

# Network optimisation with dynamic modelling: the case study of Karlsruhe

---

## ➤ Table of contents

---

1. TTK in short
2. Karlsruhe Project
3. Aim of the study
4. Procedure



---

# ➤ Table of contents

---

## 1. TTK in short

- Shareholders
- TTK 20 years of expertise in Public Transport
- Core competences

## 2. Karlsruhe Project

## 3. Aim of the study

## 4. Procedure

## ➤ Shareholders



### Majority shareholder with 51 %

**PTV Transport Consult GmbH**, a firm of the PTV Group, active worldwide in Software development, Consulting and Research in transportation and transport planning

### Majority shareholder with 49 %

**Albtal-Verkehrs-Gesellschaft mbH (AVG)**, the AVG is the operator of the regional Tram-Train and railway in the Karlsruhe area, partly on its own network, partly on the DB-Infrastructure with a 500 kilometre network



# ➤ TTK 20 years of expertise in Public Transport

- Founded in 1996
- Head office in Karlsruhe
- Branch in Lyon
- 30 employees
- Turnover 2015 : 2,6 Million Euros
- Firm fields:
  - Infrastructure
  - Transport Planning, Operation and Vehicle



## ➤ Core competences



Direct access to the operator experience and the AVG's infrastructure



Large spectrum linked to expert engineers



International expertise in design and construction of tramway, Tram-Train, suburban railway and BRT



Wide knowledge of the French Public Transport market



Know-how exchange between France and Germany as well as other countries



---

# ➤ Table of contents

---

1. TTK in short

## 2. Karlsruhe Project

- The Karlsruhe Model
- Origin of the “Kombilösung”
- The futur network

3. Aim of the study

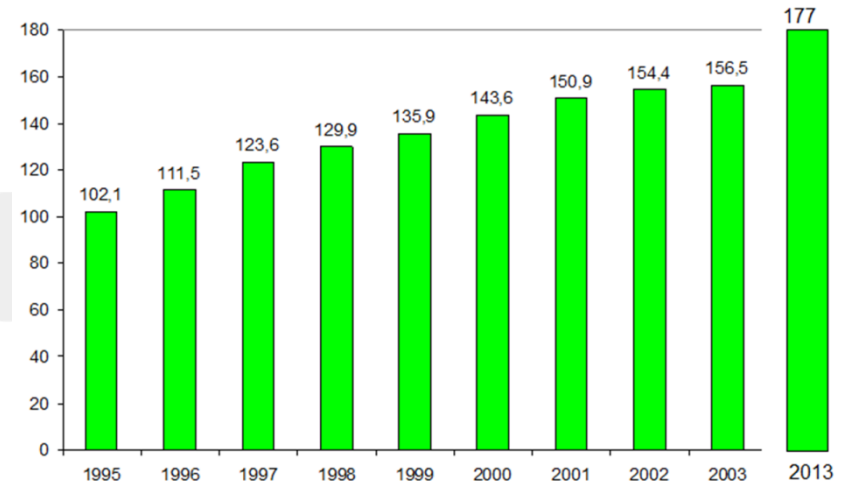
4. Procedure



# ➤ The Karlsruhe Model

## Main facts

- ❖ Inhabitants: 1,3 Mio.
- ❖ Surface: 3.550 km<sup>2</sup>
- ❖ 120 cities and local authorities
- ❖ 21 operators
- ❖ 210 railway and bus lines
- ❖ 180 Mio. passengers / year
- ❖ Shareholder: 7 cities and administrative districts



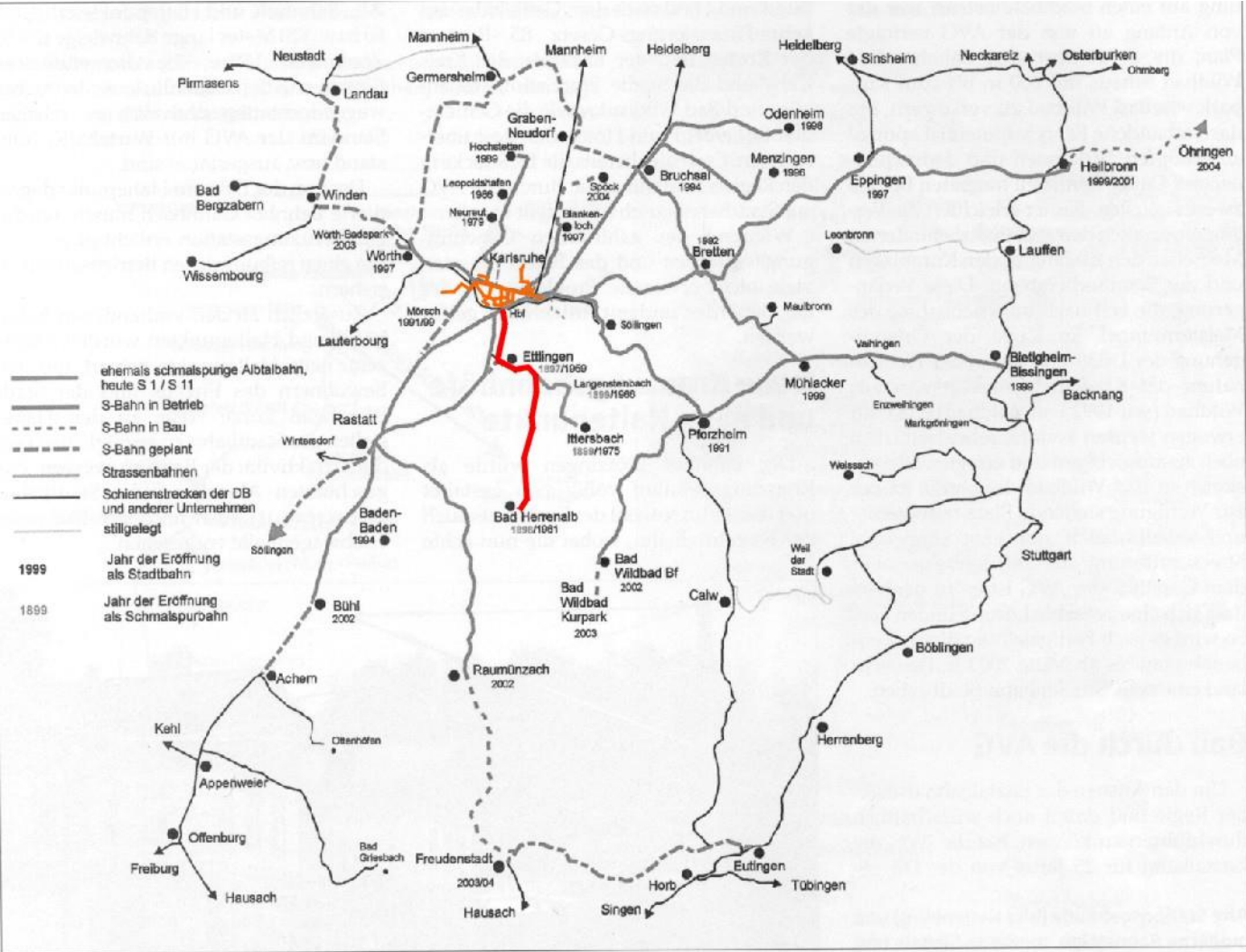
*Passengers growth*

## Principles

- ❖ Direct lines between the suburbs and the city center
- ❖ As fast as trains outside the city and as flexible as trams in the city
- ❖ Connection between railway and tramway networks
- ❖ High frequencies each day from 5 am to 1 am
- ❖ Modern vehicle fleet
- ❖ Attractive fares

