

Railway systems and their transition  
Lecture 10

# Planning and Development Medium term

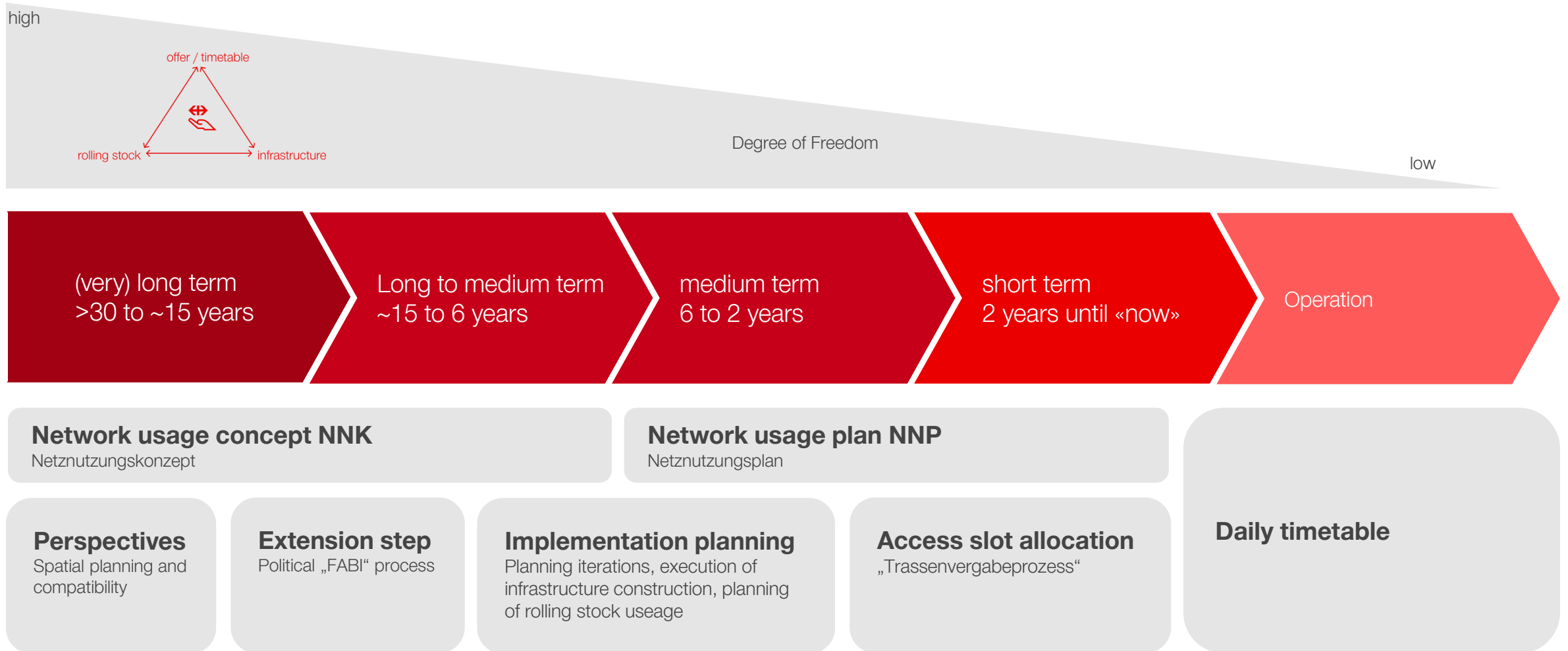
Peter Kummer  
EPFL, Autumn Semester 2025  
November 25, 2025



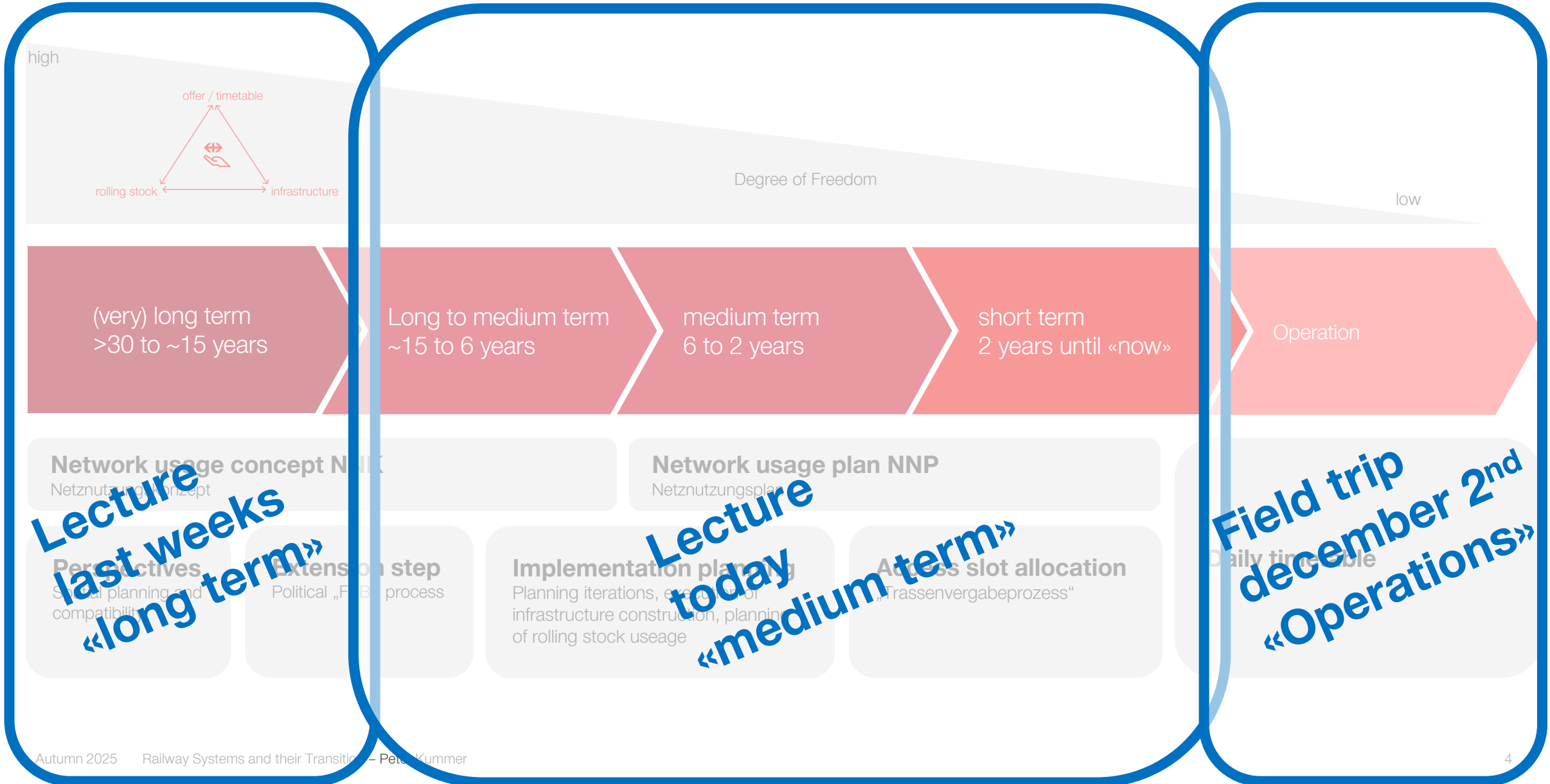
# Today's agenda.

1. Intro
2. Planning and Development – Medium term
  1. Transition from long term
  2. Deep dive Timetable (again)
  3. Usage of rolling stock (facilities, sidings & people)
  4. Interval – Infrastructure maintenance & construction
  5. Feedback loop (analyze, detail level, learning)
  6. Tools, processes and people

# Planning and Development on a time axis

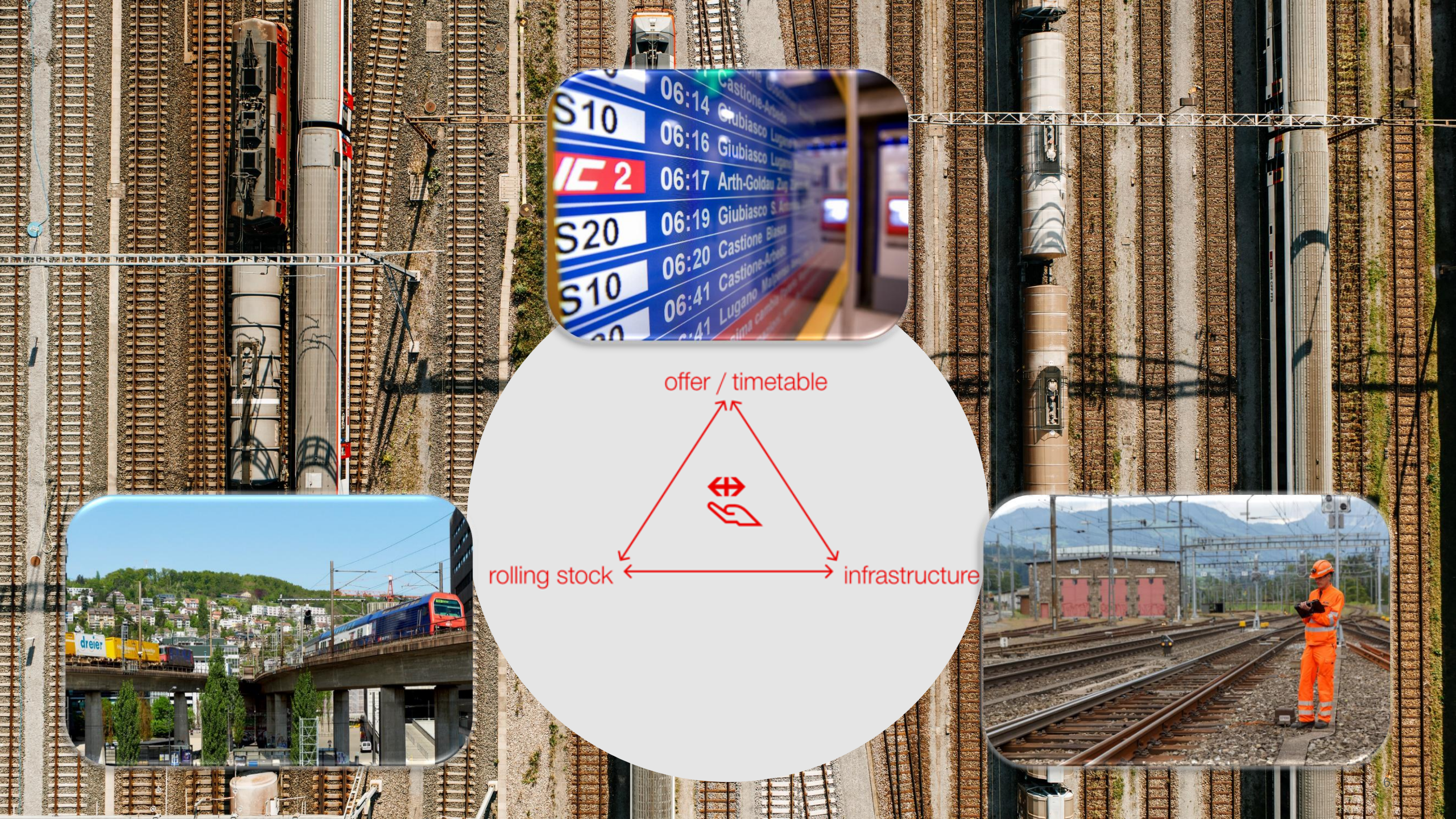


# Planning and Development on a time axis

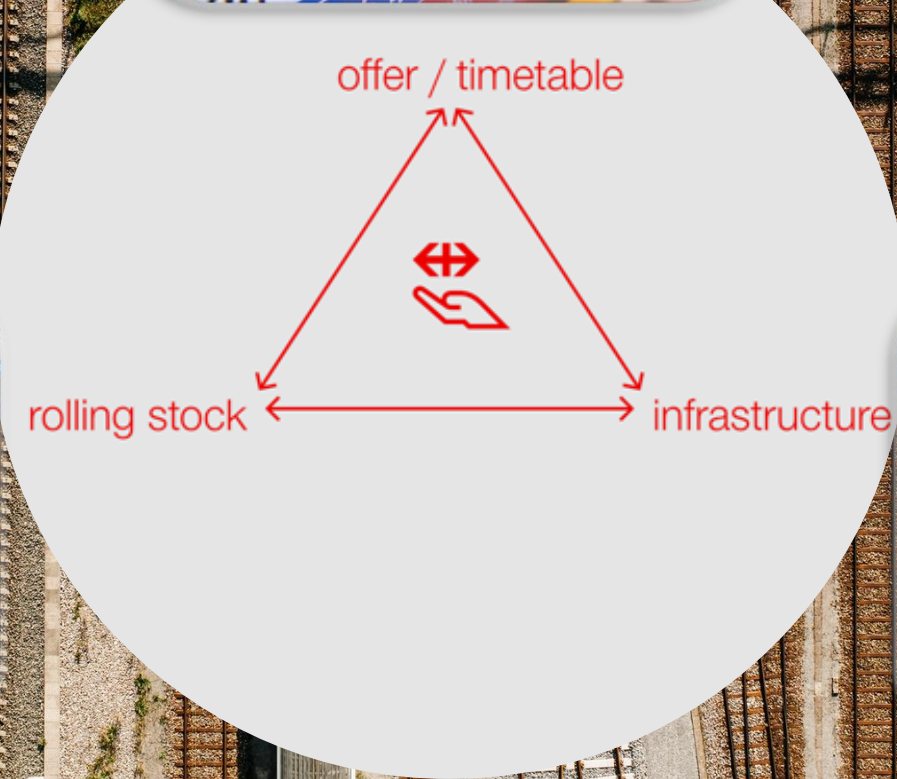


# Transition from long term (Intro)

"Planning replaces chance with error"

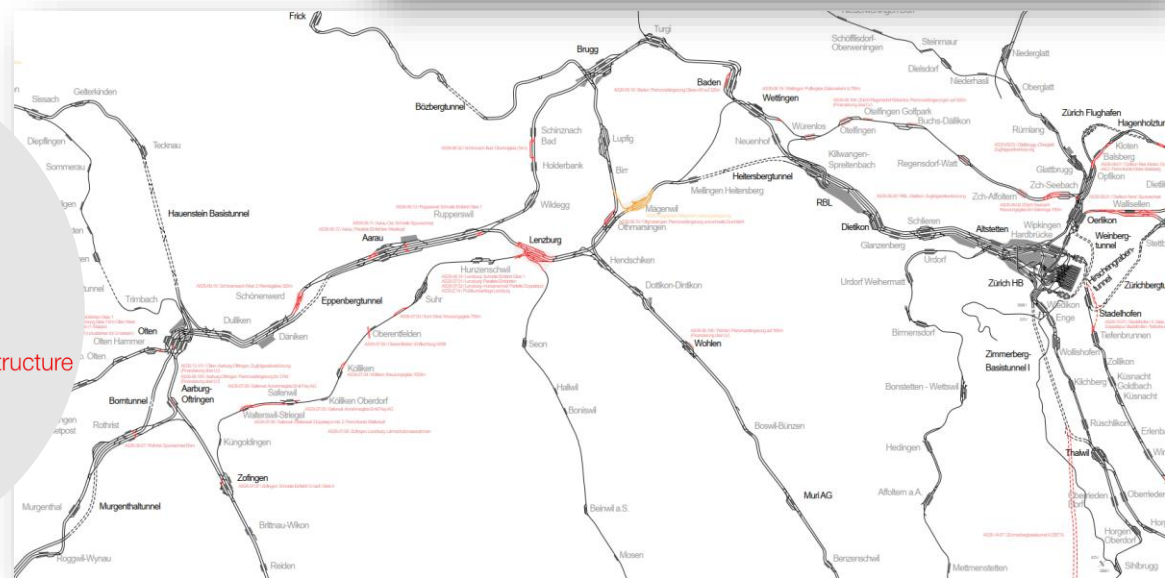
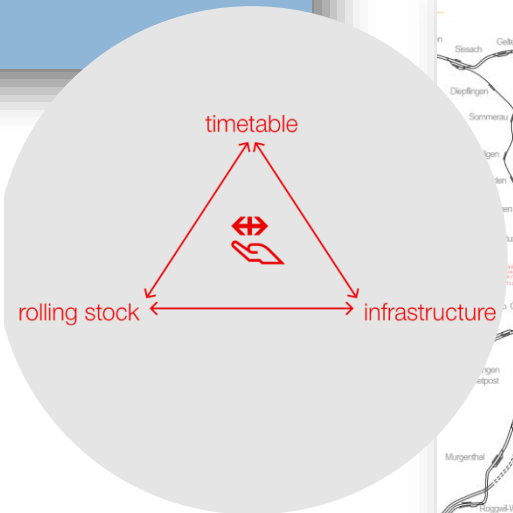
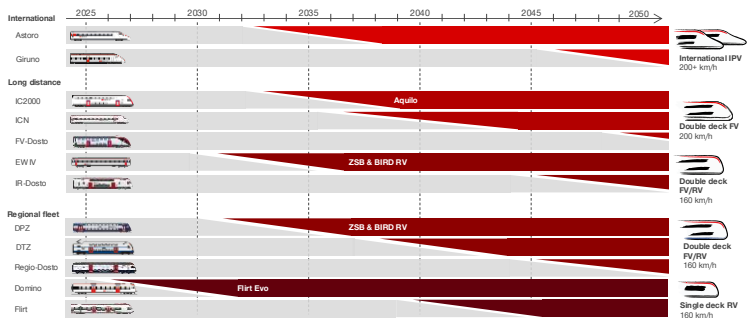
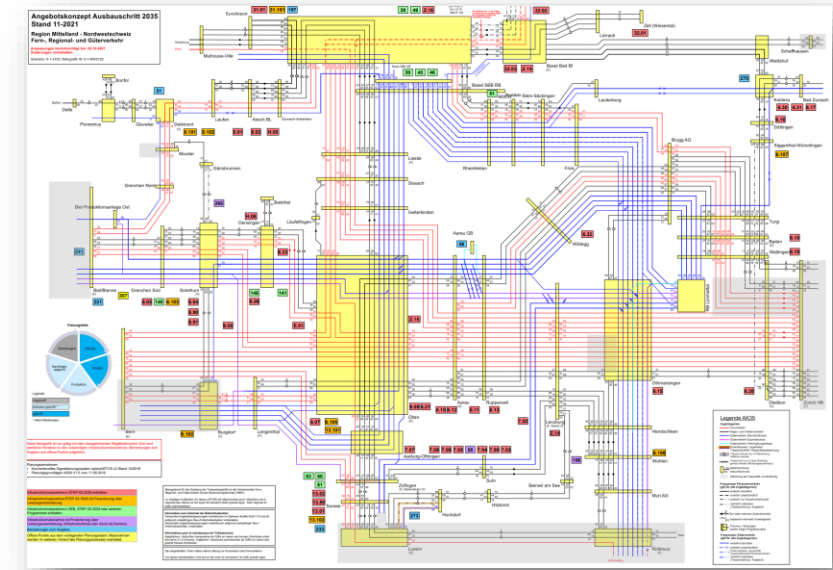
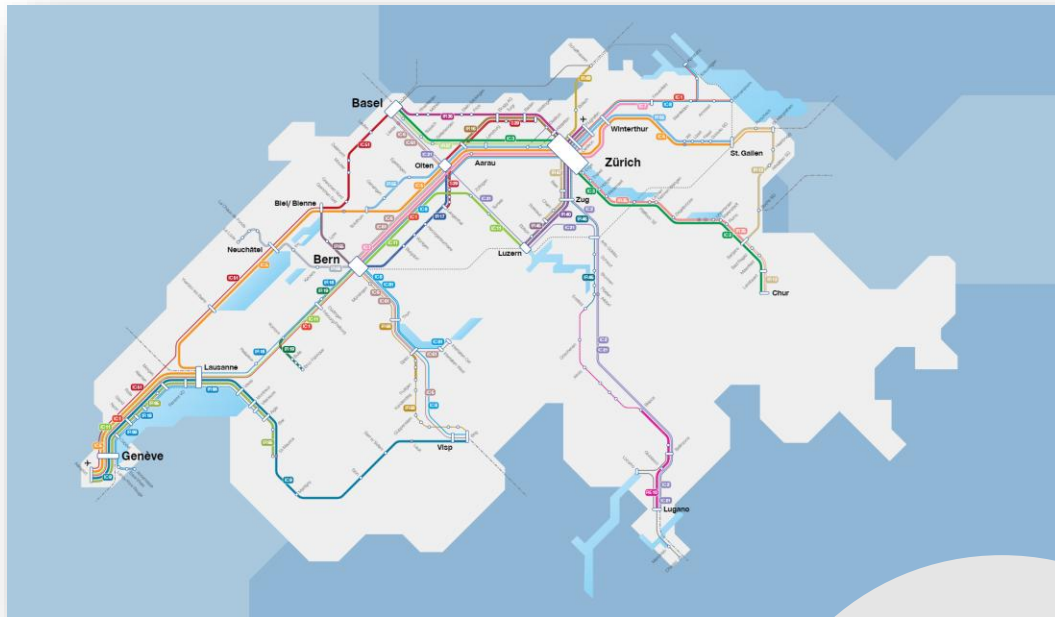


S10	06:14	Castione-Arvesio
IC 2	06:16	Giubiasco Lugano
S20	06:17	Arth-Goldau Zug
S10	06:19	Giubiasco S. Antonio
S10	06:20	Castione-Arvesio
S10	06:41	Castione-Arvesio
S10	06:41	Lugano campo



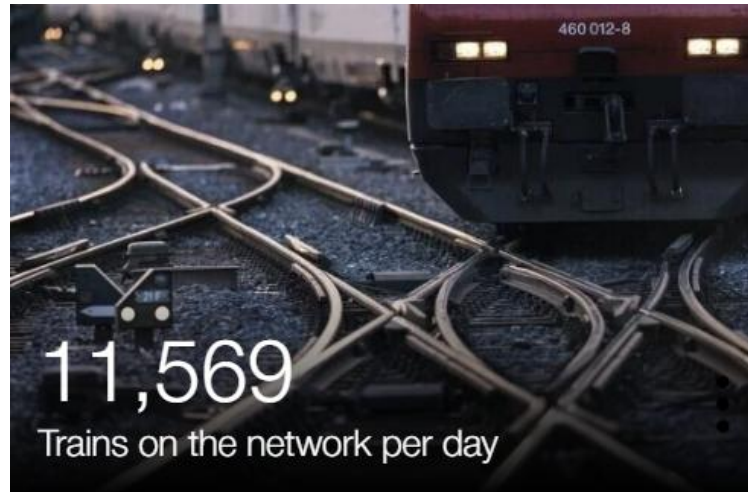
# Offer, Timetable, Rolling Stock and Infrastructure

We've got (a plan for) it ready – let's make it happen!



# Some SBB timetable-relevant figures (2024)

*reporting.sbb.ch*



# Planning the timetable to the operational detail level

There are many people involved and interactions to be managed.

