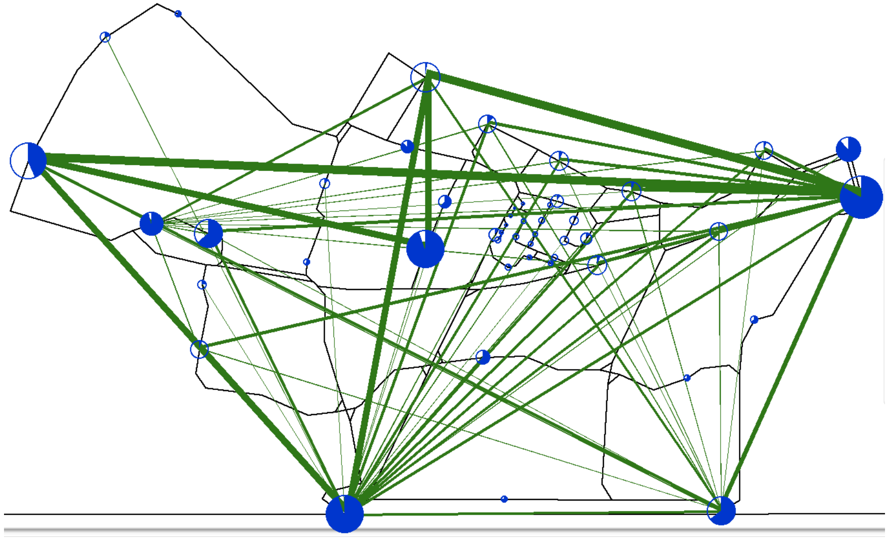
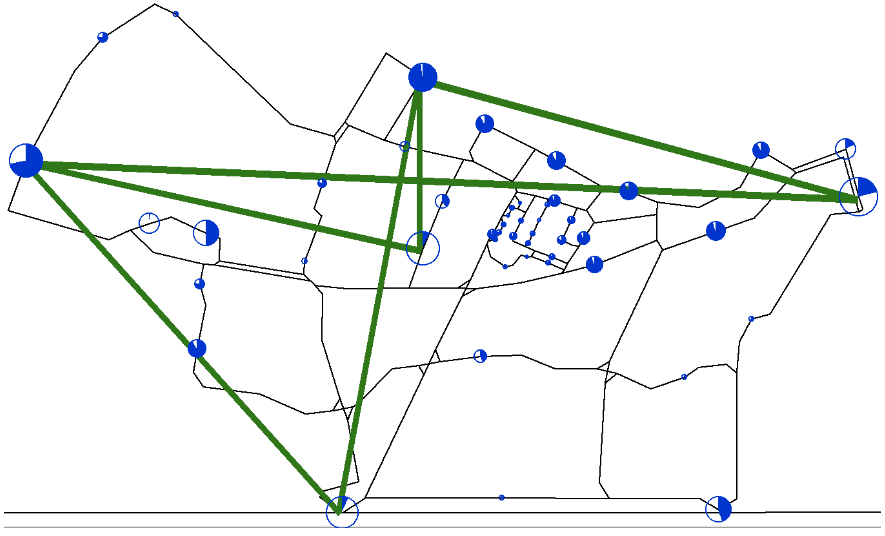
Evening peak more challenging

- Many origins with few boarding passengers
- Less opportunities for matching
- Sharing applied for 14 % of trips (vs 58 %)

Ride-sharing morning vs evening



58 % sharing



14 % sharing

Matching many-to-few

- Multiple origins to common destination (transfers)
- First passengers determine destinations and route
- Stopping en route to pick up for same destinations

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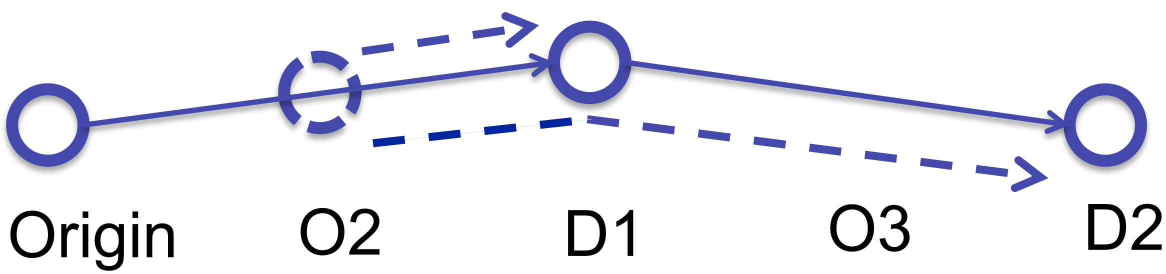
Stop en route to pick up

