Passenger Arrival Rates at Public Transport Stations

Prof. Dr. U. Weidmann, M. Lüthi, A. Nash

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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
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

Planned Headway: 200 Seconds

Planned Headway: 300 Seconds

Planned Headway: 360 Seconds

Planned Headway: 400 Seconds

Planned Headway: 600 Seconds

Planned Headway: 900 Seconds
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*

\[
U(a,b) : \quad f_{U(a,b)}(x) = \begin{cases} 
\frac{1}{b-a} & \text{if } a < x < b \\
0 & \text{otherwise}
\end{cases}
\]
Model for temporal density of passenger arrivals at bus stops - *Timetable-dependent*

Johnson-SB density:

\[ JSB(a, b, \alpha_1, \alpha_2): \]

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

\(\alpha_1 = -1.2; \quad \alpha_2 = 1\)
Model for temporal density of passenger arrivals at bus stops - *Timetable-dependent*

**Shifted Johnson-SB density:**

\[ f_{JSBsh}(a, b, \alpha_1, \alpha_2) = \begin{cases} 
\frac{\alpha_2 (b - a)}{(x + b - \delta_{ts} - a)(\delta_{ts} - x)} & \frac{\alpha_1 + \alpha_2}{\ln \left( \frac{x + b - \delta_{ts} - a}{\delta_{ts} - x} \right)} e^{-0.5 \left( \frac{\alpha_1 + \alpha_2}{\ln \left( \frac{x + b - \delta_{ts} - a}{\delta_{ts} - x} \right)} \right)^2} 
\text{if } a < x < \delta_{ts} \\
\frac{\alpha_2 (b - a)}{(x - \delta_{ts} - a)(b + \delta_{ts} - x)} & \frac{\alpha_1 + \alpha_2}{\ln \left( \frac{x - \delta_{ts} - a}{b + \delta_{ts} - x} \right)} e^{-0.5 \left( \frac{\alpha_1 + \alpha_2}{\ln \left( \frac{x - \delta_{ts} - a}{b + \delta_{ts} - x} \right)} \right)^2} 
\text{if } \delta_{ts} < x < b \\
0 & \text{otherwise}
\end{cases} \]

\[ \delta_{ts} = 0.8; \ \alpha_1 = -1.2; \ \alpha_2 = 1 \]
Model for temporal density of passenger arrivals at bus stops:
Superposition of uniform and Johnson-SB

\[ f_{pa}(x, \alpha_1, \alpha_2) = c_{sd} \cdot f_U(0, t_{hw}) + c_{si} \cdot f_{JSB}(0, t_{hw}, \alpha_1, \alpha_2) \]

\[ f_{pa}(x, \alpha_1, \alpha_2) = \begin{cases} 
\frac{c_{sd} \cdot \alpha_2 t_{hw}}{t_{hw}} + \frac{c_{si} \alpha_1 t_{hw}}{(x + t_{hw} - \delta_{ts})(\delta_{ts} - x)\sqrt{2\pi}} e^{-0.5\left(\alpha_1 + \alpha_2 \ln\left(\frac{x + t_{hw} - \delta_{ts}}{\delta_{ts} - x}\right)\right)^2} & \text{if } 0 < x < \delta_{ts} \\
\frac{c_{sd}}{t_{hw}} + \frac{c_{si} \alpha_2 t_{hw}}{(x - \delta_{ts})(t_{hw} + \delta_{ts} - x)\sqrt{2\pi}} e^{-0.5\left(\alpha_1 + \alpha_2 \ln\left(\frac{x - \delta_{ts}}{t_{hw} + \delta_{ts} - x}\right)\right)^2} & \text{if } \delta_{ts} < x < t_{hw} \\
0 & \text{otherwise}
\end{cases} \]
Results: Passenger arrival models for varying headways

Planned Headway: 600 Seconds

\[ f(x) \]

Time between Headway [min]

\[ t_{hw} = 10; c_{sd} = 0.15; \delta_{ls} = 0.8; \alpha_1 = -1.2; \alpha_2 = 1 \]

Planned Headway: 400 Seconds

\[ f(x) \]

Time between Headway [min]

\[ t_{hw} = 6.33; c_{sd} = 0.7; \delta_{ls} = 0.2; \alpha_1 = -1; \alpha_2 = 1 \]
Influence of perceived reliability (on-time departure) on passenger timetable dependence (morning peak hours/400 seconds headway)
Relation of median wait time to headway

![Graph showing the relation between average waiting time and planned service headway](image)

- Stuttgart, 1966
- Leeds, 1970, peak-period
- Manchester, 1974
- London, 1975
- Zürich, 1981, peak-period
- Zürich, 2005, off peak
- Zürich, 2005, peak-period
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!