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Passenger Arrival Rates at Public Transport Stations

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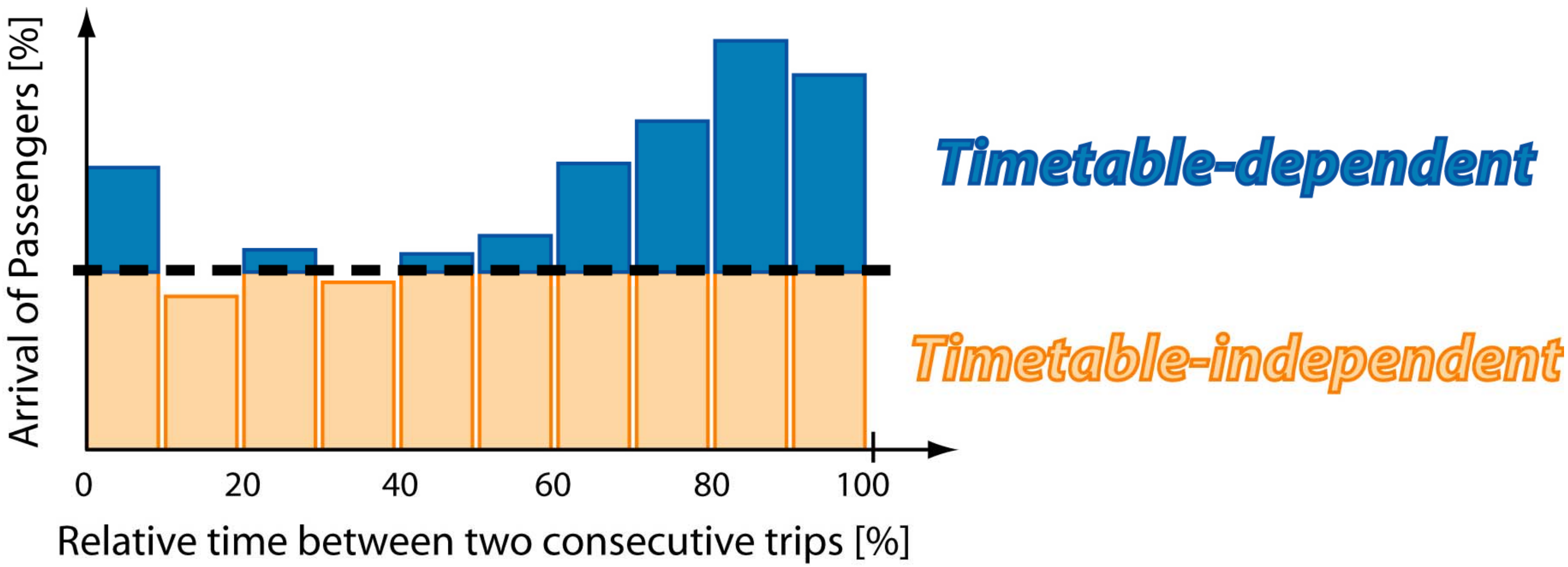
Public Transport Passenger Behavior

- Only a small share of passengers is dependant on the schedule - in contrast to railways.
- Some passengers do not know the timetable.
- Some passengers do not take their desired trip.
- Some passengers do not believe in the schedule, since the route is always late.

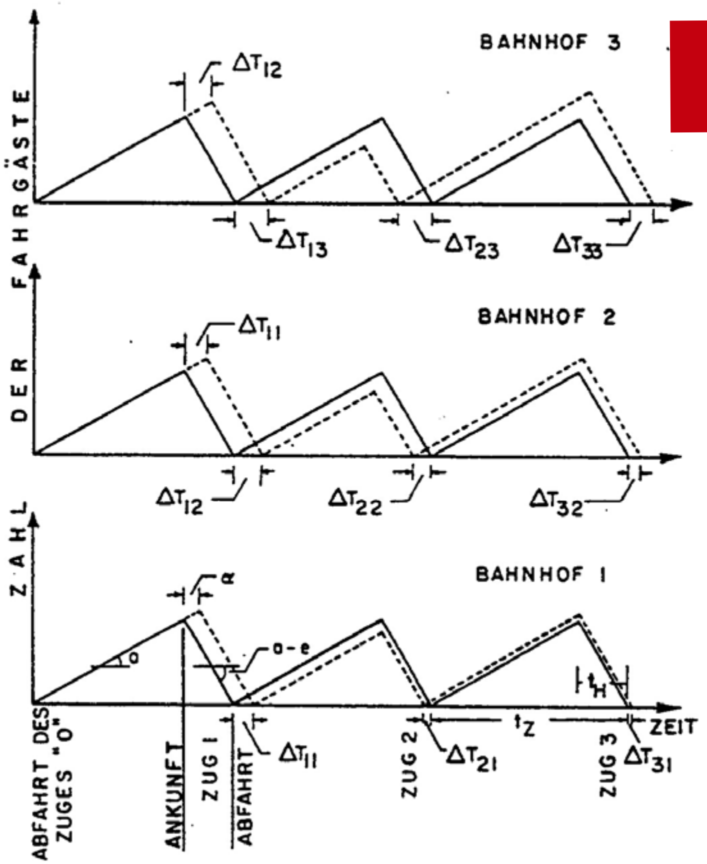
Concept: Classifying passengers as either *timetable-independent* or *timetable-dependent*



The smaller the share of passengers who know the schedule, the …

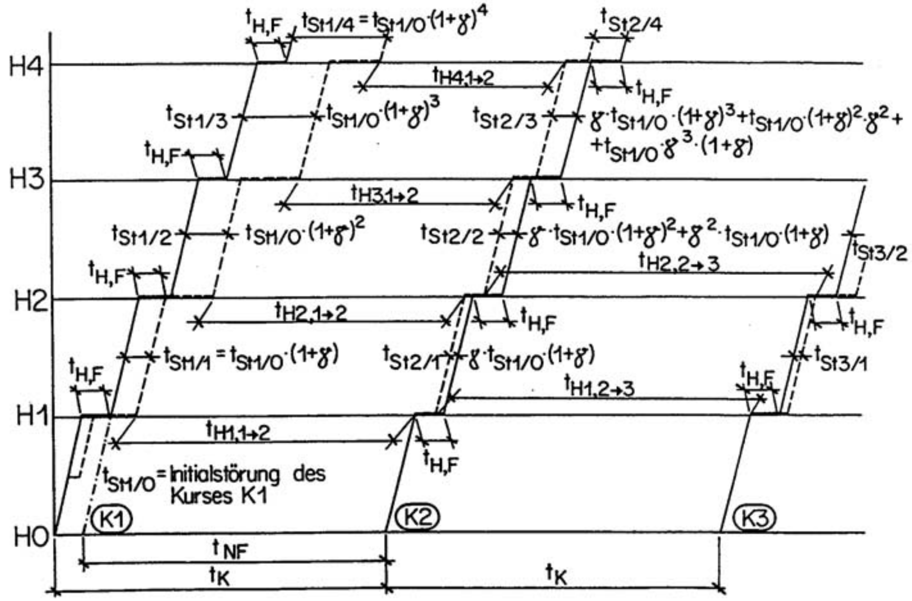
- … less notable the schedule (e.g. not a clock-face repeating headway).
- … worse the passenger information system is.
- … more unstable the service becomes.
- … higher the generalized trip costs.