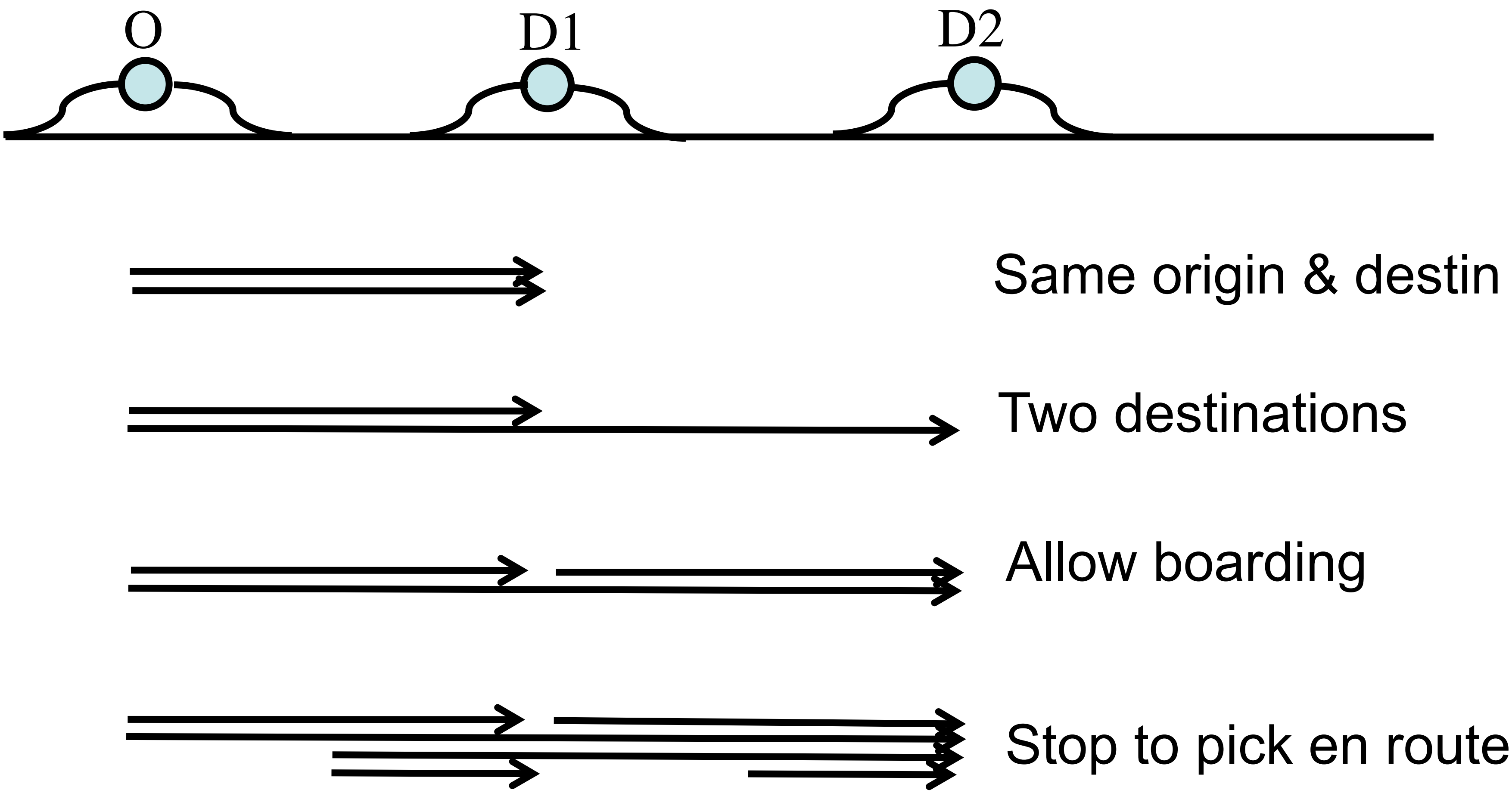


- Route fixed to one or two destinations
- Pick up passengers for same destinations
- No passenger makes more than 2 extra stops
- NOT line-haul – flexible route, on demand

Stop to pick up (evening)

- Picking up 1,850 passengers en route
- 11,600 passengers total
- 0.3 extra stops per passenger
- 5.5 passengers per vehicle
- All vehicles full (6) on max link
- 4.5 mins wait
- +5 % ride time

