Increasing Schedule Reliability on Zurich's S-Bahn through Computer Analysis and Simulation

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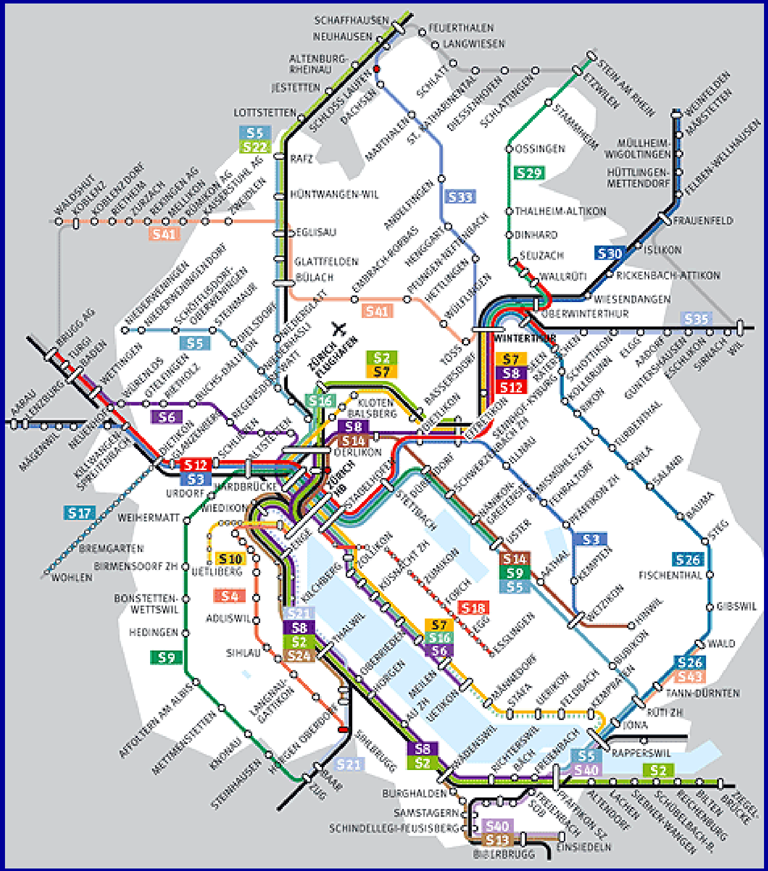
Presentation Outline

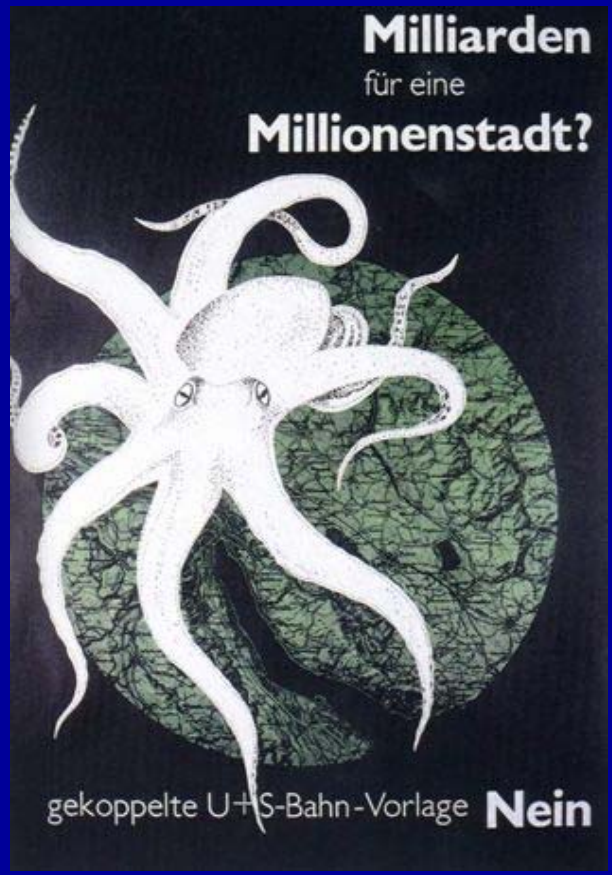
1. Zurich's S-Bahn Network
2. Rail System Computer Applications
3. S-Bahn Delay Study
4. Conclusions

1. Zurich's S-Bahn Network

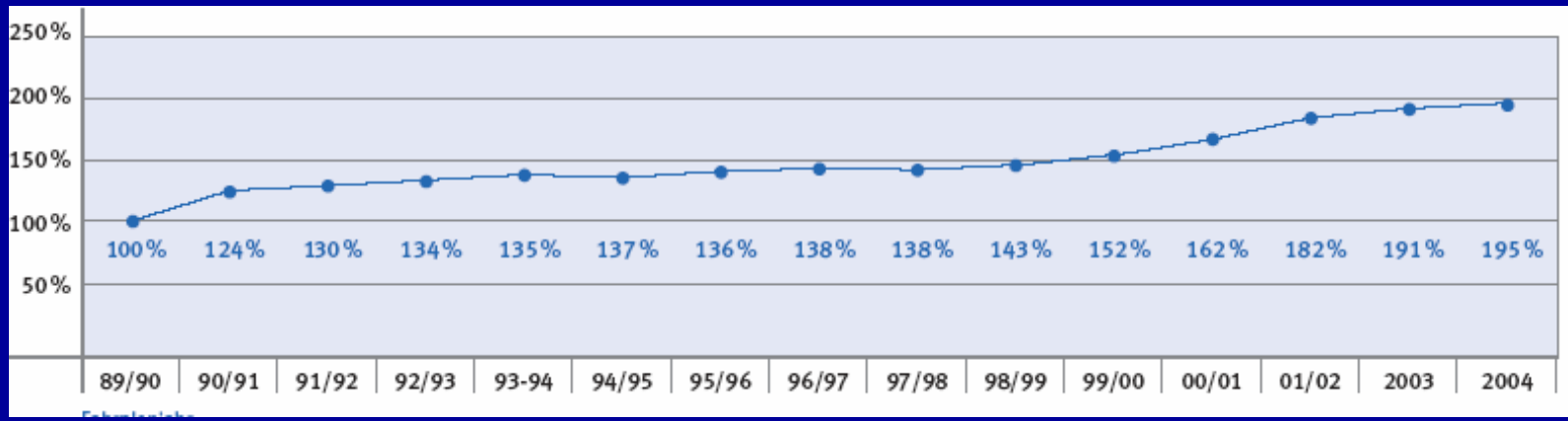
- About 316,000 daily passengers crossing city boundaries.
- 26 lines operated by SBB (20) and other railroads (6).
- Population served = 1.2 million.