7'900 passenger trains daily



**Customer-facing offer**

30'000 yearly track closures for works on the network



**Construction & Maintenance**

30 Mio. passengers yearly



**Events**

Mastering the timetable complexity



~700 Employees in planning



Safeguarding the people's expertise



Efficiency gain with data usage

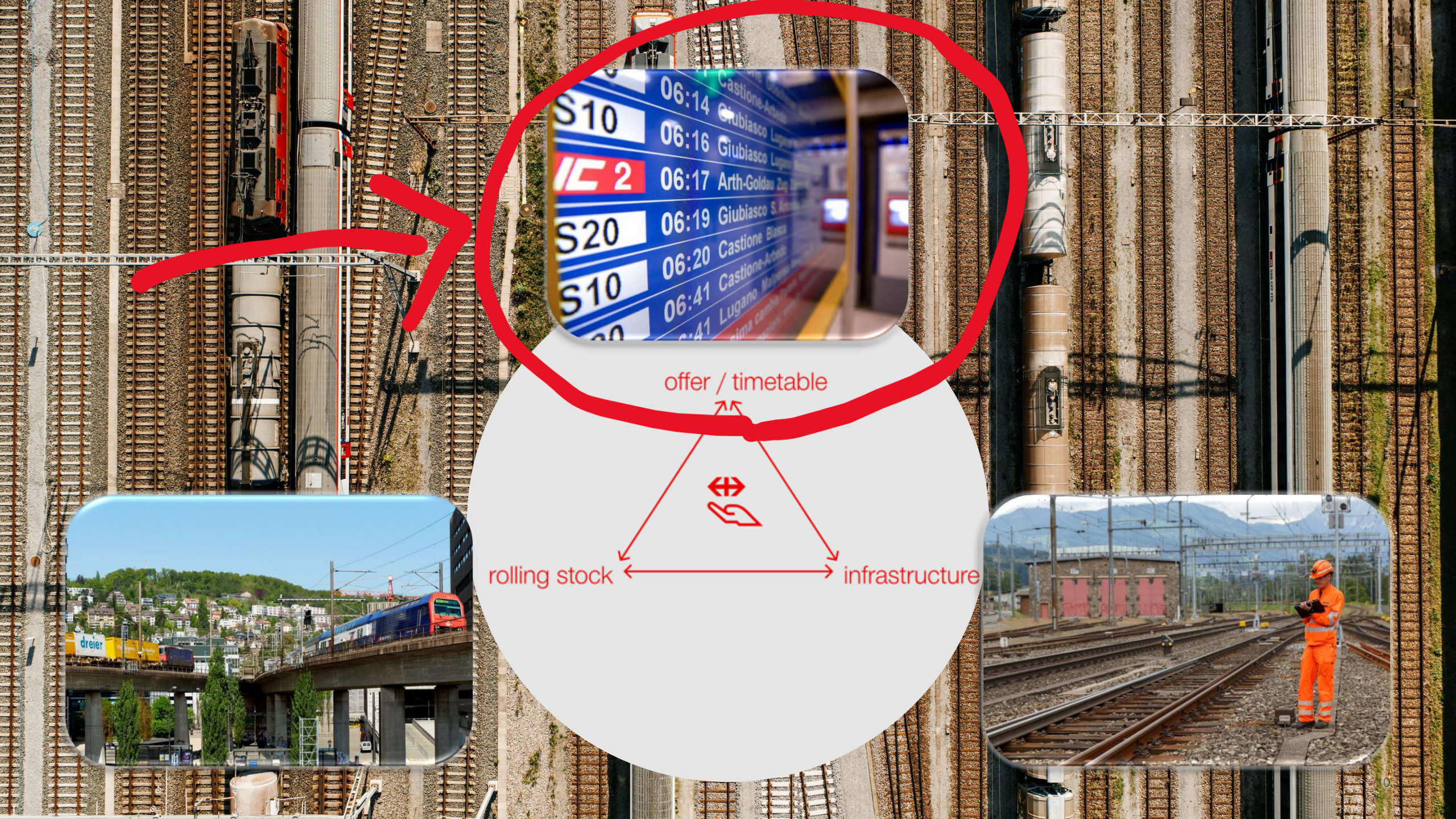
## Production plan

- Rolling stock
- Infrastructure
- ...

## Customer information

## Resource plan

- Workforce
- Sidings
- Workshops
- ...



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IC 2	06:16	Giubiasco Lugano
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offer / timetable



rolling stock

infrastructure



# Deep dive timetable (again)

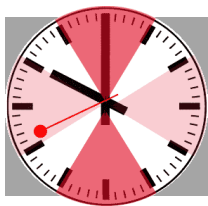
The core of a railway system

# The four pillars of public transport success in Switzerland.

Vision, timetable principle, through-ticketing and transport integration



Visionary transport policy and regulated funding of the whole transport system.



Integrated clock-face timetable.



«Direkter Verkehr» (one ticket).



Integrated railway system.

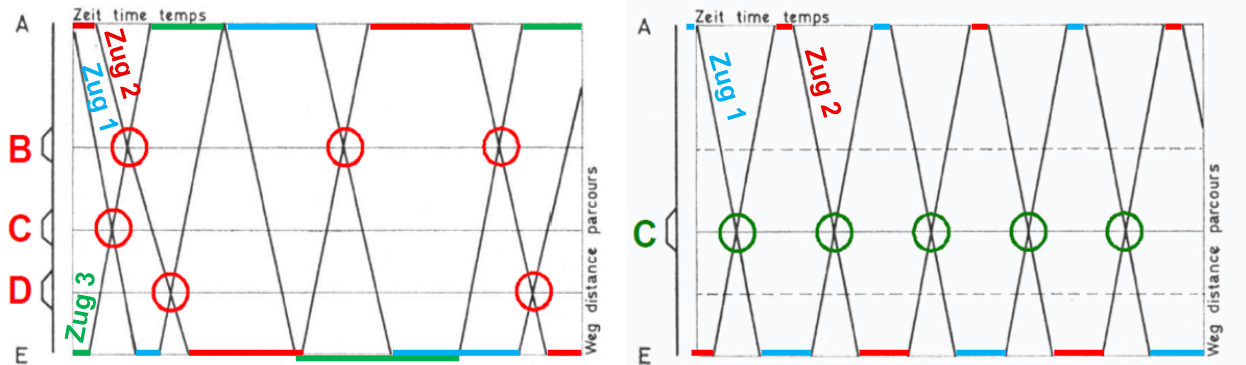
# New Travel Concept '82 – interval timetable (Taktfahrplan)

synchronized timetable with frequent departures



- Big Bang for Swiss public transport 1982
- Benefits:
  - Simplicity
  - Efficiency: short transfer times
  - seamless connections between various modes of public transport
  - Attractiveness: improved user experience
- Economical: With an additional expenditure of 1.5 %, 21 % more pkm could be produced

# Synchronized timetable with frequent departures and nodes.



S. Stähli «Grundfragen der Fahrplangestaltung» in Monatschrift der Internationalen Eisenbahn-Kongress-Vereinigung vom Juli-August 1969, bearbeitet

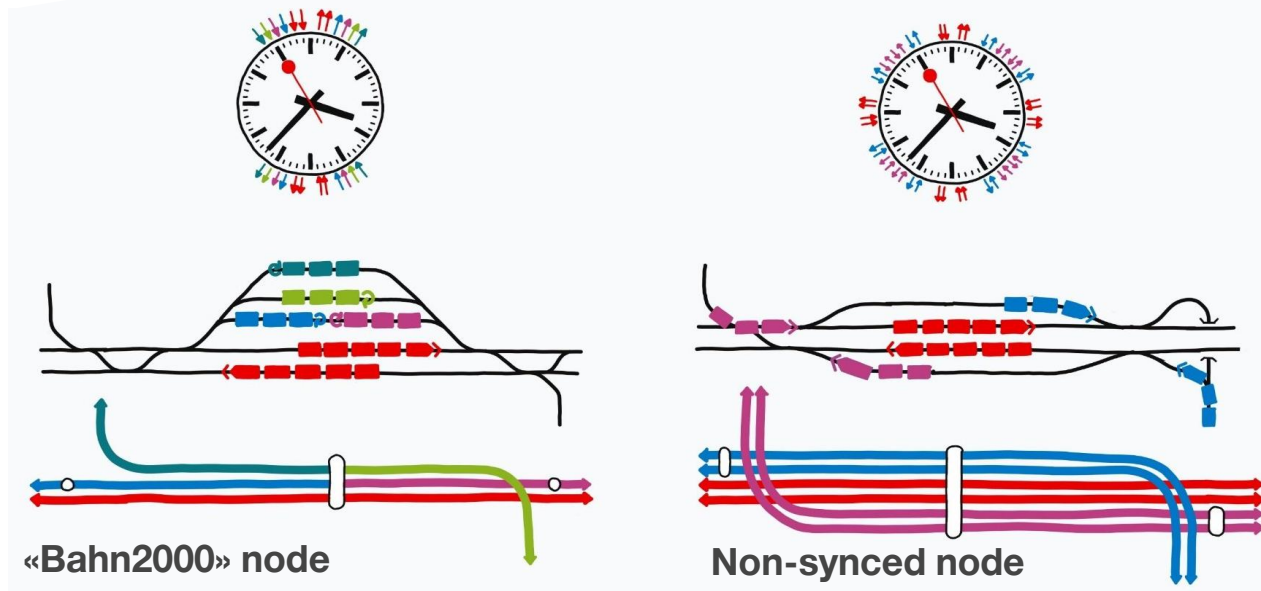
The operation of a **synchronized timetable (Taktfahrplan)** consists of periodically reoccurring lines.

An **integrated synchronized timetable (integraler Taktfahrplan)** adds the systematic coordination in **nodes**.

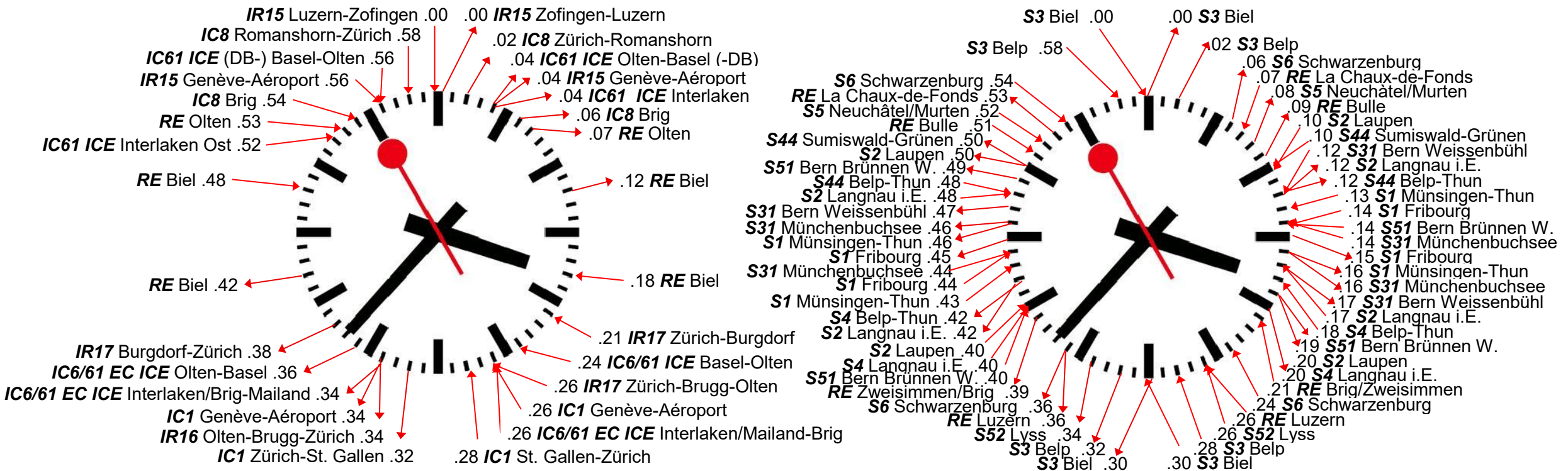
This led to

- Easier working shifts
- Less personnel required
- Better connections
- Overall more attractive offer

With **increased frequency** nodal connections can become obsolete.



# Nodal structure Bern station example in the 2019 timetable.

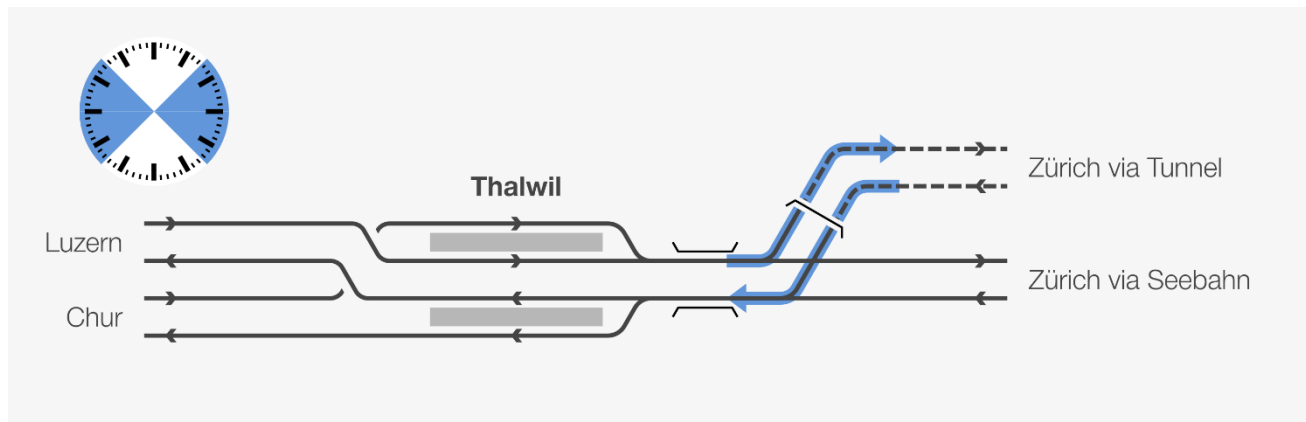
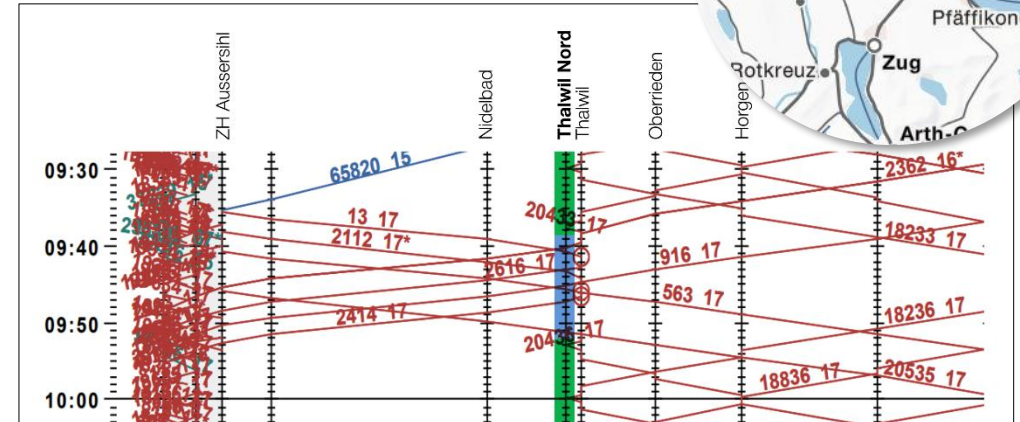
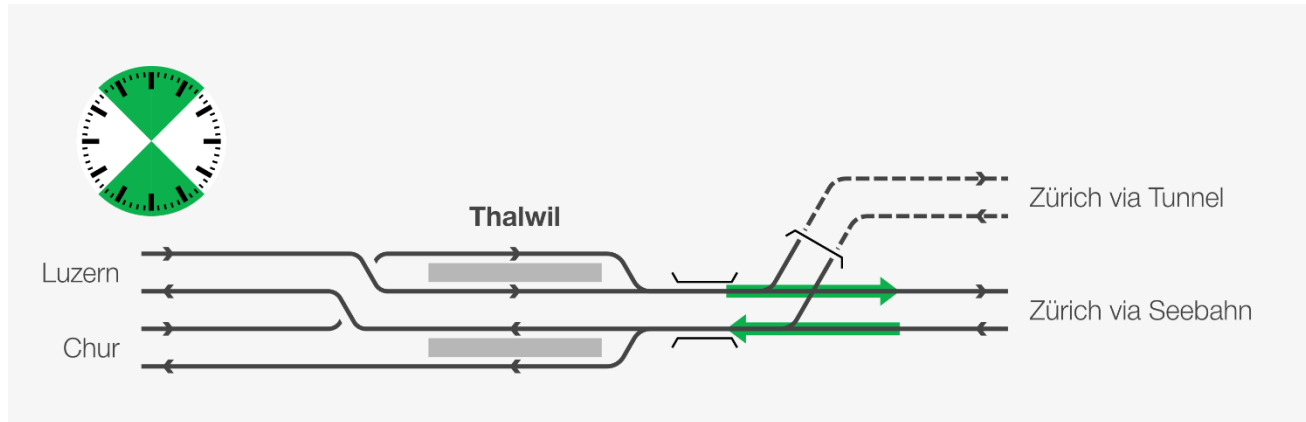


- Long-distance trains are concentrated around the full and half hour.

- Trains of the S-Bahn traffic are concentrated around minutes 15 and 45.

# Timetable planning in choke points – efficiency in track usage.

Example of a heavily used stretch of double track with branching lines.

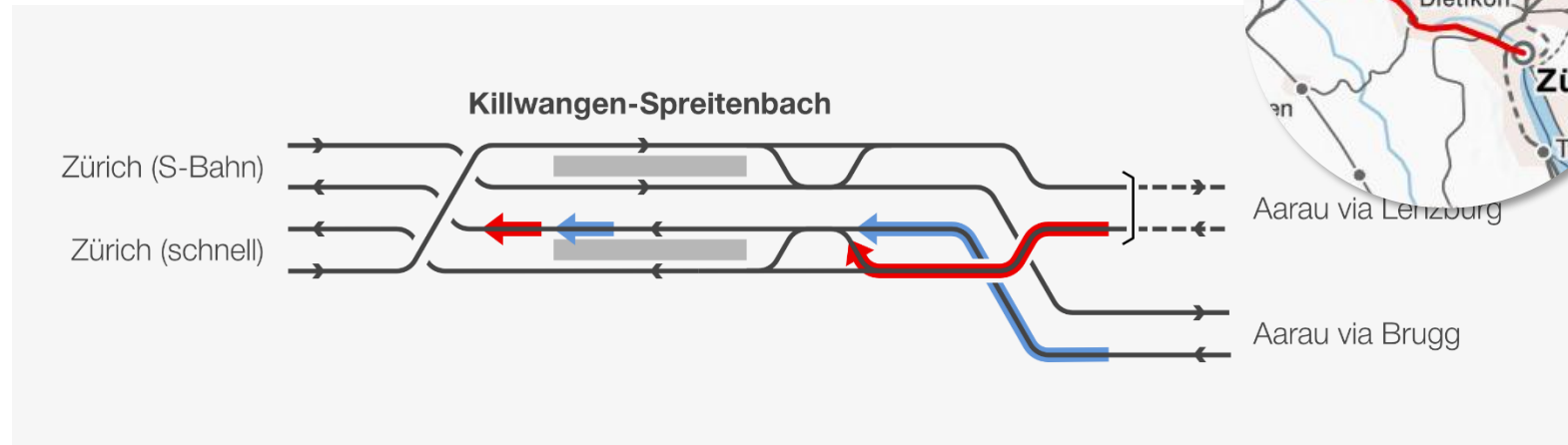


# Optimization of train runs – Stabilisation of a conflict situation.

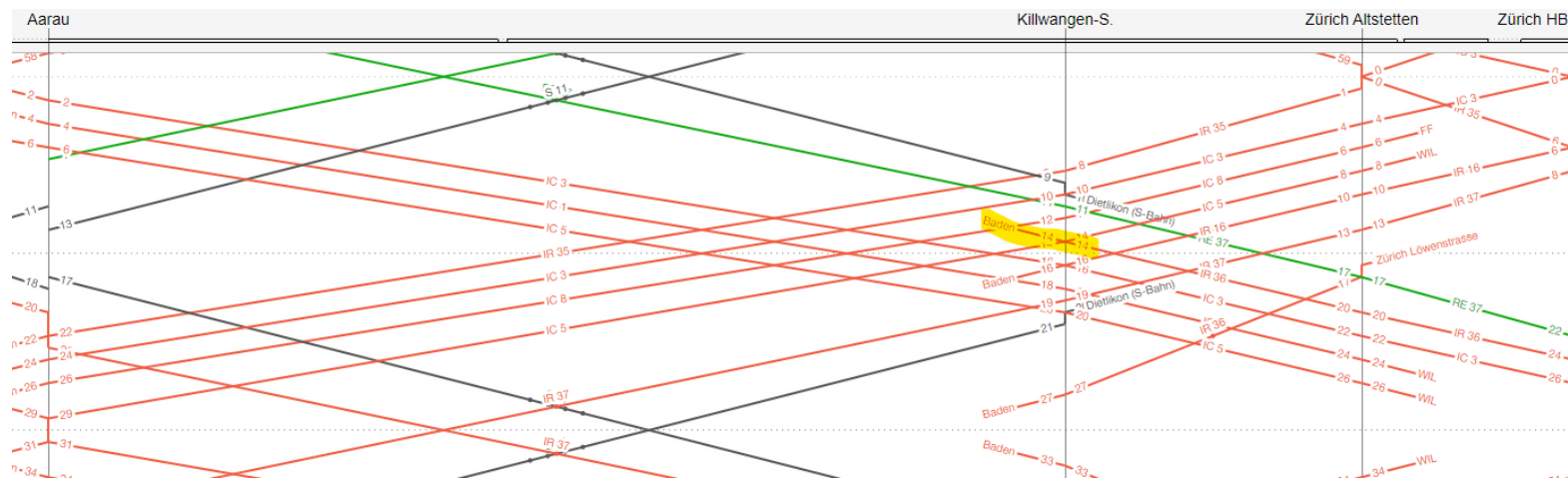
SBB Tool “RCS-HOT” one train following another with 2 Minute headway.



Ensure smooth following of trains on the conflict without stopping.



Optimize the sequence of trains based on the operating situation.



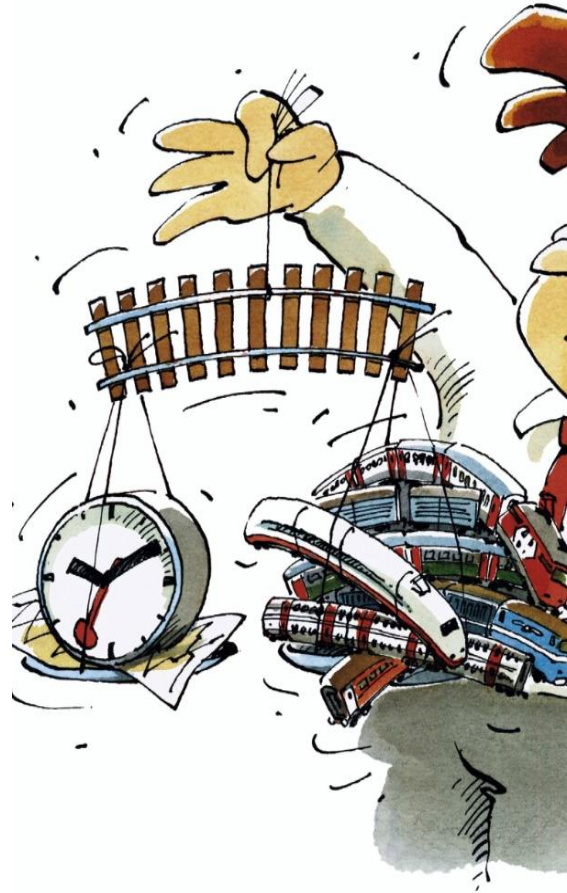
If necessary, adjust routes to avoid conflicts.

# The Swiss railway timetable – a promise to the public.

It's viewed as a one of our country's core strength and considers exceptions.



