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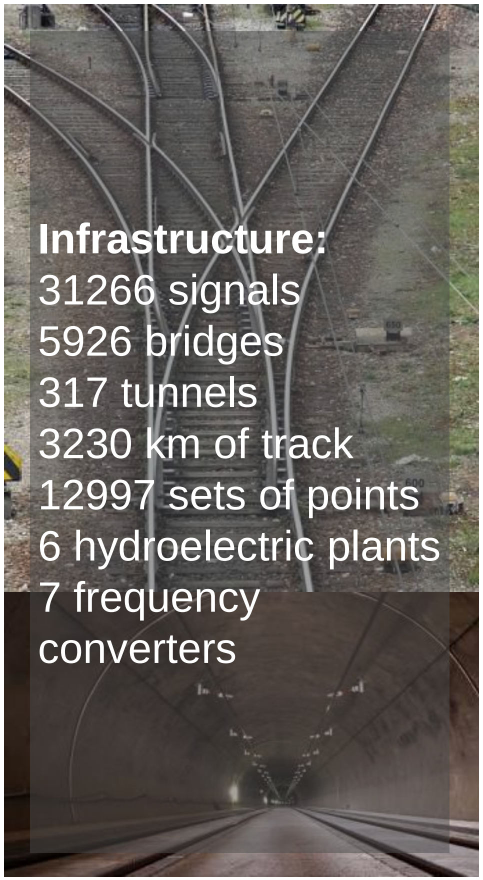
# Energy efficient timetabling @ SBB

20th of February 2018, Brüssel

# SBB infrastructure & vehicles.

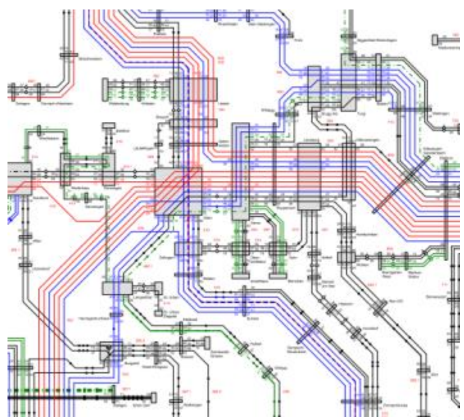
## The timetable as Link between infrastructure & vehicles.



**Infrastructure:**
31266 signals
5926 bridges
317 tunnels
3230 km of track
12997 sets of points
6 hydroelectric plants
7 frequency converters

→

| km | - | + | | AE | ETCS | | | R150 | An | Ab |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.5 | 1 | 0 | | | | **Fischermätteli** | | 90 | (16:16) | |
| 5.1 | 0 | 10 | | | | **Bern Weissenbühl** | | | (16:17) | |
| 6.6 | 0 | 5 | | | | **Wabern bei Bern** | 90 80 | | (16:18) | |
| 6.7 | | | | | | *Kurve Ausf.* | 80 | | | |
| 8.1 | | | | | | Breitenacker ▲ P308 | | | | |
| 8.8 | 0 | 4 | | | | ***Kehrsatz Nord*** | | | (16:20) | |
| 9.3 | | | | | | *Kurve* | 65 | | | |
| 9.7 | 22 | 0 | | | | **Kehrsatz** | 65 80 | 80 | (16:21) | |
| 10.7 | | | | | | Falkenhaus ▲ P310 | | | | |
| 11.9 | 6 | 0 | | | | ***Belp Steinbach*** | | | (16:22) | |
| 12.6 | 0 | 3 | | | | **Belp** | 65 85 | 100 | 16:23 | 16:24 |
| 14.4 | | | | | | km 14.400 F | | | | |
| 16.1 | 0 | 3 | 1315 | | | **Toffen** | | 120 | 16:27 | 16:28 |
| 18.5 | 0 | 8 | | | | **Kaufdorf** | | 100 | 16:30 | 16:30 |
| 21.3 | 0 | 10 | | | | **Thurnen** | | | 16:33 | 16:33 |
| 22.7 | | | | | | Block P322 | | | | |
| 22.7 | | | | | | *Kurve* | 75-65 | | | |
| 24.2 | 0 | 11 | | | | **Burgistein** | 65 85 | 85 | 16:35 | 16:35 |
| 25.7 | 13 | 6 | | | | **Seftigen** | 85 60 | 80 | 16:39 | 16:39 |
| 25.8 | | | | | | *K Ausf* | 60 | | | |