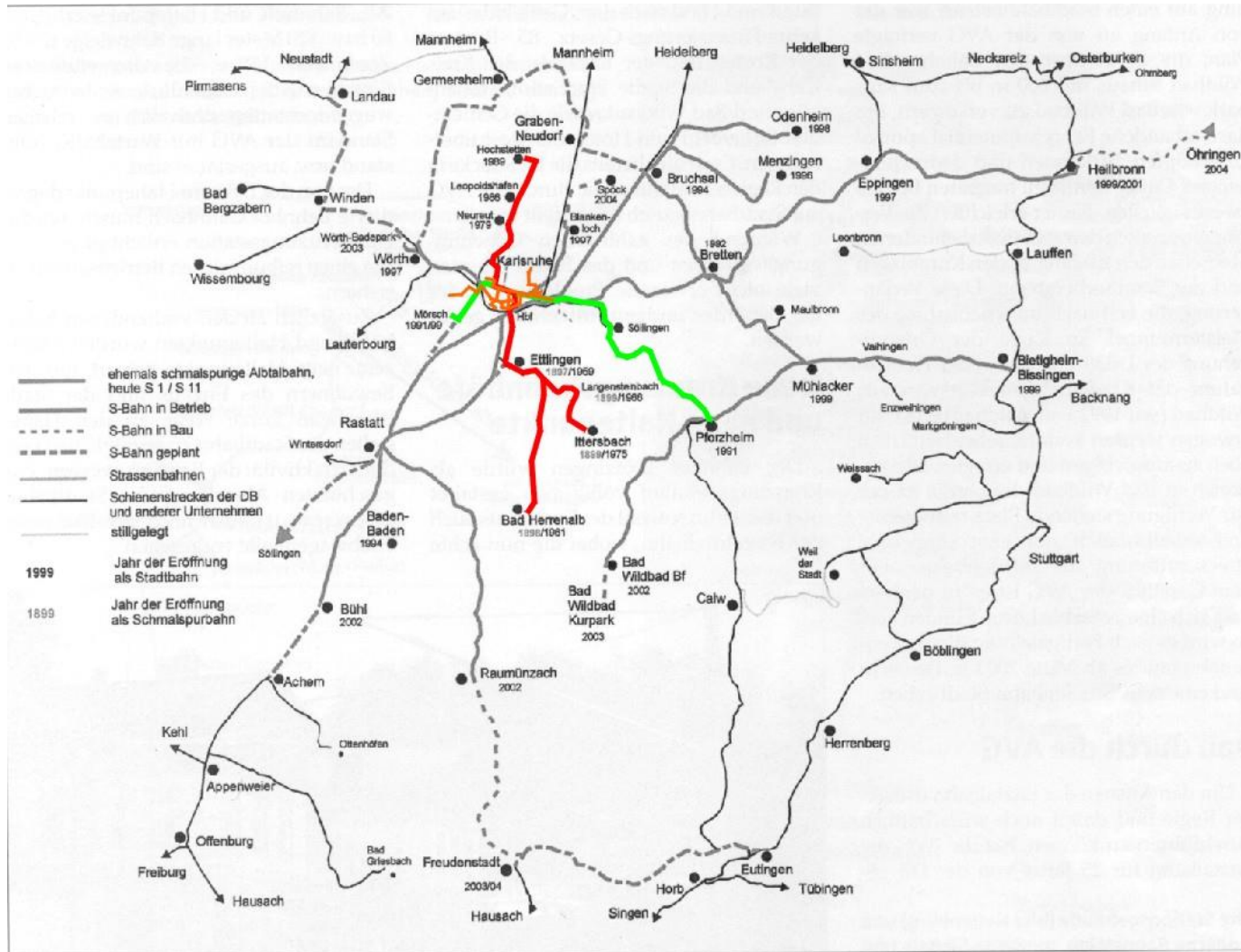


# Network development: 1961



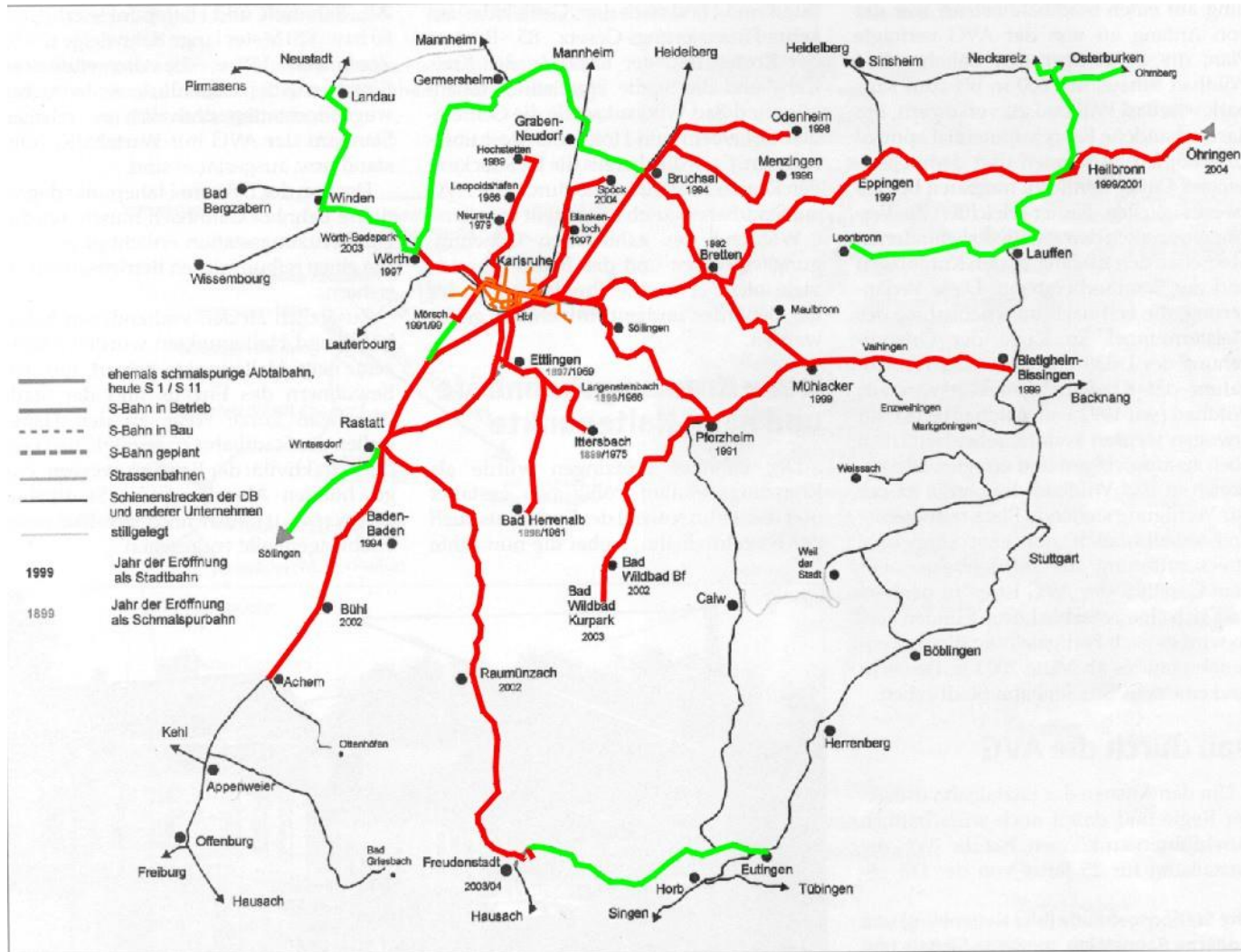
# The Karlsruhe Model

## Network development: 1991



# The Karlsruhe Model

Network development: since 2005



## ➤ Origin of the „Kombilösung“

Due to the high tram and tram-trains traffic through the pedestrian area, it has been decided to build a tunnel in the city centre after a referendum at local level.