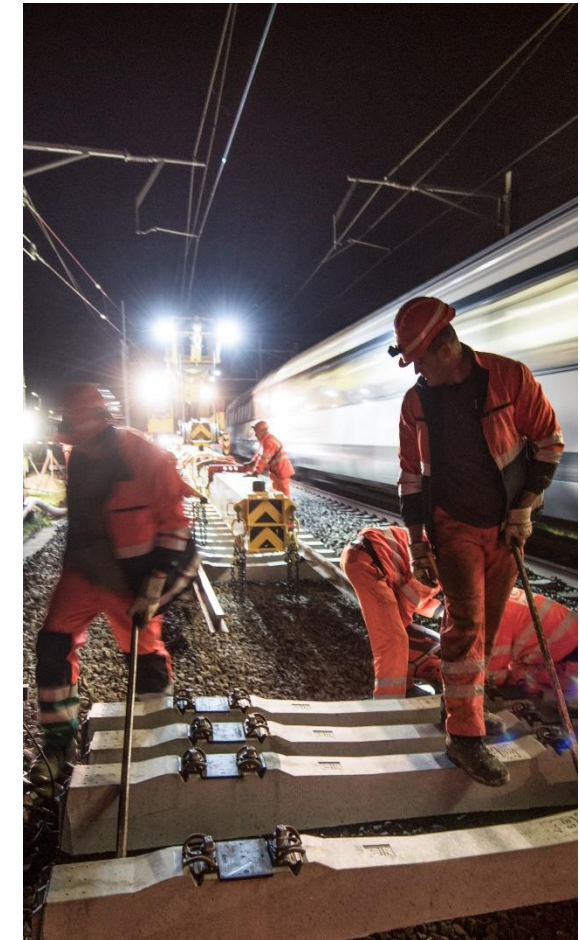
**Punctuality**



**Compromises**

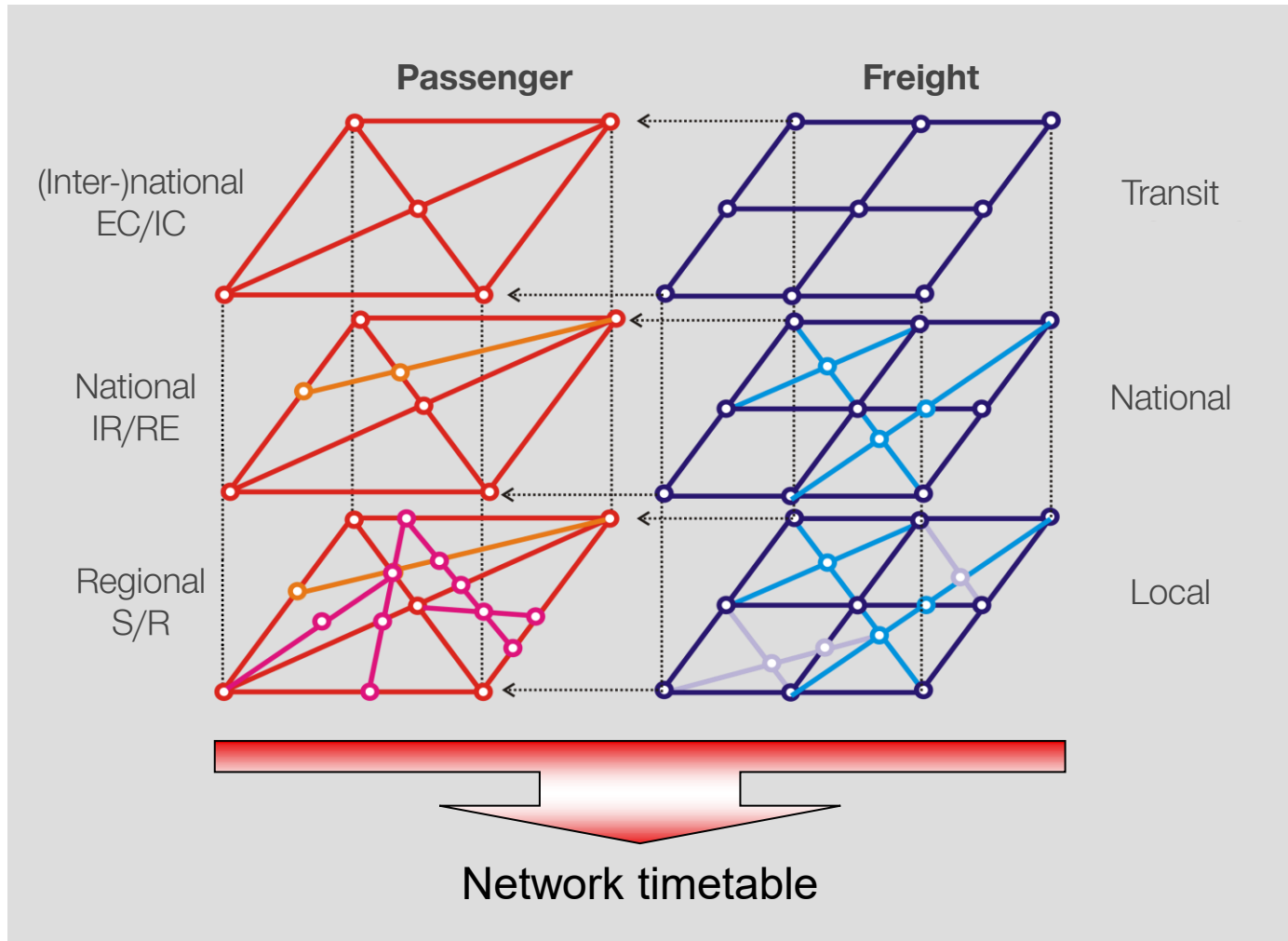


**Demand surges**



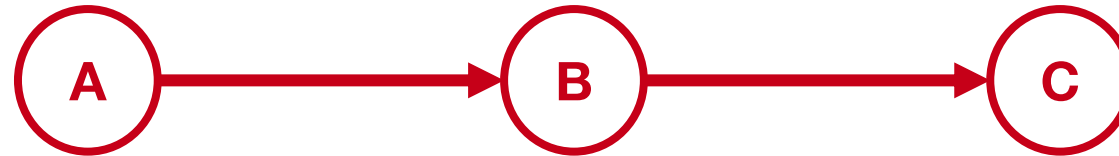
**Reduced capacity**

# Timetable – overlaying all the trains running on the network. The times train are running between stops and the stopping times.



# Timetable – the calculation of train times.

The times train are running between stops and the stopping times.



Technical travel times

+ Reserve for travel time variations

+ Stopping times

+ Reserve for stopping time variations

**= Timetable travel time**



# Passenger and freight train planning philosophies.

They share the same network but the way they are planned differs significantly

**Passenger transport: Integrated clock-face timetable regular service, homogeneous train configurations.**

**Freight transport: Low systematic standardisation heterogeneous train configurations.**

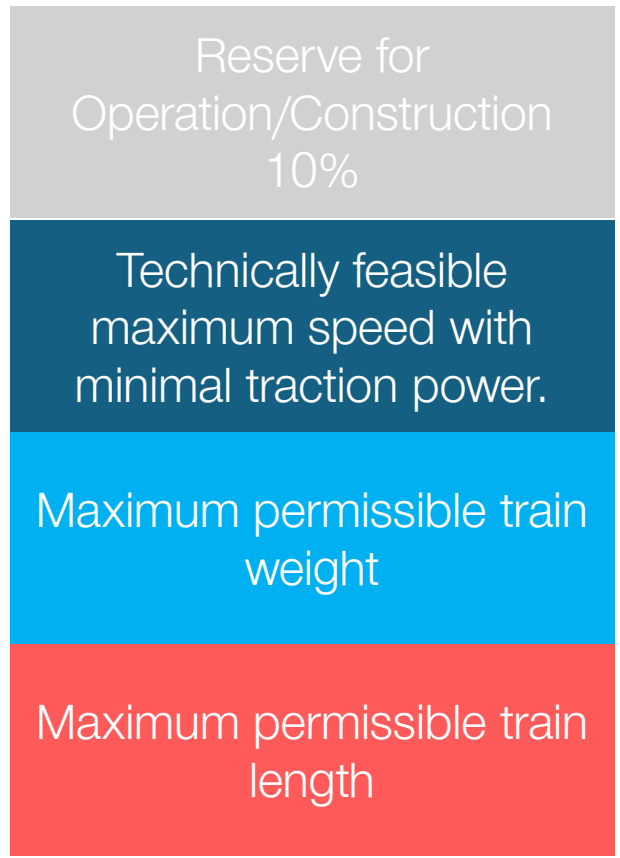
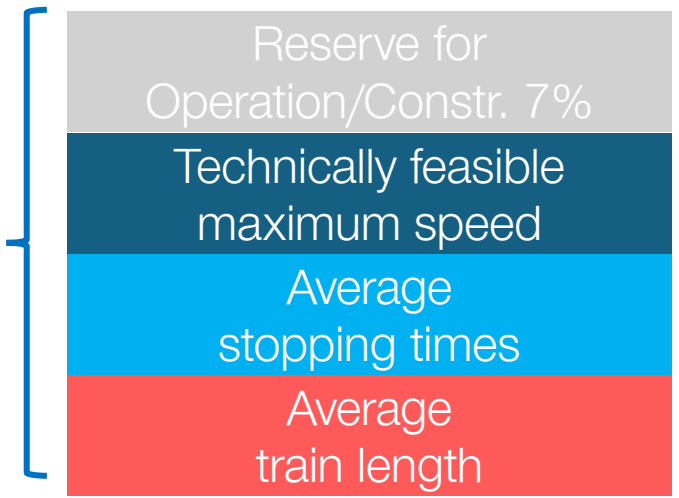
Planning parameters freight

Targeted risk management to control

Effects of peak hours, exceptional cases

Planning parameters Passenger

Planning parameters are calibrated with production data. The planning is tight and leaves little room for operation.



Defensive planning parameters cover fluctuations. There is a great deal of operational leeway in day-to-day operations.

# Maximum speed of a train

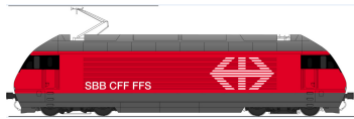
What's influencing the possible maximal speed of a train on a piece of track?

Composition, brakes, brake weight, traction (distribution)



Line / Tracks

**RADN & Signals or SSP & DMI**  
 RADN = Train type grouping  
 SSP = Static Speed Profile / DMI = Driver-Machine-Interface

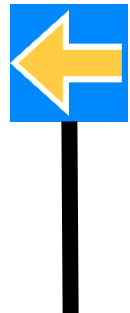


*RADN on drivers pad (LEA)*  
*R135 = Train type R, brake percentage 135%*

km	+	AE	Olten	R135	PRO	An	Ab	09:58:00
48.2	1	6	(1312)	125	105			06:10:21
44.1								SSP
42.8	1	4		125	105			8940
								ADL
38.3	0	10	1302	#				
40.7				115				01:23:19
41.3								
42.4				80				
43.8	0	9	1306					
47.8	0	6	1303	sms	1-3			
50.5	0	6						
53.8	0	6						
53.8	0	6						
55.8	0	6						
58.7	2	10						
59.2				100				
60.8								
61.9								
62.4	2	8	1303					
63.1								
65.0								



*Driving permission on DMI with ETCS L2*



# The stopping time

One of the most important and most difficult parameters to define in timetable planning

JO	98	10:16.4	10:17.2	10:16	10:16	3.5	0.2	0.1	0.8	0.5	0.0	0.3
RUE	1	10:21.0	10:22.0	10:21	10:21	2.2	0.2	0.0	1.0	0.7	0.0	0.3
BUB	2	10:24.4	10:25.2	10:24	10:24	3.9	0.3	0.0	0.8	0.5	0.0	0.3
WZ	5	10:29.4	10:30.6	10:29	10:30	1.8	0.1	0.0	1.2	0.9	0.0	0.3
AAT	2		10:32.5			2.5	0.2	0.0				
UST	1	10:35.2	10:36.3	10:35	10:36	2.0	0.1	0.0	1.1	0.7	0.1	0.3



Planning/operational relevance for **track occupancy**



Published timetable time, **useable for passengers**



**Not useable for passengers**, not part of commercial stopping time. Various process sequences until train departs.

## Passenger dwell time

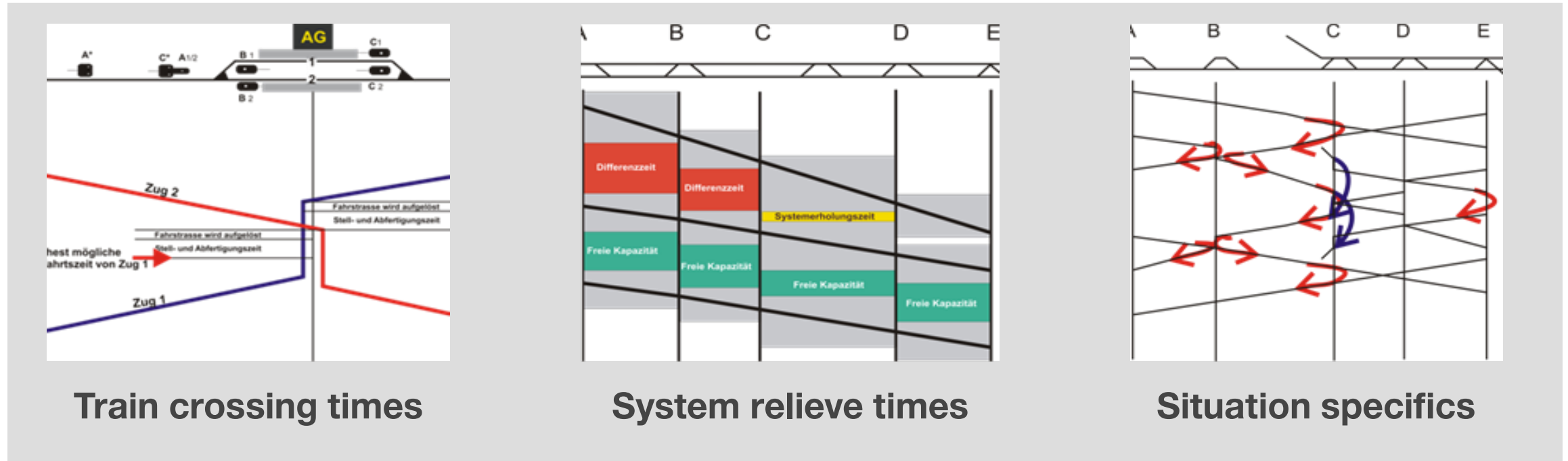
- Passenger numbers
- Mix of alighting and boarding passengers
- Dispersion of passengers along the train
- Rolling stock properties (Door area, door spacing, ...)

## Plus: process times (train dispatch time)

- Rules & Regulation
- Rolling stock properties (door closing time, «moving step» movement time, brake release, traction power gain)

# Planning is mental work.

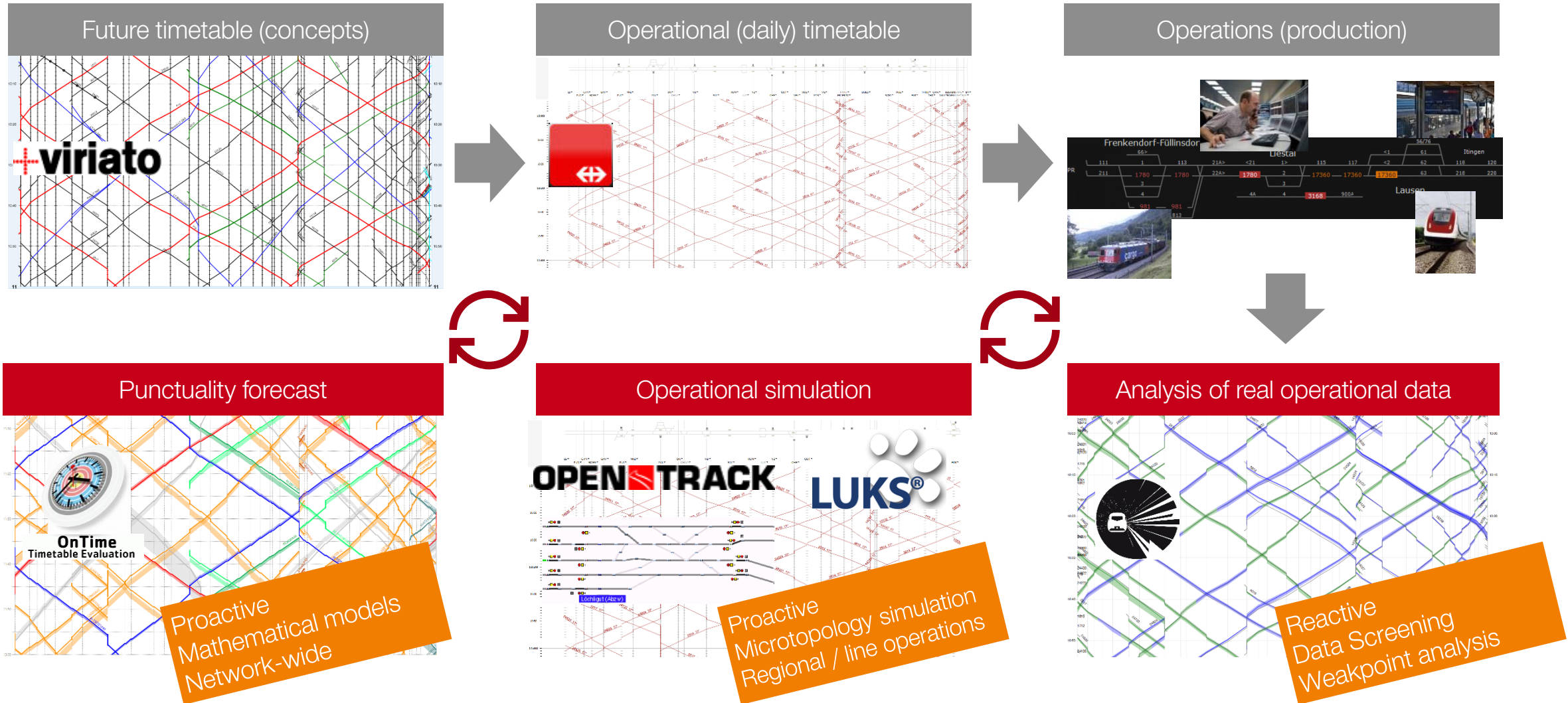
Experienced planners use more than 500 more rules or boundary condition flexibly.



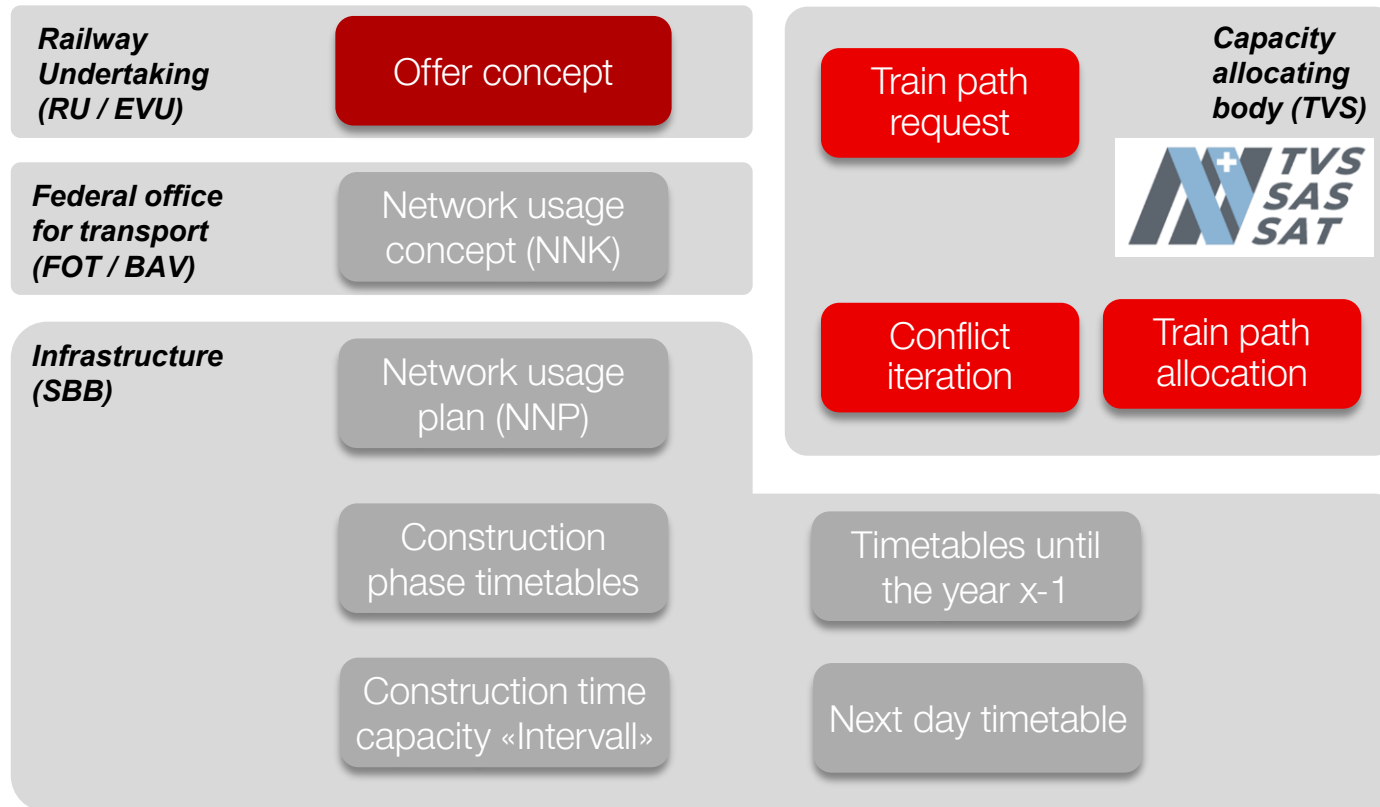
- Strict adherence to physical parameters (example: one train per track segment).
- Overriding of experience-based planning parameters with structured risk management (example: System relieve times with heterogenous train speed, situation specific conflicts, ...)

# The timetable planning roadmap.

Use of various tools to reactively or proactively identify and correct weak spots.