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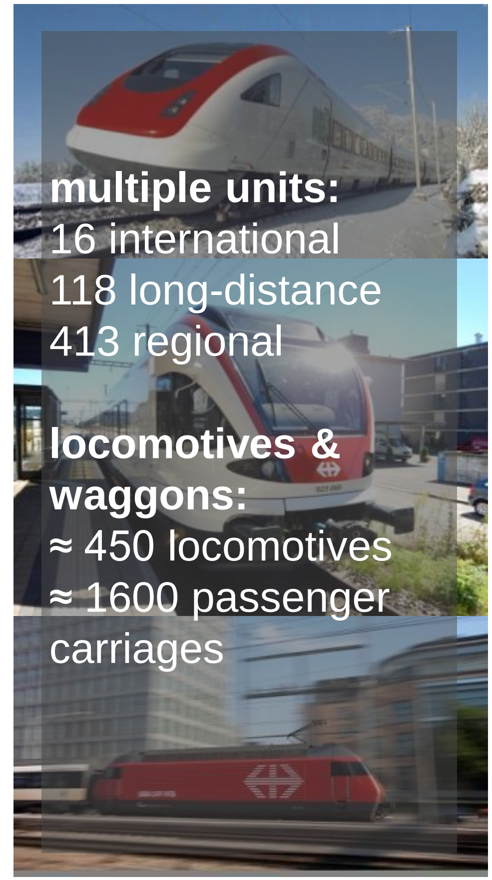
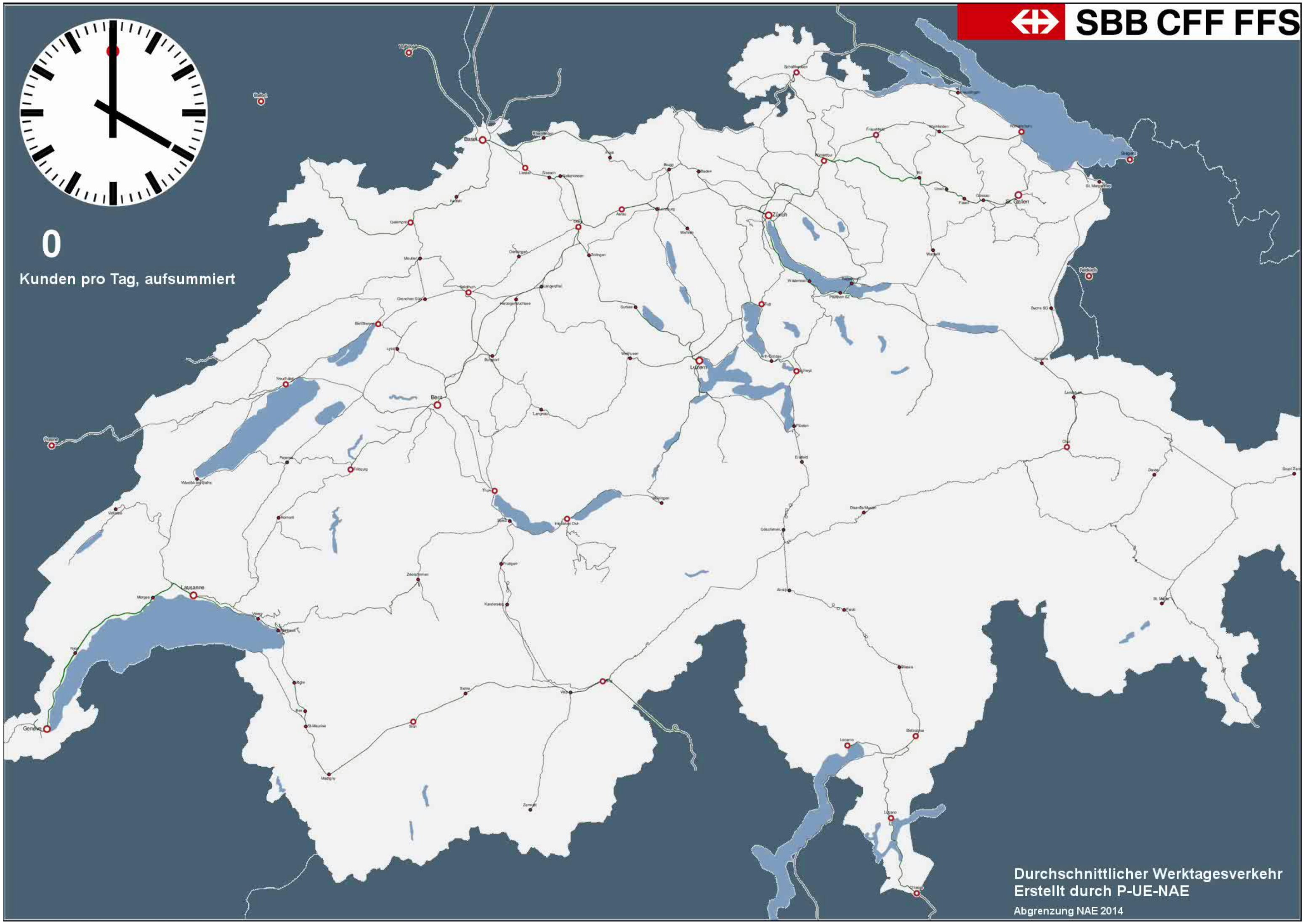


**multiple units:**
16 international
118 long-distance
413 regional

**locomotives & waggons:**
≈ 450 locomotives
≈ 1600 passenger carriages

# Main traffic time in Switzerland.
Demand per hour in transport of people.



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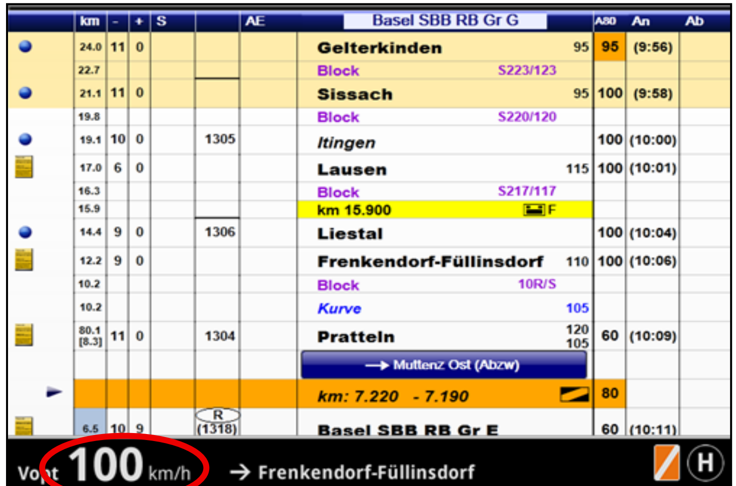
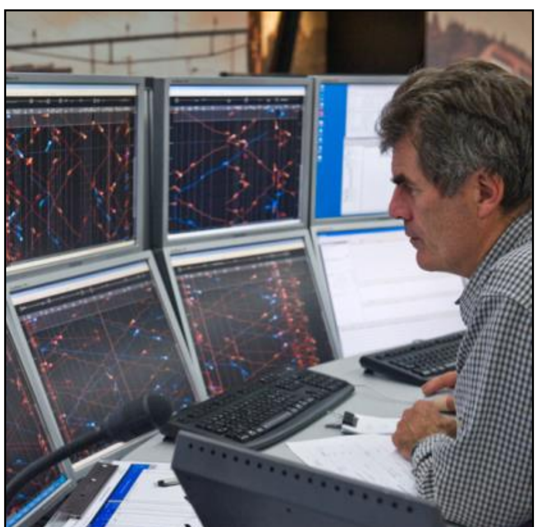
# ADL as link between dispatchers and train drivers.

