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
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
22 mph feeder guideway (with slowing at stations)
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?
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
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
Sharing to 2 destinations

- First acceptable 2\textsuperscript{nd} destination (<20 % detour)
- 28 % of departures serve 2 destinations
- 49 $\rightarrow$ 57 % of passengers matched
- Vehicle load 3.4 $\rightarrow$ 4.4
- 9,900 $\rightarrow$ 11,600 passengers carried
- 4.4 $\rightarrow$ 3.9 mins waiting
Second destination before or after

- Detours within 20 %
Allow boarding to same destination

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

- Same O, same D
- Two destinations
- Allow boarding
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
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
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

- Same origin & destination
- Two destinations
- Allow boarding
- Stop to pick en route
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
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
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

<table>
<thead>
<tr>
<th>Strategy</th>
<th><strong>Morning peak</strong></th>
<th><strong>Evening peak</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass/h / Wait-mins</td>
<td>Pass/h / Wait-mins</td>
</tr>
<tr>
<td>True PRT</td>
<td>3,200 / 2.6</td>
<td>3,000 / 3.5</td>
</tr>
<tr>
<td>Ridesharing one to one</td>
<td>9,900 / 4.4</td>
<td>8,300 / 6.5</td>
</tr>
<tr>
<td>Ridesharing one to two</td>
<td>11,600 / 3.9</td>
<td>9,900 / 5.0</td>
</tr>
<tr>
<td>Ridesharing one to three</td>
<td>11,800 / 3.6</td>
<td>10,000 / 4.6</td>
</tr>
<tr>
<td>Sharing and stopping to pick up</td>
<td>12,000 / 3.1</td>
<td>11,600 / 4.5</td>
</tr>
<tr>
<td>Sharing, stopping and coupling</td>
<td>14,400 / 2.9</td>
<td>14,900 / 2.0</td>
</tr>
</tbody>
</table>
Improvements by strategy (am/pm)

- **True PRT**
- **Sharing 1–1**
- **Sharing 1–2**
- **Sharing 1–3**
- **Share+pick up**
- **Share+pick+couple**

- **Capacity/1000 am**
- **Capacity/1000 pm**
- **Waiting mins am**
- **Waiting mins pm**
## Results with combined strategies

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