Ride-sharing patterns



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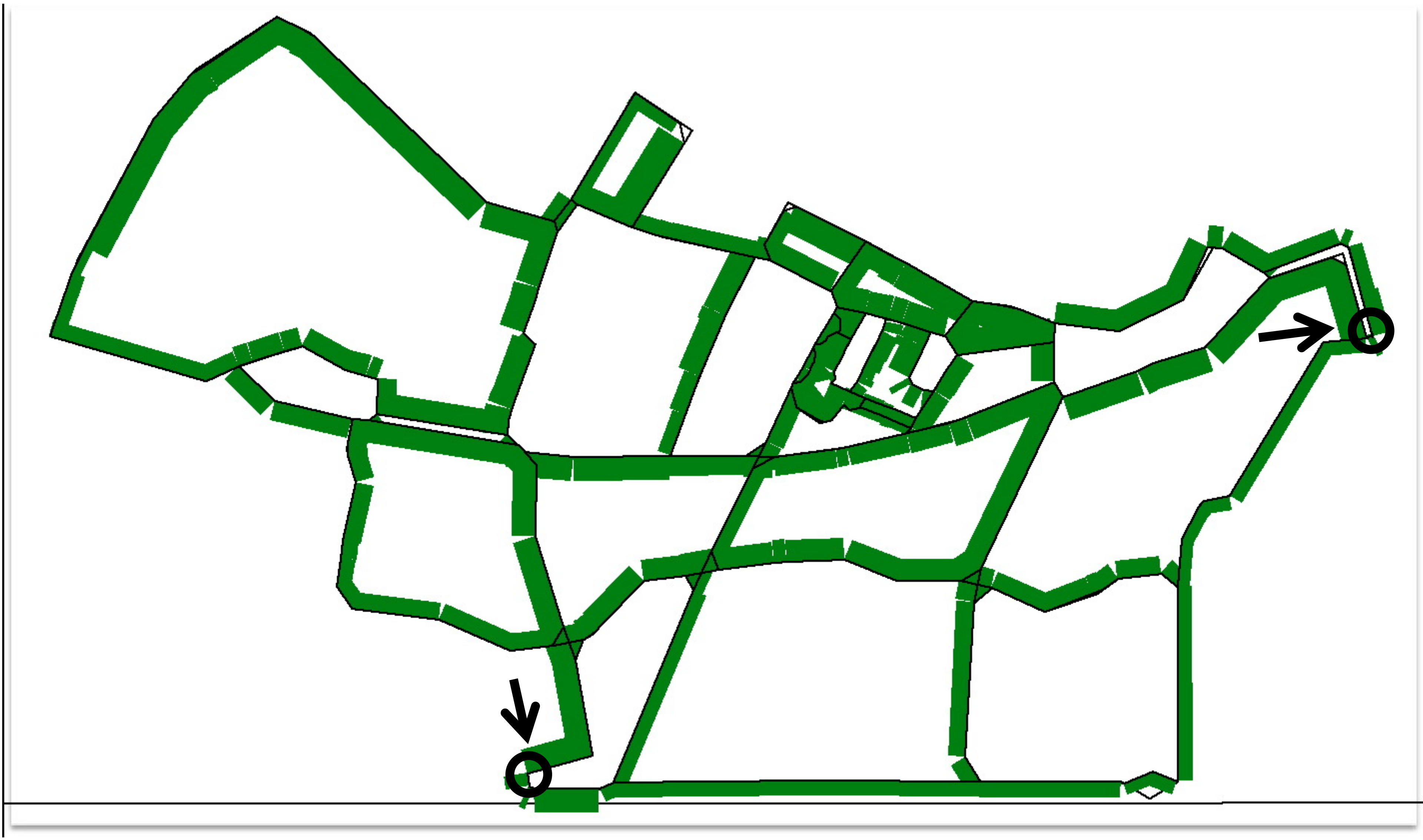
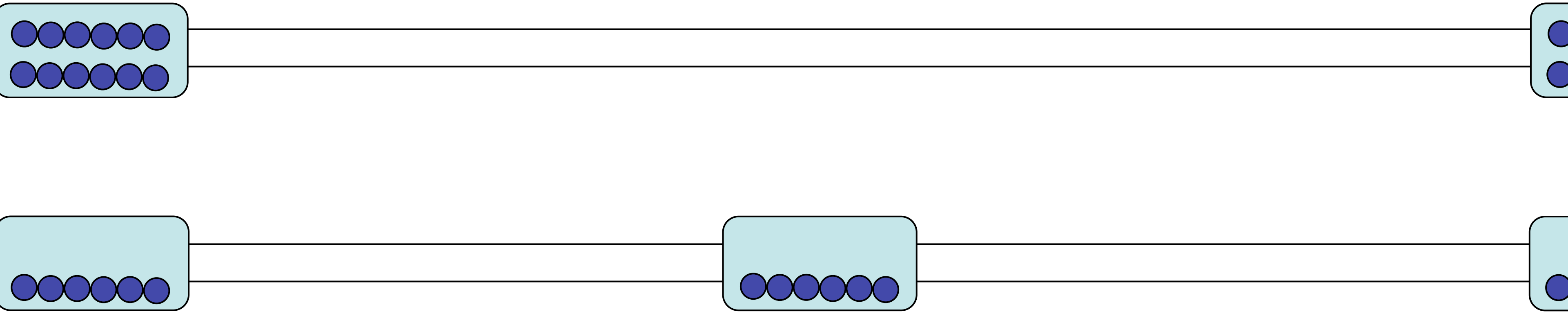
Full vehicles to destination (evening)



Standing passengers?