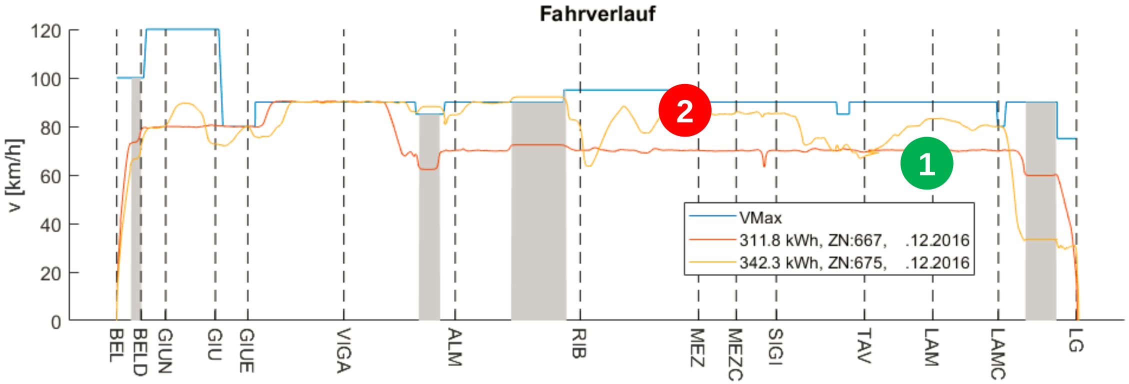
Solving conflicts and saving energy with direct connection.

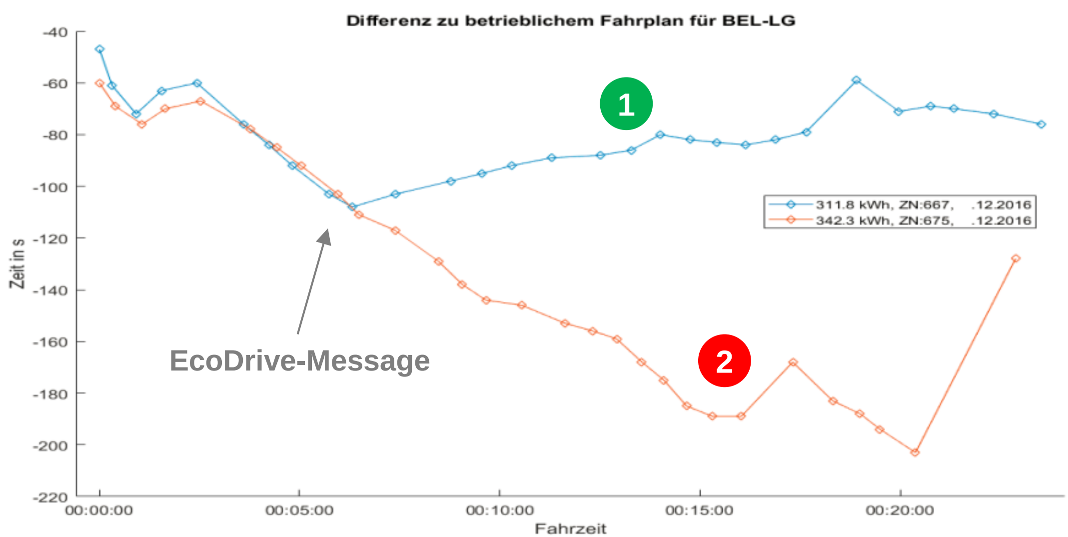



# EcoDrive creates punctuality & energy efficiency

## Example: ICN Bellinzona – Lugano




- Train 1 uses the travel time reserves and does not build up any further prematurity.
- Energy demand 311.8 kWh
- Train 2 builds up with taut driving over 200 seconds ago.
- Before Lugano, he is slowed down by a signal.
- Energy demand 342.4 kWh

**Result**

- Train 2 requires significantly more energy (+ 9.8%).
- Both trains arrive slightly ahead of schedule in Lugano.

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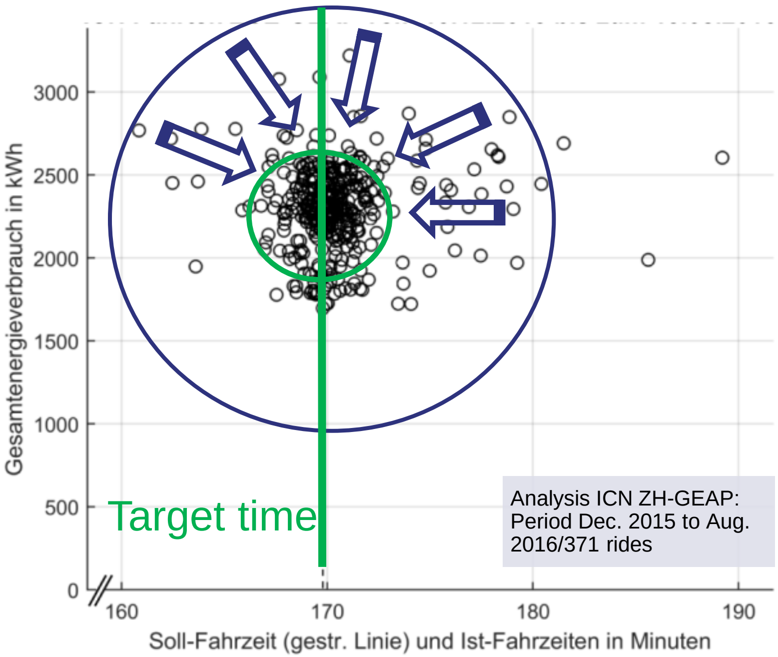
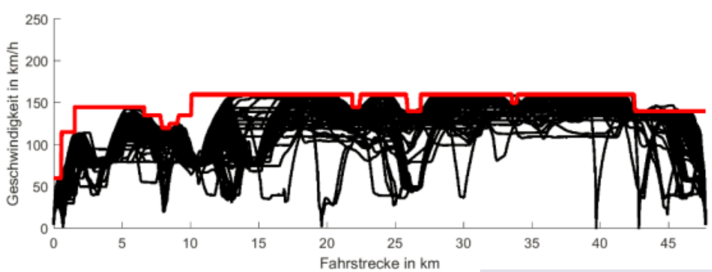
# Reduction of variation for more efficient production

