PERSONAL RAPID TRANSIT
VEHICLE MANAGEMENT BASED ON FLOW PREDICTIONS

Joerg Schweizer, Federico Rupi
University of Bologna

Advanced Transit Association www.advancedtransit.org/
Outline

1. What is PRT?
2. PRT simulation with SUMO
3. Vehicle management
4. Simulation results
5. Conclusions
What is PRT?

Personal Rapid Transit (PRT) - To down development

Defining specifications

- Non-stop origin-destination
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- Emission-free, low-noise
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- Low interference with present traffic
- High capacity (in development)
- Profitable, affordable (in development)
What is PRT?

Standardized, exclusive PRT guideways

High safety, reliability

High capacity

Precise timing ⇒ reduce wait time, avoid congestions

Allows electrification of transport (without batteries!)

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- High capacity
- Precise timing $\implies$ reduce wait time, avoid congestions
- Allows electrification of transport (without batteries!)
Guideway implementation options
What is PRT?

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PRT Vehicles

Fully automated (driverless)
Electric (rotary or linear) motor
On board switching

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PRT simulation with SUMO

SUMO - Simulation of Urban MObility

Source: http://sumo.dlr.de/wiki
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- Open source
- Micro-simulator

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PRT simulation with SUMO

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- Simulates all individual and collective transport modes
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⇒ Allows to simulate PRT in a multi-modal environment (SUMOPy)

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Vehicle distribution problem

Stop $d$

Pax flow $W[d,k]$

Veh. flow $F[d,k]$

Waiting passengers at station during time $k$: $D[d,k] \approx k \sum_{\kappa=0}^{\infty} W[d,\kappa] - F[d,\kappa]$
Waiting passengers at station $d$ during time $k$:

$$D[d, k] \approx \sum_{\kappa=0}^{k} W[d, \kappa] - F[d, \kappa]$$
Objective function $z(d, \kappa)$ of stop $d$ at $\kappa$ time-steps in the future:
**Objective function** $z(d, \kappa)$ of stop $d$ at $\kappa$ time-steps in the future:

$$ z(d, \kappa) = \left( \hat{F}[d, k + \kappa] - \hat{W}[d, k + \kappa] - K_D \hat{D}[d, k] \right) \exp(-\lambda \kappa T_S) $$

- $\hat{F}[d, k + \kappa]$ Veh. flow
- $\hat{W}[d, k + \kappa]$ Pax. flow
- $\hat{D}[d, k]$ Pax. wait
Vehicle by vehicle assignment
Assignment of pushed and pulled empty vehicle

Objective function $z(d, \kappa)$
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Test network

Simulation results

Medium demand

<table>
<thead>
<tr>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
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<td>4</td>
<td>6</td>
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High demand

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Simulation results

Test network

Medium demand

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<tr>
<th>Zones</th>
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<th>3</th>
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<tbody>
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</tr>
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<td>0</td>
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<td>0</td>
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Simulation results

Number of waiting passengers at stations

Medium demand with 250 vehicles

Number of waiting passengers at stations with different PRT stop IDs.
Simulation results

Critical vehicle flows

Medium demand with 350 vehicles
Optimizing the number of vehicles

Average waiting passengers per station over number of vehicles

![Graph showing the relationship between the number of vehicles and average waiting passengers per station. The graph indicates a minimum average waiting of passengers around 320 vehicles.]
Optimizing the number of vehicles

Average waiting passengers per station over number of vehicles

Minimum at approx. 320 vehicles
Vehicle platooning to increase capacity
Vehicle platooning to increase capacity

Scharfenberg coupling
Vehicle platooning to increase capacity

Scharfenberg coupling
Optimizing the number of vehicles with platooning

Average waiting passengers per station over number of vehicles

![Graph showing the relationship between number of vehicles and average waiting passengers per station, as well as critical flow rate over number of vehicles.]
Optimizing the number of vehicles with platooning

Average waiting passengers per station over number of vehicles

Platooning did not improve capacity (problems with platoon merging)
Validating flow predictability

Station 8, 320 vehicles, medium demand
Normalized cross correlation between flows $F[8, k]$ and scheduled flows $\hat{F}[8, k]$
**Validating flow predictability**

**Station 8**, 320 vehicles, medium demand

Normalized cross correlation between flows $F[8, k]$ and scheduled flows $\hat{F}[8, k]$

$⇒$ travel time estimation under estimates travel time
Validating flow predictability

**Station 8**, 400 vehicles, high demand

Normalized cross correlation between flows $F[8, k]$ and scheduled flows $\hat{F}[8, k]$. 

![Graph showing cross-correlation](image)
Validating flow predictability

Station 8, 400 vehicles, high demand
Normalized cross correlation between flows $F[8, k]$ and scheduled flows $\hat{F}[8, k]$

⇒ congestions reduces predictability
Optimization of flow control parameters

Parameter $K_D$ is controlling the “integrative” component of the Objective function

$$z(d, \kappa) = \left( \hat{F}[d, k + \kappa] - \hat{W}[d, k + \kappa] - K_D \hat{D}[d, k] \right) \exp(-\lambda \kappa T_S)$$
Waiting passengers at station for different $K_D$

Medium demand with 320 vehicles

$K_D = 0.025$

$K_D = 0.25$
Optimization of $K_D$

Lowest average waits per station at $K_D \approx 0.025$ vehicles
Optimization of $K_D$

Lowest average waits per station at $K_D \approx 0.025$ vehicles

Similarity to a PI-feedback controller
Conclusions

- Implementation of PRT with SUMO with 100% shared vehicles
Conclusions

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- Implementation of vehicle redistribution based on flow prediction
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- Implementation of vehicle redistribution based on flow prediction
- Optimization of parameters
- Future work:
  - Comparison with optimal occupied/empty vehicle flows (Schweizer et al, VEHITS 2016)
  - Improvement of vehicle platoon merge to further increase capacity
Questions welcome