Delay propagation



Haltepunkt-Belastung als Funktion der Zeit: ihr Einfluß auf die Potenzierung der Fahrplanstörungen

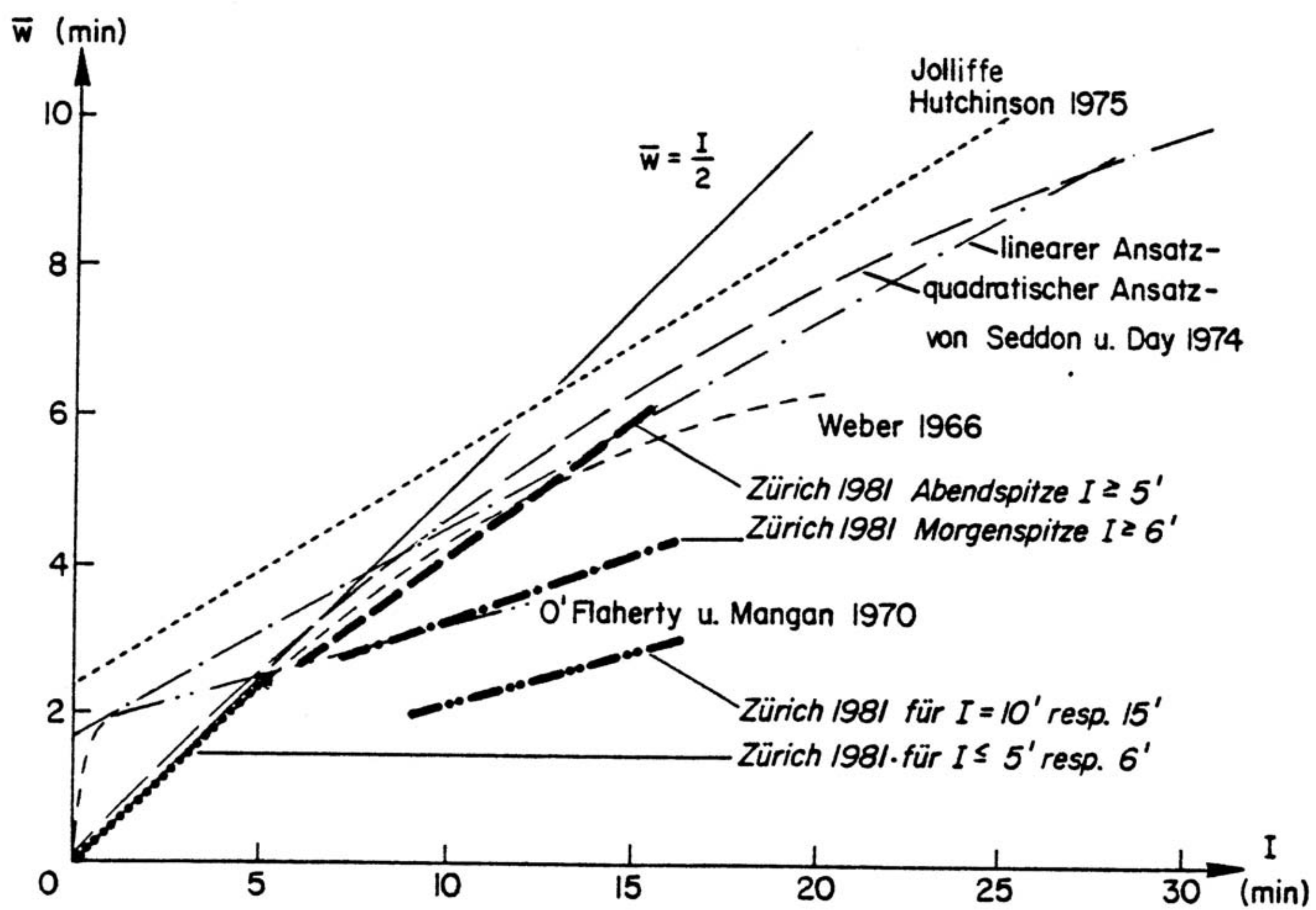
—— planmäßiger Betrieb
– – – Betrieb mit Fahrplanstörung
a — Fahrgast-Zulauf
e — Fahrgast-Einsteig



State of Knowledge - 1981

- For headways of 5 min and less: passengers arrive independently.
- For headways of 7 min and more: passengers arrive based on schedule.
- Peak period: passengers are strongly oriented to schedule.
- Non peak period: passengers have weak orientation to schedule.
- Central influence: How easy it is to remember the schedule.

Previous Research (all earlier than 1981)