## Better predictability and greater energy efficiency




Driving profile between Geneva and Morges, the red line shows the RADN profile

- Today, the driving style differs both in terms of travel time and energy requirements. This complicates the planning of the operation and brings a higher energy demand.
- One reason is the fact that the locomotive crew today, despite ADL, does not have all the necessary information to derive an ideal driving style (from the point of view of the overall system).
- Thus, the train reaches the target relatively often before the actual target time.
- A reduction of the scatter by means of improved information therefore improves the predictability of the railway operation and increases the energy efficiency.

# Findings of the pilot of energy efficient timetable and DAS

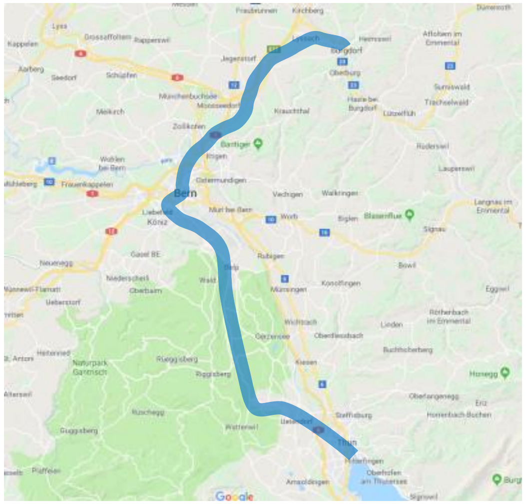
Thomas Graffagnino, SBB I-FN-FPA

# Pilot project of BLS with SBB infrastructure
## Joint test of energy optimised timetable and DAS

BLS and SBB infrastructure tested in Spring 2017 **an energyoptimised timetable** and two driving advisory systems. The aim was to save energy (at least 5%) with the same level of operational stability / punctuality.

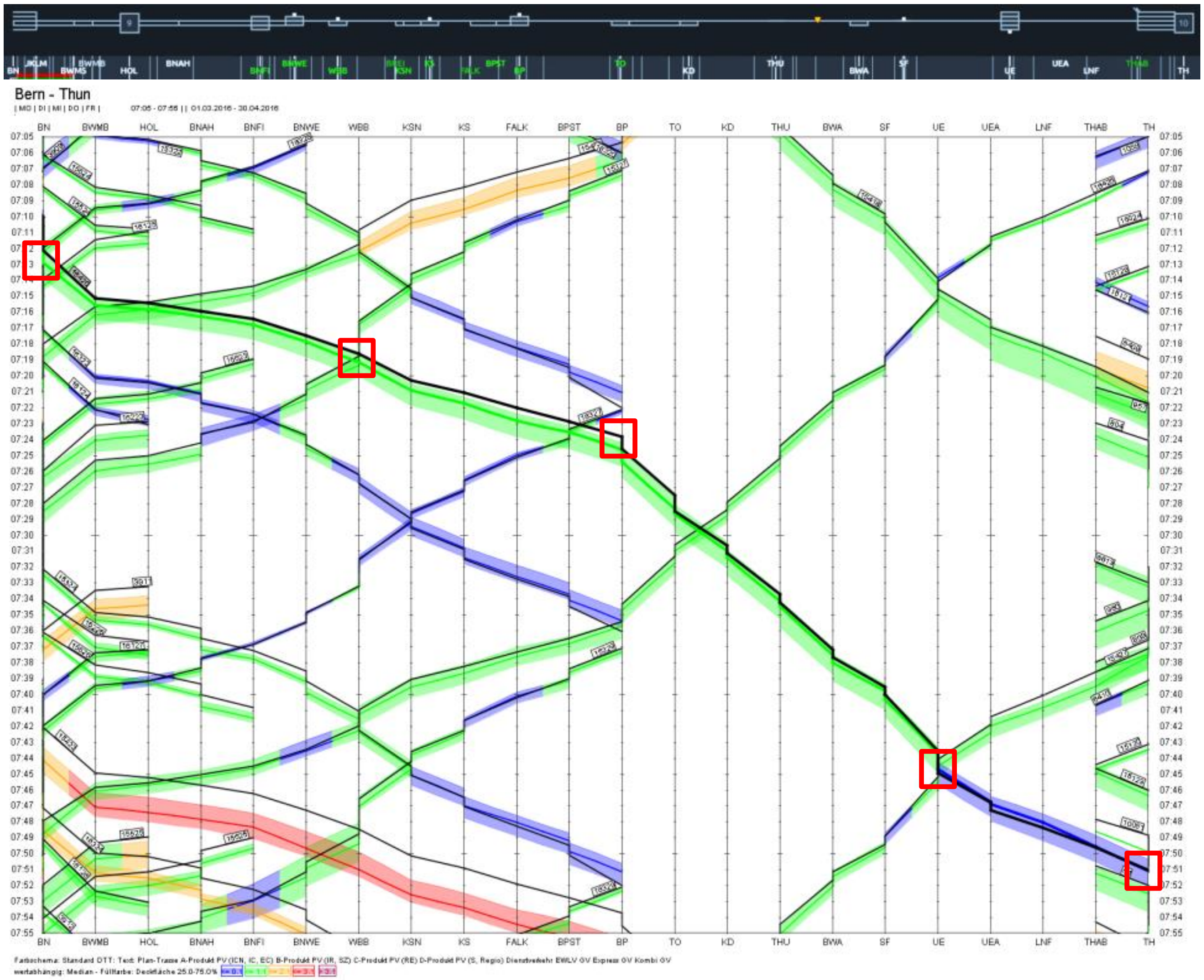
- Q1/2017: Preparation of data (timetable, track journey, vehicle data)