S-Bahn project political campaign



Zurich S-Bahn Project - 1990



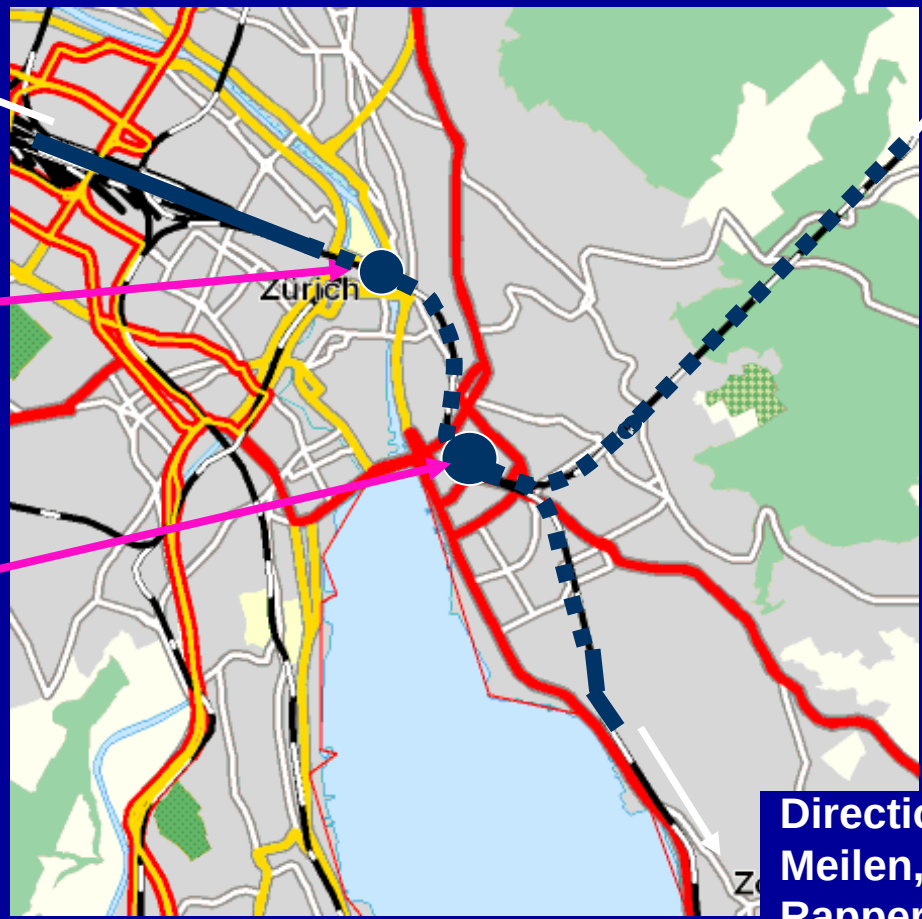
- New underground through station at Hauptbahnhof with a tunnel under the city to Stadelhofen station.
- ZVV formed to coordinate transit fares and schedules throughout the canton.
- S-Bahn ridership and service increased significantly.

Zurich S-Bahn Project - 1990

Direction
Zürich Oerlikon
Limmattal

Zürich HB

Stadelhofen



Direction
Zürcher Oberland,
Winterthur

Direction
Meilen,
Rapperswil

Zurich's S-Bahn: A victim of success?

By 2003 the S-Bahn was experiencing increasing delays caused by:

- More trains; and
- More passengers.

And, many communities wanted more service!

S-Bahn Delay Study

Goal:

- Improve S-Bahn punctuality and reliability.

Objectives:

- Identify causes of delay;
- Analyze delays in detail; and
- Propose improvements to reduce delays.