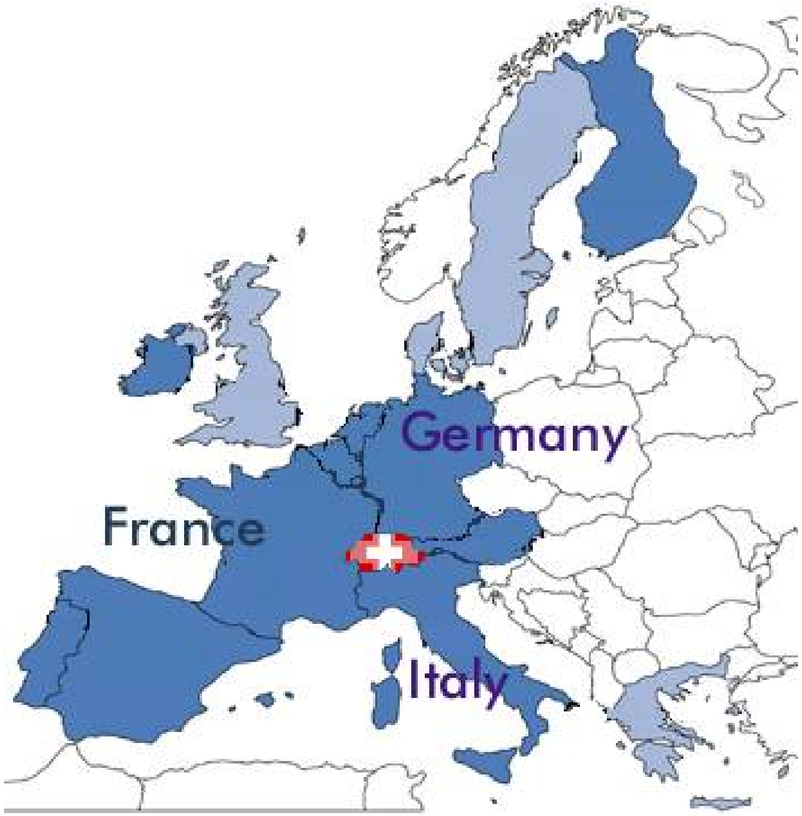
Developments since 1981 and Hypothesis

- Introduction of stop-specific schedule information.
- Public transport schedules available on Internet.
- General social changes.
- **Hypothesis: the share of schedule-oriented passengers has increased since earlier research.**

Research Design: Passenger Observation + Questionnaire

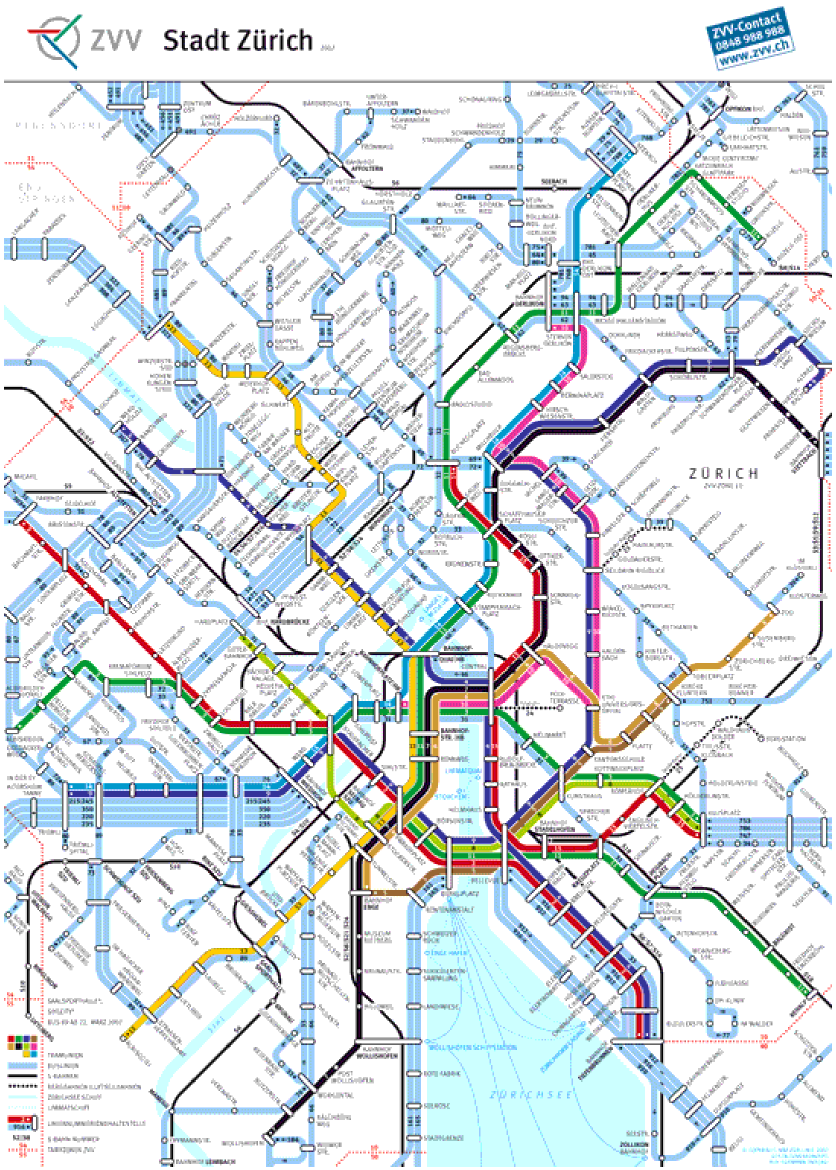
- Station must be served by a single route.
- Route must operate with constant headway.
- No alternate waiting areas near the station.
- No transfer possibilities.
- Not the first or last station on a route.
- Not the location of an intermediate turn.
- Busy enough to obtain sufficient data.

Research Area:
City of Zurich, Switzerland (pop. 365,000)

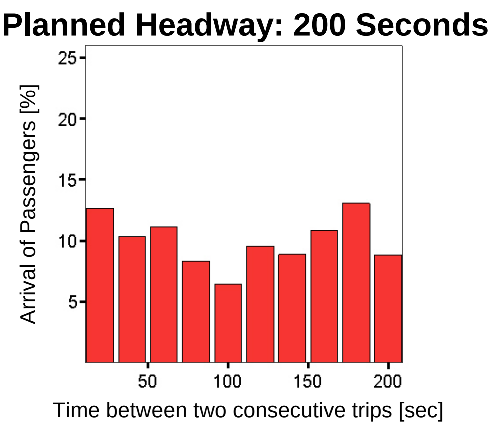


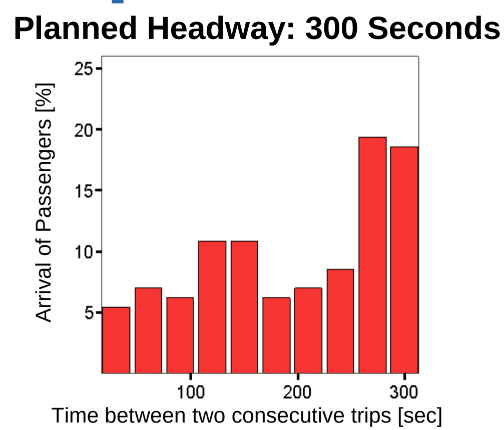
Zurich Public Transport

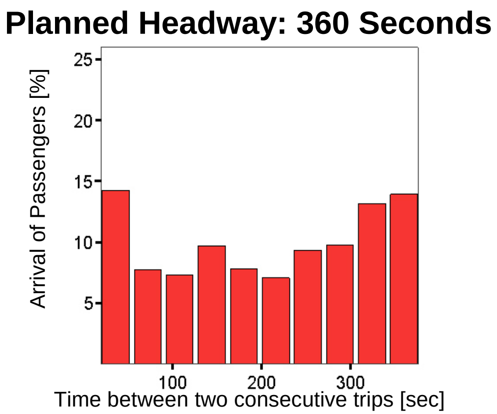
- 13 Tram lines
- 18 Bus routes in Zurich
- 6 Trolleybus routes
- 9 Shortline bus routes
- 32 Bus routes around Zurich
- 293 Mio passengers/year
- 503 kilometers
- 521 stations