- Q2/2017: Test on S44 in (Thun to Burgdorf), total 133 rides
- Q3/2017: Evaluation (energy savings, punctuality, variance, ergonomy)




# Step 1: Determine the fixpoints

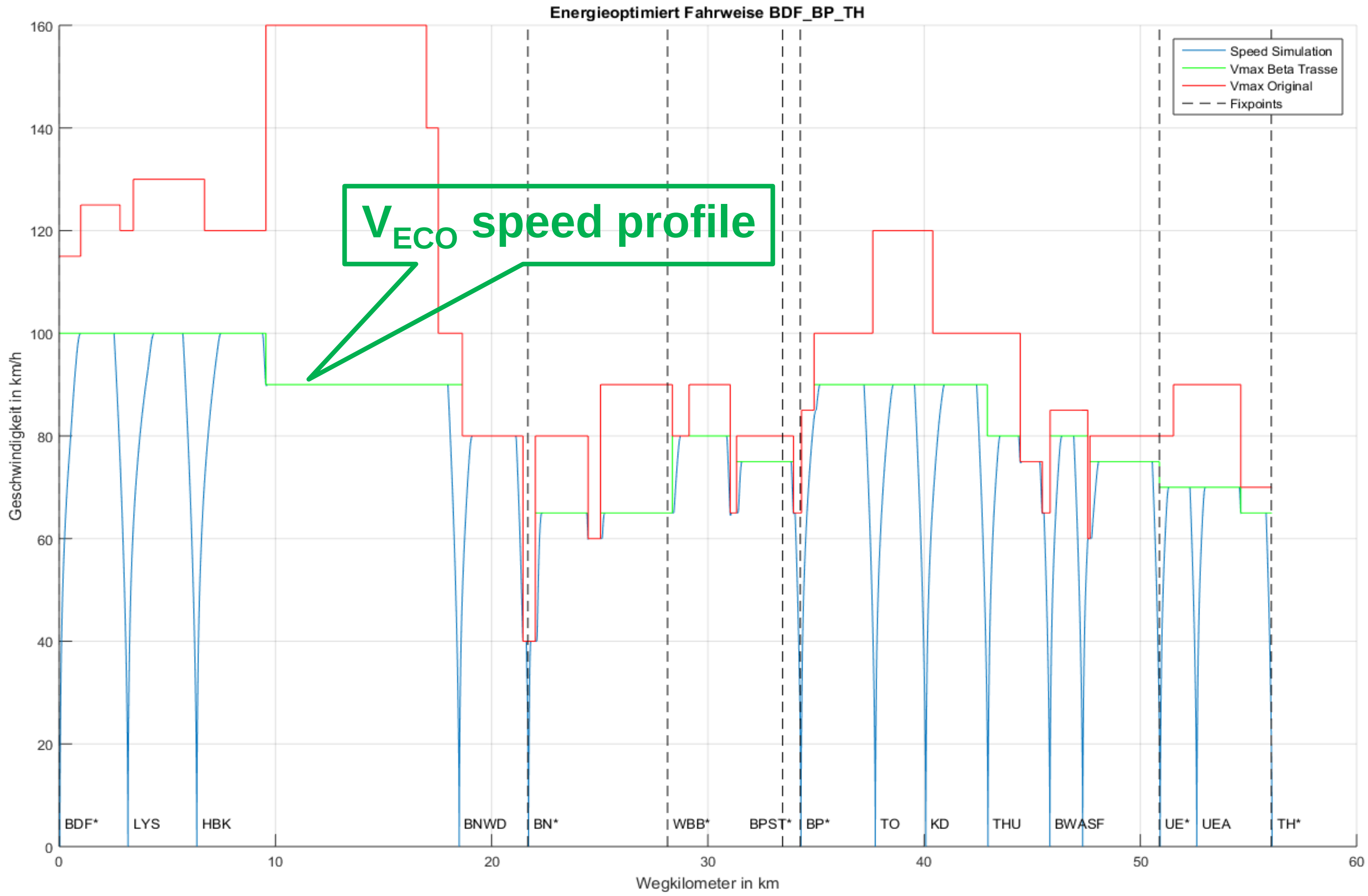
Fixpoints are critical places where time are advisory for a conflict free train path