Karlsruhe Network  
in 2008

- 6 lines between Europaplatz and Marktplatz
  - $(6 \cdot 6) \cdot 2 = 62$  tramways or trams-trains / hour
- 8 lines between Marktplatz and Kronenplatz
  - $(6 \cdot 7 + 4) \cdot 2 = 82$  tramways or trams-trains / hour

## ➤ Origin of the „Kombilösung“

### Overview of the future tunnels

- an east-west tunnel (2.5 km) under the pedestrian area (Kaiserstraße)
- a north-south tunnel (0,9 km) towards the main station (Ettlinger Straße)
- an east-west new tram track (Kriegsstraße)





---

# ➤ Table of contents

---

1. TTK in short

2. Karlsruhe Project

**3. Aim of the study**

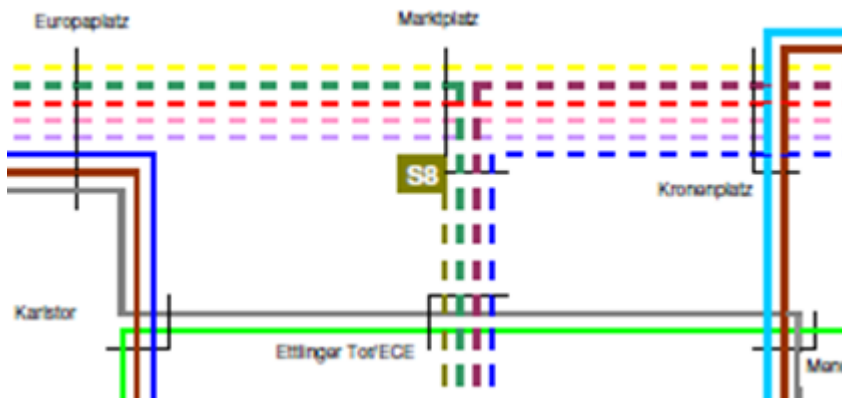
- Comparison of the planned network with a new network
- Tool

4. Procedure

# ➤ Comparison of the planned network with a new network

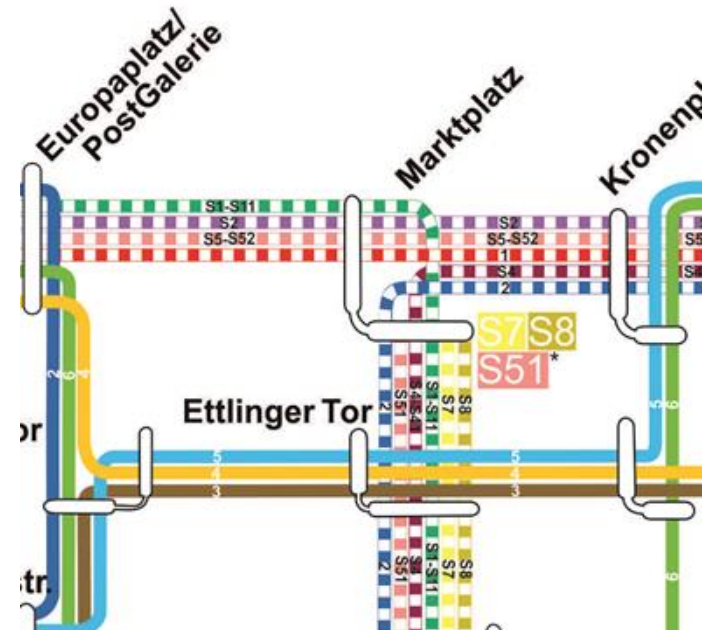
## Planned network

- 5 lines between Europaplatz and Marktplatz (east-west tunnel)
- 6 lines between Marktplatz and Kronenplatz (east-west tunnel)
- 4 lines between Marktplatz and Hauptbahnhof (north-south tunnel)
- 2 lines on the new east-west track



## New developed network

- Among another study with Prof. Dr. Ralf Borndörfer Berlin and PTV-TC
- Study of several optimised network solutions for the time after opening of the tram tunnel under construction



# Tool

## Major Strengths

## Typical Use

### Forecasting key line

**parameters** (journey times, headways), without details, to get results quickly.



**SPREADSHEET  
TOOL**

### Upstream strategic stage

Journey times  
Rolling stock evaluation

### Assessing journey times and potential timetables,

(not taking into account "real-life" variability)



**FBS**

*Statistical tool*

### Preliminary stage

Journey times  
Theoretical train diagram  
Rolling stock evaluation  
Timetables

### Detailed testing of various operational or infrastructure choices on network performance

(journey times, delays, reliability, line robustness).



**OPENTRACK**

*Dynamic tool*

### Feasibility studies

Journey times  
Functioning of turn around  
Realistic train diagram  
Regularity analysis  
Capacity study  
Simulation of incidents

### Combining LRT testing with junctions analysis

impacts on traffic and on the LRT network of low, medium and high level of priority at some junctions.



**OPENTRACK  
&  
VISSIM**

### Deepening stage

Study of traffic light cycle  
Interaction car/LRT  
Road crossing capacity  
Realistic train diagram  
Consideration of all modes

---

# ➤ Table of contents

---

1. TTK in short.

2. Karlsruhe Project

3. Aim of the study

## 4. Procedure

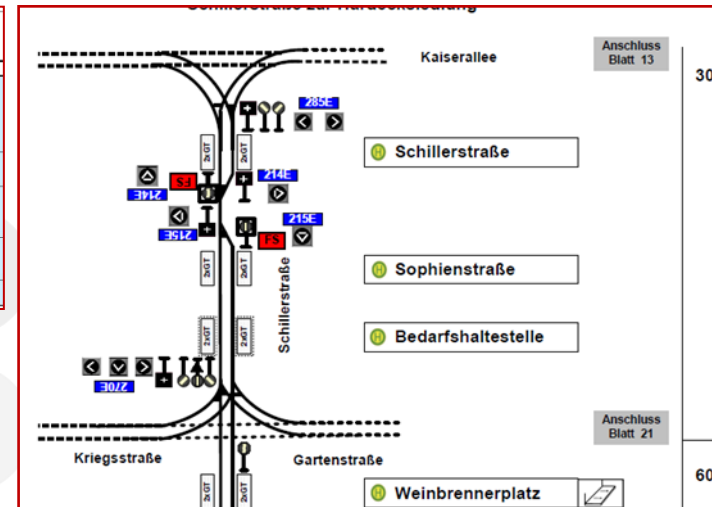
- Creation of the infrastructure
- Analysis of the actual operation data
- Dynamic parameters
- Calibration of the model
- Update of the model
- Results from the modelling

# Creation of the infrastructure

## Different data

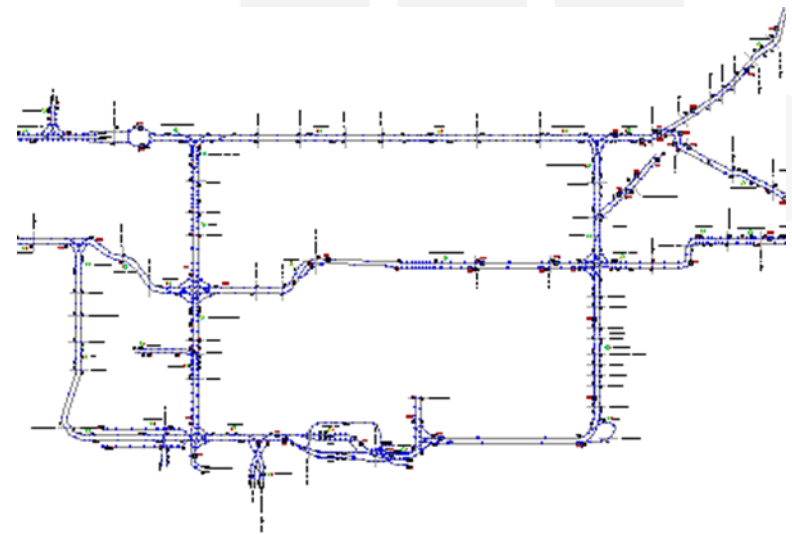
- Aerial view
- Track plan
- Speed limits
- Signals location
- Stations, etc.