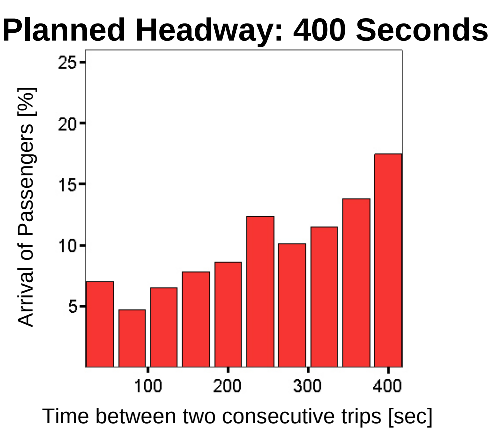


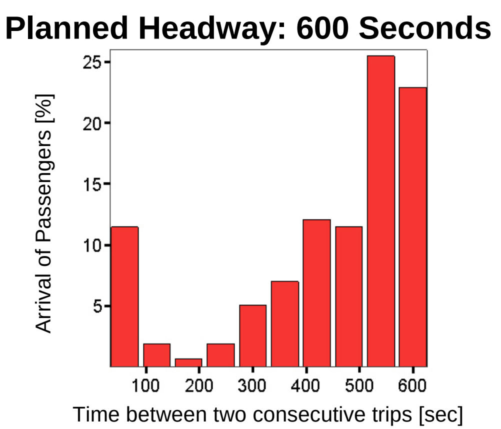
Temporal density of passenger arrivals at stops between scheduled departure times for successive trips in morning peak