# Step 2: Extract the timetable for the fixpoints

| BP (timing points) | Voie (platform) | Arrival time | Departure time | Commercial arrival time | Commercial Departure time | Fixed Arrival | Latest possible Arrival | Fixed Departure | Minimal Dwelling Time |
|---|---|---|---|---|---|---|---|---|---|
| **BDF**** | **2** | | **15:51.1** | | **15:51** | **-** | **-** | **15:51:05** | **-** |
| LYS | 386 | 15:54.0 | 15:54.6 | 15:53 | 15:53 | - | - | - | 00:00:20 |
| SAAC | | 15:55.5 | 15:55.5 | | | | | | |
| HBK | 2 | 15:57.2 | 15:57.8 | 15:57 | 15:57 | - | - | - | 00:00:20 |
| HRDF | | 15:59.4 | 15:59.4 | | | | | | |
| MATA | | 15:59.7 | 15:59.7 | | | | | | |
| AESP | | 16:00.1 | 16:00.1 | | | | | | |
| LGUT | 73 | 16:03.6 | 16:03.6 | | | | | | |
| LGUS | | 16:05.0 | 16:05.0 | | | | | | |
| BNWD | 704 | 16:05.5 | 16:06.1 | 16:05 | 16:05 | - | - | - | 00:00:20 |
| BWY | 2 | 16:06.8 | 16:06.8 | | | | | | |
| BWYW | | 16:08.0 | 16:08.0 | | | | | | |
| **BN**** | **6** | **16:10.0** | **16:12.1** | **16:10** | **16:12** | **16:10:00** | **-** | **16:12:05** | **00:01:00** |
| JKLM | J7 | 16:13.2 | 16:13.2 | | | | | | |
| BWMS | | 16:14.9 | 16:14.9 | | | | | | |
| BWMB | | 16:15.1 | 16:15.1 | | | | | | |
| HOL | A62 | 16:15.4 | 16:15.4 | | | | | | |
| BNAH | 303 | 16:15.9 | 16:15.9 | | | | | | |
| BNFI | 5 | 16:16.4 | 16:16.4 | | | | | | |
| BNWE | 701 | 16:17.5 | 16:17.5 | | | | | | |
| **WBB**** | **201** | **16:18.6** | **16:18.6** | | | **16:18:35** | **16:18:35** | **16:18:35** | **-** |
| BREI | | 16:19.9 | 16:19.9 | | | | | | |
| KSN | 309 | 16:20.3 | 16:20.3 | | | | | | |
| KS | 1 | 16:21.1 | 16:21.1 | | | | | | |
| FALK | | 16:22.0 | 16:22.0 | | | | | | |
| BPST | 412 | 16:22.9 | 16:22.9 | | | | | | |
| **BP**** | **3** | **16:23.8** | **16:24.6** | **16:23** | **16:24** | **16:23:45** | **-** | **16:24:35** | **00:00:30** |
| TO | 32 | 16:27.5 | 16:28.5 | 16:27 | 16:28 | - | - | - | 00:00:20 |
| KD | 72 | 16:30.6 | 16:31.1 | 16:30 | 16:30 | - | - | - | 00:00:20 |
| **THU*** | 151 | 16:33.7 | 16:34.2 | 16:33 | 16:33 | - | 16:34:10 | - | 00:00:20 |
| BWA | 52 | 16:37.2 | 16:37.7 | 16:35 | 16:35 | - | - | - | 00:00:20 |
| **SF*** | 1 | 16:39.5 | 16:40.0 | 16:39 | 16:39 | - | 16:40:00 | - | 00:00:20 |
| **UE**** | **2** | **16:43.5** | **16:44.9** | **16:43** | **16:43** | **16:43:30** | **-** | **16:44:55** | **00:00:20** |
| UEA | 331 | 16:46.8 | 16:47.3 | 16:45 | 16:45 | - | - | - | 00:00:20 |
| LNF | | 16:48.4 | 16:48.4 | | | | | | |
| THAB | | 16:49.6 | 16:49.6 | | | | | | |
| **TH**** | **5** | **16:51.0** | | **16:51** | | **16:51:00** | **-** | **-** | **-** |

# Step 3: Calculate $V_{ECO}$ speed profile in ZLR from RCS



# Step 4: Translate the results to the driver

In case of delay MAX-Speed, if punctual $v_{ECO}$-Speed

- Ste

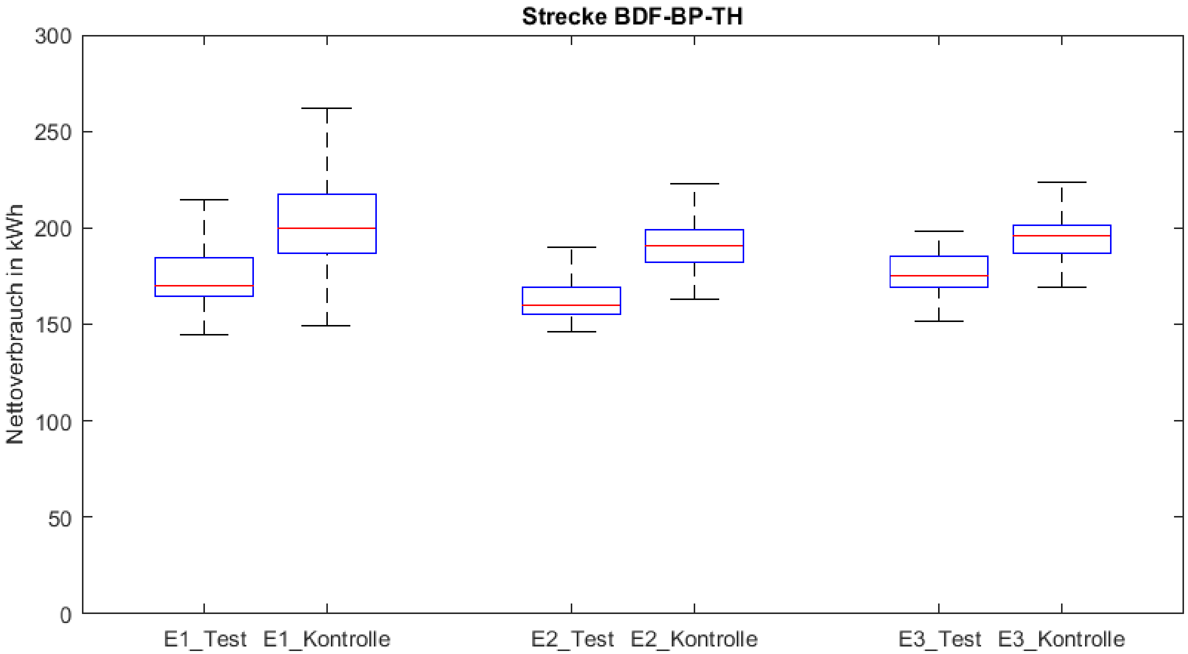
Gültig ab 04.12.2016 — Seite 371/1

| Signale der Block- und Spurwechselstellen, Pfeiftafeln usw. (km Name Bez.) | Kilometr. d. Bahn km | Massgebende Neigung ↘‰ | ↗‰ | Funkkanal GSM | Abfahrerlaubnis | R Bremsverhältnis in % | 150 135 | An Ab | Min. : Sek. | Opt. Km/h |
|---|---|---|---|---|---|---|---|---|---|---|
| 95.8 Block 0 U900/800 | 97.2 | 0 | 9 | R # 1301 | | **Bern** 40-80 | 80 | **12** | **12:10** | **65** |
| | 95.0 | | | 1302 (1306) | | **Bern W'haus** | | (14) | | |
| 0.9 Block P202/102<br>1.3 Block P201/101 | 0.0 | 20 | 21 | R # 1301 | | **Bern** *via Donnerbühl* | 80 | | | |
| | 2.5 | | | P 1314 | | **Holligen** | 60 | (15) | | **60** |
| 2.9 Block 2P/2Q | 3.1 | 11 | 14 | | | *Bern Europa* | | | | |
| | 3.5 | | | | | **Fischermä** | | | | |
| | | 1 | 0 | | | | | | | |
| | 5.1 | | | | | **Weissenbü** | | | | |
| | | 0 | 10 | | | | | | | |

**$V_{ECO}$ speed profile**

# Savings of 10-15% of energy.

An energyoptimised timetable with paper solution is equal to an electronical driving advisory system.