- Vehicle for 6 seated + 6 standing
- Limited braking => double headway
- Same capacity
- Longer station ramps

Same capacity without standees



- Can serve 2 destinations non-stop

Vehicle pairs can split safely at speed

- Can serve different destinations
- More total load with two possible destinations
- Each vehicle goes non-stop

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Coupled vehicles

- Couple in stations – decouple in diverges
- Safe distance between couples
- Average consort 1.3 vehicles
- 11,600 –> 14,900 passengers
- 4.5 –> 2.0 mins wait

Electronic or mechanical coupling

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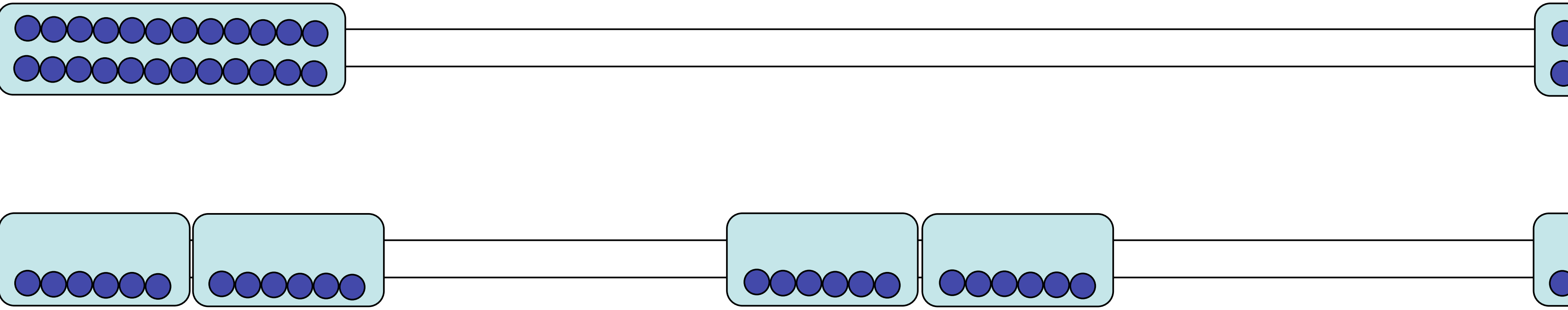
Larger vehicle?

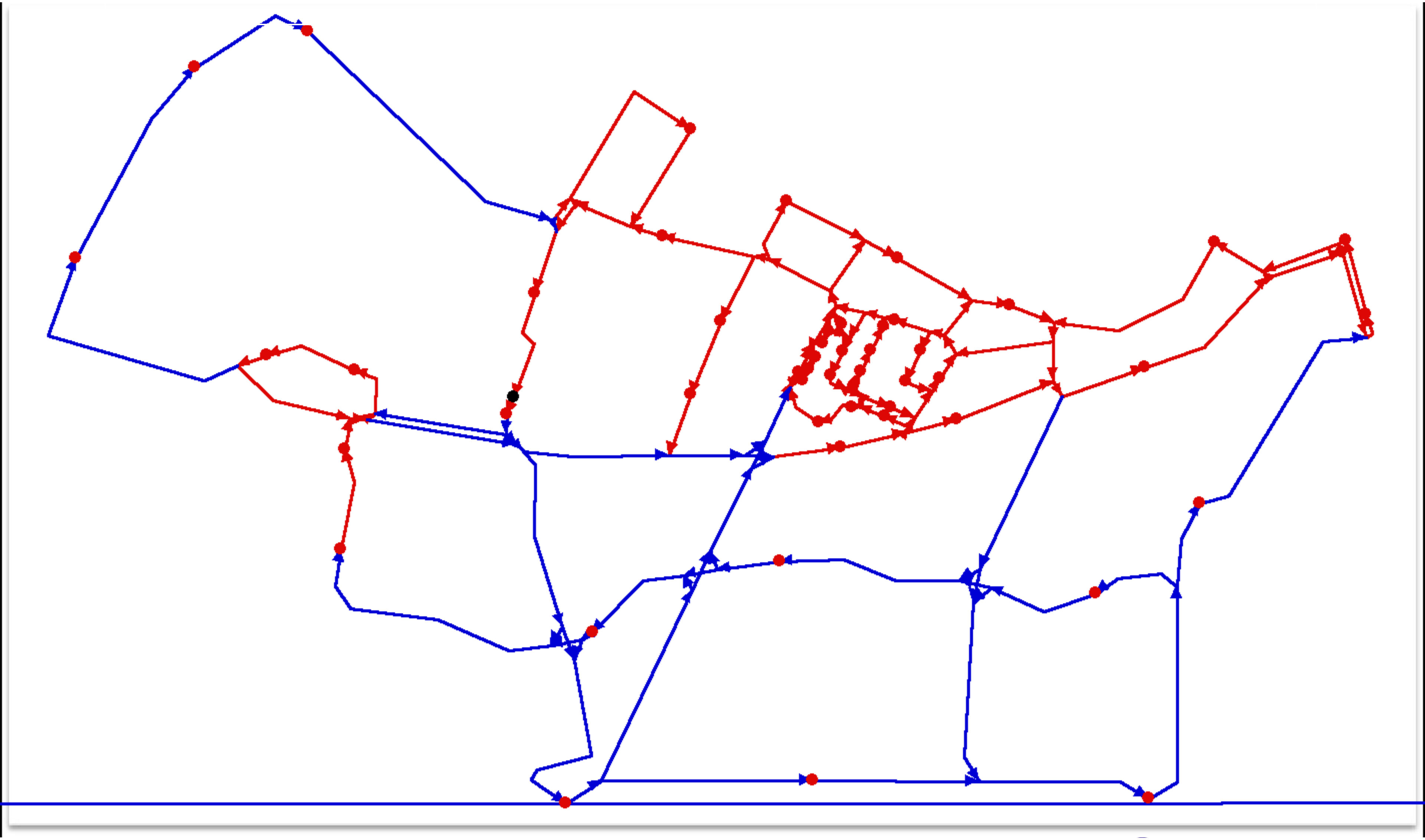
- 24 passengers including standees
- 6 sec headway
- Couple 2 x 6 seated has same capacity
- …and can split up en route