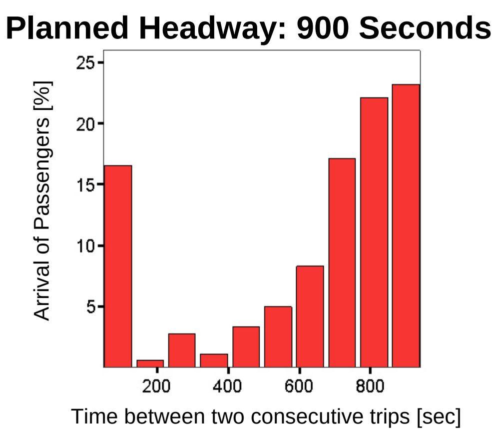




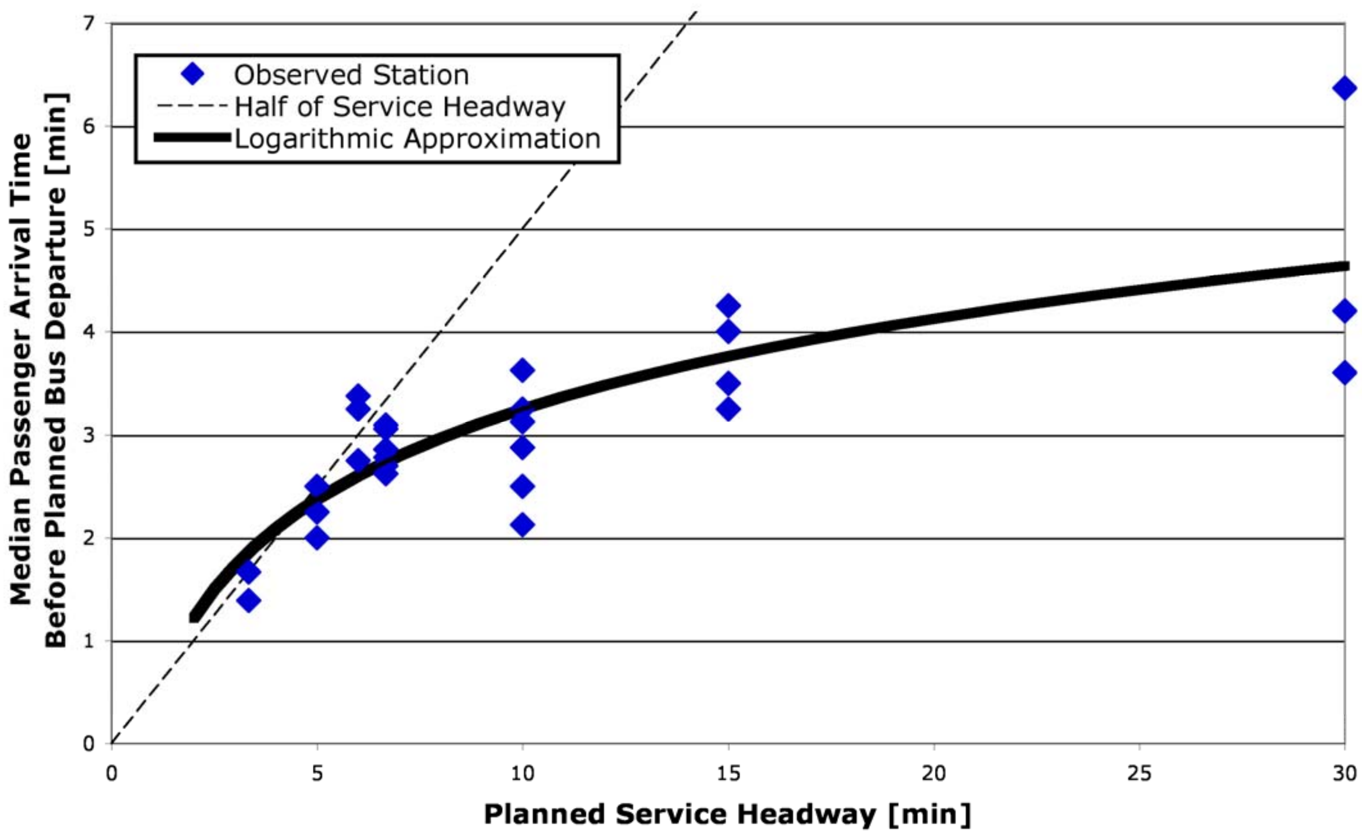




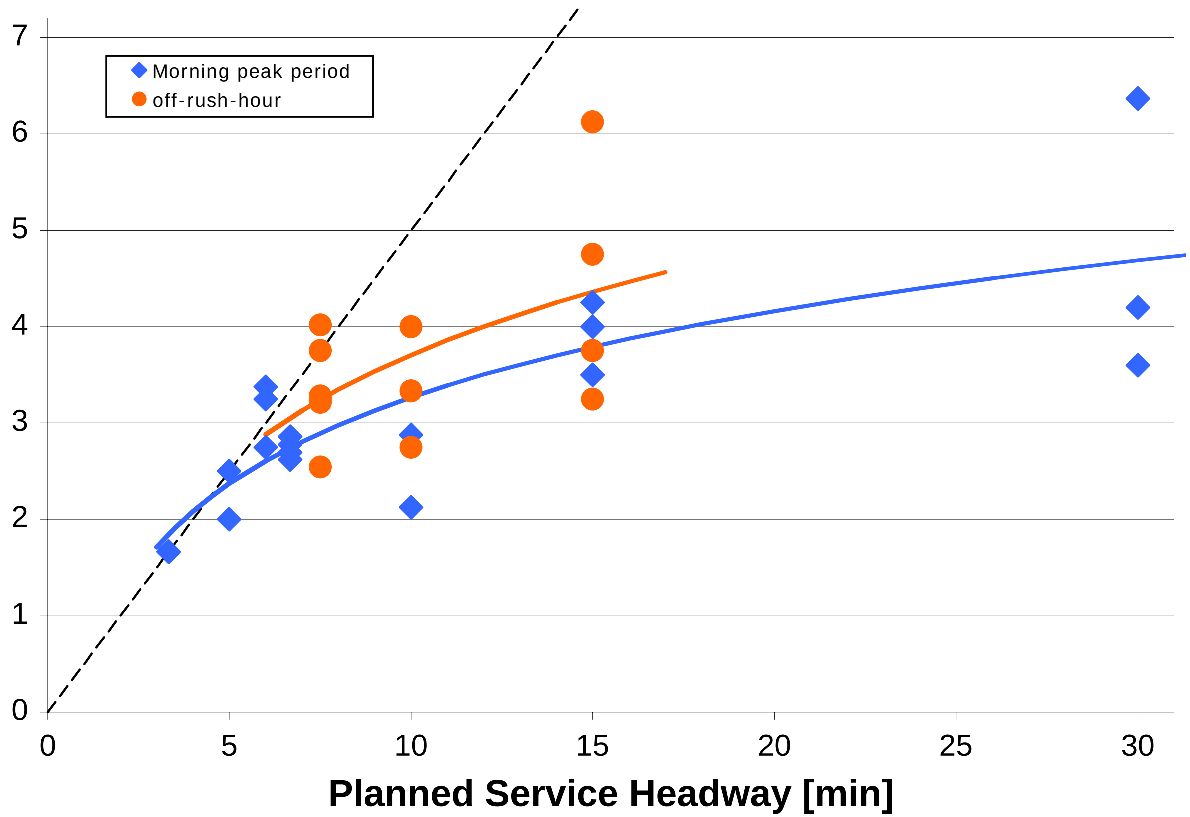




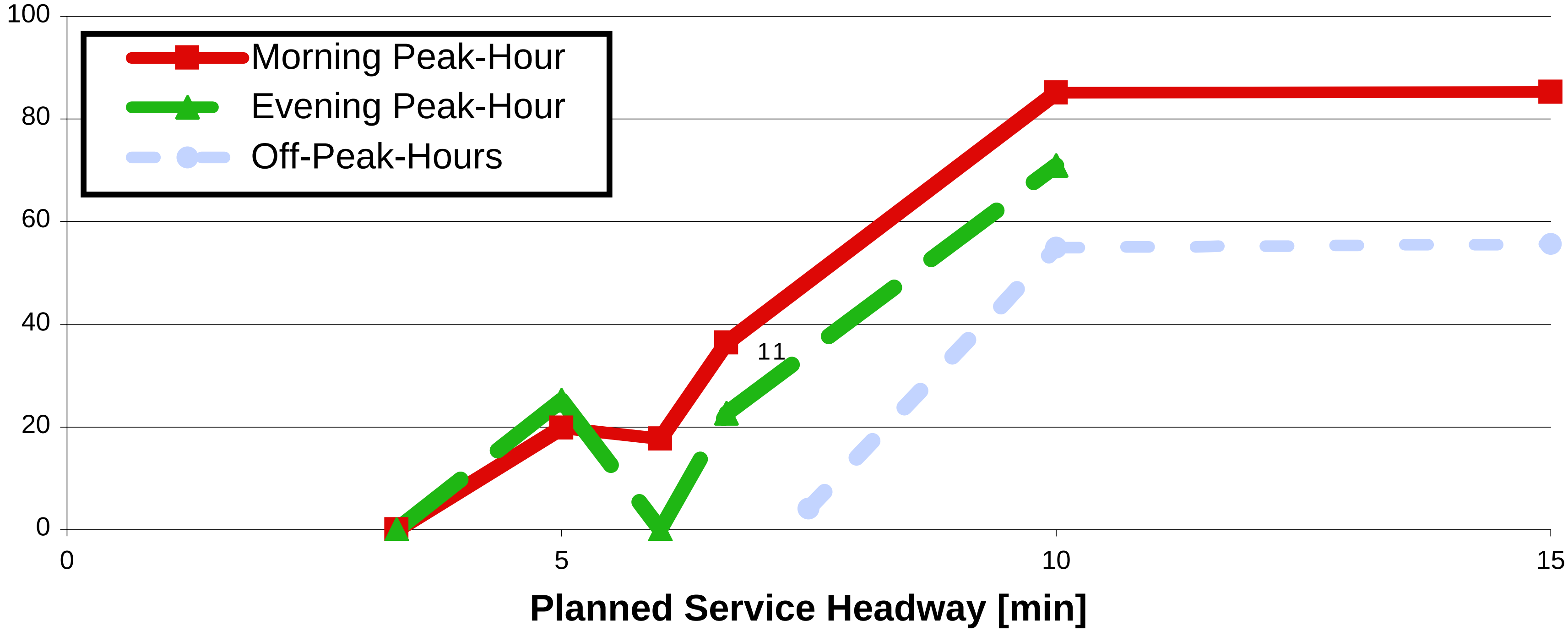
Median passenger waiting time versus headway for Zurich peak periods