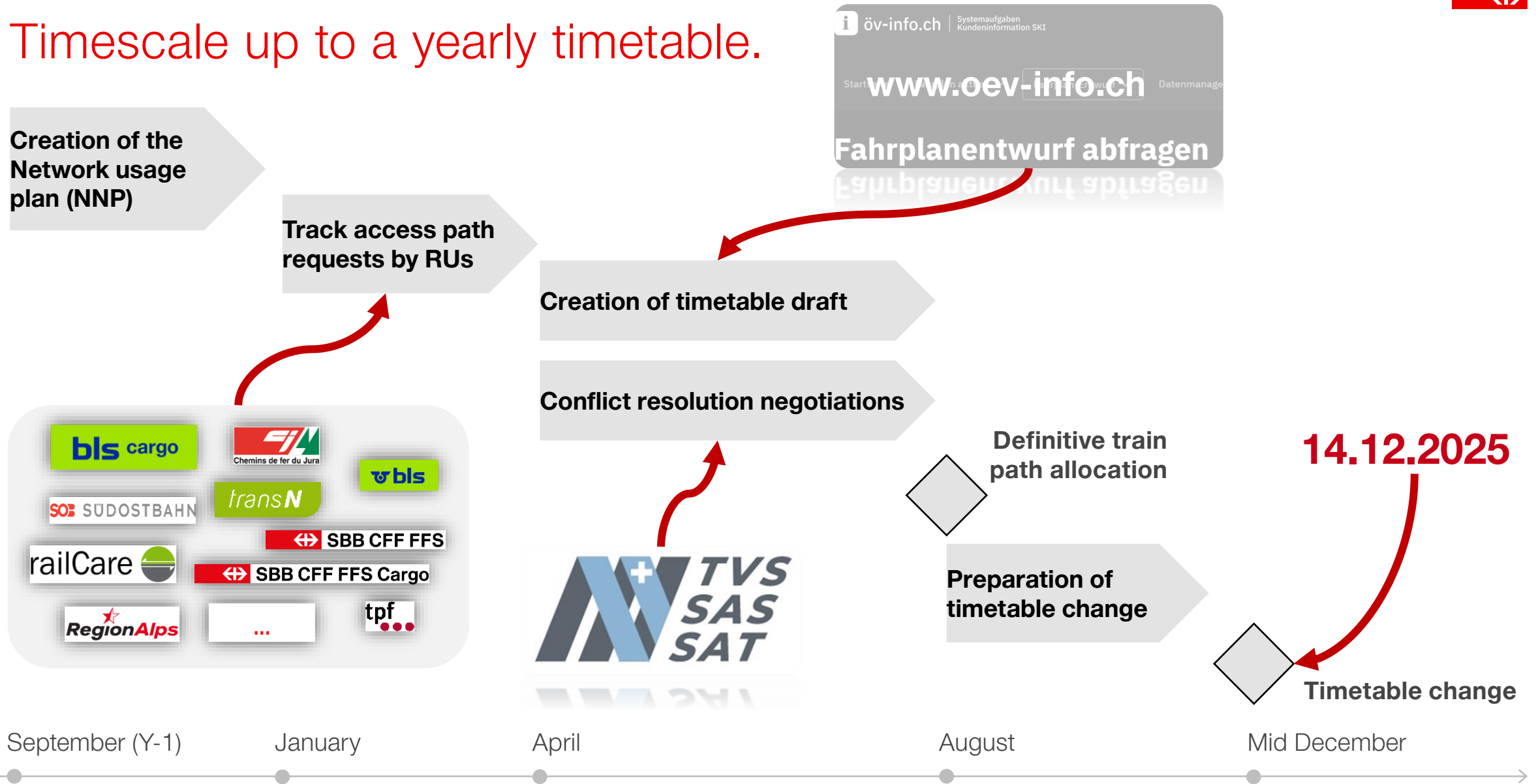


# Regulatory process until a timetable is finished.

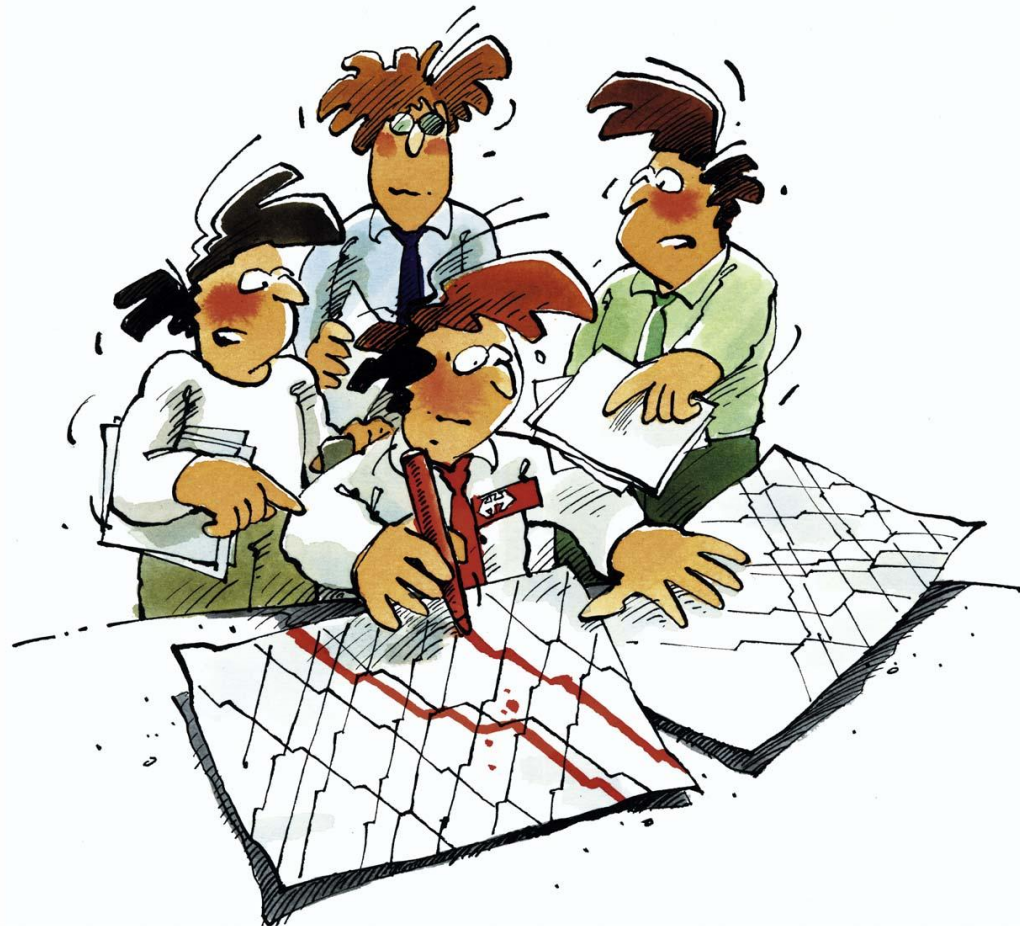


- To ensure the non-discriminatory **allocation of timetable slots** (network capacity) to all railway undertakers (RU) there is a referee role involved:  
Trassenvergabestelle Schweiz TVS
- SBB has multiple roles, it as an
  - Operator (passenger or freight)
  - Infrastructure provider
  - Construction planner
  - ...

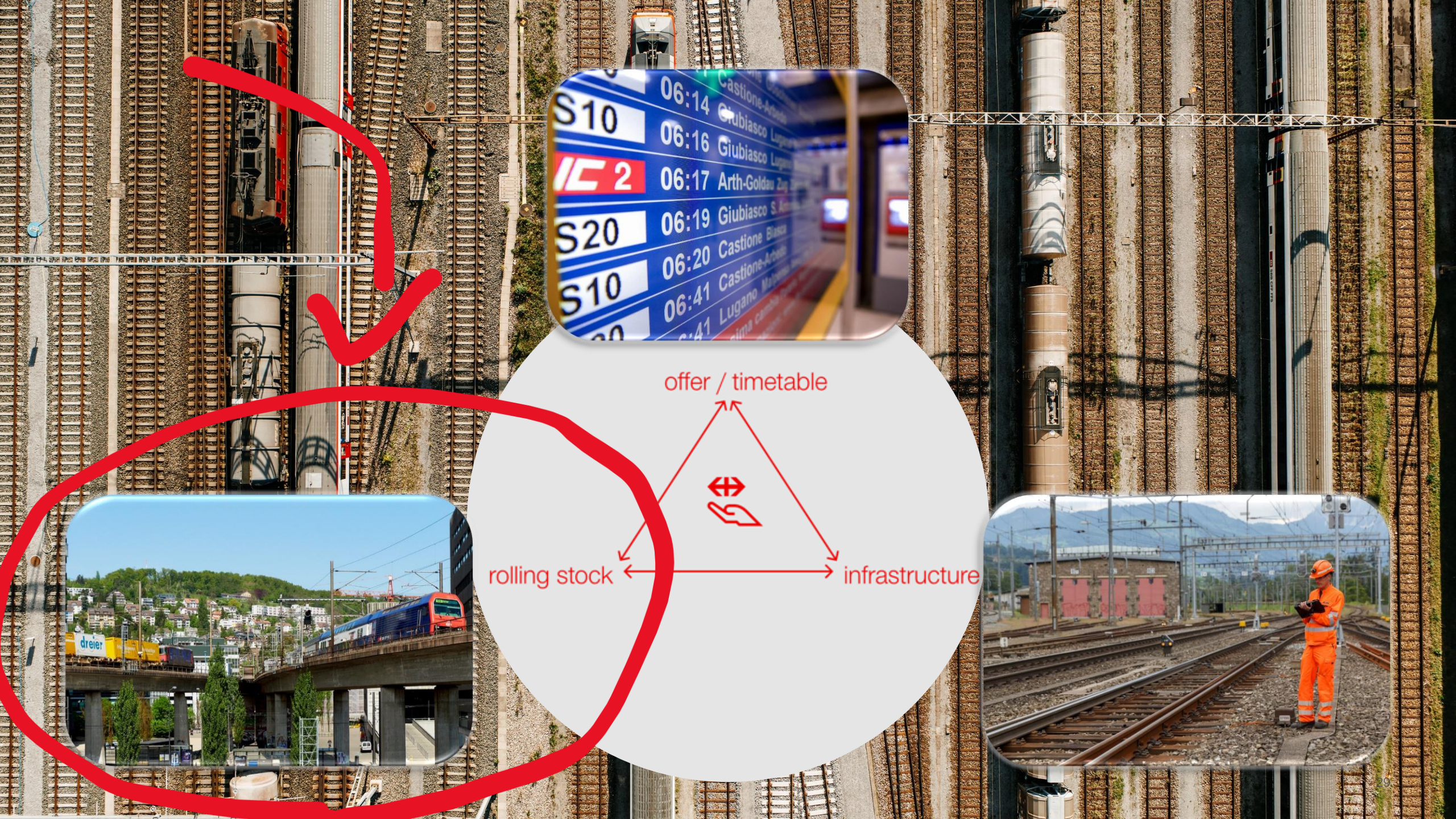
# Timescale up to a yearly timetable.



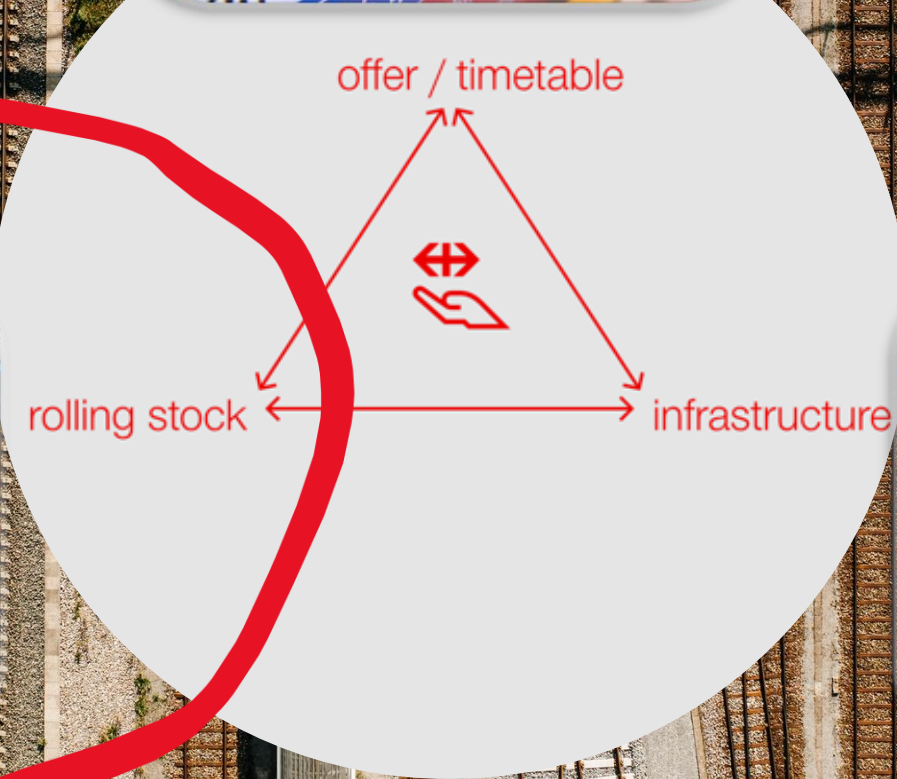
# Timetabling is a piece of artwork.



- The timetable and subsequent information grow in detail level the closer to the actual production day they come.
- The regular interval clock-face timetable is a funding design principle of Swiss public transport success. Refined with the nodal “Bahn2000” system.
- Timetabling is a piece of art – including reserves, tooling, stakeholder complexity and a lot of manual and brainpower work.
- There are many actors involved with their specific interest (TVS, RU, IM, ...).



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	06:41	Lugano capolinea



# Rolling stock usage

facilities, sidings & people

# Rolling stock strategy.

Linking offer, planning principles, resources and production.

## Input

Regulation / technical specifications

Existing fleet availability

Resource availability

Calculated needs for rolling stock numbers

**Goal:  
Optimization of  
the utility value.**



Customer experience



Offer production feasibility



Economy



Robustness & maintainability.

## Three strategic levels of action.

Optimizing lifecycle of the existing fleet



Target fleet design



Orchestrate fleet replacement planning.

## Output

Feedback for Implementation

Fleet phaseout planning

Rolling stock numbers

Planning for existing fleet enhancements

# The SBB fleet – more than 4'500 vehicles.

All differ in age, technology, life cycle state, availability, and so on ...



RABe 511 / RegioDosto  
(Zürich S-Bahn / regional)



RABe 502 / FV-Dosto  
(Long distance double deck)



ETR 610 / Astoro  
(International Italy / Germany)



Infrastructure fleet  
(Shunting, working, measuring  
and snow clearing equipment)



Stadler Flirt  
(different sub fleets)



RABe 501 Giruno  
(long distance / International)



Re460 with IC2000 / EW IV  
(long distance)



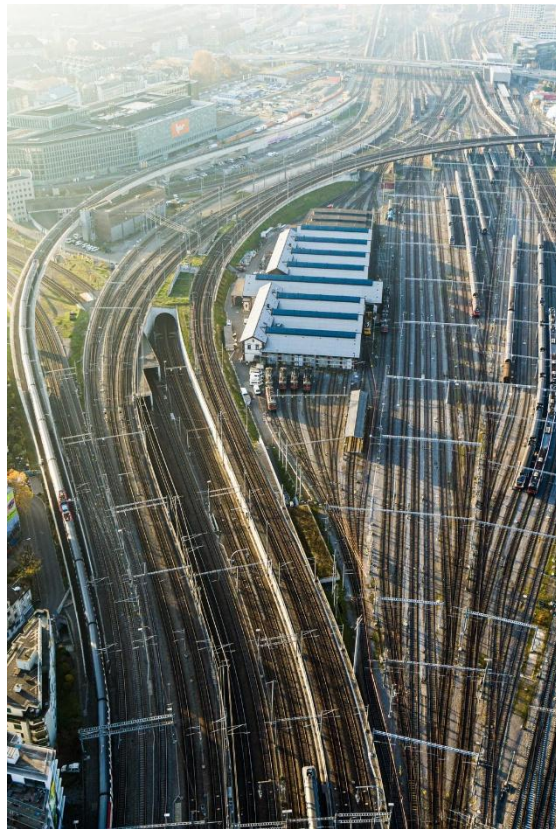
Cargo fleet  
(locomotives, shunting locomotives  
and wagons)

# Planning for the rolling stock in use

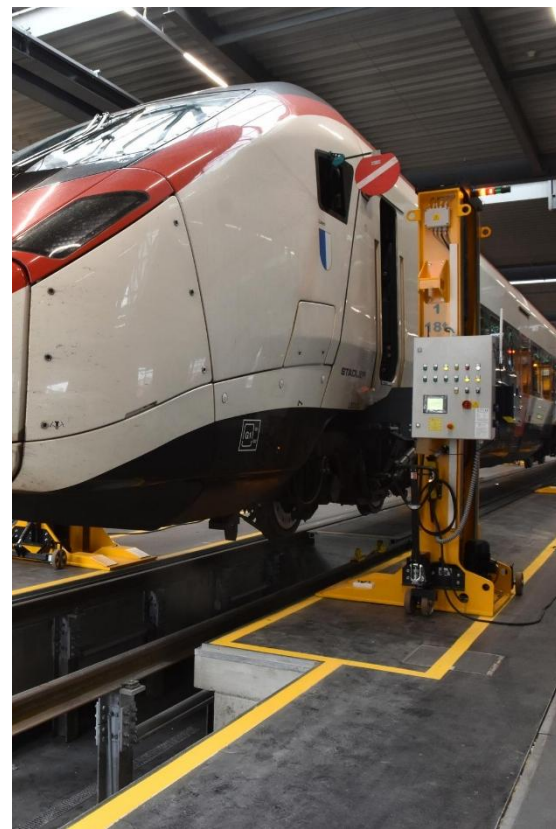
What's needed that your train will be there when you expect it.



**Rolling stock**



**Sidings**



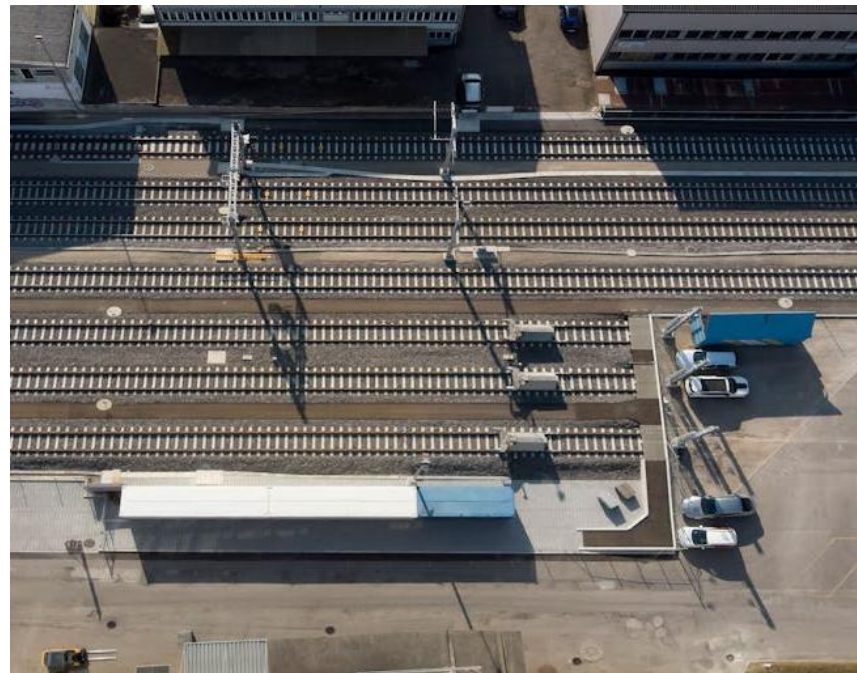
**Maintenance  
(facilities)**



**People!**

# Sidings – more than just a parking slot for train sets.

Modern train sets increase requirements for siding facilities.



Sidings need to be ...

- ... equipped with room for all operational staff.
- ... accessible for staff starting and ending their shift.
- ... able to dispose of waste and wastewater.



While running and braking trains become quieter the noise of parked trains is an increasing issue.

In the planning of land-intensive railway facilities, conflicts between spatial planning and railway planning are increasing.



Abo Interview mit BLS-Chef

«Jeder will ÖV, doch niemand will die Werkstätte»

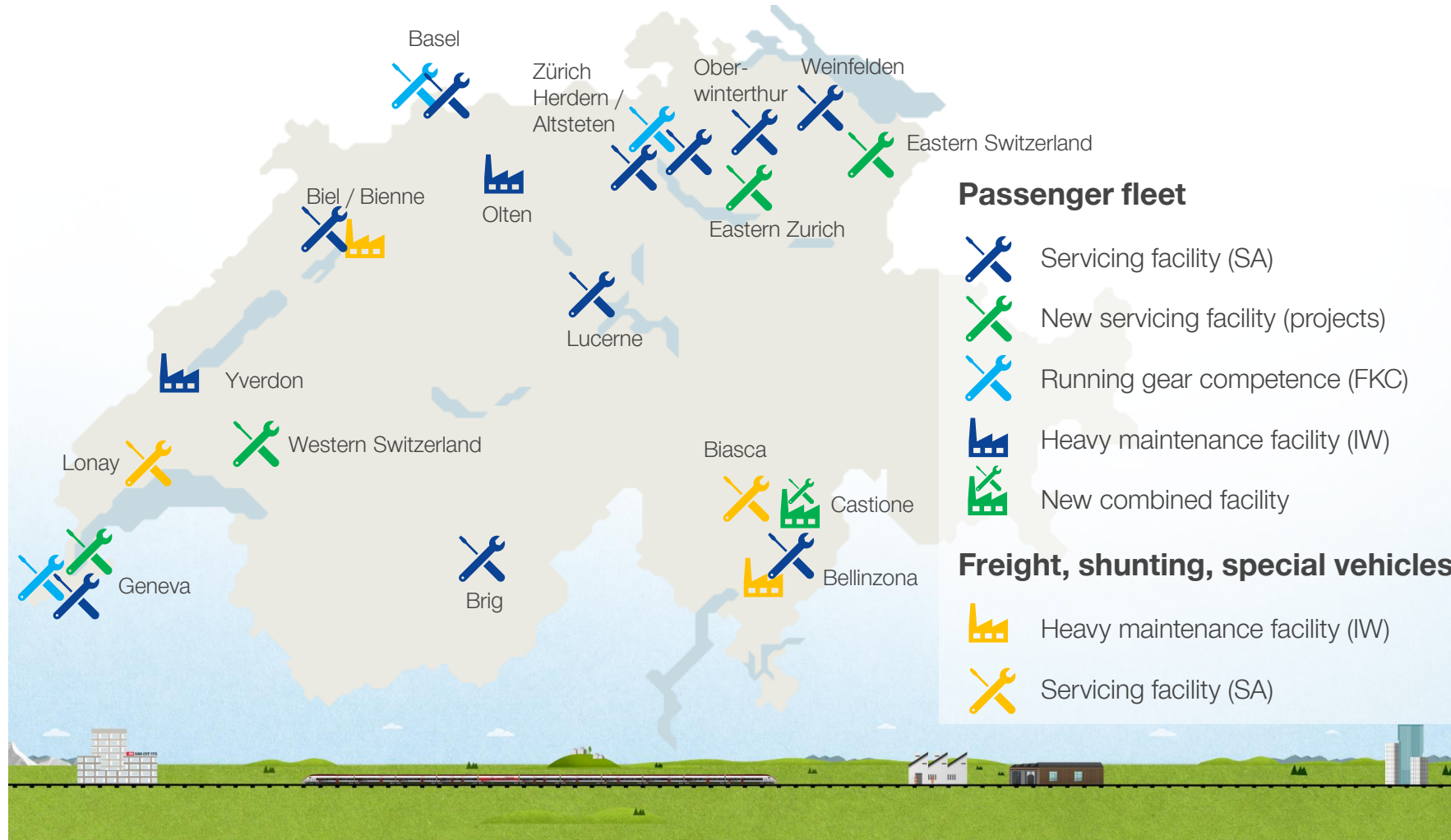


Headline:

«Everybody wants public transport but nobody wants the maintenance facilities.»

# SBB train servicing facilities across Switzerland

About 700 trains are being cleaned, serviced and maintained daily.



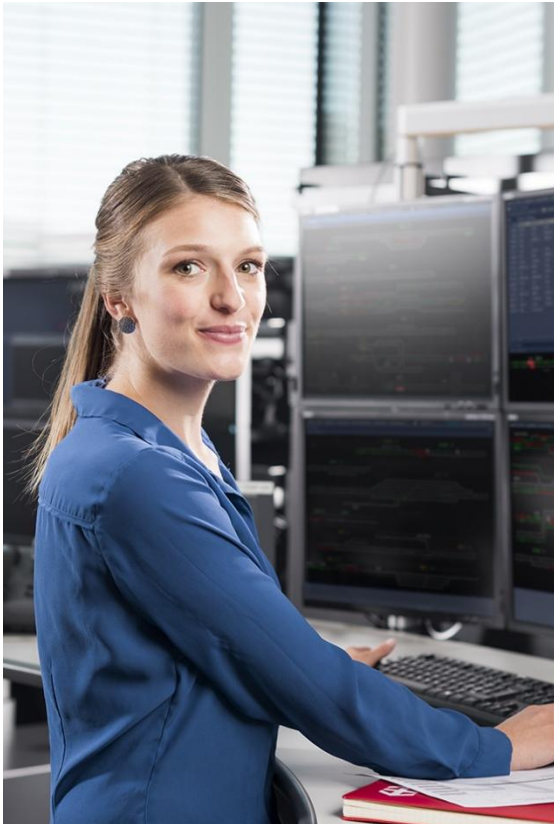
Maintaining and refurbishing the fleet with the aim to:

- Ensuring the future viability of maintenance capacities beyond the horizon of 2035 thanks to modern facilities.
- Standardization and polyvalence of facilities and people.
- Utilization of the plants is optimized and industrialized processes are supported.