1 Durlach - Tullastraße - Durlacher Tor - Marktplatz - Europaplatz - Schillerstraße - Europahalle/-bad - Hardecksiedlung - Oberreut															
Montag - Freitag															
VERKEHRSSCHNITT	ab	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Durlach Turnberg	0.14	0.44	1.12	2.11	3.11	4.11	—	4.42	5.02	5.22	19.42	19.54	23.54	—	—
Karl-Weyser-Straße	0.15	0.45	1.12	2.12	3.12	4.12	—	4.43	5.03	5.23	19.43	19.55	23.55	—	—
Schlossplatz	0.16	0.46	1.13	2.13	3.13	4.13	—	4.44	5.04	5.24	19.44	19.56	23.56	—	—
Friedrichstraße	0.17	0.47	1.14	2.14	3.14	4.14	—	4.45	5.05	5.25	19.45	19.57	23.57	—	—
Auer Straße/Dr. Willmar Schwabe	0.19	0.49	1.16	2.16	3.16	4.16	—	4.46	5.06	5.26	19.46	19.58	23.58	—	—
Karlruhe Unterhohstraße	0.20	0.50	1.17	2.17	3.17	4.17	—	4.47	5.07	5.27	19.47	19.59	23.59	—	—
Weinweg	0.22	0.52	1.19	2.19	3.19	4.19	—	4.51	5.11	5.31	19.51	20.02	24.02	—	—
Tullastraße / Verkehrsbetriebe	0.23	0.53	1.20	2.20	3.20	4.20	—	4.52	5.12	5.32	19.52	20.03	24.03	—	—
Gottessauer Platz / BGV	0.24	0.54	1.21	2.21	3.21	4.21	—	4.53	5.13	5.33	19.53	20.04	24.04	—	—
Durlacher Tor / KTT-Campus Süd	0.27	0.57	1.24	2.24	3.24	4.24	—	4.56	5.16	5.36	19.56	20.07	24.07	—	—
Kronenplatz (Kaiserstraße)	0.29	0.59	1.26	2.26	3.26	4.26	—	4.58	5.18	5.38	19.58	20.09	24.09	—	—
Marktplatz	0.30	1.00	1.27	2.27	3.27	4.27	—	5.00	5.20	5.40	20.00	20.10	24.10	—	—
Herrenstraße	0.32	1.02	—	—	—	—	—	5.02	5.22	5.42	20.02	20.12	24.12	—	—
Europaplatz/Galerie (Kaiser)	0.34	1.04	—	—	—	—	—	5.04	5.24	5.44	20.04	20.14	24.14	—	—
Mühlburger Tor (Kaiserallee)	0.37	1.07	—	—	—	—	—	5.07	5.27	5.47	20.07	20.17	24.17	—	—
Schillerstraße	0.38	1.08	—	—	—	—	—	4.38	5.08	5.28	20.08	20.18	24.18	—	—
Sophienstraße	0.39	1.09	—	—	—	—	—	4.39	5.09	5.29	20.09	20.19	24.19	—	—
Weinbrennerplatz	0.41	1.11	—	—	—	—	—	4.41	5.11	5.31	20.11	20.21	24.21	—	—
Landeshauparkhaus	0.42	1.12	—	—	—	—	—	4.42	5.12	5.32	20.12	20.22	24.22	—	—
Europahalle/Europabad	0.43	1.13	—	—	—	—	—	4.43	5.13	5.33	20.13	20.23	24.23	—	—
Hardecksiedlung	0.44	1.14	—	—	—	—	—	4.44	5.14	5.34	20.14	20.24	24.24	—	—
Oberreut, Albert-Braun-Str.	0.45	1.15	—	—	—	—	—	4.45	5.15	5.35	20.15	20.25	24.25	—	—
Zentrum	0.46	1.16	—	—	—	—	—	4.46	5.16	5.36	20.16	20.26	24.26	—	—
Wilhelm-Leuschner-Str.	0.47	1.17	—	—	—	—	—	4.47	5.17	5.37	20.17	20.27	24.27	—	—
Badensiedlung	0.48	1.18	—	—	—	—	—	4.48	5.18	5.38	20.18	20.28	24.28	—	—
an	0.49	1.19	—	—	—	—	—	4.49	5.19	5.39	20.19	20.29	24.29	—	—