The energy consumption in suburban railway operation can be reduced by up to 10-15% if,

- the operational schedule is energy-optimized
- the driving recommendations are ergonomically displayed to the locomotive crew.

The effect of a driving recommendation system in practice depends less on the quality of the driving profile modeling, than on the way the information and recommendations are displayed and implemented.

Source: Studer T., Graffagnino T., Schäfer R.: Fahrempfehlungen im S-Bahn-Betrieb: Pünktlich und energiesparend am Ziel, ETR SWISS, 2017, Nr. 10/2017, S. 75-80.

# The next steps to integrate "$v_{ECO}$" at SBB

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# Composition of the core group

## Cross-divisional from planning to execution

**Core group**

| | |
|---|---|
| I-EN-EFF: | Matthias Tuchschmid, Philipp Keiser |
| P-OP-ZF | Markus Kröpfli, Stephan Gut, Marcel Tonini |
| G-PN: | Dominik Baumberger |
| I-B: | Fabian Flück |
| I-FN: | Thomas Graffagnino |
| IT: | Martin Kyburz, Alexander Helm |
| SBB Innoteam: | Charles von Grünigen |

# Five action fields at all levels

## From timetable to education of driving personal

- Energy-efficient railway production is based on interconnected solutions:
  - The driver implements the optimum driving strategy based on the information displayed in the LEA.
  - On the basis of the timetable, the most efficient operation is organized in the operation center.
- Fields of action were identified in all levels, in some cases one field of action affects several levels:

a) Education & further education

b) Quickwin «Optimization LEA»

c) $v_{ECO}$-column and  und Eco-Trasse

d) Dynamic transit times

e) Indicator of punctuality

| | a) Aus- und Weiterbildung, Feedback über EVA-App | b) Quickwin «Optimierung LEA» | c) $v_{ECO}$-Spalte und Eco-Trasse | d) Dynamische Durchfahrtszeiten | e) Pünktlichkeitsanzeige |
|---|---|---|---|---|---|
| **Fahrweise Lokführer** P-OP-ZF / G-PN / I-B, HR-BIL K-UE | ✓ | (✓) | (✓) | (✓) | (✓) |
| **Anzeige (LEA)** P-OP-ZF G-PN IT, I-B | | ✓ | (✓) | (✓) | ✓ |
| **Bahnproduktion (ADL, RCS)** I-B, IT | | | ✓ | ✓ | ✓ |
| **Fahrplan** I-FN | | | ✓ | | |

✓ = hauptsächlich betroffen (✓) = unterstützend

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# Benefits for the SBB
# A higher accuracy of trains, lower energy costs.

The implementation of $v_{ECO}$ / EcoPath and the other improvements offers the following advantages:

- ➔ **Better information situation** for the locomotive staff in order to derive the ideal driving style from the point of view of the overall system.
- ➔ **Increase the acceptance of locomotive staff** by focusing on relevant information.
- ➔ **Better predictable journeys** for the train management and reduction of dispersion.
- ➔ **Energy savings** amounting to around 50 GWh, equivalent to railway costs of around CHF 5 million per year.


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Thank you for your attention.

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# Backup

# SBB's overall strategy.

## **To reduce energy and power consumption by 20%.**


Efficiency goal:
600 GWh/year from 2025

Technology

Service planning

Railway production

Anchor energy efficiency in the company

Create transparency and manage energy consumption

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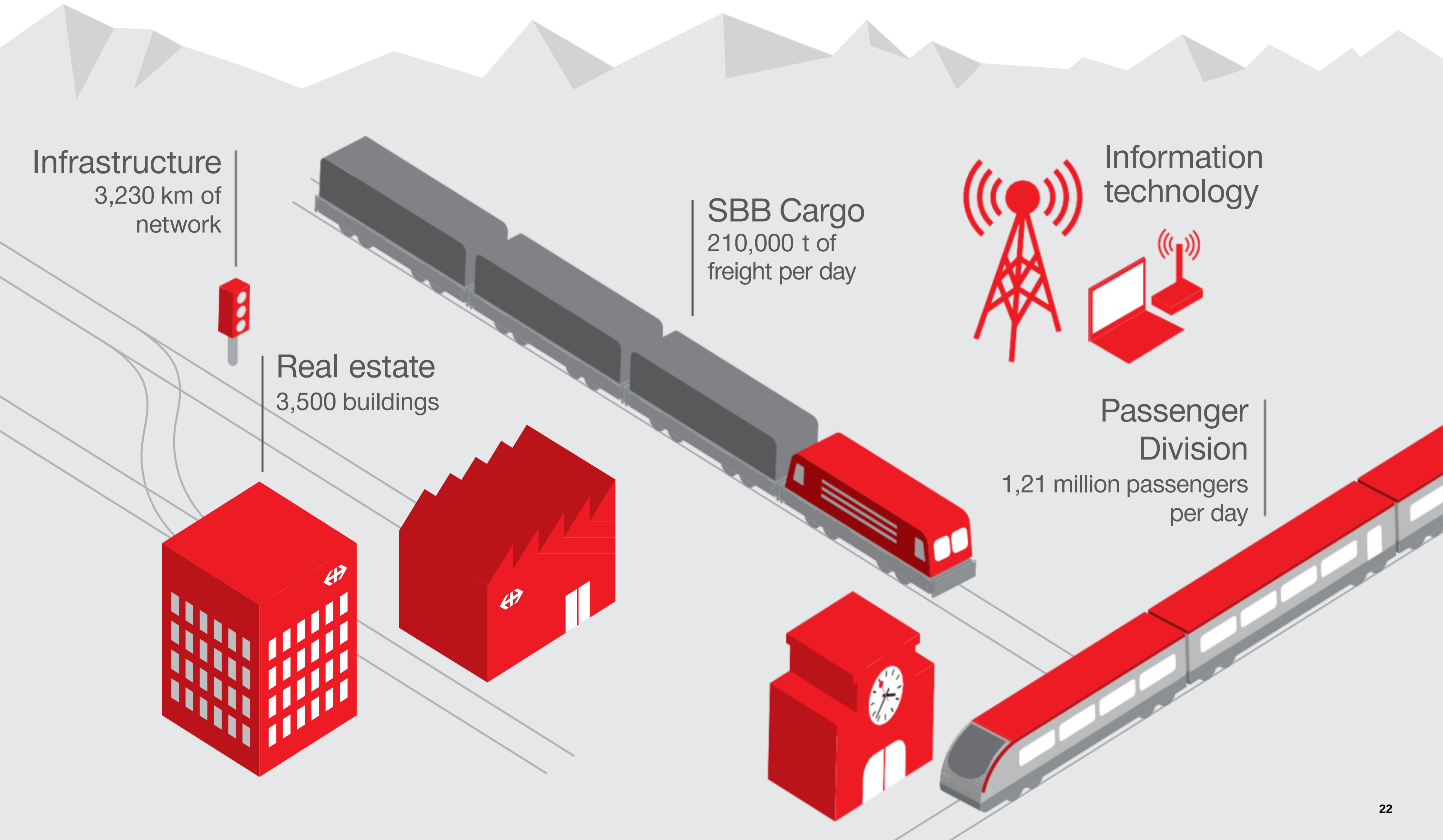
# SBB.
# We keep Switzerland moving.