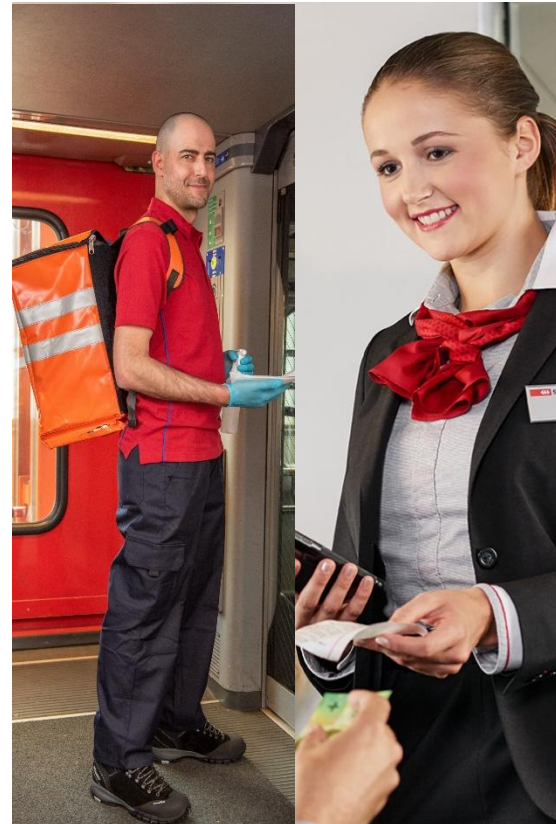
# Running the SBB passenger fleet

About 7'600 employees are involved for the production of our passenger trains

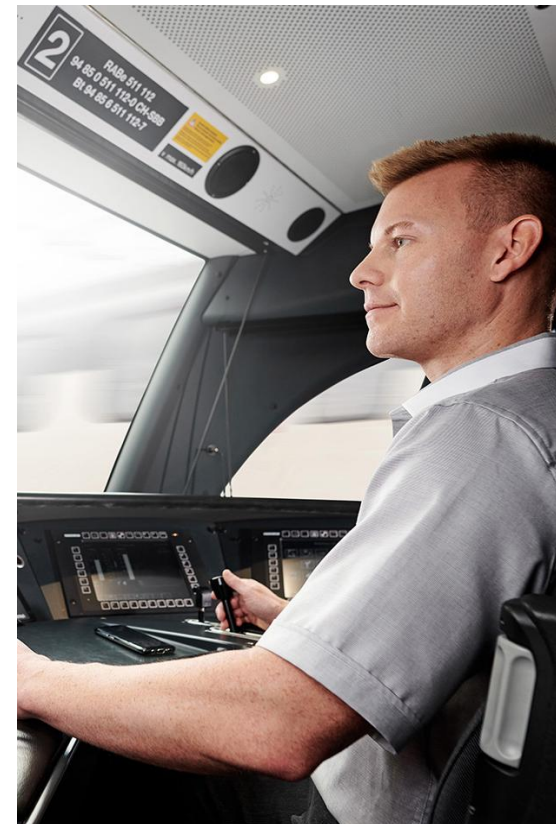
**Planning, Management and  
Traffic Control Center**



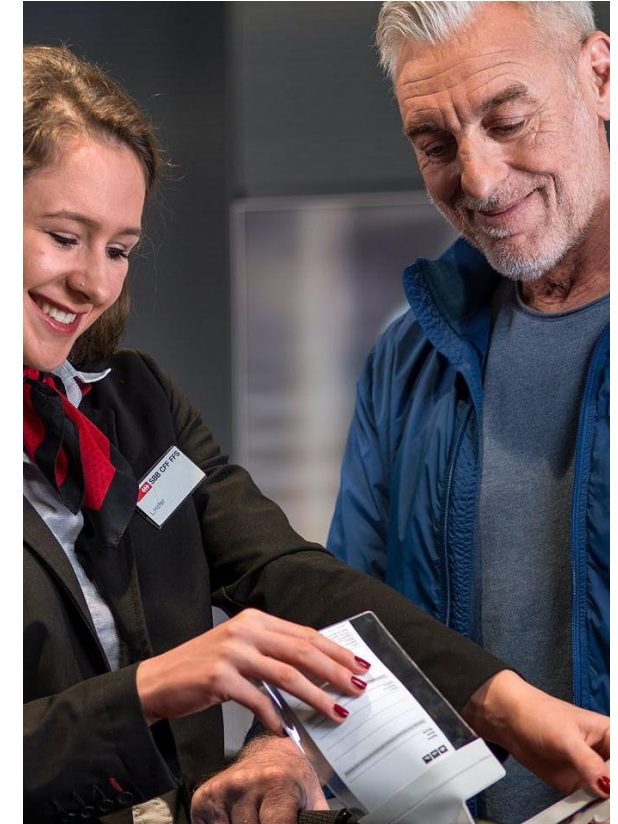
**Train staff and cleaning**



**Locomotive drivers and  
shunting personal**

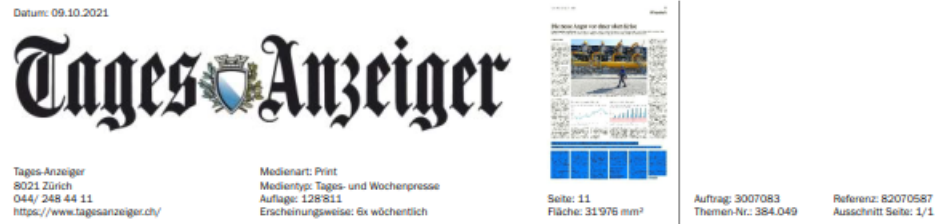


**Transport and logistics**



# Consistent resource planning for operational personnel

It is critical to our reliability in running our trains and to our success.



## LE TEMPS

ACCUEIL > SUISSE

### Faute de conducteurs, les CFF suppriment des trains pour trois semaines

Malgré de nombreux recrutements, la pénurie de personnel continue de peser sur le trafic des CFF. Du 8 au 25 octobre, des trains RegioExpress seront supprimés les week-ends dans la région de l'arc lémanique

### SBB lassen wegen Lokführermangels zahlreiche Züge ausfallen

**Schieneverkehr** Vor allem in der Romandie kann es zu kurzfristigen Ausfällen kommen. Erst Ende Jahr normalisiert sich die Lage.

**Peter Burkhardt**

Noch im Sommer versuchten die SBB mit Pressemitteilungen den Eindruck zu vermitteln, als wäre der Lokomotivführermangel behoben. Doch nun zeigt sich: Das ist nicht der Fall – ganz im Gegenteil. Am letzten Dienstag gaben die SBB bekannt, dass seit gestern Freitag zahlreiche Züge ausfallen. Da die Mitteilung nur auf Französisch verfasst wurde, wurde sie diesseits des Röstigrabens bisher nicht beachtet.

Die SBB begründen die Zugausfälle ausdrücklich mit dem

— Betroffenen waren auch alle Ver-

bindungen Genf–La Plaine und Freiburg–Yverdon-les-Bains.

— Auf anderen Linien wurde am 27., 28. und 29. September der Fahrplan ausgedünnt. So sahen sich die SBB aufgrund des Personal mangels gezwungen, die Frequenz der Regioexpress-Züge zwischen Vevey und Annemasse von halbstündlich auf einmal pro Stunde zu reduzieren.

**Situation im Raum Zürich «besonders angespannt»**

Die SBB schätzen, dass die

abschliessen.

Die SBB geloben Besserung. Das Unternehmen habe Massnahmen ergriffen, um «mittelfristig» den Personalbestand zu erhöhen. In den nächsten sechs Monaten würden in der ganzen Schweiz rund 200 Lokomotivführer ihre Ausbildung abschliessen. Die Lage werde sich darum bis Ende Jahr wieder normalisieren.

Der Verband Schweizer Lokomotivführer begrüsst die Streichung von fahrplanmässigen Zügen in der Westschweiz. Da-



Les CFF espèrent que l'arrivée de mécaniciens nouvellement formés permettra d'éviter de nouvelles perturbations jusqu'à la fin de l'année. (photo d'illustration) — © KEYSTONE/Jean-Christophe Bort



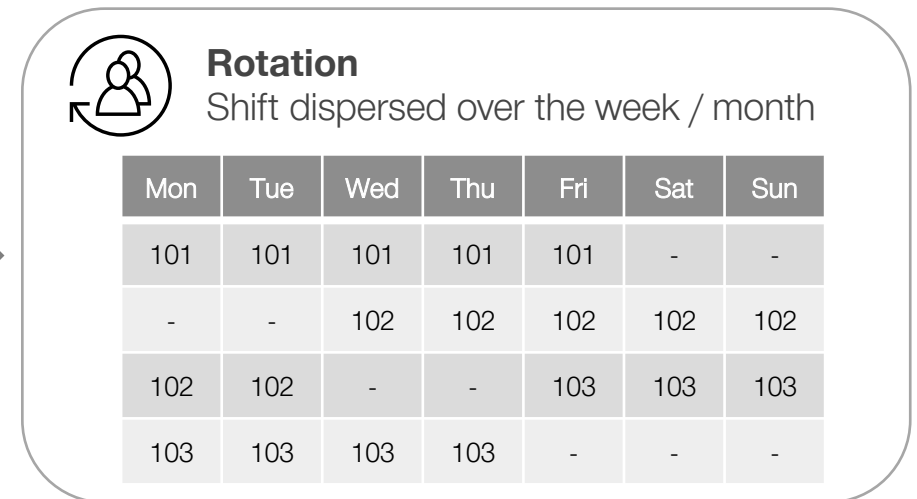
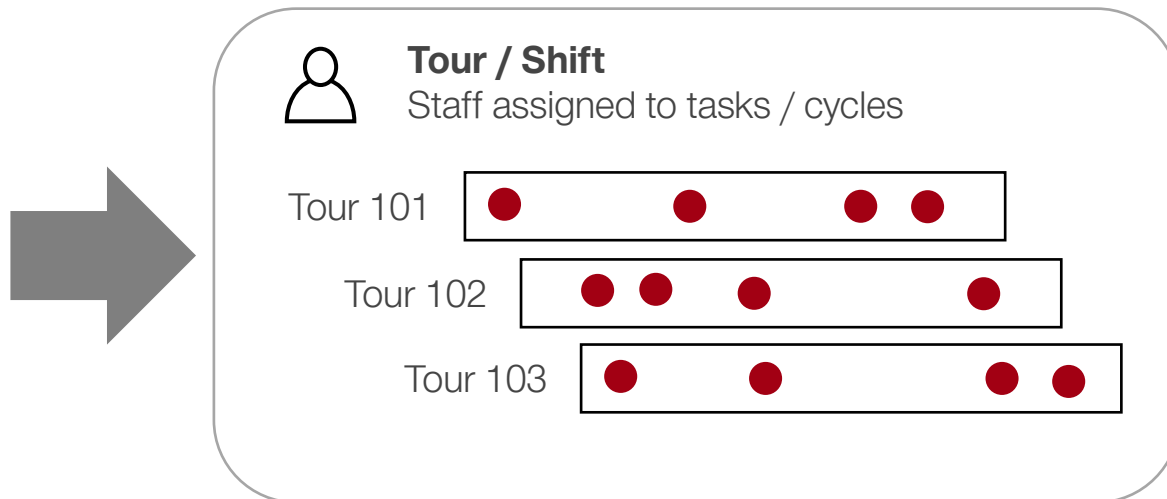
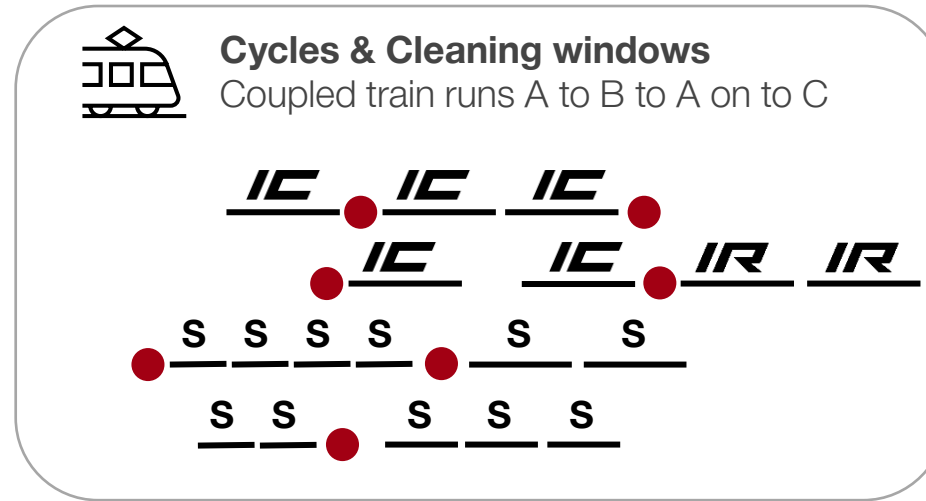
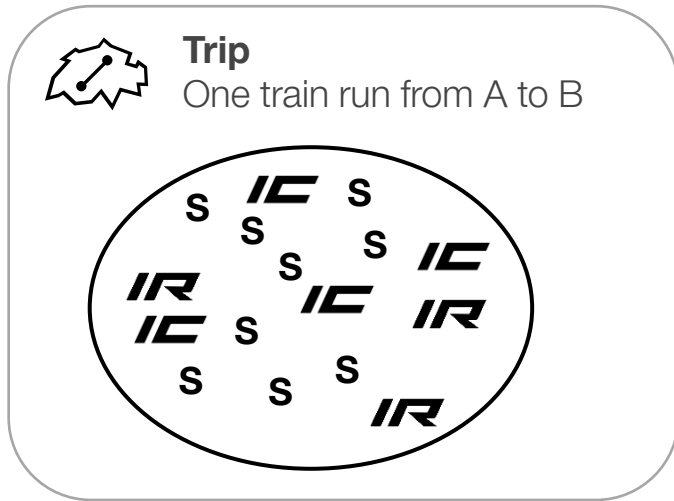
## Train drivers and shunting personal

- Train drivers are responsible for the safe and punctual transport of the customers.
- The shunting guard prepares the trains safely, correctly formed and according to the order.



# From train run to employee shifts.

Trips combined into duty cycles, supplemented with tours and embedded in rotations.



# Organized railway staff

Unions have been a fundamental partner in railway managements history

 RailFreight.com

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STARTING ON 25 OCTOBER

## Italy approves regulation for single freight train driver

Published on 16-10-2025 at 11:45

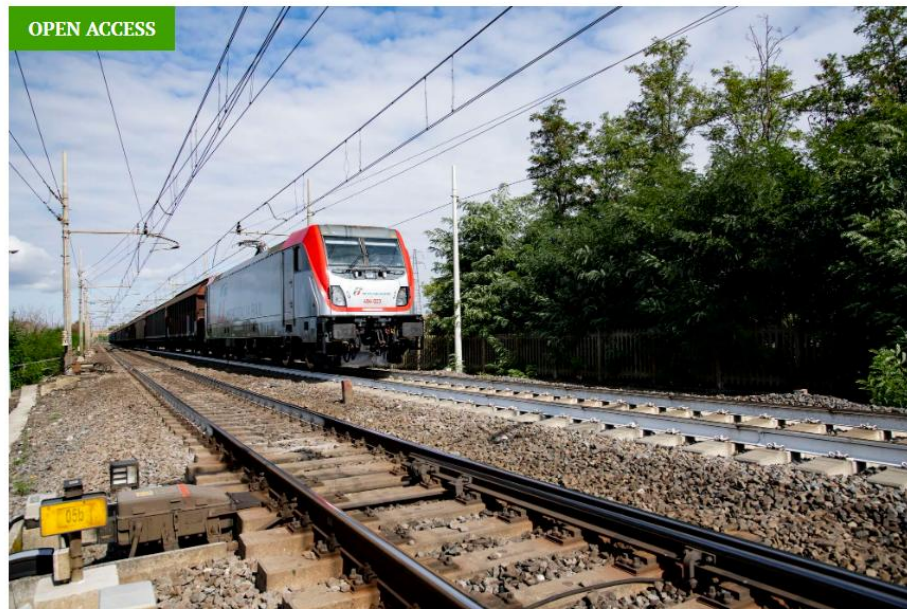


Image: © Mercitalia Logistics

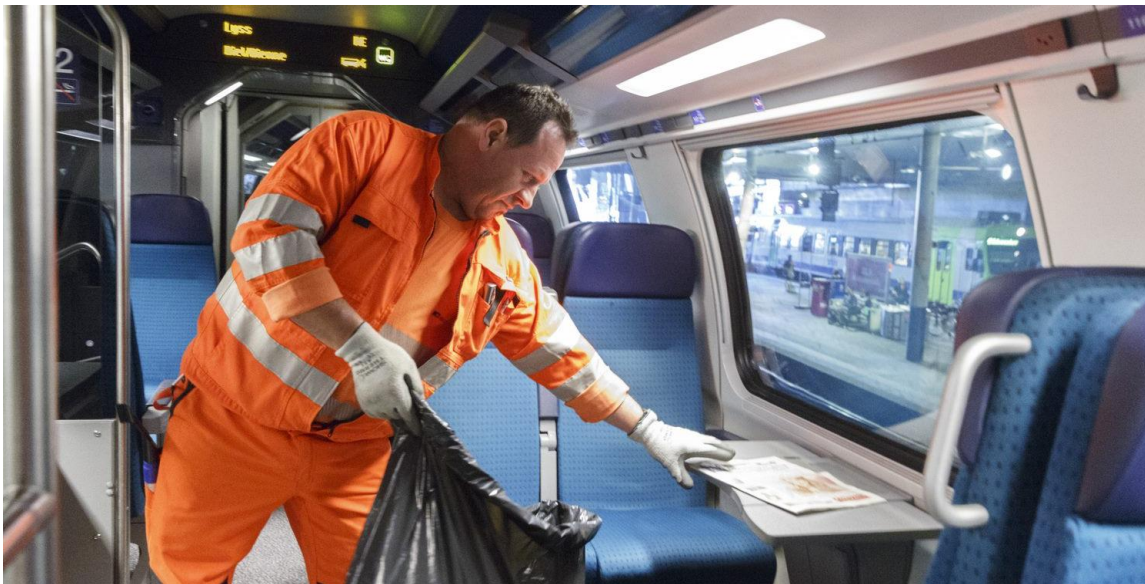
Freight trains in Italy still require two people in the locomotive due to safety reasons. However, the country's ministry of transport approved a new regulation, which will enter into effect on 25 October 2025, eliminating this requirement.

- Unions have a fundamental part in decisions in the railway system and are the voice of the operational staff especially.



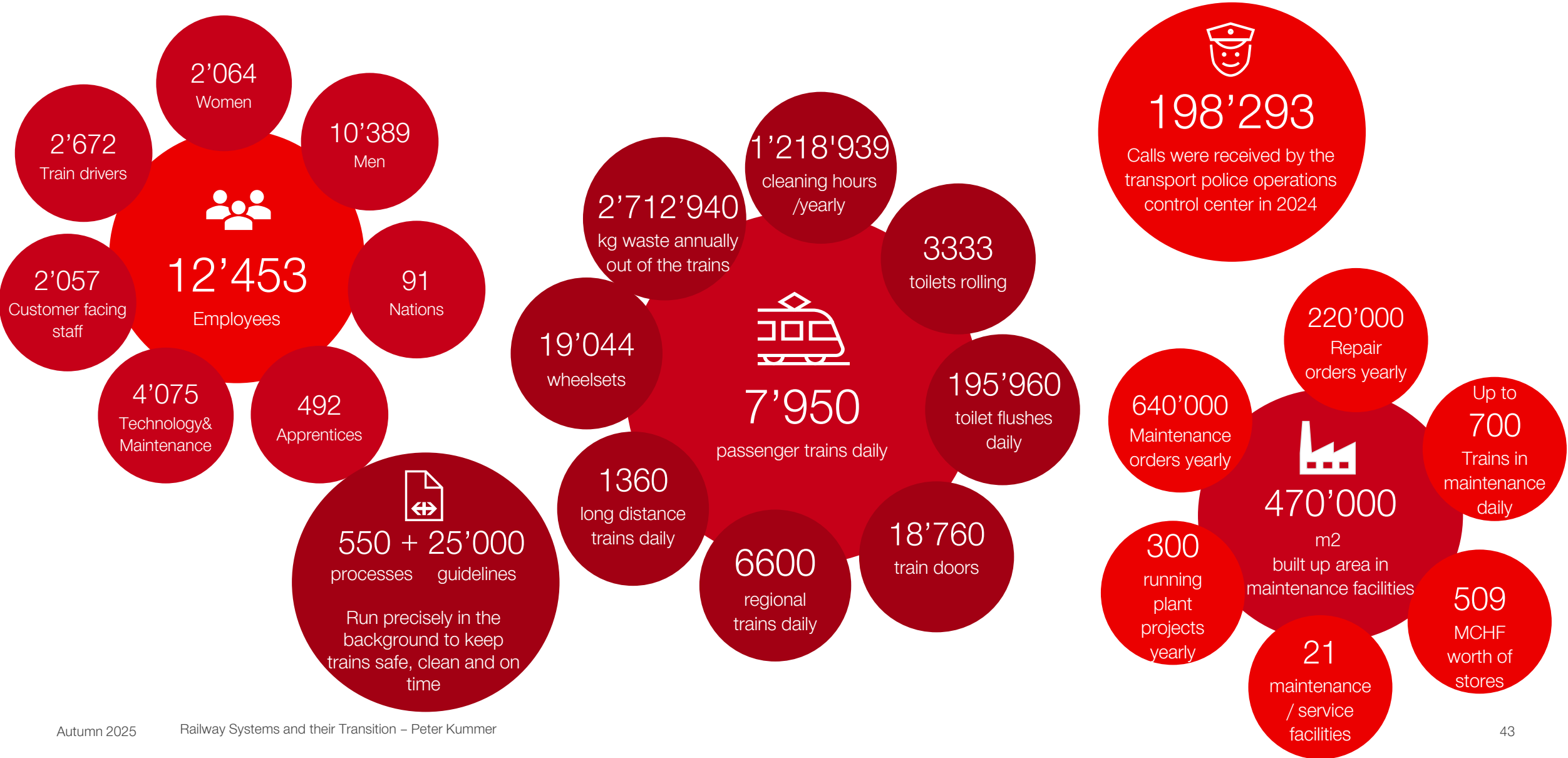
## Onboard customer service staff

- responsible for quality and customer satisfaction in the three important topics of "personal support", "cleanliness of the train" and "income security".