## Creation in OpenTrack

- Vehicles
- Lines
- Timetable

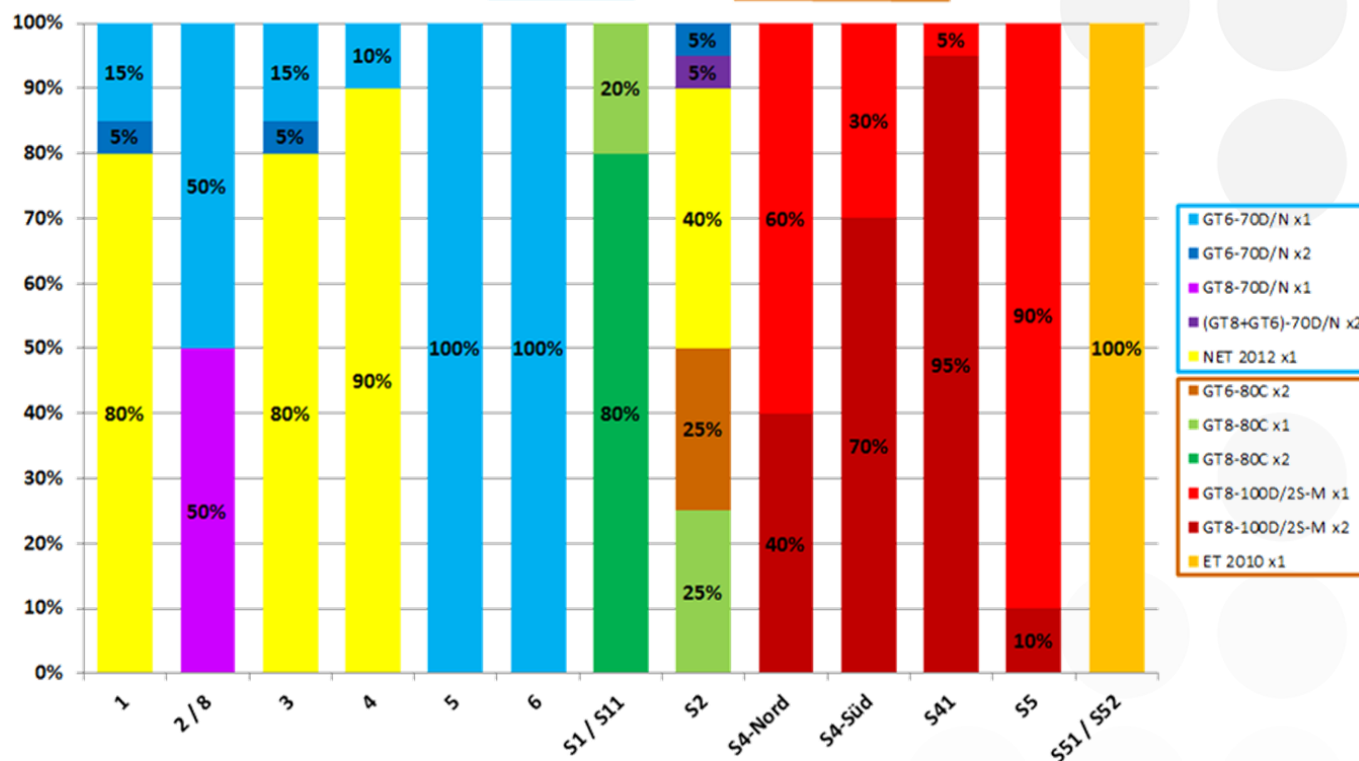


# Creation of the infrastructure

6 different vehicles

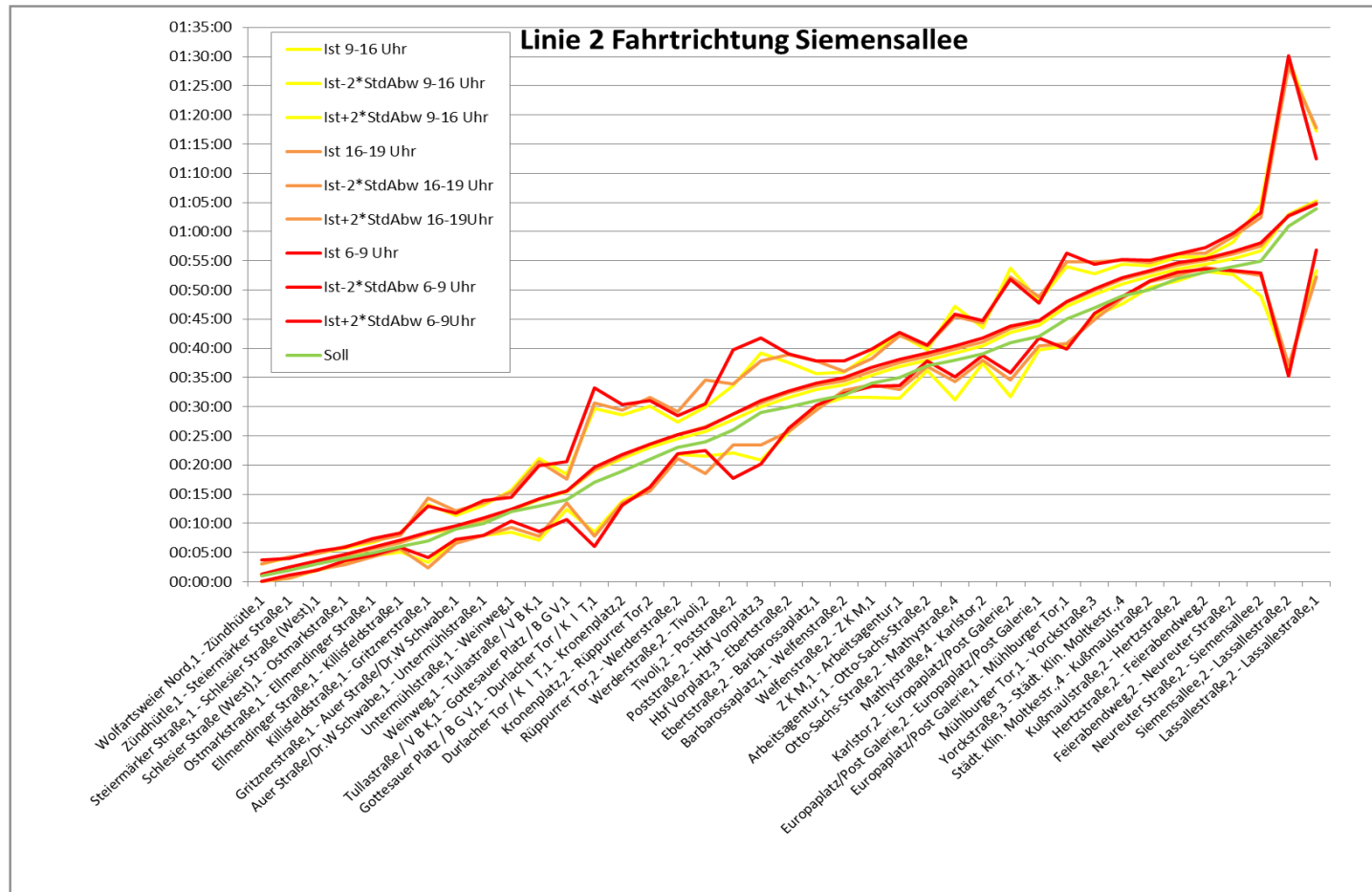
- A fleet of 3 different trams
- A fleet of 3 different trams-trains

Wageneinsatz pro Linie  
für Strassen- und Stadtbahnen



# Analysis of the actual operation data

## Travel times and variation along the day



# ➤ Analysis of the actual operation data

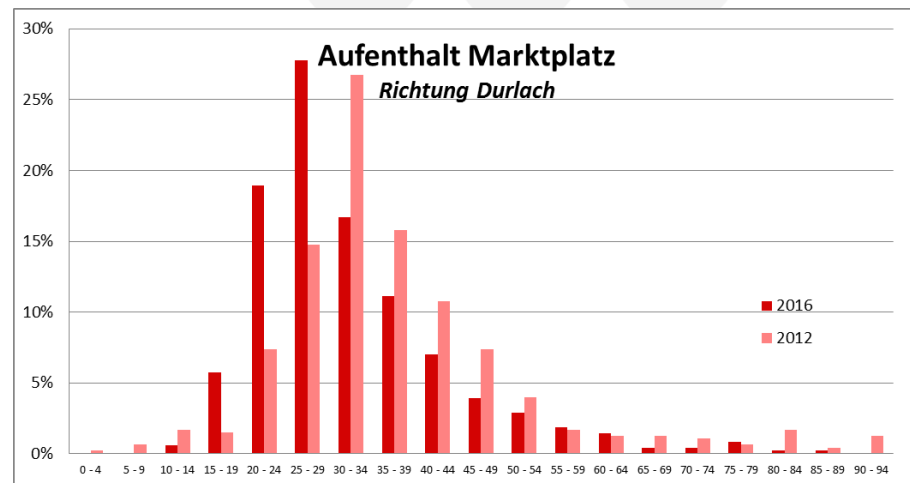
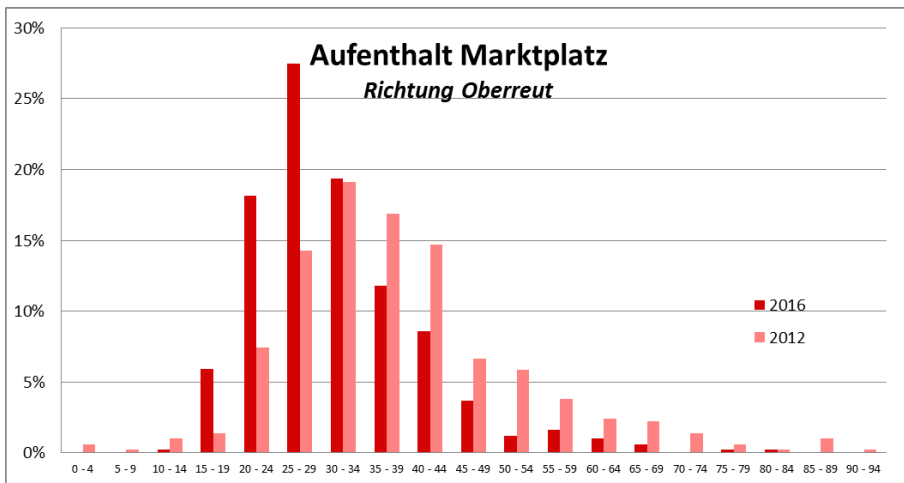
## Dwell times distributions

- Study for all the stations
- Definition of standard distributions, except for some specific stations as the main station

## Delay at the departure

## Delay at the arrival

## Frequency at major stations



# ➤ Dynamic parameters

## Performance

- Each tram, in relation to their drivers, will have a specific behaviour in terms of speeds (some variation in the travel times).