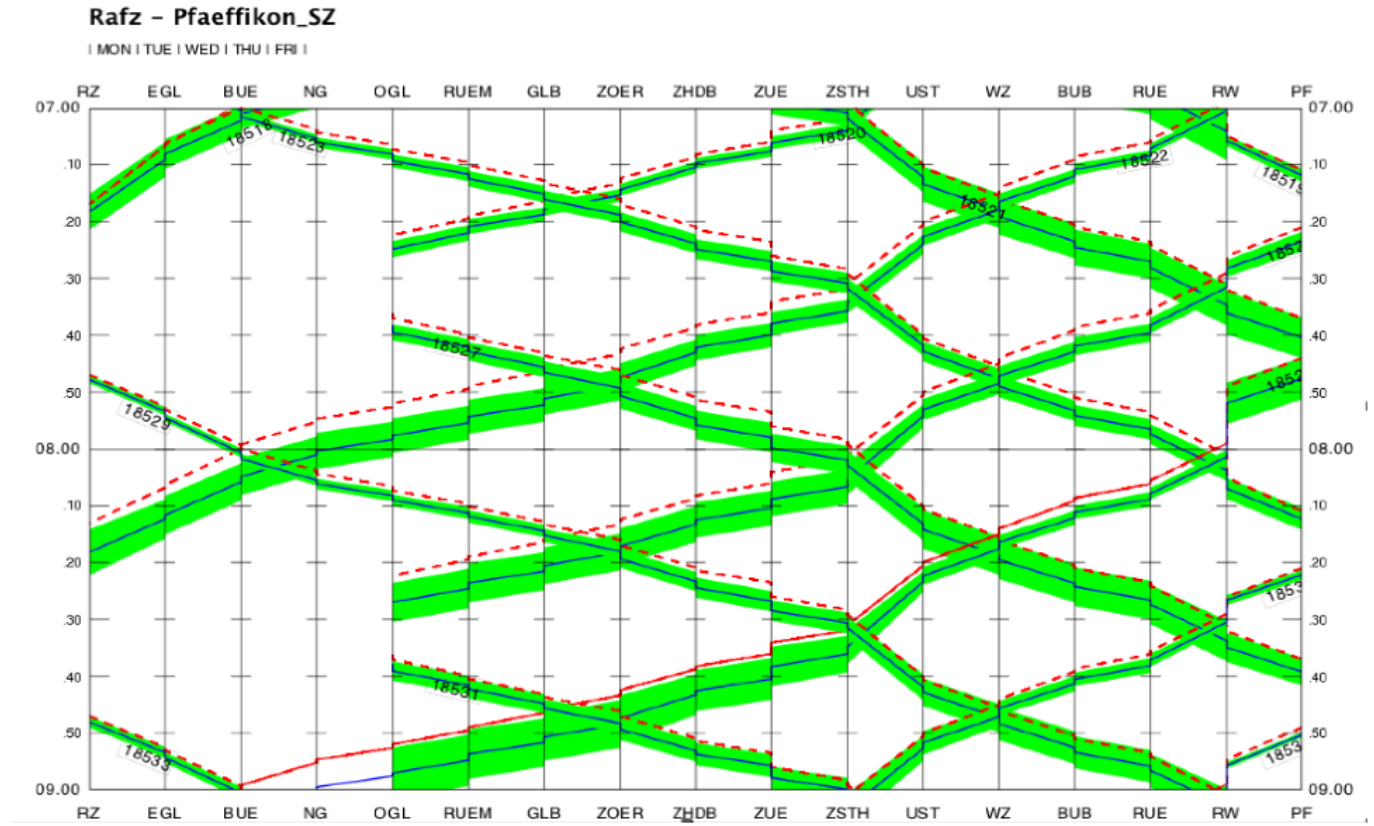
2. Rail System Analysis Software

- OpenTimeTable
- OpenTrack
- Pedestrian Simulation

OpenTimeTable

- Identifies and analyzes systematic delays using automatically collected schedule data;
  - NetAnalyzer - Notifies users when user-defined limit is exceeded.
  - CorridorAnalyzer - Provides statistical information in a wide variety of formats for selected data sets.
- Developed at IVT; and
- Commercial use since 2003.