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# SBB Infrastructure.
## 3 Networks: Rail, Telecom, and Energy.

**31,266** signals

**12,997** sets of points

**10,000** employees

**5,926** bridges

**3,230 km** of track

**10,000** Trains each day for **20** RU

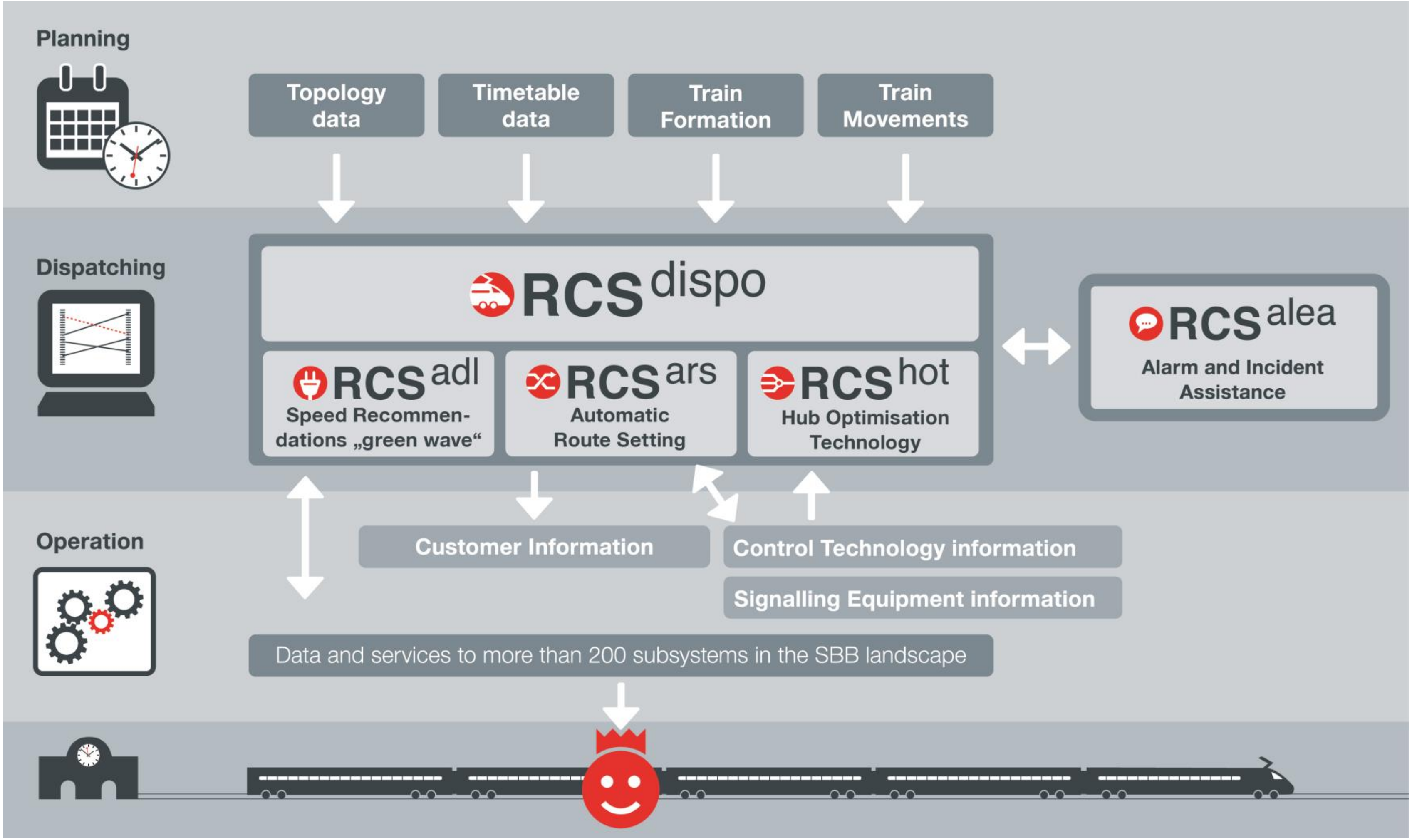
**317** tunnels

**7** Frequency converters

hydroelectric plants **6**

**2** GSM-R operation centres

# Rail Control System.
## The RCS system.



# Rail Control System.
## The RCS system.