Median passenger waiting time vs. headway based on time of day (Zurich data)

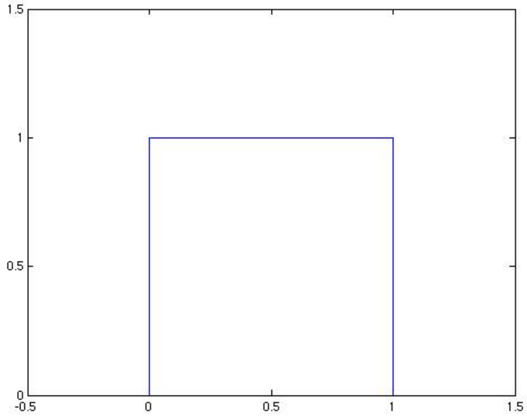


Portion of timetable-dependent passengers based on time of day and headway



Model for temporal density of passenger arrivals at bus stops - *Timetable-independent*

$$U(a,b): \qquad f_{U(a,b)}(x) = \begin{cases} \dfrac{1}{b-a} & \text{if } a < x < b \\ 0 & \text{otherwise} \end{cases}$$

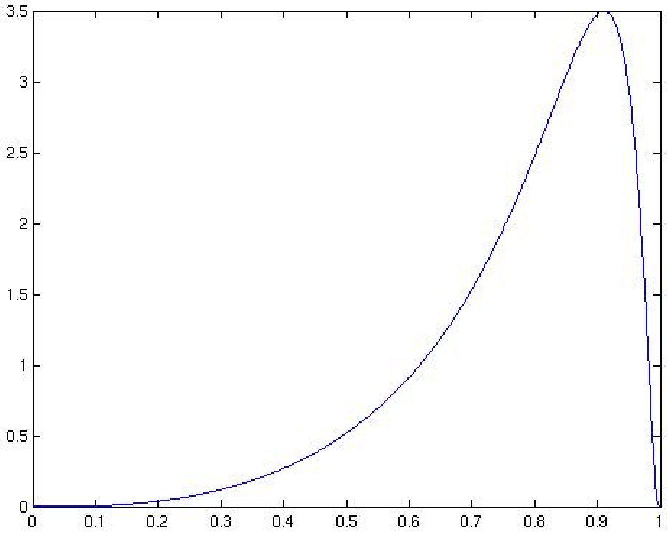


Model for temporal density of passenger arrivals at bus stops - *Timetable-dependent*

Johnson-SB density:

$$JSB(a,b,\alpha_1,\alpha_2):$$

$$f_{JSB(a,b,\alpha_1,\alpha_2)}(x)=\begin{cases}\dfrac{\alpha_2(b-a)}{(x-a)(b-x)\sqrt{2\pi}}e^{-0.5\left\{\alpha_1+\alpha_2\ln\left(\frac{x-a}{b-x}\right)\right\}^2} & \text{if } a<x<b\\ 0 & \text{otherwise}\end{cases}$$



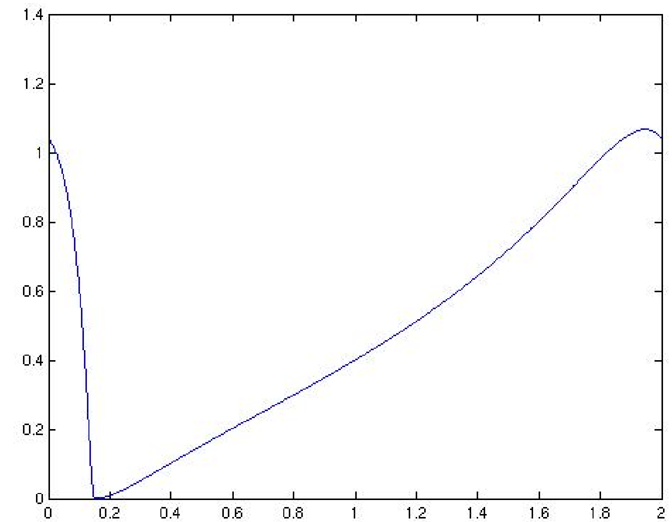
α_1 = -1.2; α_2 = 1

Model for temporal density of passenger arrivals at bus stops - *Timetable-dependent*

Shifted Johnson-SB density:

$JSB_{sh}(a,b,\alpha_1,\alpha_2):$

$$f_{JSB_{sh}(a,b,\alpha_1,\alpha_2)}(x) = \begin{cases} \dfrac{\alpha_2(b-a)}{(x+b-\delta_{ts}-a)(\delta_{ts}-x)\sqrt{2\pi}} e^{-0.5\left\{\alpha_1+\alpha_2 \ln\left(\frac{x+b-\delta_{ts}-a}{\delta_{ts}-x}\right)\right\}^2} & \text{if } a<x<\delta_{ts} \\ \dfrac{\alpha_2(b-a)}{(x-\delta_{ts}-a)(b+\delta_{ts}-x)\sqrt{2\pi}} e^{-0.5\left\{\alpha_1+\alpha_2 \ln\left(\frac{x-\delta_{ts}-a}{b+\delta_{ts}-x}\right)\right\}^2} & \text{if } \delta_{ts}<x<b \\ 0 & \text{otherwise} \end{cases}$$