OpenTimeTable graphical timetable

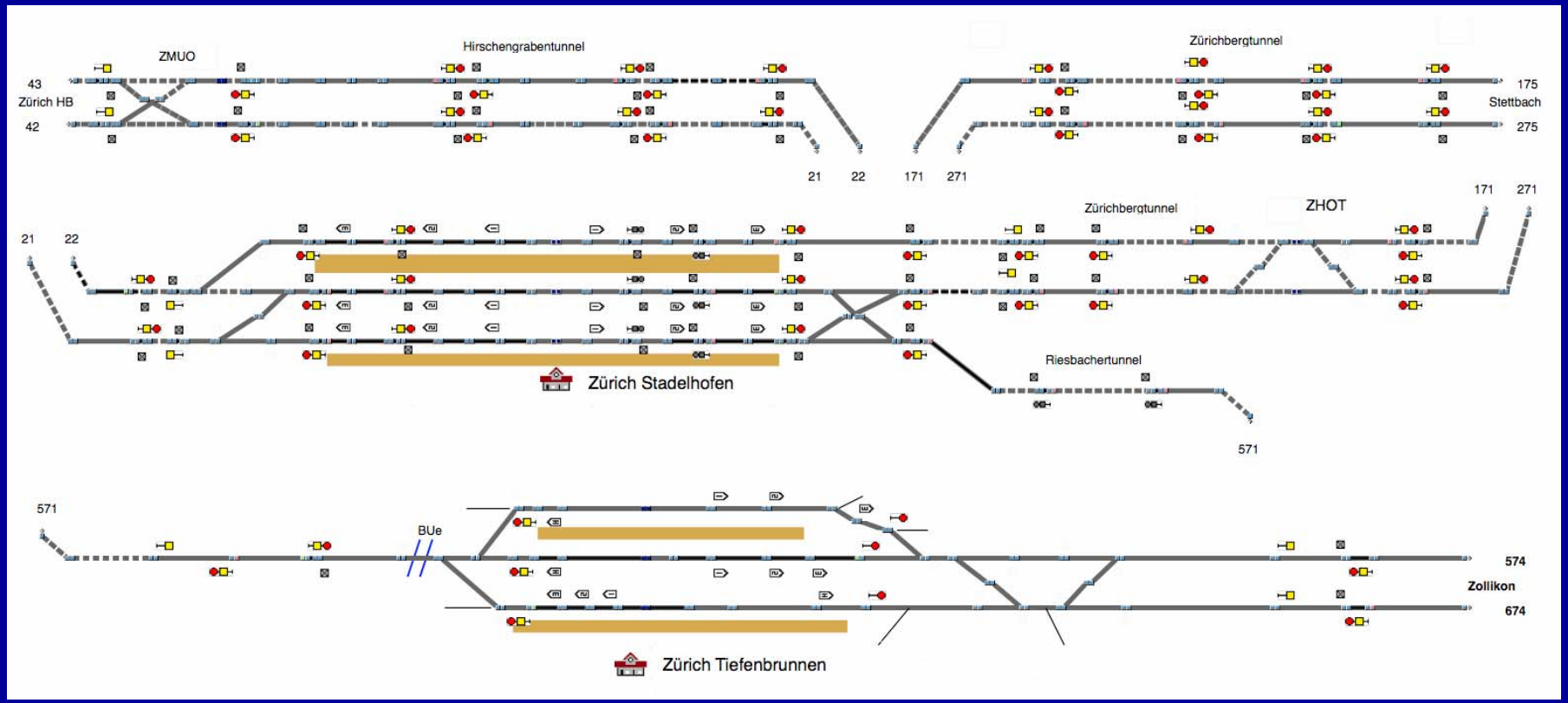


Rot-gestrichelt: Soll-Trassen der Züge
Blau: Ist-Mittelwert aller ausgewerteter Züge
Grün: Standardabweichungen der Züge (dieser Wert zeigt an, wie stark die Züge sich streuen).

OpenTrack

- Microscopic railroad simulation program;
- Allows users to better understand rail network operations and problems;
- Allows users to test various infrastructure, rolling stock, and schedule improvements;
- Developed at IVT; and
- Commercial use since 2000.

OpenTrack representation



Pedestrian Simulation Applications

- Analyze pedestrian movement and behavior in a variety of settings;
- Three pedestrian simulation programs were used in the analysis:
  - PedGo - microscopic multi-agent simulation, cellular automation (CA) model;
  - SimWalk - multi-agent simulation, social force model;
  - SimPed - microscopic multi-agent simulation combined with macroscopic process modeling.

3. S-Bahn Delay Study

A. Identify most delayed S-Bahn lines;

B. Identify main causes of delay;

C. Analyze passenger boarding/alighting process;

D. Simulate Stadelhofen Station operations; and,

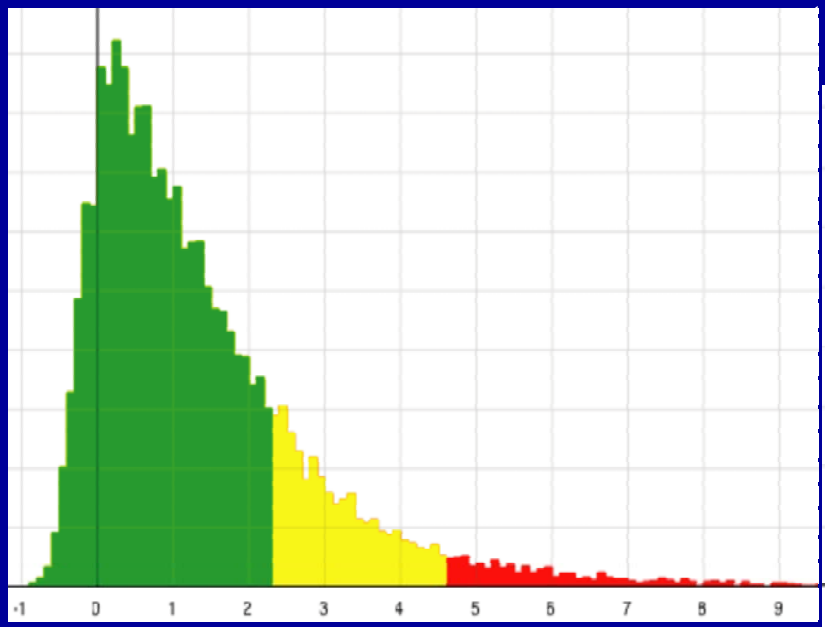
E. Recommendations for reducing delays.

A. Identify most delayed S-Bahn lines

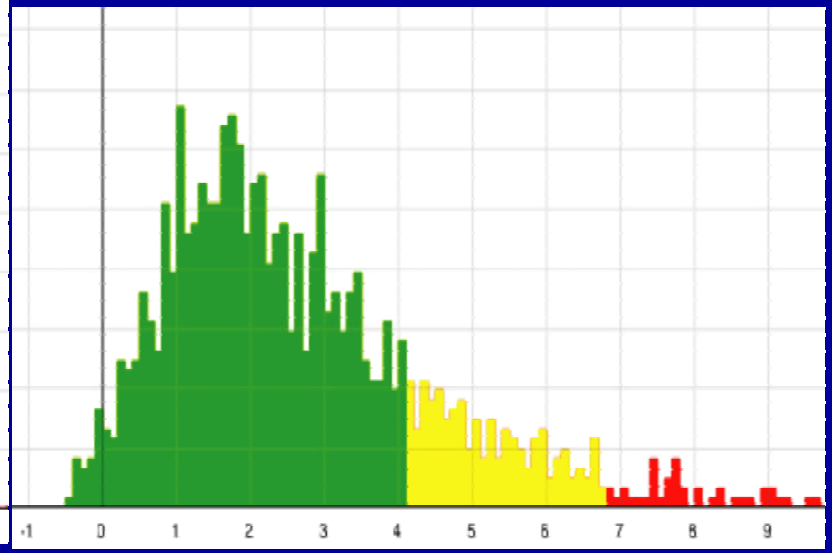
- OpenTimeTable analysis with SBB delay definition:
  - 75% of trains arrive w/in 2 min of schedule; &
  - 95% of trains arrive w/in 5 min of schedule.
- Core network S-Bahn lines;
- Morning peak period;
- Months of: January, July, & November 2004.