# Facts and figures passenger traffic operations (as of 2024)



# Cost overview passenger and freight transport operation

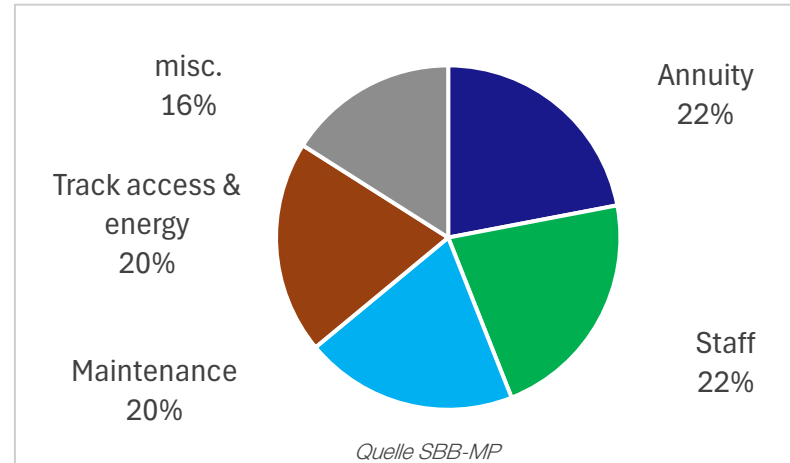
## Regional passenger train



≈ 25 CHF/km

RegioDosto RABe511 150m, seating 535

- Invest: 21 Mio. CHF
- Mean speed: 52 km/h
- Kilometrage: 190'000 km/year
- Operational staff: 1 driver



## Freight train (international)



≈ 15-20 CHF/km

North-south international, 600m, 1600 t

- Invest (loco only): 4-5 Mio. CHF
- Mean speed: 55 km/h
- Kilometrage (loco only): 150'000 km/year
- Operational staff: 1 driver & technical control

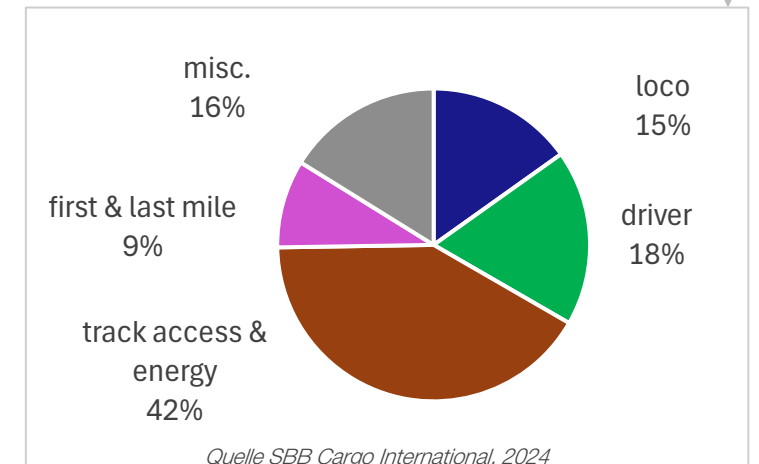
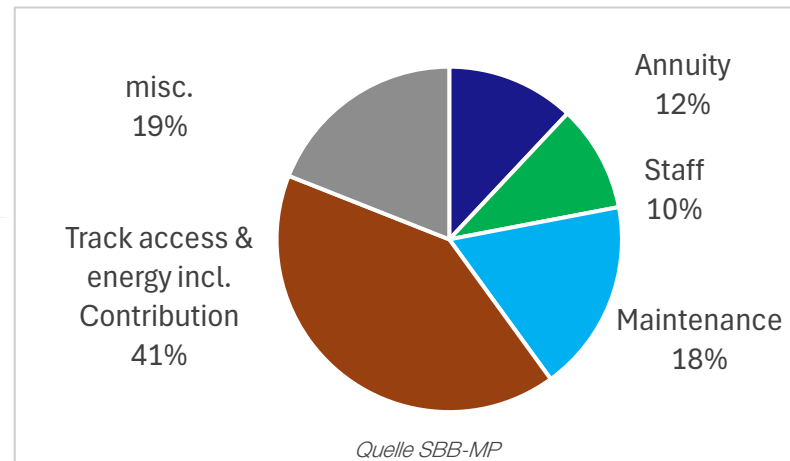
## Long distance passenger train



≈ 50 CHF/km

FVDosto IC RABe502 200m, seating 606

- Invest: 34 Mio. CHF
- Mean speed: 85 km/h
- Kilometrage: 410'000 km/year
- Operational staff: 1 driver & 2 customer attendant

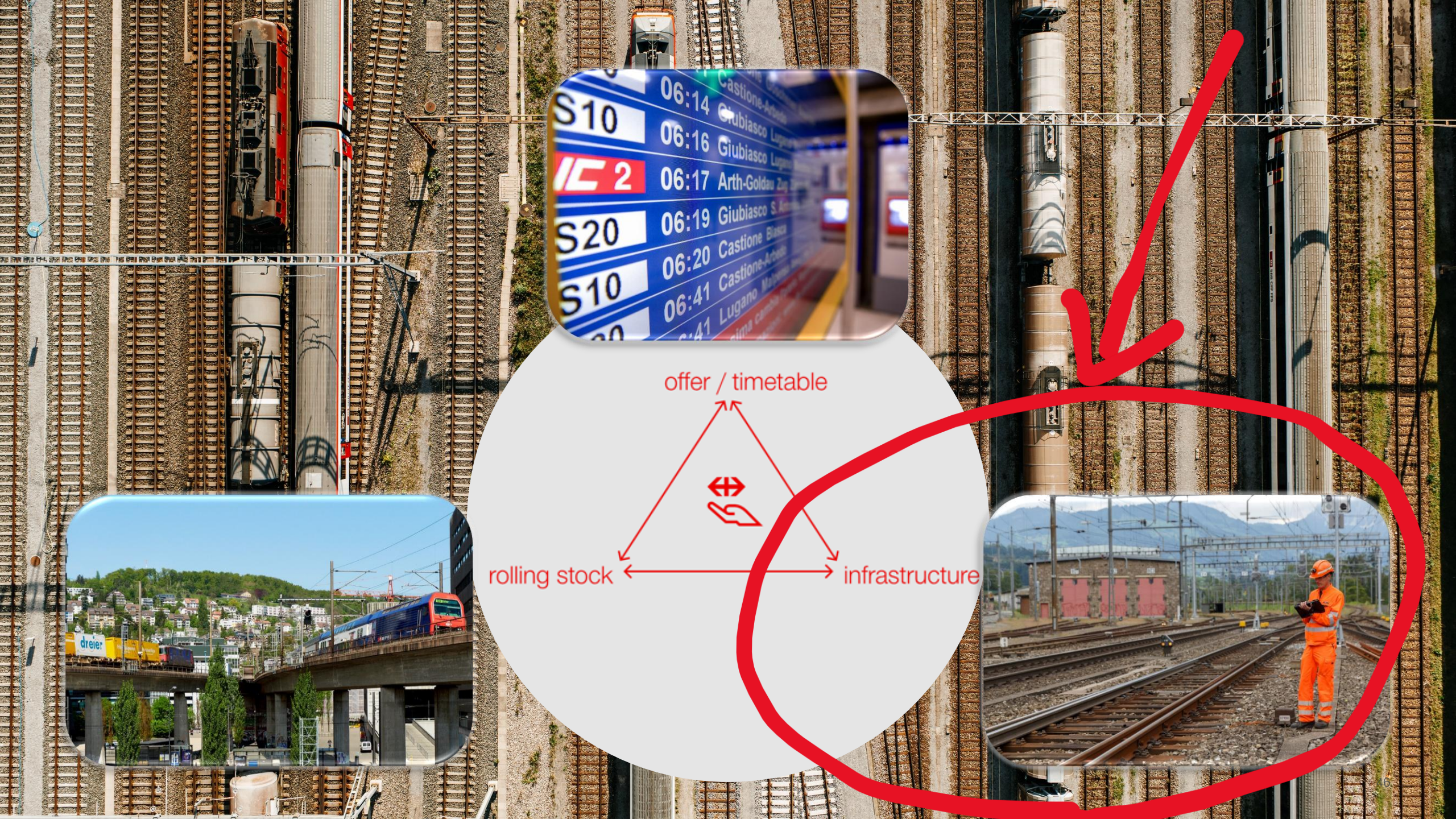


# Summary Rolling stock

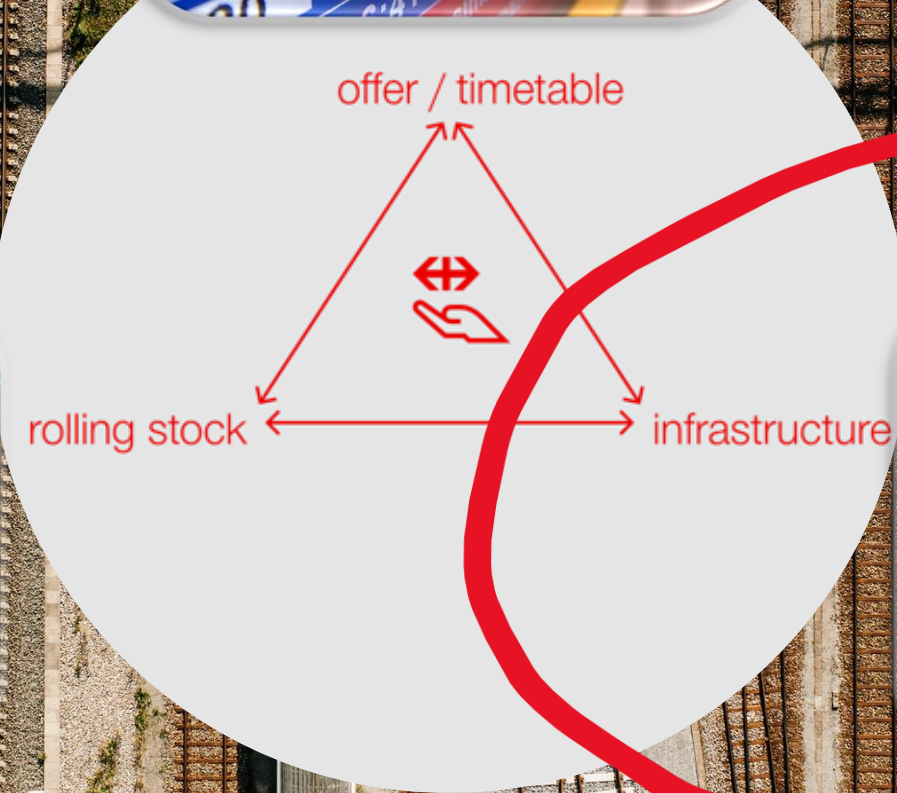


«Could you speed up? I should be in St. Gallen at 16:41»

- For the physical rolling stock see the respective deep-dive, lecture 30.09.2025
- We need the right people with the right skills at the right location to drive & maintain our rolling stock and take care of our customer needs.
- This staff is a huge and important part of our employee's population.
- Railway has regulated the relationship with this population with unions and sector specific contracts (GAV).



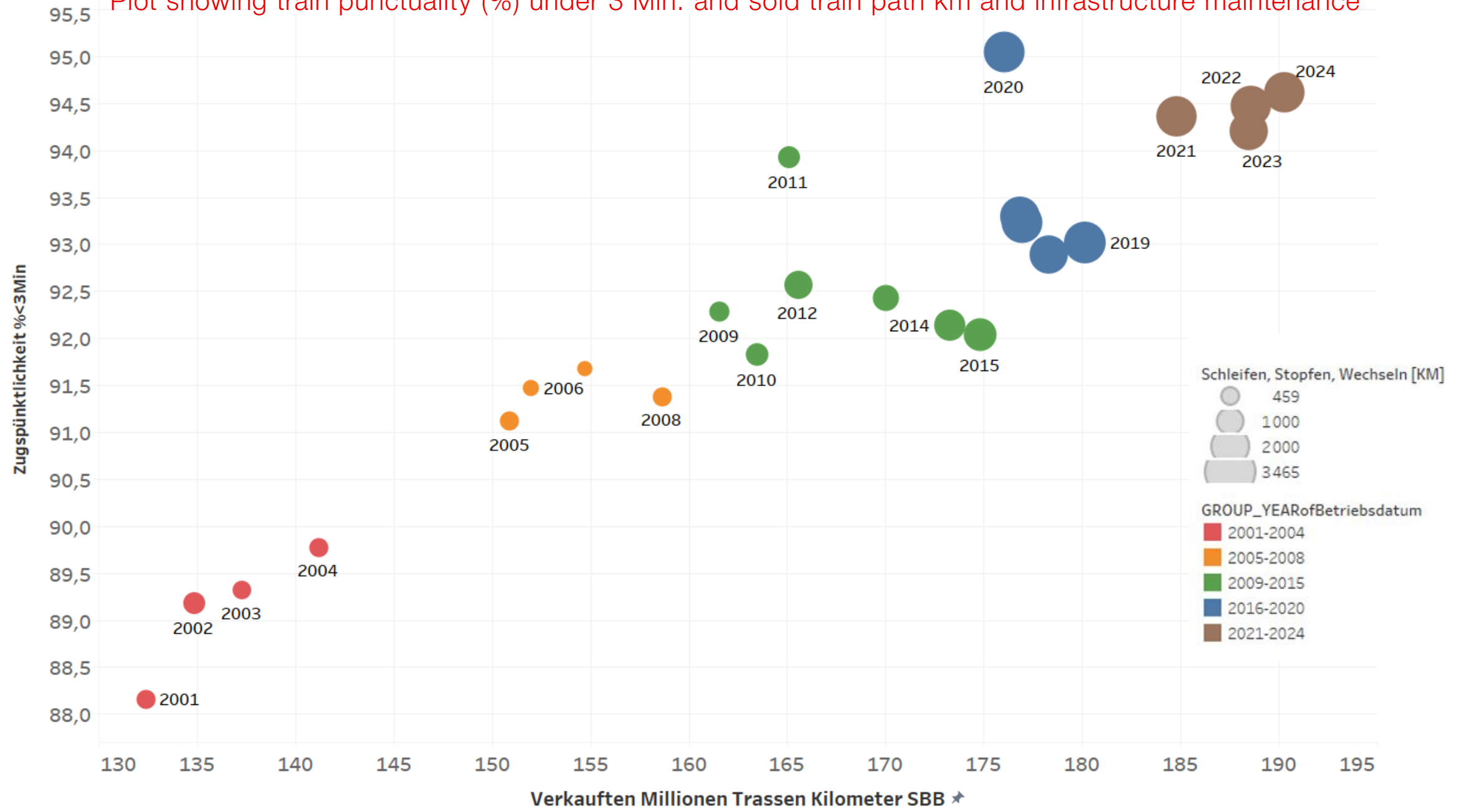
S10	06:14	Castione-Arvesio
IC 2	06:16	Giubiasco Lugano
S20	06:17	Arth-Goldau Zug
S10	06:19	Giubiasco S. Antonio
	06:20	Castione-Arvesio
	06:41	Castione-Arvesio
	06:41	Lugano campo



# Interval (work interval)

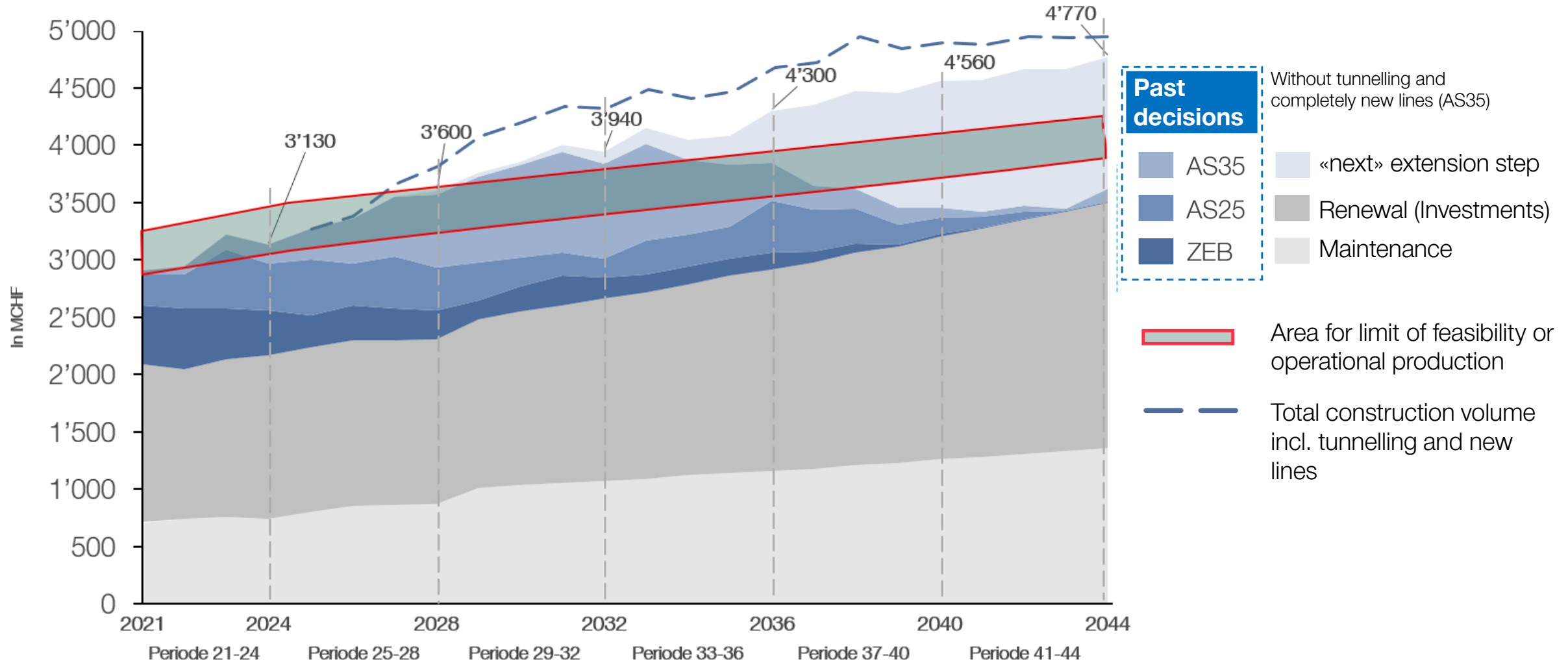
Capacity allocation for maintenance & construction works

Higher construction and maintenance and higher punctuality in the last decades.  
Plot showing train punctuality (%) under 3 Min. and sold train path km and infrastructure maintenance



# Testing the limits of feasibility

The construction portfolio 2025ff is getting close to what we can handle.



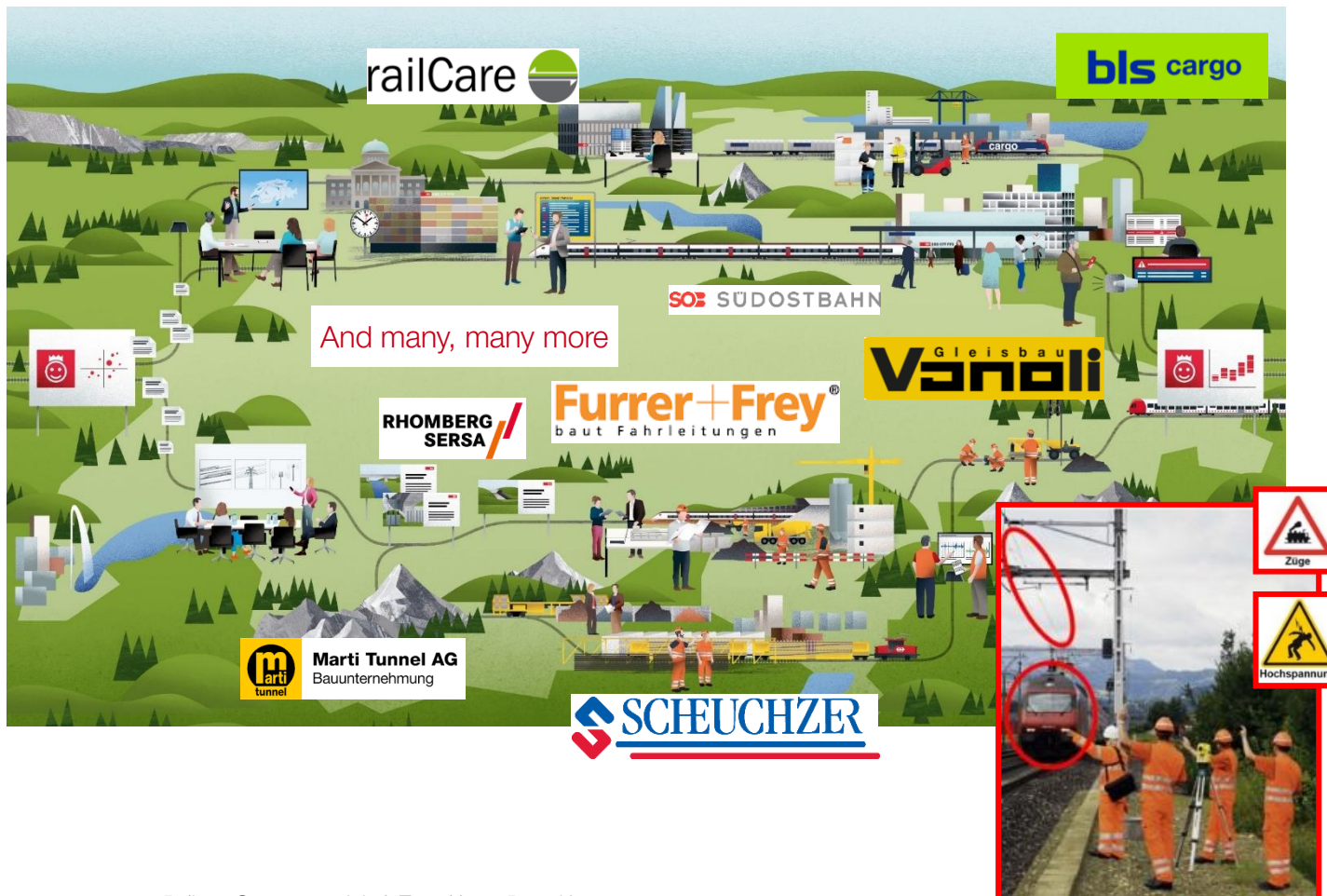


## Interval

An interval is the authorization to restrict the operation of asset (parts) and thus the capacity compared to the normal state for work in the track area or near the railway at fixed times.

# Conflicting interests with safety, quality and efficiency.

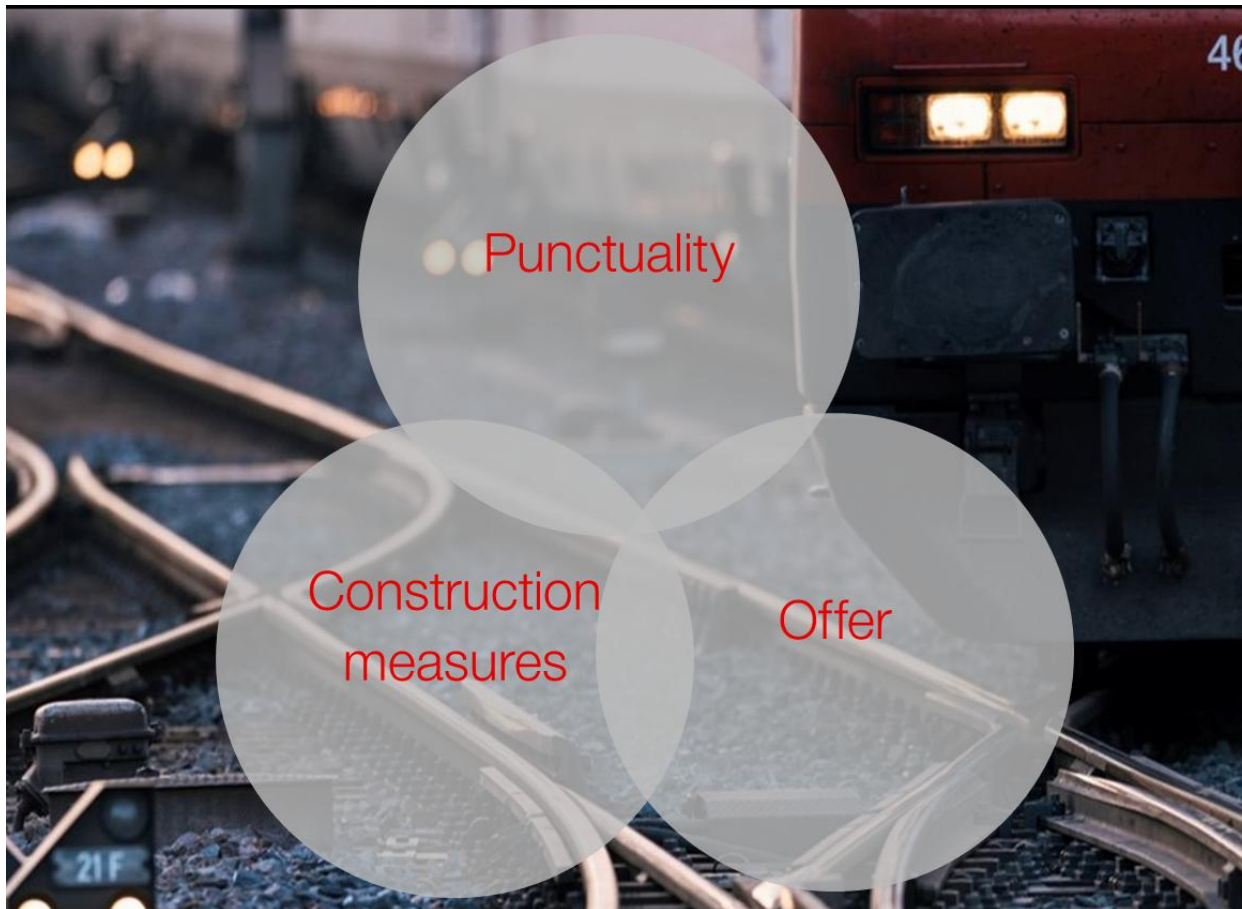
An interval is the authorization to restrict the operation of asset (parts) and thus the capacity compared to the normal state for work in the track area or near the railway at fixed times.



- **Safety and punctuality** for the construction personnel and passing trains.
- **Efficient utilisation** of personnel and machinery as well as reserve for "surprises" (underground, weather, logistics, breakdowns, machines,...).
- **High quality of execution** to ensure a long service life (Total cost of ownership TCO) and high availability.