$\delta_{ts} = 0.8;\ \alpha_1 = -1.2;\ \alpha_2 = 1$

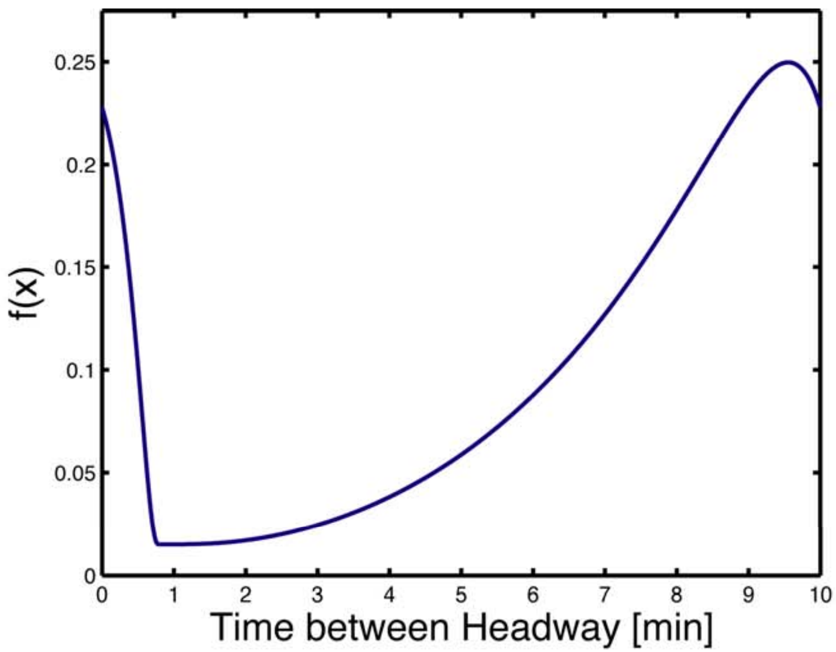
Model for temporal density of passenger arrivals at bus stops: Superposition of uniform and Johnson-SB

$$f_{pa}(x,\alpha_1,\alpha_2) = c_{sd} \cdot f_{U(0,t_{hw})} + c_{si} \cdot f_{JSB_{sh}(0,t_{hw},\alpha 1,\alpha 2)}$$

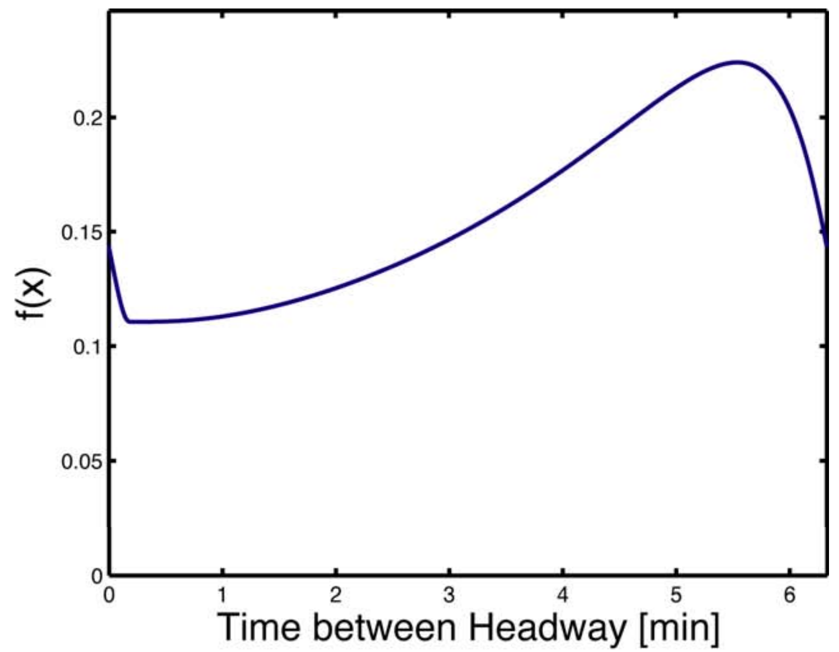
$$f_{pa}(x,\alpha_1,\alpha_2) = \begin{cases} \dfrac{c_{sd}}{t_{hw}} + \dfrac{c_{si}\alpha_2 t_{hw}}{(x+t_{hw}-\delta_{ts})(\delta_{ts}-x)\sqrt{2\pi}} e^{-0.5\left\{\alpha_1+\alpha_2 \ln\left(\frac{x+t_{hw}-\delta_{ts}}{\delta_{ts}-x}\right)\right\}^2} & \text{if } 0 < x < \delta_{ts} \\ \dfrac{c_{sd}}{t_{hw}} + \dfrac{c_{si}\alpha_2 t_{hw}}{(x-\delta_{ts})(t_{hw}+\delta_{ts}-x)\sqrt{2\pi}} e^{-0.5\left\{\alpha_1+\alpha_2 \ln\left(\frac{x-\delta_{ts}}{t_{hw}+\delta_{ts}-x}\right)\right\}^2} & \text{if } \delta_{ts} < x < t_{hw} \\ 0 & \text{otherwise} \end{cases}$$