Arrival times for S-5 line in Zürich HB (OTT)

All trains (Jan. - Nov. 2004)

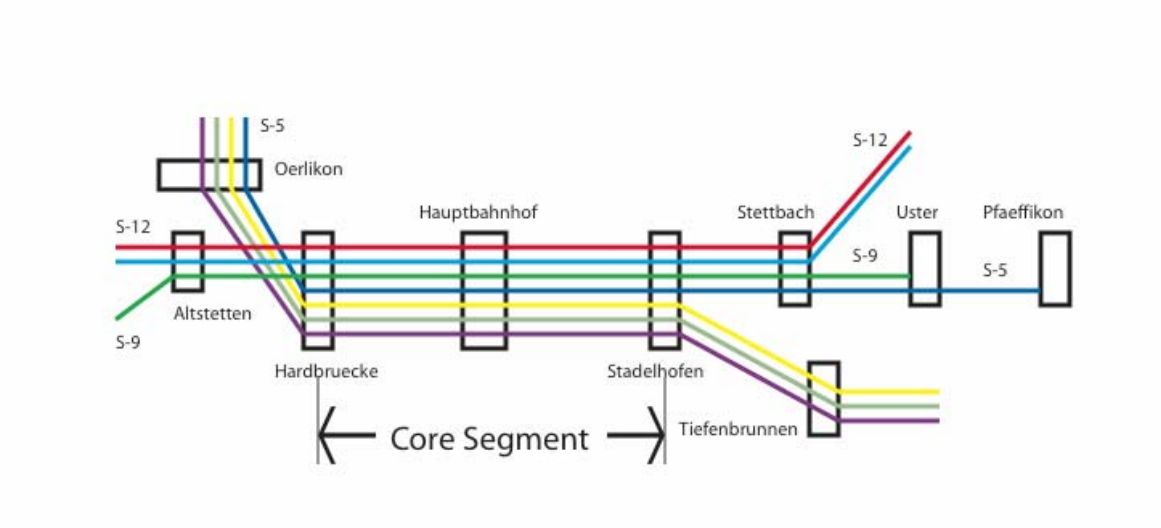


Peak period trains



Green = 80% of trains
Green + Yellow = 95% of trains

S-Bahn Line Segmentation

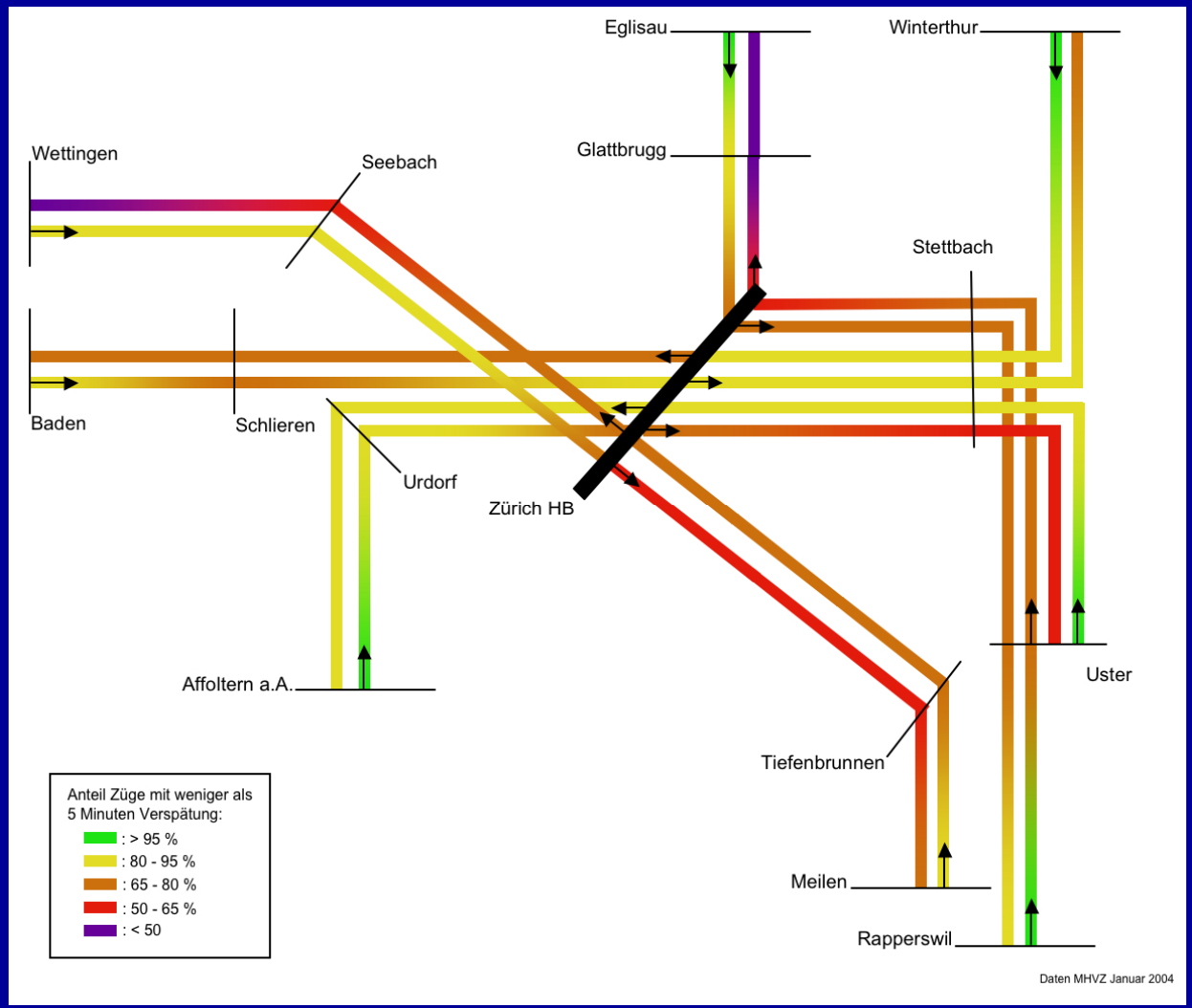


1. Periphery (starting station)
2. Periphery to core network (inbound)
3. Core network (Stadelhofen - Hauptbahnhof - Hardbrucke)
4. Core network to Periphery (outbound)
5. Periphery (end station)

Network Analysis Findings

- Trains lose up to 2 minutes between periphery station inbound and core network.