# Current challenges: capacity allocation operation vs. maintenance

The trade-off between trains running (on time and frequent) vs. downtime of a line.



- Maintenance and expansion of the railway network puts a strain on punctuality and restricts the offer **now**.
- Postponing maintenance works on the network will put the strain on punctuality and capacity reduction **to the future**.

# Example: Total closure of the line Fribourg – Bern 2025

Line closure for two months (27.06-25.08.2025) with many worksites simultaneously.

**Bümpliz Süd-Europaplatz:**  
Fahrbahnerneuerung und Bau einer Lärmschutzwand. Gehört zum Projekt «Leistungssteigerung Bern West».

**Düdingen:**  
Fahrbahnerneuerung und Weichenersatz. Bau einer Unterführung durch die Gemeinde.




**Fribourg/Freiburg und Flamatt:**  
Böschungsverstärkungen.

**Ostseite des Bahnhofs Fribourg/Freiburg:**  
Weichenerneuerung.

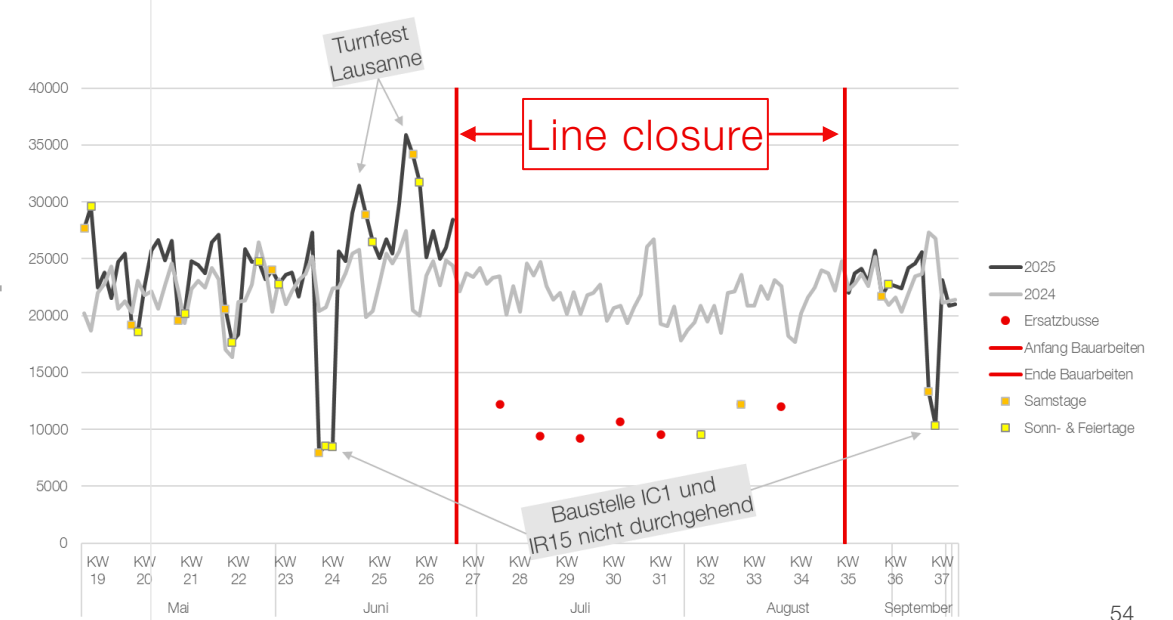
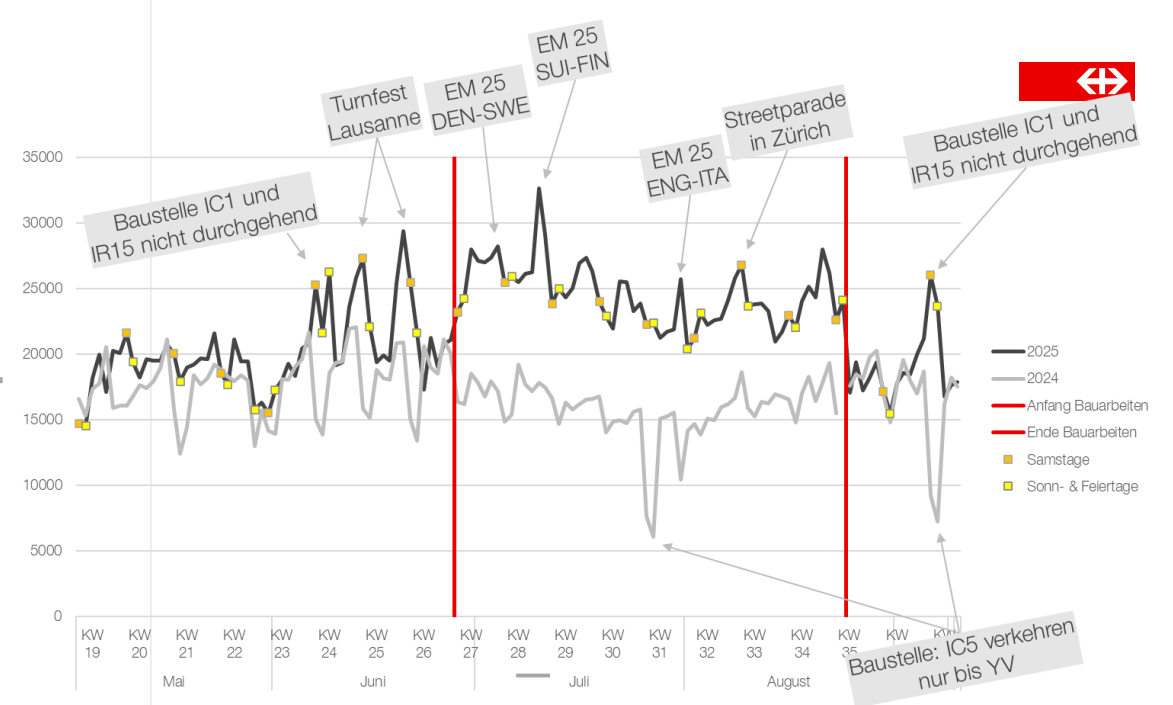
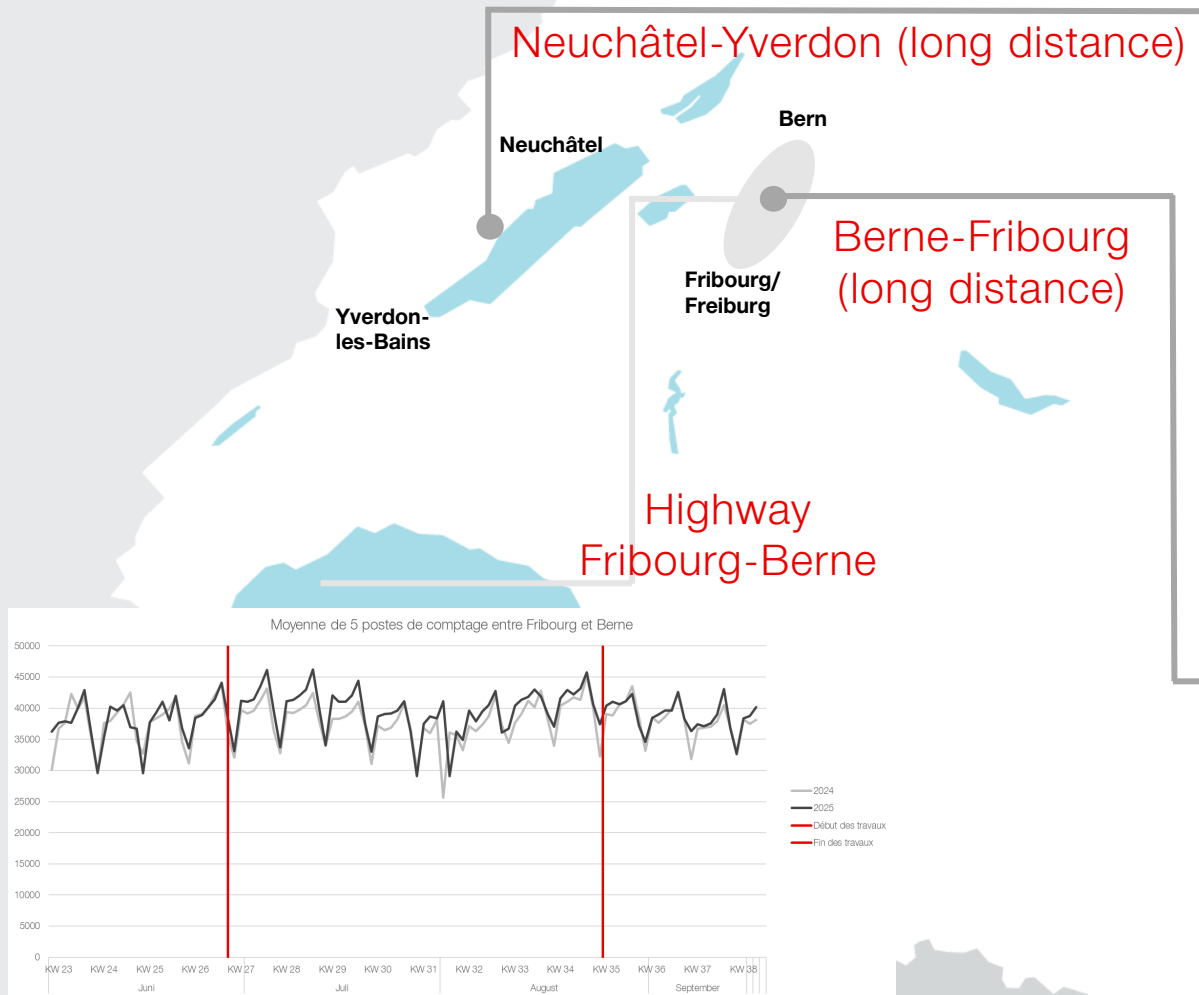
**Schmitten FR:**  
Umbau des Bahnhofs, damit die Reisenden die Perrons und Züge stufenfrei erreichen können, sowie Fahrbahnerneuerung im Bahnhofsbereich.

**Flamatt-Bern Bümpliz:**  
Fahrbahnerneuerung auf 6,5 Kilometern und Ersatz der Bachdurchlässe Thörishaus Station und Oberwangen. Totalerneuerung der Fahrleitungsanlage zwischen Flamatt und Thörishaus Station.

**Stations and locations on the map:** Bern, Bern Europaplatz, Bern Bümpliz Süd, Niederwangen, Oberwangen, Thörishaus Station, Thörishaus Dorf, Flamatt Dorf, Flamatt, Wünnewil, Schmitten FR, Düdingen, Laupen BE, Neuenegg, Fribourg/Freiburg Poya, Givisiez, Ittaux CFF, Fribourg/Freiburg.



Facts and information: impressive passenger shift to the 'southern Jura-foot' line and the customers are back in our trains.



# There is no difference when using train replacement buses. The customers travel “in the train on the road”.

No single bus partner able to bring that many buses and drivers during summer holidays.

**3 Bus partners**



Replacement designed for **23'000 passengers/daily**



**10' frequency**  
Fribourg–Bern

Dimension for 23'000 travellers and maximal travel time loss <15'

No space for 5 to 6 buses in the cities. Turning production-related constraint into customer-advantage with a bus every 10'.

Crucial stakeholder management, critical operational feasibility and space constraint in inner-city streets and curbs.

**50 Employees**  
Cantons/Cities  
BERNMOBIL,  
TPF



**59 days continuous**

First time closing a main line for so long, in favor of a short, intensive and efficient construction period.

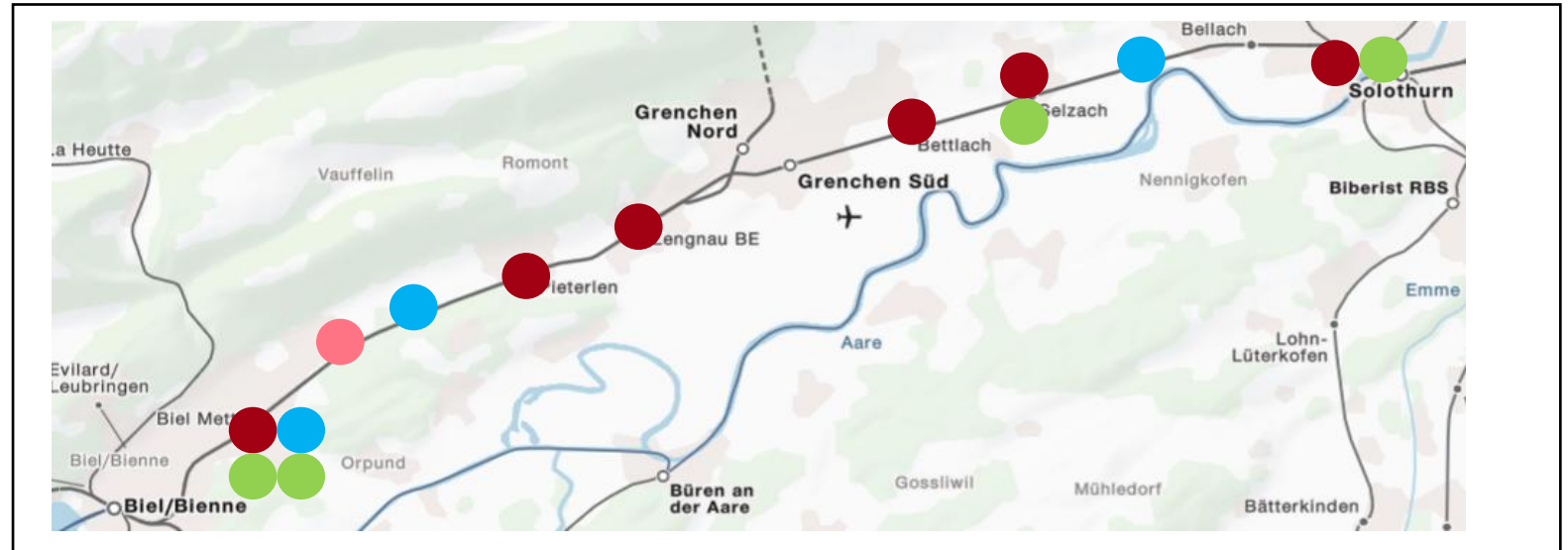
# 2027 Clustering Biel/Bienne – Solothurn is being planned

20 weeks single track line operations instead of 1'000 nightly closures (= 4 years).

## Construction objects

- 6 station projects (PRM) ●
- Track total 8,5 km ●
- Noise abatement ●
- Engineering structures ●

**Costs 150 Mio. CHF**



## Duration and variants clustering

- Start of main construction phase: 19.06.27 (20 weeks continuous single-track operation)
- With conventional 8h Interval this would result in around 1000 night shifts (= 4-year period)
- Original variant with 2x4 weeks single track operation replanned to allow for 4 train slots per hour and direction.
- Total closure rejected at early stage due to major operational impact and necessary topology adjustments on detour routes.

# SBB Target “improving interval management”

## 1a Clustering needed works

Knowing what, where and when there is upcoming maintenance and construction work.

## 1b Traffic planning concepts

Integrating customer needs and focused replacement concepts.

## 1c Maintenance windows

Using systematized time slots for regular maintenance in “non-cluster” years.

## 2 Stable and formal cluster planning

### Stable and formal cluster planning

Integrating interval- and replacement concepts at an early state into capacity planning (x-5/7 years)

## 3 Keeping promises

Stable fit to milestones

## 4 Optimal construction

Financial benefits and good execution quality with optimal construction conditions.

## 5 Maximize customer benefit

Integration the customer view in the best possible way and reliable execution.

Dimension

Planning and concept

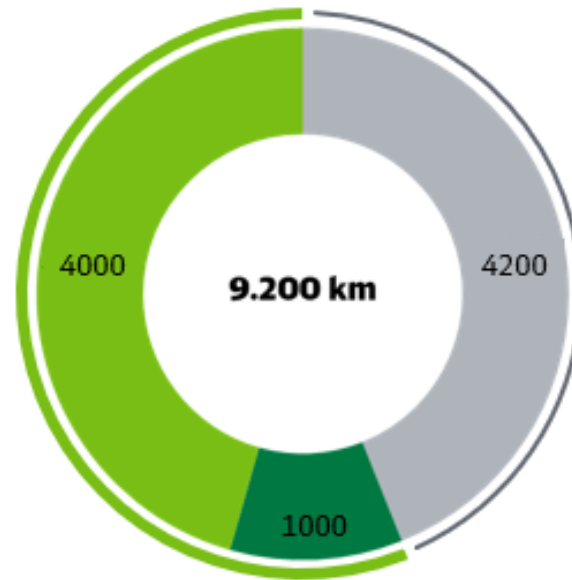
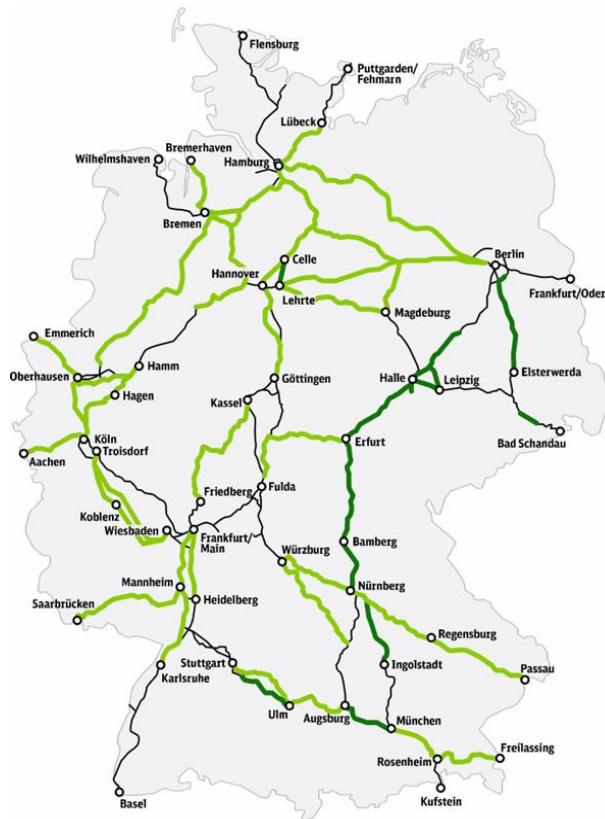
Dispatch and execute

# Example Germany: The general refurbishment plan

Over 4,000 km planned to create the new high-performance network by 2030.

## High-performance network in 2030

[in distance km]



- General renovation
- Track in good to very good condition
- Maintenance

Failure-resistant systems ensure a more reliable infrastructure and thus increase punctuality for our customers

Optimal equipment and layout standards ensure more train volumes and thus increase the performance of the infrastructure

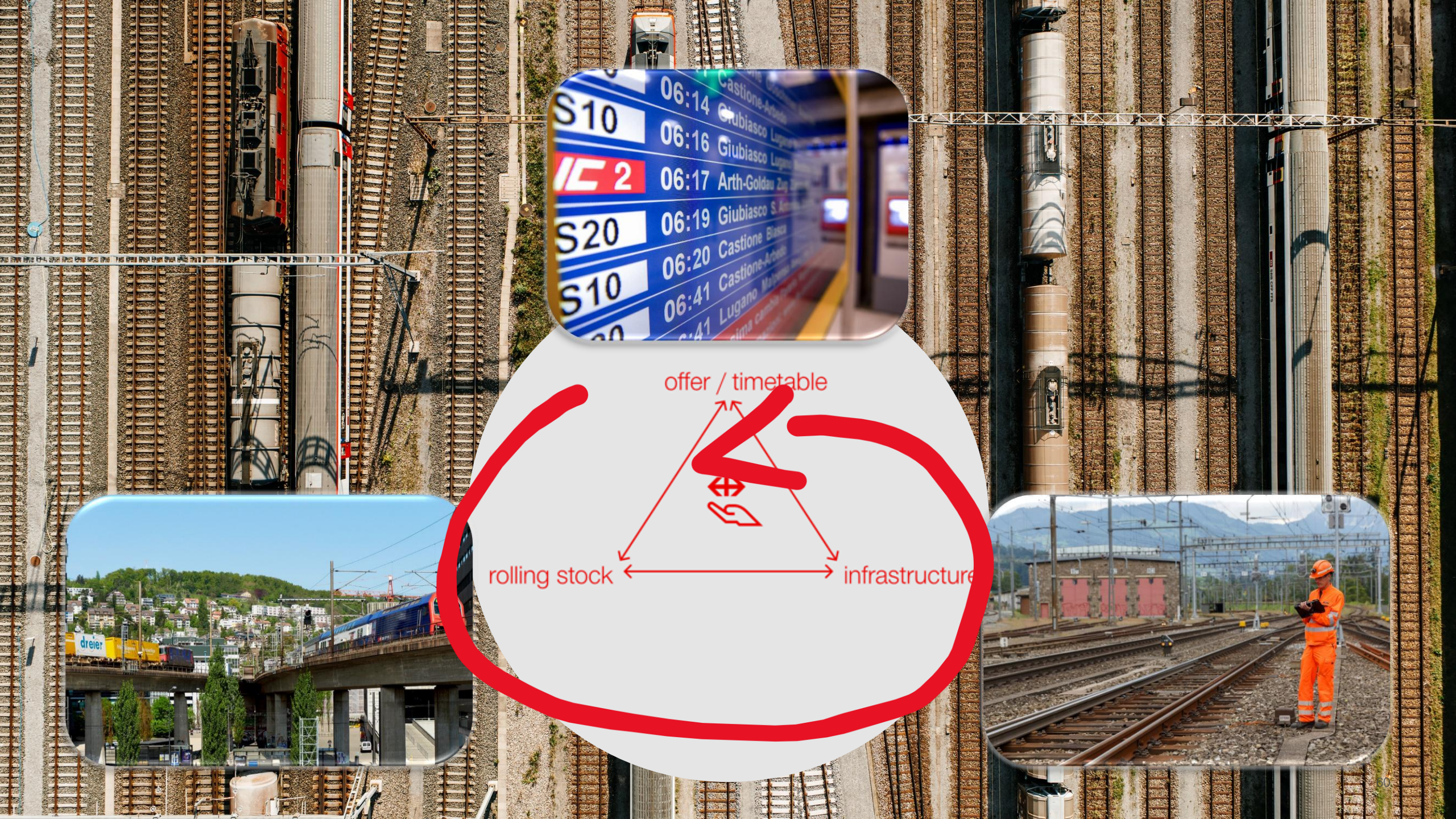
We improve the customer experience through attractive, clean and barrier-free stations

We are reducing future traffic restrictions to a minimum and thus creating more predictability for our customers

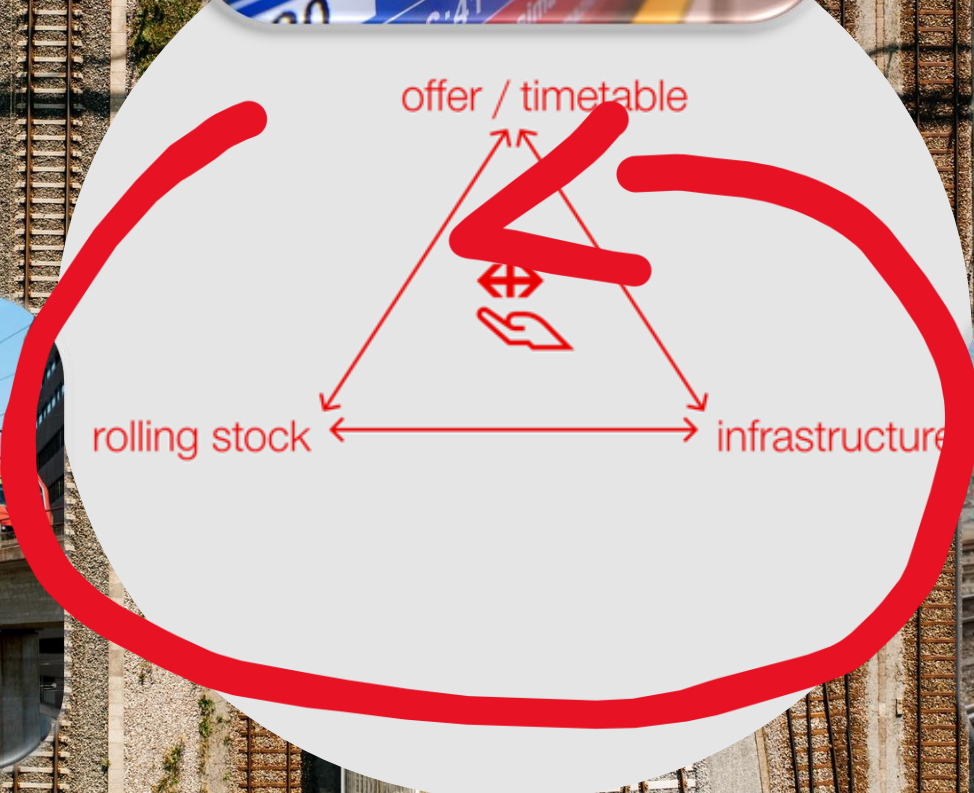
# Summary Interval



- Interval are a precious piece of capacity.
- The conditions for work execution are fundamental for the price tag and the quality of the work.
- The interdependencies between work requirements and customer needs are not trivial.
- Clustering and stable planning are the way to go.