## Dwell times distributions

- Each tram will stop with specific dwell times based on a distribution (which can change during the day).

## Delay at the departure

- Each tram will enter in the model with a specific advance / delay.

## Junctions

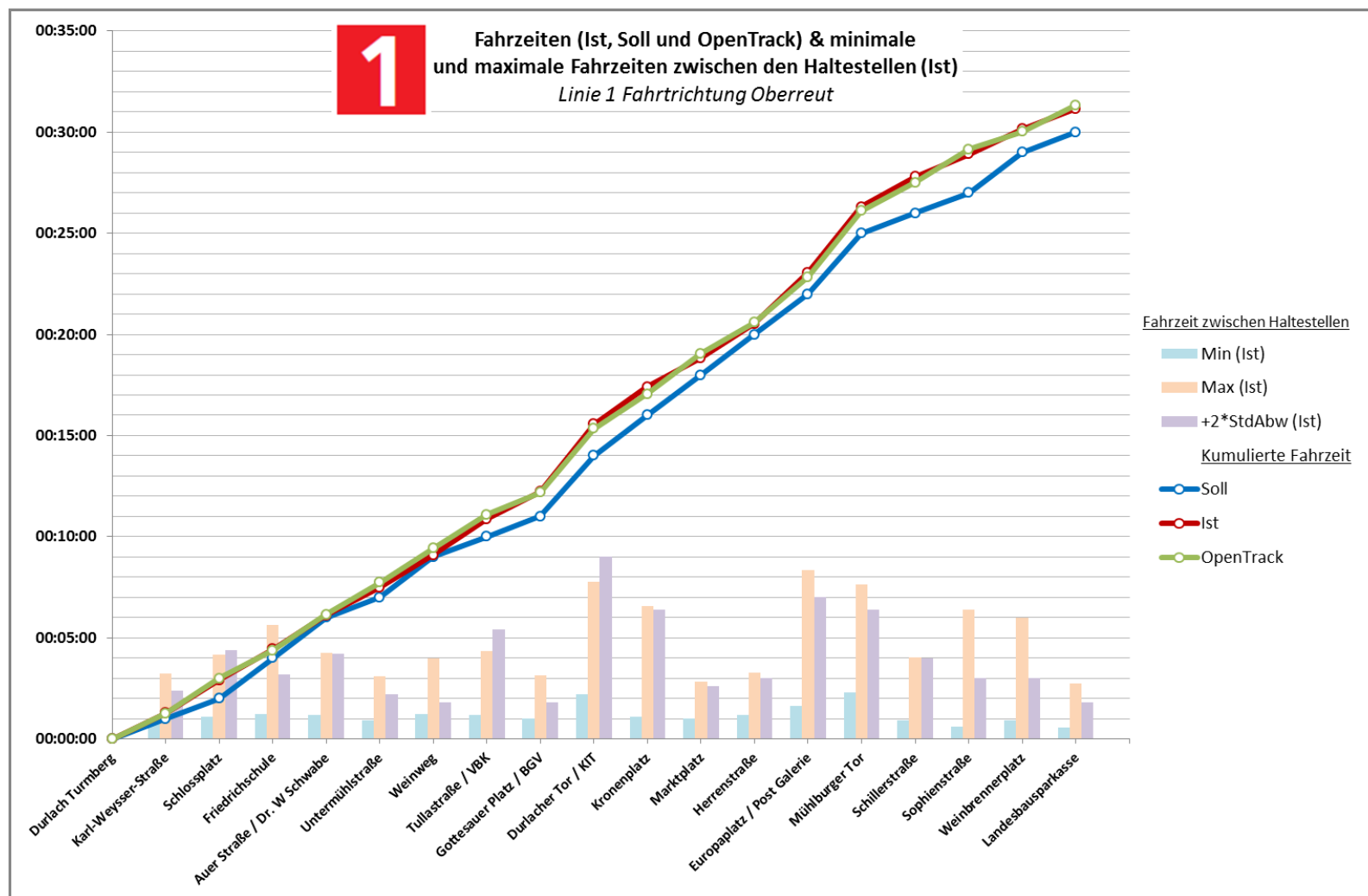
- Some junctions will be crossed with different levels of priority.

## Delay amplification

- A delayed train will have a longer dwell time based on its delay regarding the timetable.