  - *Trains leave starting station late; and*
  - *Continue losing time on periphery segment.*
- Trains lose an average of 1 minute traveling on the core network.
- Some trains even lose time on the outbound segment.

Delays as a function of location



Most Delayed S-Bahn Lines

- S-5: Pfaeffikon to Zurich
- S-12: Brugg to Zurich
- S-9: Zug to Zurich

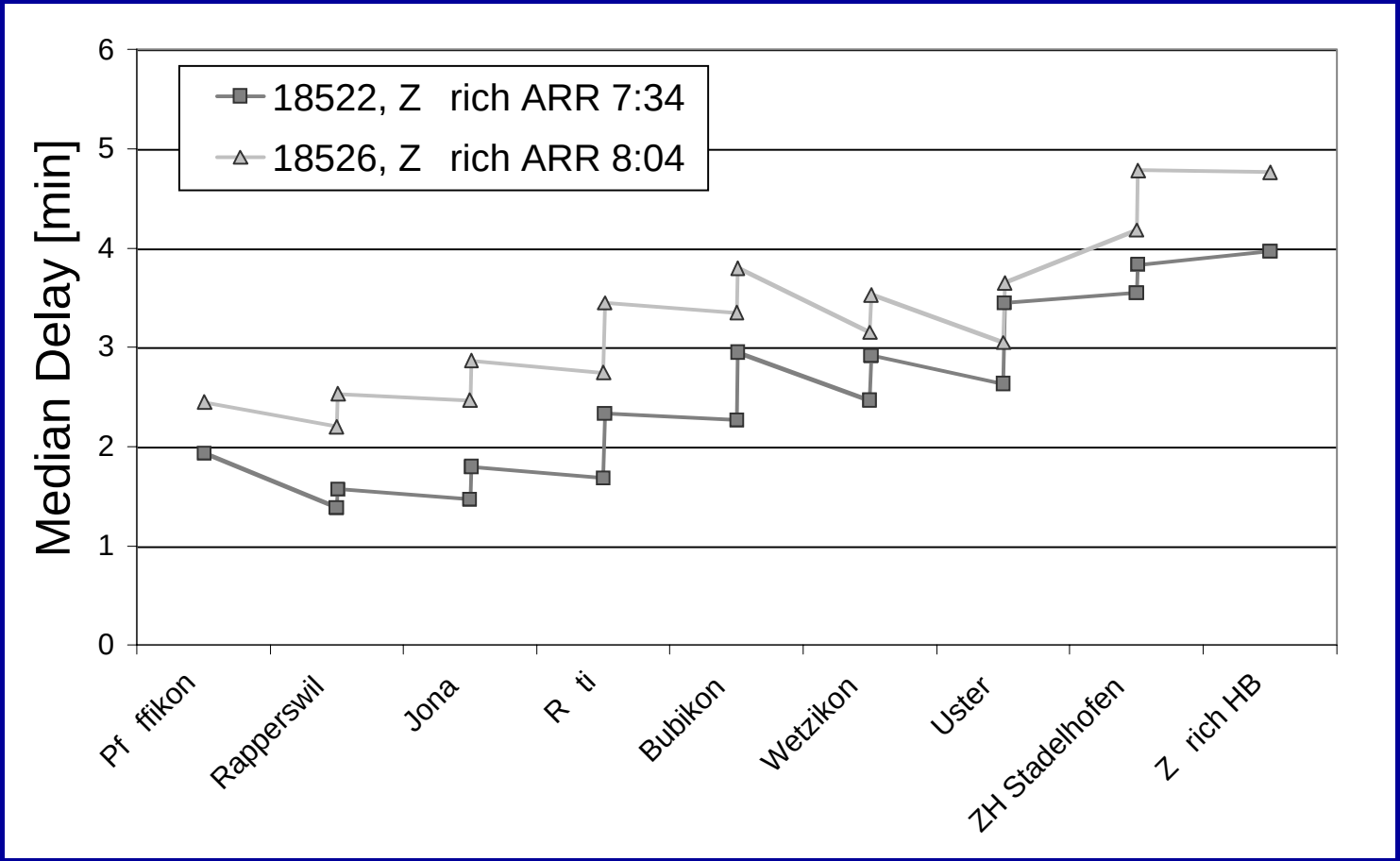
In January 2004, over 70% of S-5 line peak period trains were delayed by over 2-minutes - therefore it was chosen for more detailed study.