Coupled vehicles better than big



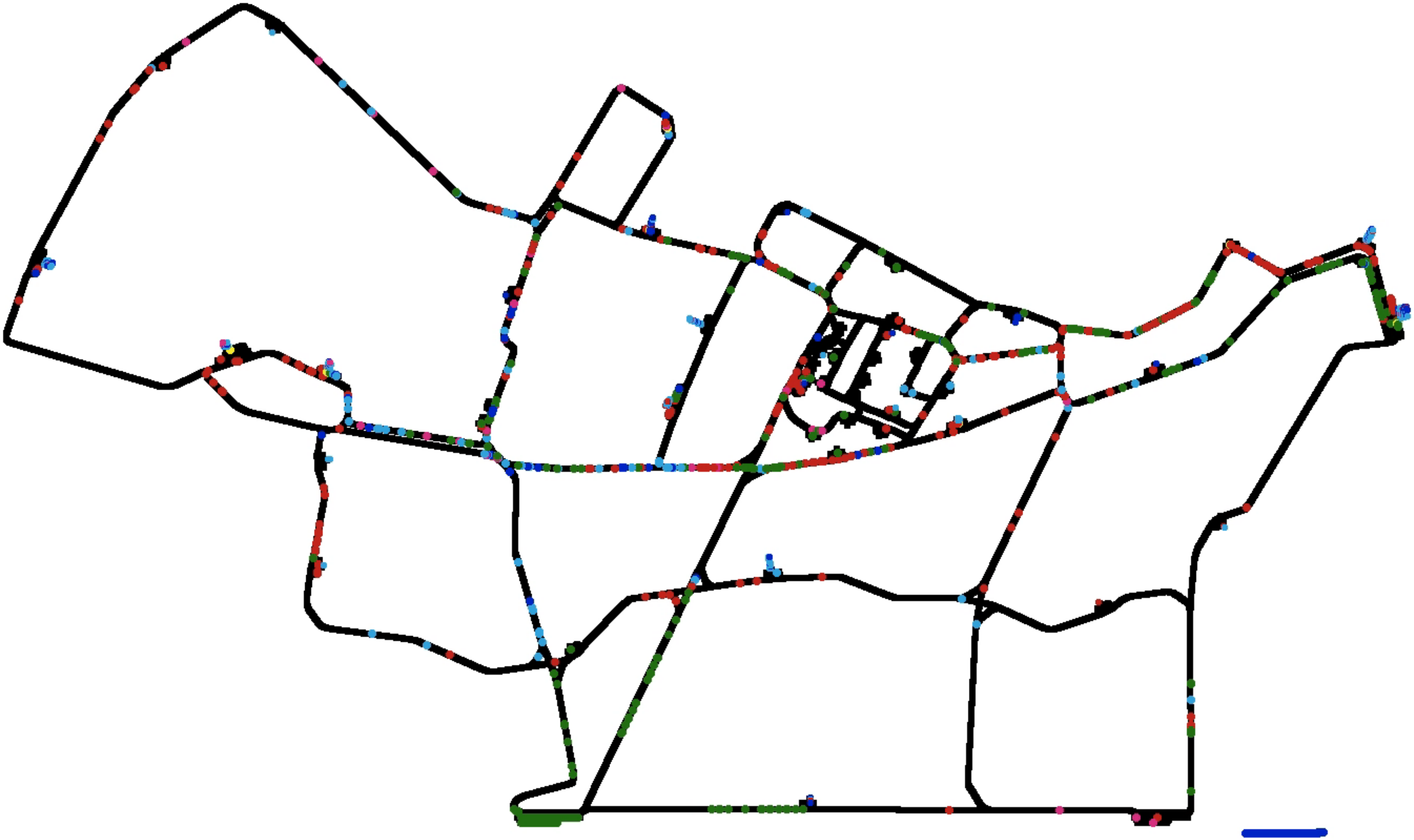
- Can serve 4 destinations non-stop
- All passengers seated