Results: Passenger arrival models for varying headways

Planned Headway: 600 Seconds

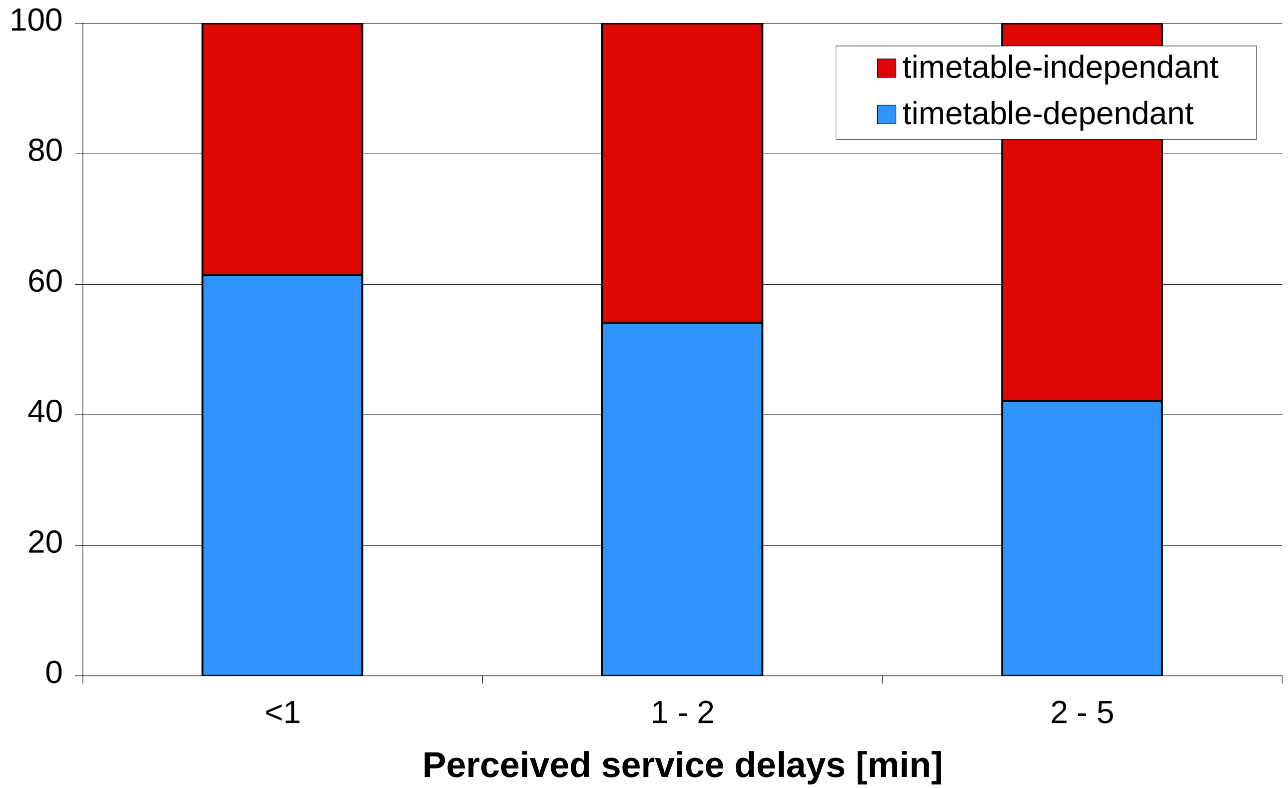


Planned Headway: 400 Seconds

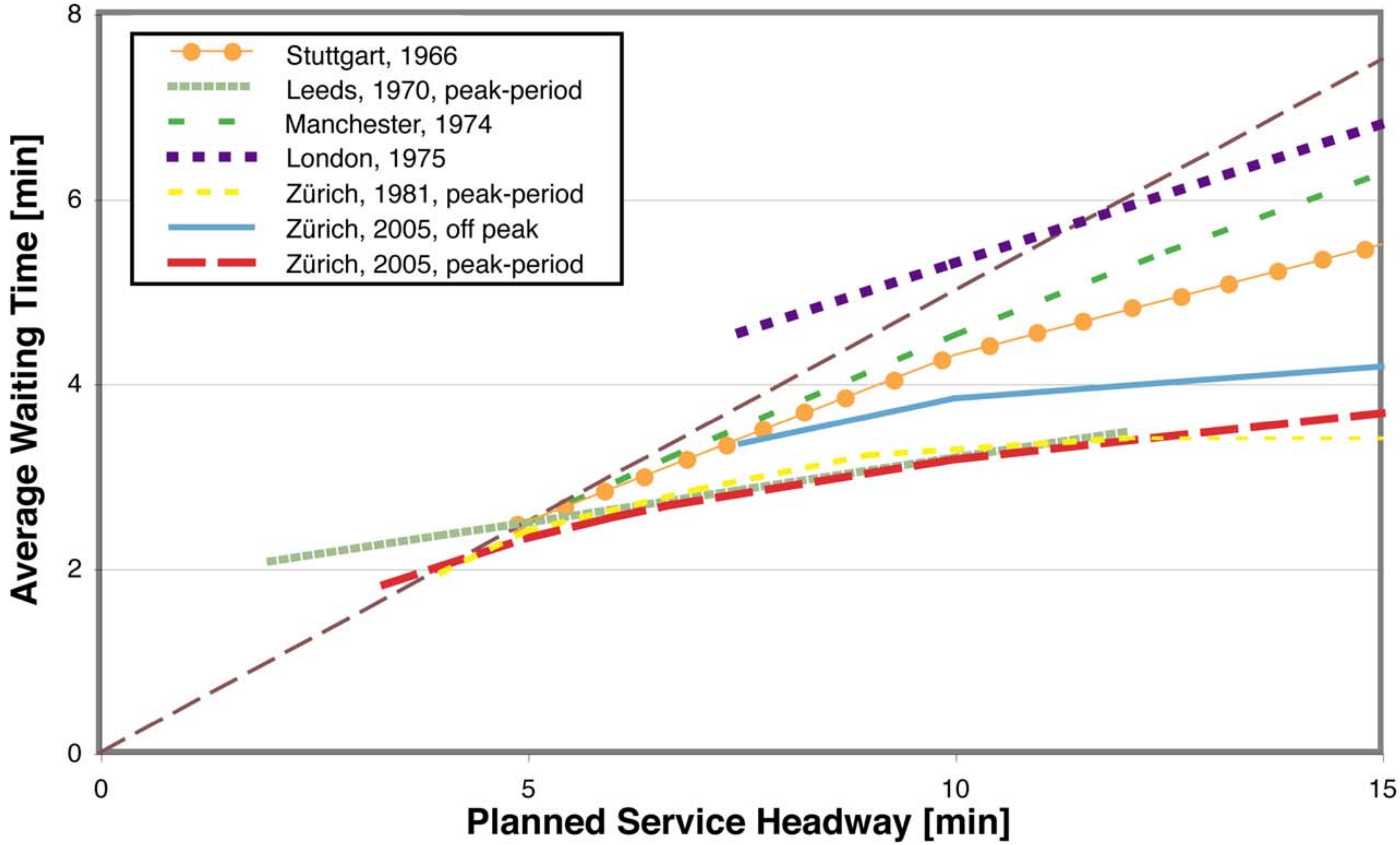


$t_{hw} = 10;\ c_{sd} = 0.15;\ \delta_{ts} = 0.8;\ \alpha_1 = -1.2;\ \alpha_2 = 1$	$t_{hw} = 6.33;\ c_{sd} = 0.7;\ \delta_{ts} = 0.2;\ \alpha_1 = -1;\ \alpha_2 = 1$

Influence of perceived reliability (on-time departure) on passenger timetable dependence (morning peak hours/400 seconds headway)



Relation of median wait time to headway



Main Study Results - 1

- Average waiting time has decreased.
- In peak periods many passengers arrive following the schedule, even at 5 minute headways.
- There remains a difference between peak period and off-peak period passenger behavior.
- Schedule remember-ability remains important.

Main Study Results - 2

- The average wait time is well less than half the headway; for example:
  - at 15 min headways the average wait time was only 4 min (27% of headway).
- The more punctual the line is, the more strongly passengers depend on the schedule.

Conclusions

- The more punctually a line operates, the more passengers depend on the timetable; thus the line becomes even more stable!
- The more punctually a line operates, the lower the average waiting period.
- The more punctually a line operates and the better the passenger information, the lower the total travel time - at the same transport speed!