B. Identify the main causes of delay

Using OpenTimeTable and statistical analysis:

- Station dwell times were longer than scheduled;
- Trains started late;
- Routes were occupied by long-distance trains;
- Delays accumulated in the core network (chain reaction);
- Single track sections; and
- Extra trains in the core network caused delays.

Excess Station Dwell Time (S-5 Line)

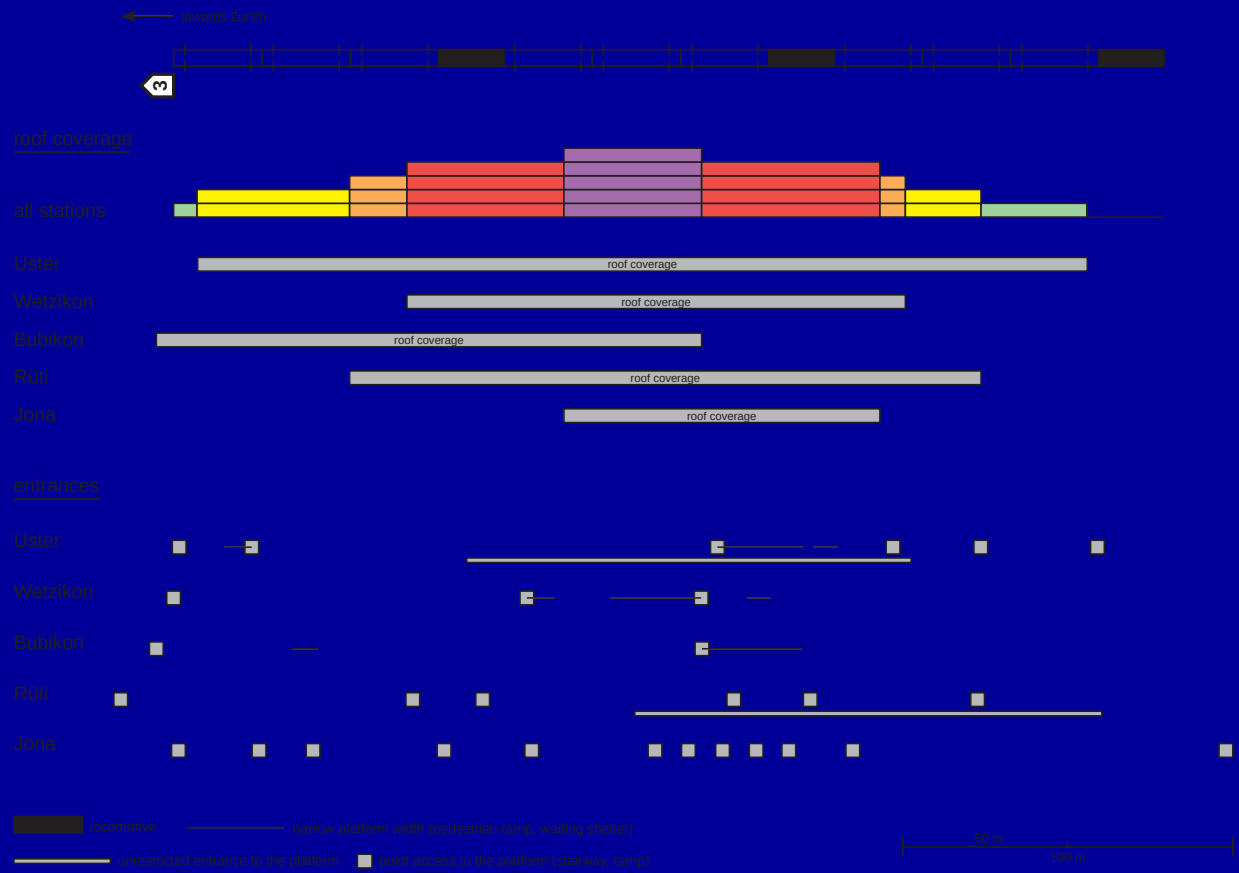


C. Analyze boarding/alighting process

A detailed analysis of S-5 Line (peripheral to core network segment) was completed to analyze excess station dwell times:

- Assess station physical layout;
- Assess rolling stock configuration;
- Observations; and
- Pedestrian simulation models.

Station physical layout

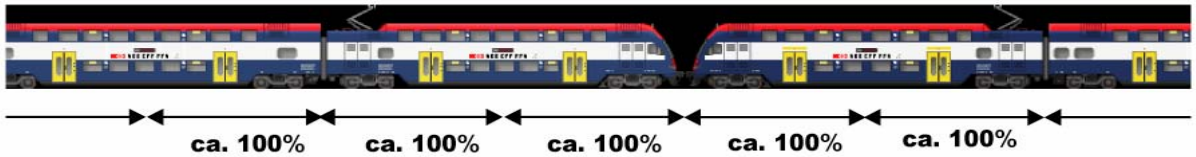


Rolling stock configuration

Original Two Level Commuter Train - DPZ - 1990

- 6 doors per unit (100 m)
- Access: 3 steps (60 cm)

