Network optimisation with dynamic modelling: the case study of Karlsruhe
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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
1. TTK in short

2. Karlsruhe Project
   - The Karlsruhe Model
   - Origin of the “Kombilösung”
   - The future network

3. Aim of the study

4. Procedure
Main facts
- Inhabitants: 1.3 Mio.
- Surface: 3.550 km²
- 120 cities and local authorities
- 21 operators
- 210 railway and bus lines
- 180 Mio. passengers / year
- Shareholder: 7 cities and administrative districts

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
The Karlsruhe Model

Network development: 1961
The Karlsruhe Model

Network development: 1991
The Karlsruhe Model

Network development: since 2005
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.

- 6 lines between Europaplatz and Marktplatz
  - \((6 \times 6) \times 2 = 62\) tramways or trams-trains / hour
- 8 lines between Marktplatz and Kronenplatz
  - \((6 \times 7 + 4) \times 2 = 82\) tramways or trams-trains / hour
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 (Kriegstraße)
The future network

Planned network with the „Kombilösung“
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
<table>
<thead>
<tr>
<th>Major Strengths</th>
<th>Typical Use</th>
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</thead>
</table>
| 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 |
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.

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
Analysis of the actual operation data

Travel times and variation along the day

![Graph showing travel times and variation along the day for Linie 2 Fahrtrichtung Siemensallee]
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

Verfrühungen und Verspätungen
an der Haltestelle Durlach Turmberg

Richtung Durlach

Verfrühung und Verspätungen (in Minuten)
Update of the model

Mühlburger Tor <> Lammstraße / Marktplatz

Marktplatz <> Gottesauer Platz
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

Fahrzeiten (Ist, Soll und OpenTrack) & minimale und maximale Fahrzeiten zwischen den Haltestellen (Ist) Linien S1 & S11 Fahrtrichtung Neureut / Hochstetten

+1,5 Minuten im Vergleich mit Soll-Fahrplan 2020

Längere Durchfahrt im Bereich Gleisdreieck
Results from the modelling: punctuality analysis

Verfrühungen und Verspätungen
an der Haltestelle Städtische Klinikum / Moltkestraße

Richtung Neureut

Verfrühung und Verspätungen (in Minuten)

- ITCS
- OpenTrack
## 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

<table>
<thead>
<tr>
<th>Beschreibung</th>
<th>Linie</th>
<th>Strecke</th>
<th>Fahrplan 2020 (in Minuten)</th>
<th>OpenTrack 2020 (in Minuten)</th>
<th>Zeit-Gewinn / -Verlust</th>
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<tbody>
<tr>
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</table>
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!

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