Network high/low speed + train

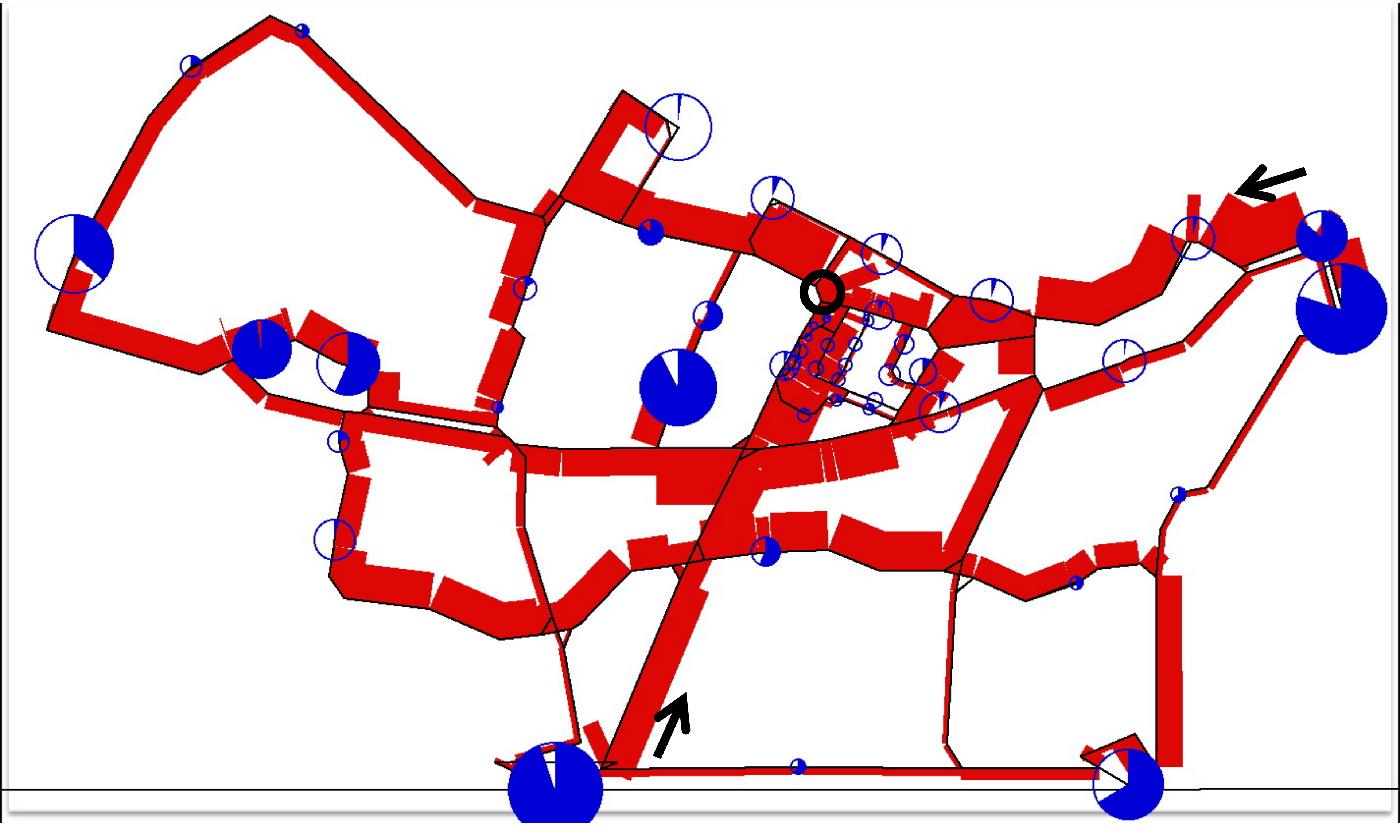


Animation 10 x real speed

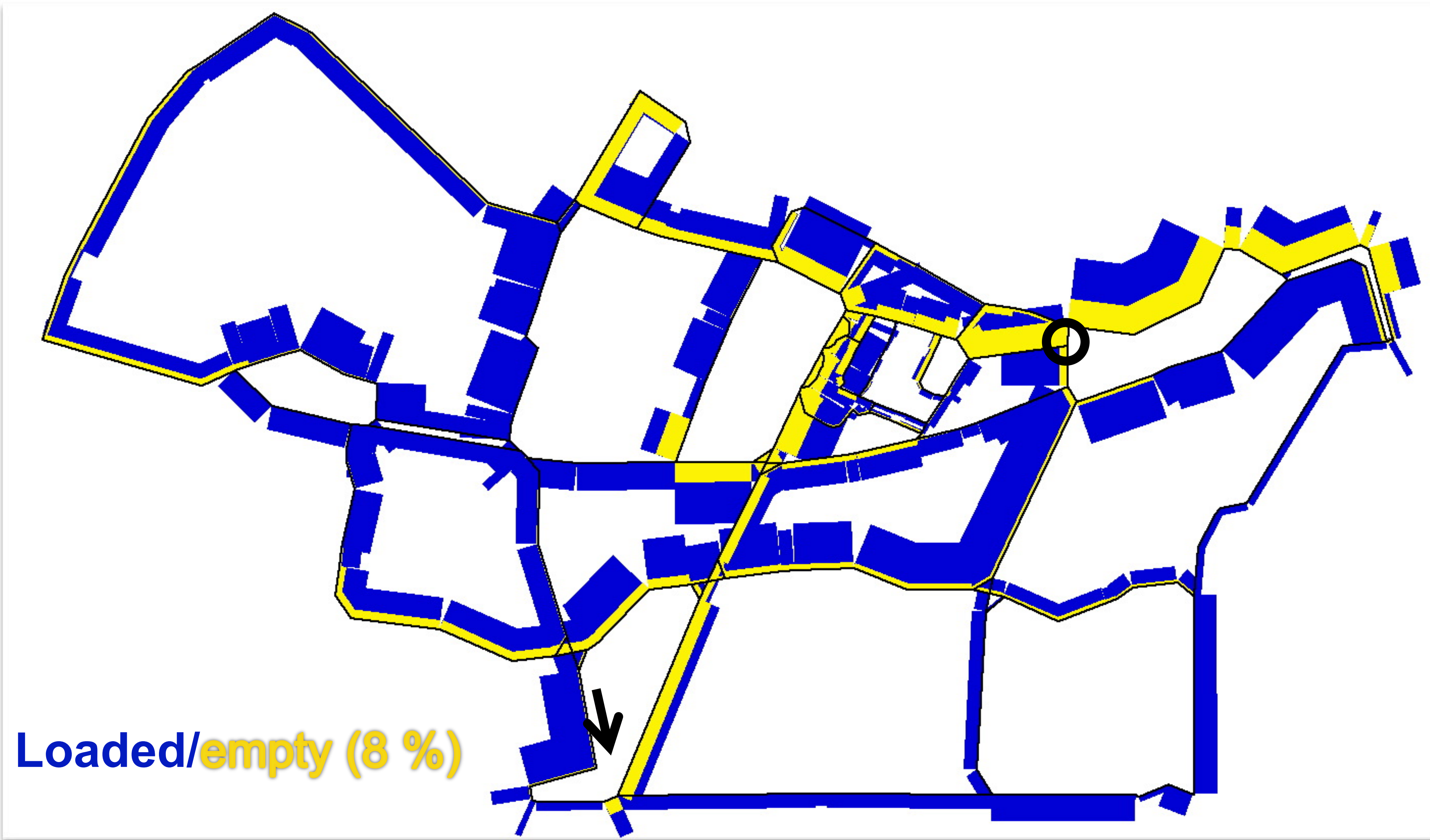
- Empty vehicle
- 1 passenger
- 2
- 3
- 4 or more
- Load/unload
- Couple



14,400 pph morning (6,900 on link)



910 vehicles evening (2,000 vph)



Capacity x 5 and less waiting

Strategy	**Morning peak** Pass/h / Wait-mins	**Evening peak** Pass/h / Wait-mins
True PRT	3,200 / 2.6	3,000 / 3.5
Ridesharing one to one	9,900 / 4.4	8,300 / 6.5
Ridesharing one to two	11,600 / 3.9	9,900 / 5.0
Ridesharing one to three	11,800 / 3.6	10,000 / 4.6
Sharing and stopping to pick up	12,000 / 3.1	11,600 / 4.5
Sharing, stopping and coupling	14,400 / 2.9	14,900 / 2.0