New Two Level Commuter Train - DTZ - 2006



- 8 doors per unit (100 m)
- Access: level boarding

↔ Catchment area for a specific door

Pedestrian simulation models

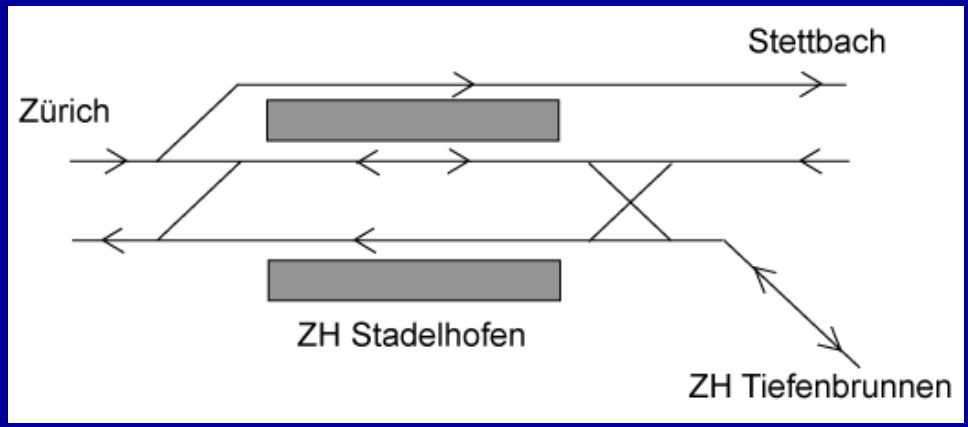
- The three models were used and compared.
- Models were helpful evaluating the motion of pedestrians (platforms, stairs) but less so in the vehicle boarding/alighting process (note: they were not designed for this).
- Consequently, IVT has started research on extending pedestrian simulation models to include transit vehicle boarding/alighting process.

Boarding/alighting analysis results

Increased station dwell times were caused by:

- Unequal vehicle door catchment areas;
- Over crowded vestibules;
- Counter flows (many stations have 2-direction demand);
- Narrow station platforms and bottlenecks;
- Non-homogeneous distribution of waiting passengers;
- Events (holding doors, baby carriages, disabled access).

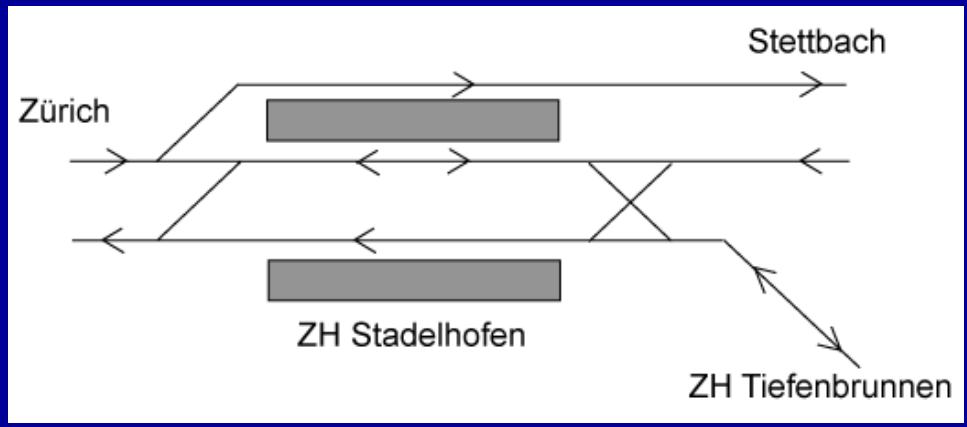
D. Simulate Stadelhofen Station operations



Operational delays on the core network (Stadelhofen - Hauptbahnhof - Hardbruecke) were a second significant cause of delay and therefore OpenTrack was used to model operations on the core network.

Stadelhofen Station

Recommended operational changes

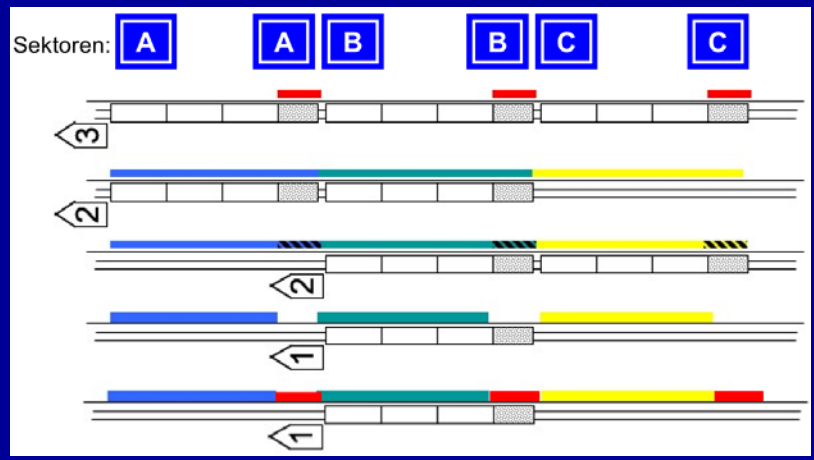


- Schedule adjustments (<1-minute) to several trains;
- Platform change (middle platform used for trains in both directions); and
- Change in train order (one line).

E. Key delay study recommendations

- Revise station dwell times systematically throughout the S-Bahn network;
- Increase scheduled dwell time at stations just outside core network (enabling trains to enter core network on time);
- Implement low cost measures to encourage more even passenger distribution along platforms;
- Develop a prioritized infrastructure improvement program to reduce single track sections; and
- Implement measures in a systematic and coordinated fashion.

Passenger distribution on platforms: door signs, platform markings.



4. Research Conclusions

- Computerized analysis and simulation applications are critical to helping plan and improve regional rail systems;
- Schedule analysis software helps planners identify and understand systematic delays - the first step in improving service;
- Rail simulation software helps planners balance infrastructure - rolling stock - schedule improvements to develop the most cost effective plans; and
- Pedestrian simulation software needs to be improved to better model the passenger boarding/alighting process.

Thank-you

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