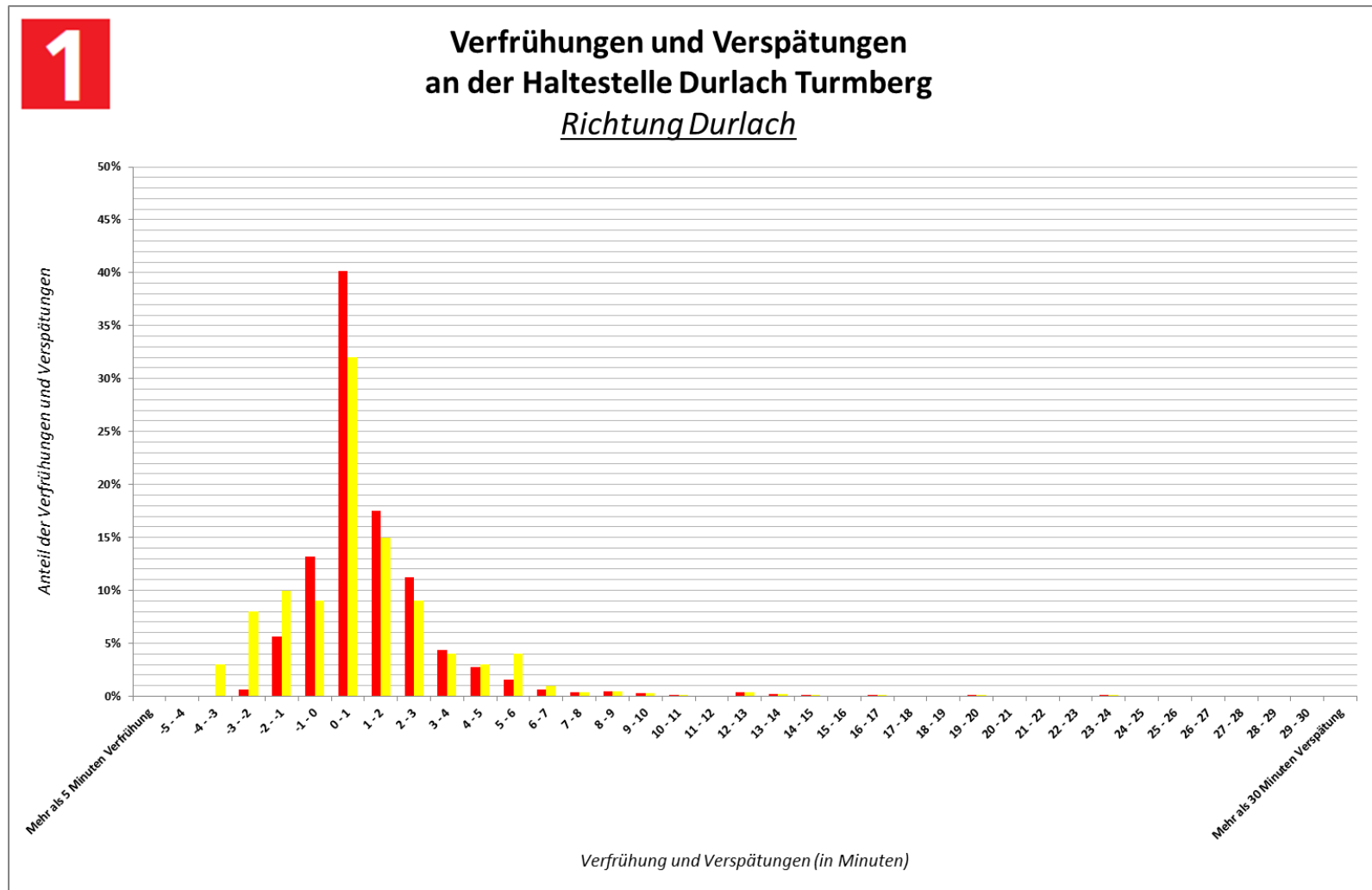
# Calibration of the model

Average travel time : planned timetable, real data and OpenTrack data



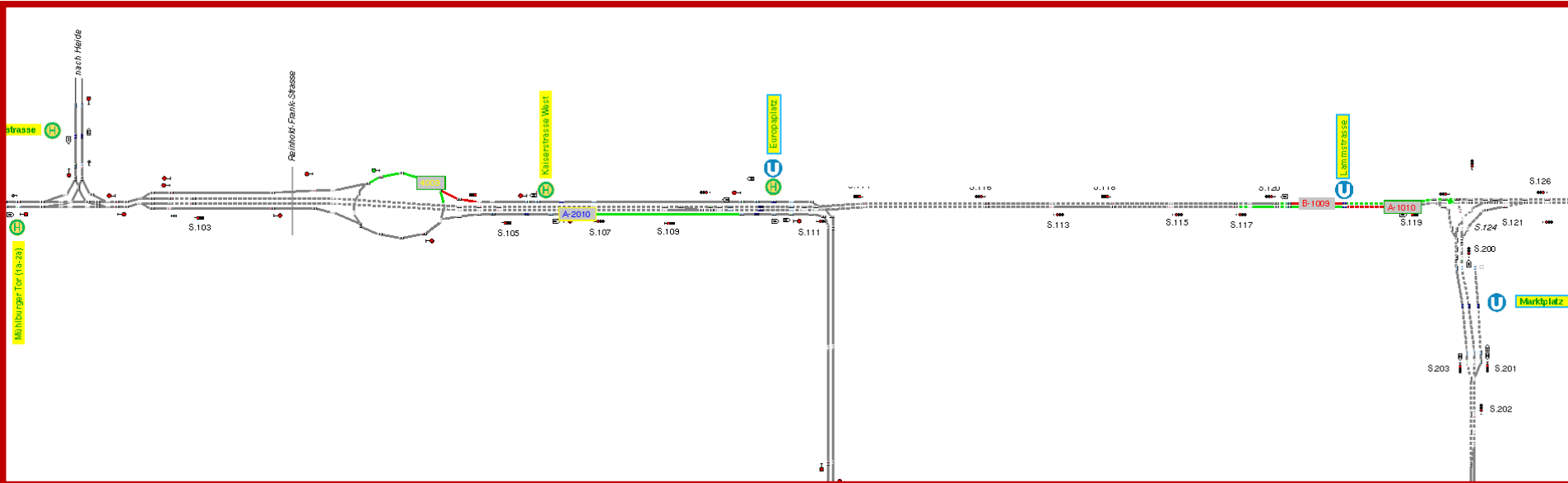
# ➤ Calibration of the model

Example of distribution for arrivals ahead and behind schedule at a station

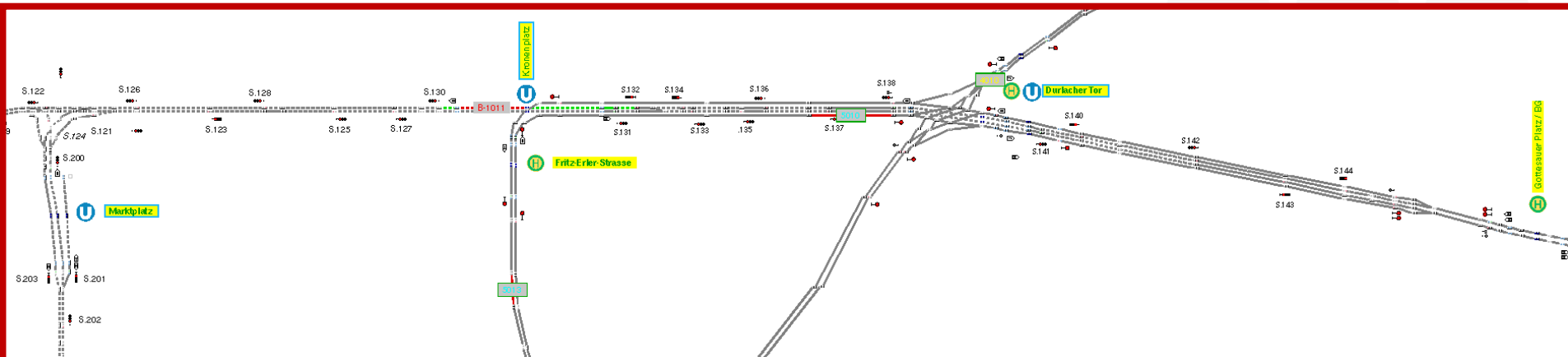


# Update of the model

## Mühlburger Tor <> Lammstraße / Marktplatz



## Marktplatz <> Gottesauer Platz



## ➤ Update of the model

**New fleet on each line depending on the rolling stock available in the near future (2020-2021)**

- New rolling stock for tram lines
- New rolling stock for tram-train lines

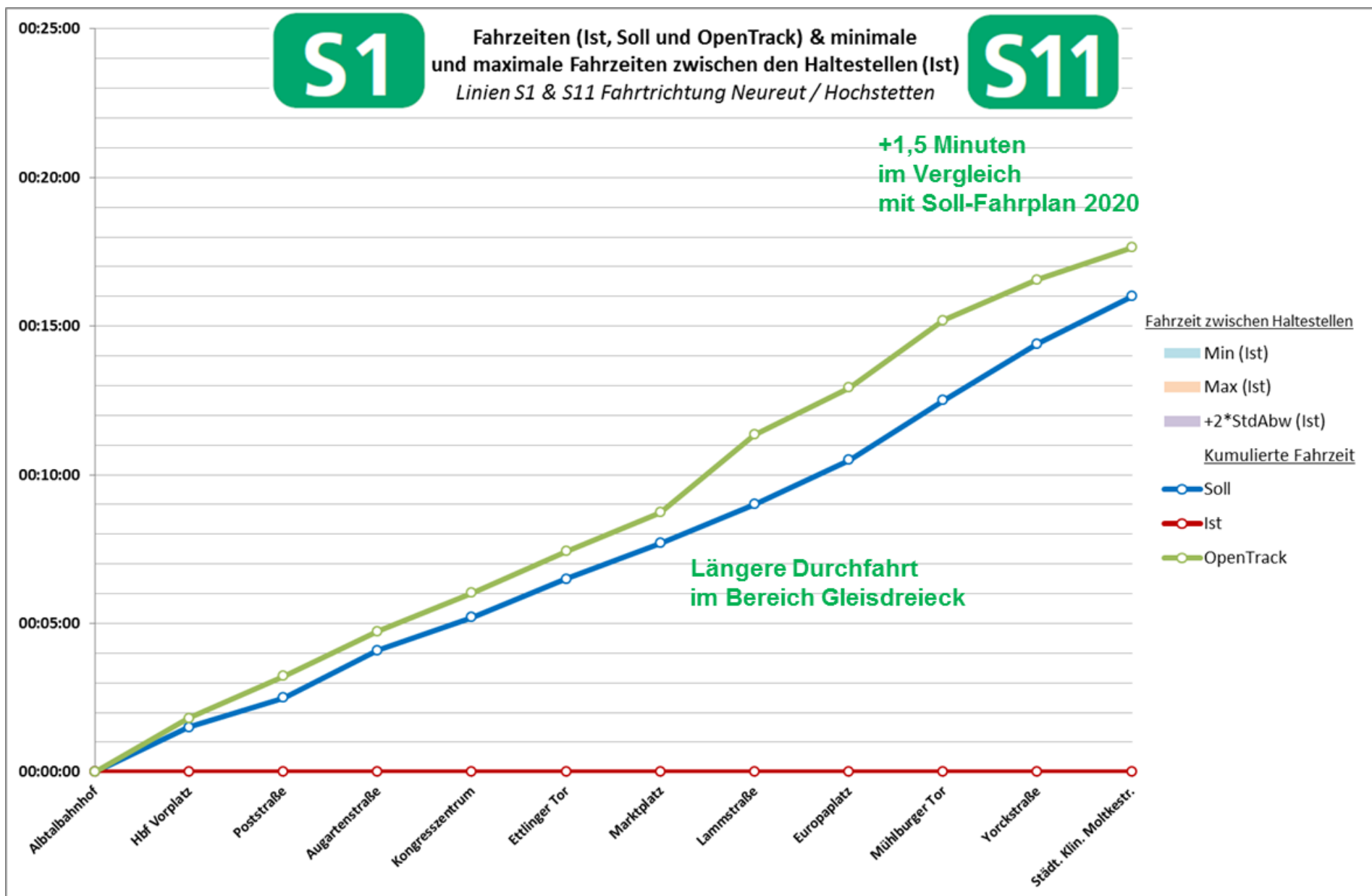
**Assumption for dwell time distributions at some major stations**