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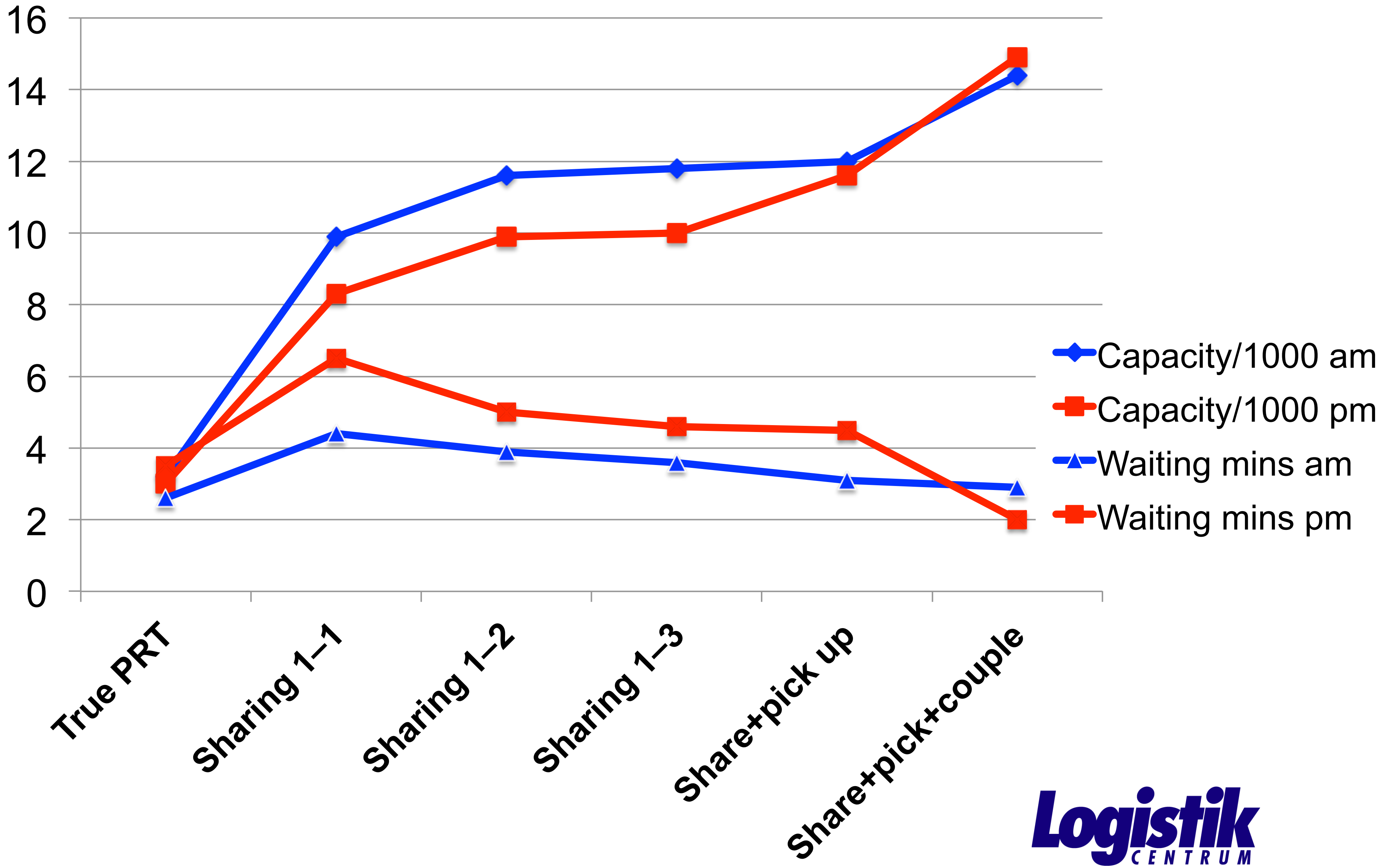
Improvements by strategy (am/pm)



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Results with combined strategies

	Morning peak hour	Evening peak hour
Vehicle fleet	910	910
Passenger trips	14,400	14,900
Average load	4.7 of 6	4.7 of 6 (78 %)
Departures for 2 and 3 stops	25+7 %	23+4 %
Extra stops per passenger	0.30	0.30
Average wait	2.9 minutes	2.0 minutes
Average ride including stops	7.9 minutes	8.0 minutes
Maximum vehicle link flow	1,950 vph	2,000 vph (1.7 / 3 sec
Maximum passenger link flow	6,900 pph	6,400 pph
Fleet running with passengers	72 %	85 %

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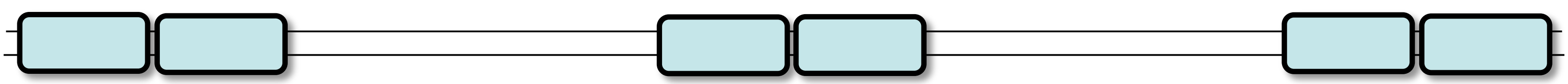
Line-haul for similar capacity

- Stopping on-line => double travel time
- One line cannot serve all (50) stations
- Minimum headway 90 secs (on-line)
- Needs to load 170 for link flow 6,900 pphpd
- Off-line stations is key

Line-haul

170 pass / 90 sec = 6,900 pph

PRT



6+6 pass / 3 sec = 14,400 pph (case 6,900)

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Conclusions

- Apply ride-sharing and pick-ups during peaks
- Can serve bursts of (400) transferring passengers
- Pair-coupled vehicles can handle mass transit flows
  - 6,900 pphpd on link, 14,900 in network
- Not Personal during peak, but very Productive

➢ Capacity as Mass Transit

…plus networked, fast and on demand

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