- Depending on the location of the new stations: station in or outside the tunnel
- Depending on the new network: new interchange points

**Assumption for the junctions**

- Public Transport priority increased at some junctions due to the whole project

# Results from the modelling: travel time analysis

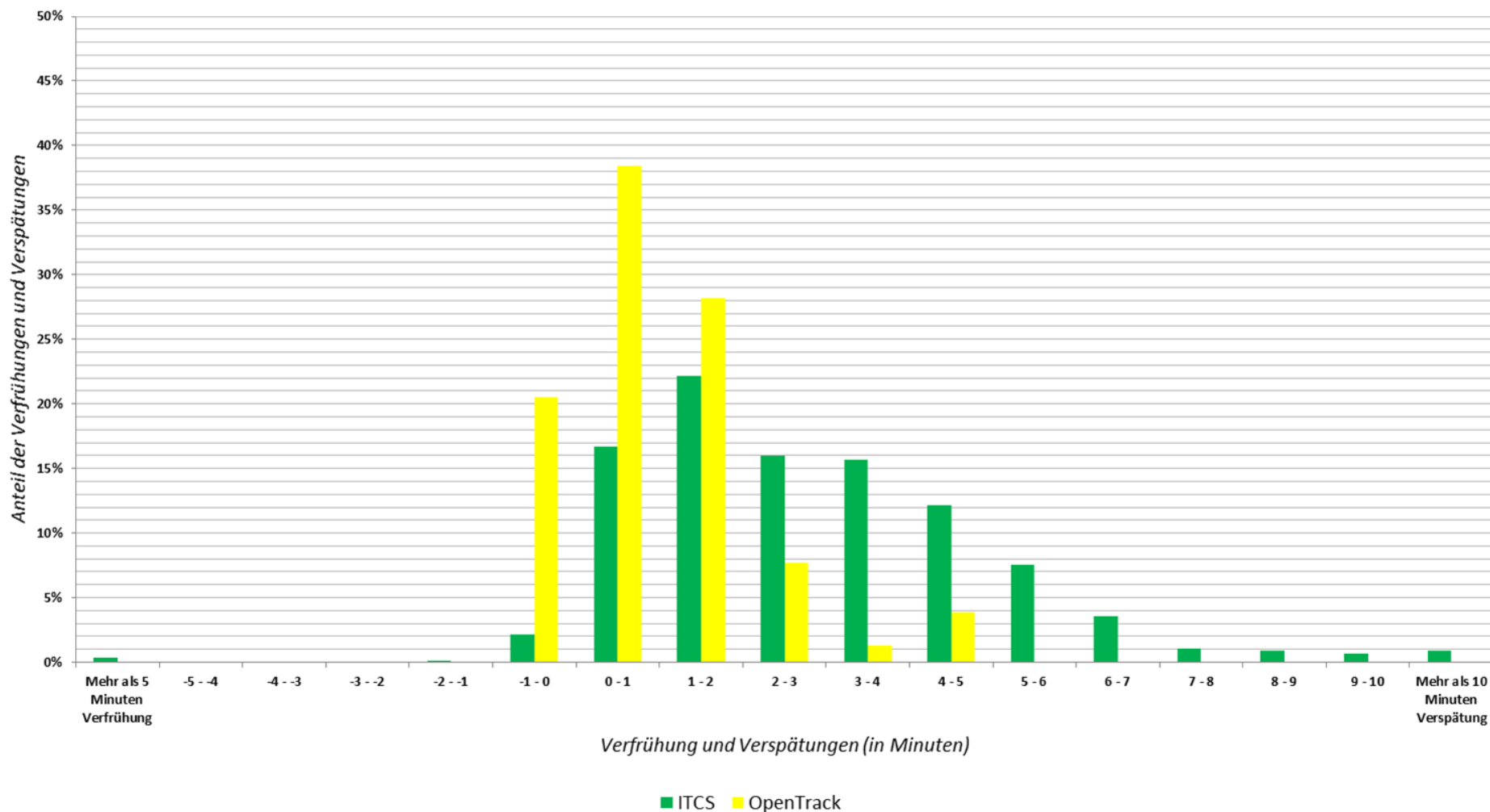


## Results from the modelling: ponctuality analysis

S1

### Verfrühungen und Verspätungen an der Haltestelle Städtische Klinikum / Moltkestraße Richtung Neureut

S11



## ➤ Results from the modelling

### 1. Comparison of the travel times before and after the project

### 2. Comparison of the travel times planned and „simulated“

- on the east-west / west-east tunnel section
- on the east-south / south-east tunnel section
- on the west-south / south-west tunnel section

Beschreibung	Linie	Strecke	Fahrplan 2020 (in Minuten)	OpenTrack 2020 (in Minuten)	Zeit-Gewinn / -Verlust (in Minuten)
Tunnel Ost-West	1	Mühlburger Tor <> Gottesauer Platz / BGV	8,5	Confidential	
		Gottesauer Platz / BGV <> Mühlburger Tor	8,5		
	S2	Mühlburger Tor <> Gottesauer Platz / BGV	8,0		
		Gottesauer Platz / BGV <> Mühlburger Tor	8,5		
	S5	Mühlburger Tor <> Gottesauer Platz / BGV	8,0		
		Gottesauer Platz / BGV <> Mühlburger Tor	8,5		

Beschreibung	Linie	Strecke	Fahrplan 2020 (in Minuten)	OpenTrack 2020 (in Minuten)	Zeit-Gewinn / -Verlust (in Minuten)
Tunnel Ost-Süd	2	Augartenstraße <> Gottesauer Platz / BGV	9,0	Confidential	
		Gottesauer Platz / BGV <> Augartenstraße	9,0		
	S4	Augartenstraße <> Gottesauer Platz / BGV	9,0		
		Gottesauer Platz / BGV <> Augartenstraße	9,0		
Tunnel Süd-West	S1	Mühlburger Tor <> Augartenstraße	9,0		
		Augartenstraße <> Mühlburger Tor	8,5		

# PROJECT PROGRESS

1. Calibration



2. Integration in the model of the new network developed



3. Modelling of the optimised network and analysis



4. New scenarios?





**Thank you  
for your attention!**

**Contacts**

**Pierre-Alain.Boeswillwald@ttk.de / +49 721 62503-26**

**Marc.Perez@ttk.de / +49 721 62503-15**