S10	06:14	Castione-Arvesio
IC 2	06:16	Giubiasco Lugano
S20	06:17	Arth-Goldau Zug
S10	06:19	Giubiasco S. Angelo
S10	06:20	Castione-Arvesio
S10	06:41	Castione-Arvesio
S10	06:41	Lugano





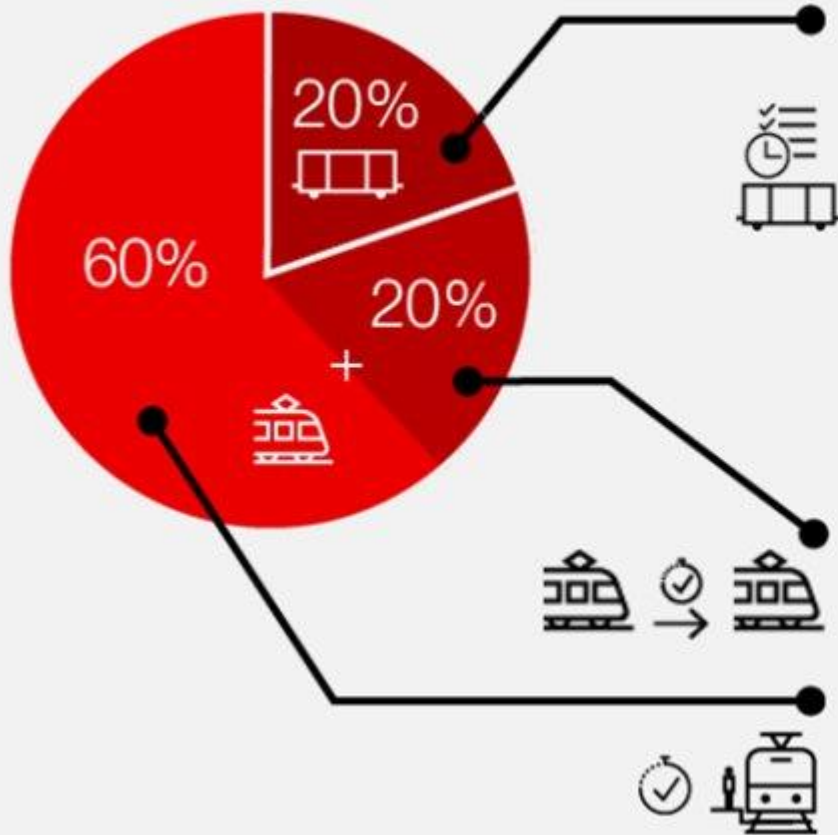
# Feedback loop

analyze, detail level, learning and improving

# Punctuality as a technical target (KPI)

Good punctuality means reliability for the customers and the system.

The 100% of the target value for punctuality are calculated as follows:



## Freight traffic punctuality

### Punctuality SBB Cargo (target 2023: 93%)

Consignment punctuality single wagon load traffic

Target value of consignments that arrived at their destination with the communicated time slot

## Passenger traffic punctuality

### Connection punctuality (target 2023: 98.8%)

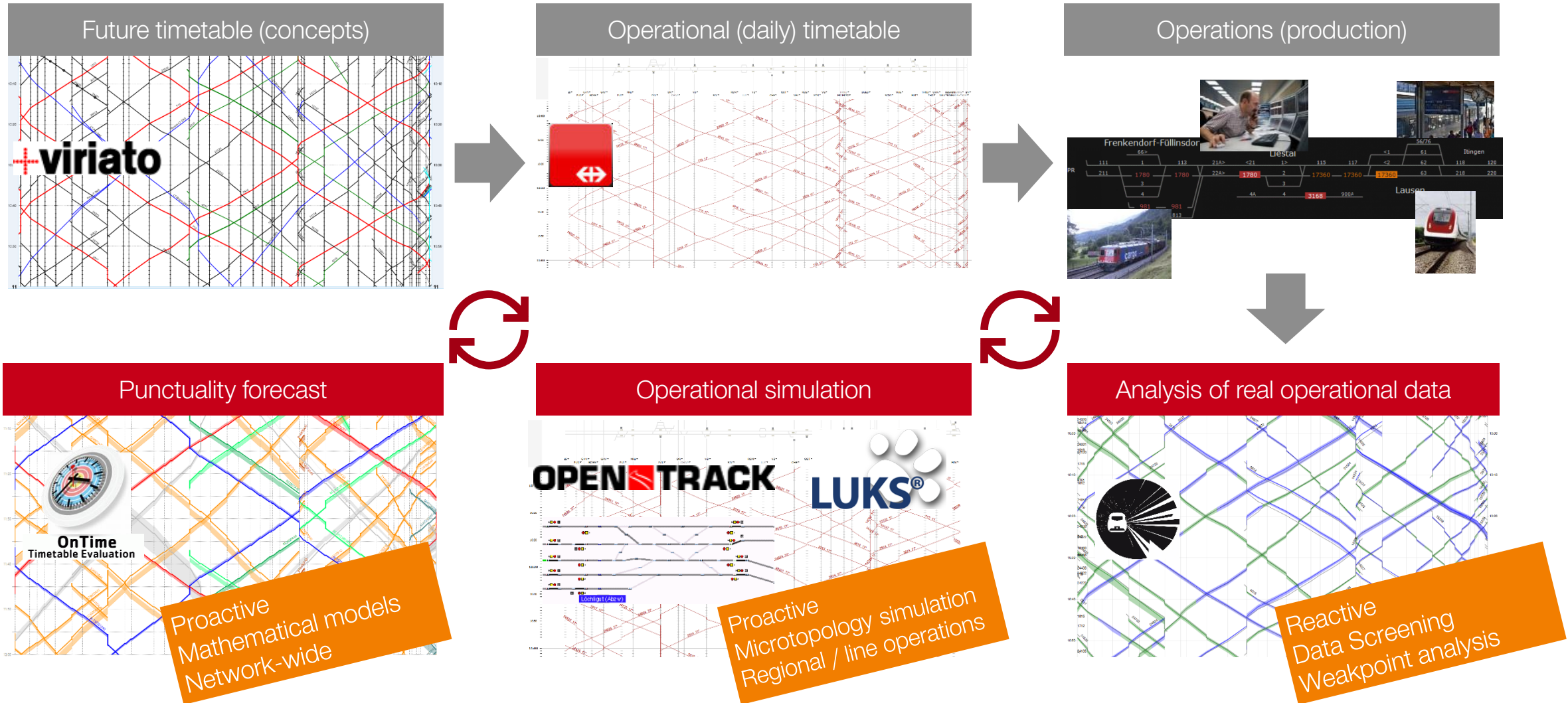
percentage target of all connections adhered to

### Train punctuality (target 2023: 90.5%)

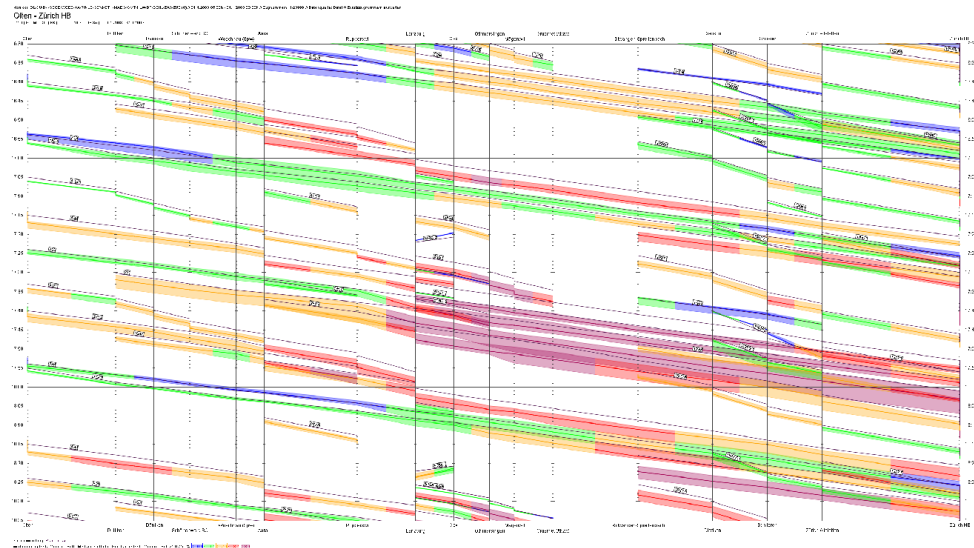
percentage target of all trains arriving on time at their scheduled stops

# The timetable planning roadmap - Recap

Use of various tools to reactively or proactively identify and correct weak spots.

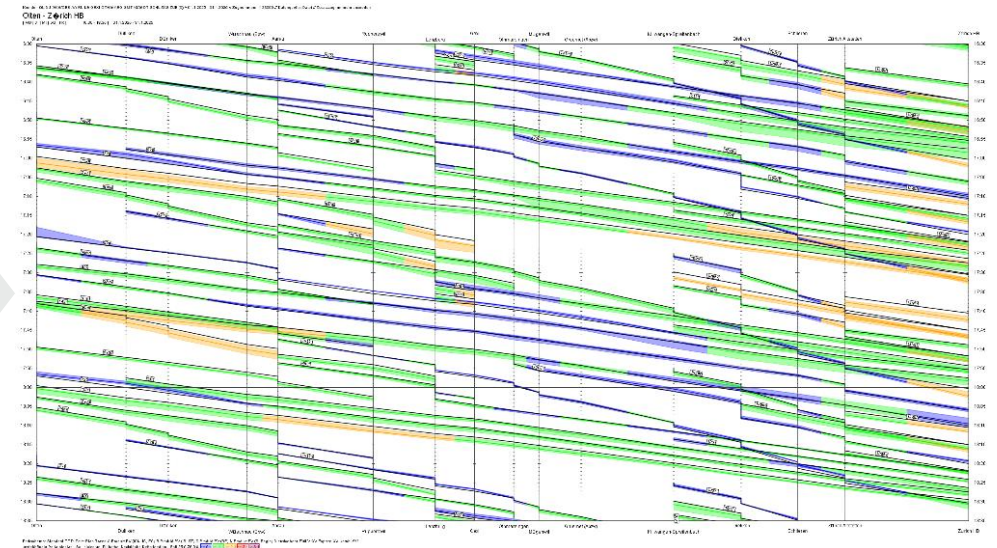


# A significant increase in train numbers and density. The operations need to be precise on a much higher level.



2003

2003 until 2025  
significantly  
more trains,  
tighter  
headways



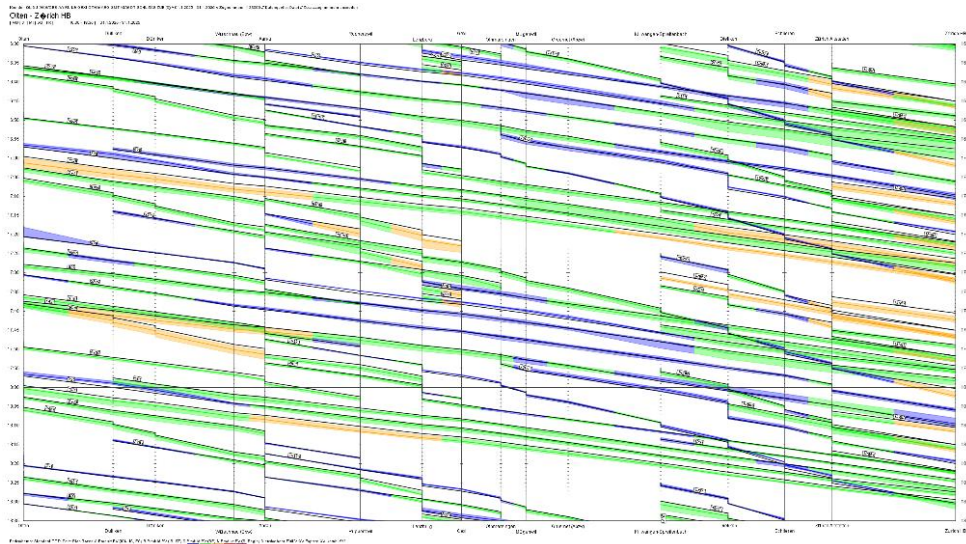
2025

- Delayed (or ahead of time) trains **reduce capacity** on a highly charged network.



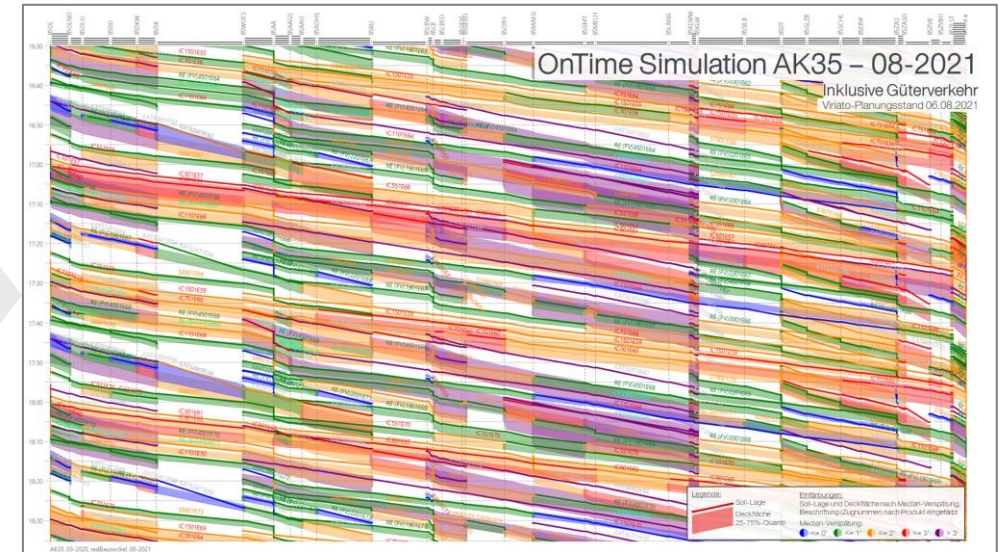
# Even more traffic increase brings new challenges for rail production.

Increasing capacity with adding more trains to the network led to growth pains.



**2025**

2025 until ~2035  
more trains,  
even tighter  
headways



**Concept 2035**

- Delayed (or ahead of time) trains **reduce capacity** on a highly charged network.
- The **production quality** must be further improved
- The planning (evaluation) is improved for a **stable and punctual timetable** .



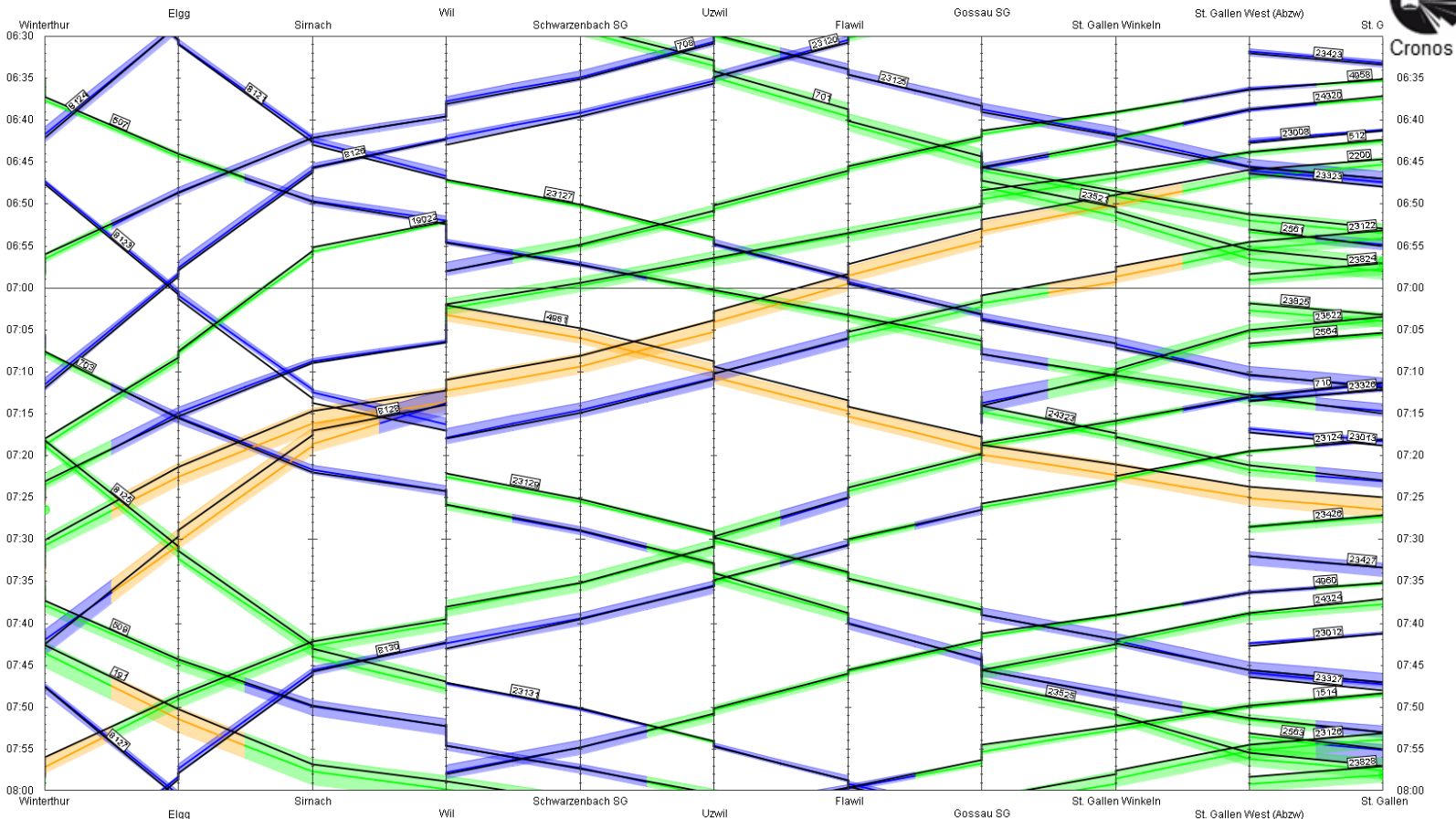
# Learning from operations

Analyses from actual data show stability and punctuality of the timetable.

Konfidor: - // W-EL-SIR-WIL-SCHZ-UZWF-FLA-GSS-SGW-SGW-SG // 02.03.2015 - 27.04.2015 // Zugnummern, -gruppen: 1-29999 // Zusatzzugnummern auswerten: Nein

Winterthur - St. Gallen

| MO | DI | MI | DO | FR | SA | SO | 06:30 - 08:00 | 02.03.2015 - 27.04.2015



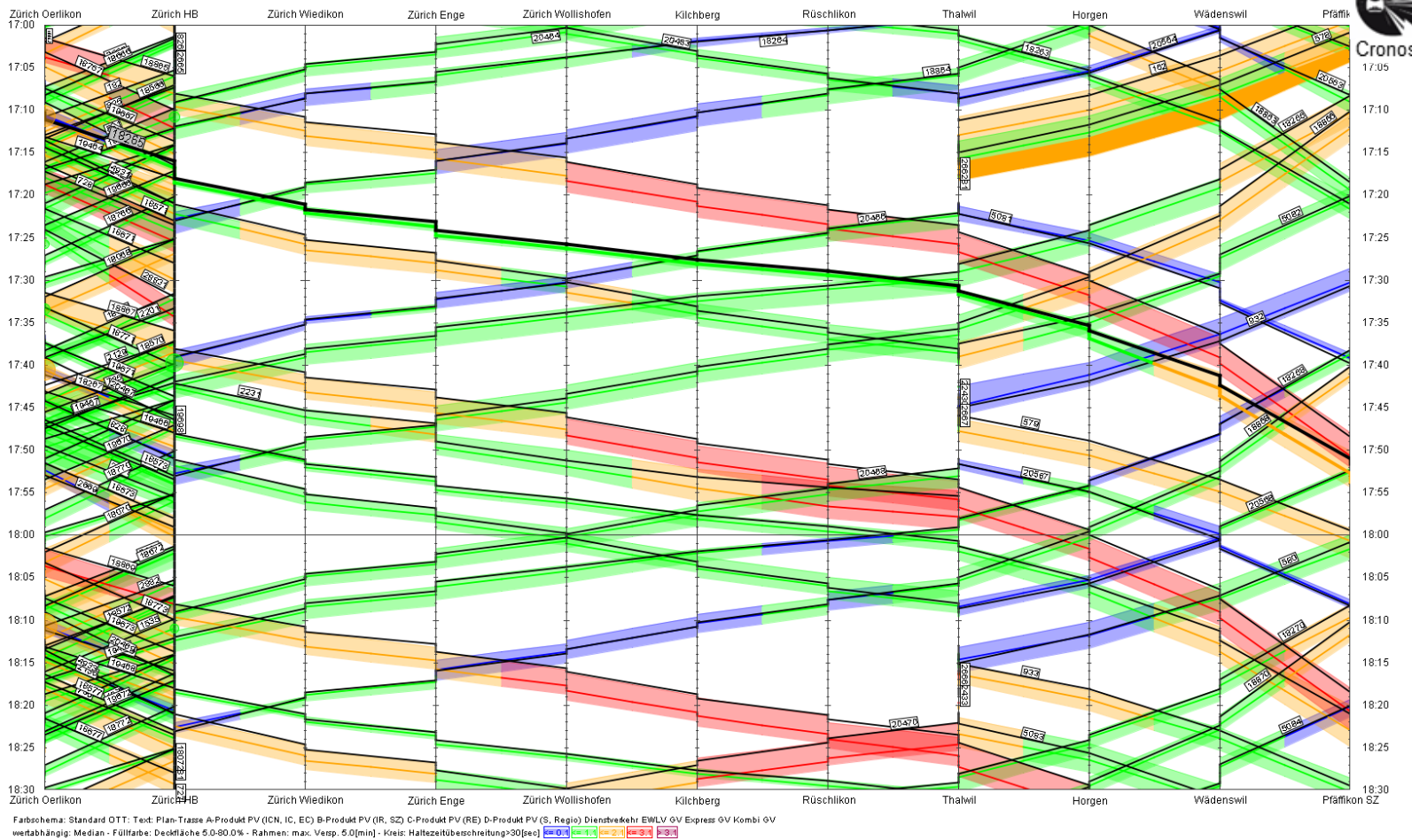
Farbschema: Standard OTT: Text: Plan-Trasse A-Produkt PV (ICN, IC, EC) B-Produkt PV (IR, SZ) C-Produkt PV (RE) D-Produkt PV (S, Regio) Dienstverkehr EWLV GV Express GV Kombi GV wertabhängig: Median - Füllfarbe: Deckfläche 5.0-80.0% - Rahmen: max. Versp. 5.0[min] - Kreis: Haltezeitüberschreitung>30[sec] [0-1] [1-2] [2-3] [3-4] [4-5]

- Example of a **very punctual line** (including morning peak hours)
- Mean delays at max. 2 min and within 3 min tolerance.
- Stable timetable and low daily spreading of train runs (narrow coloured areas).
- No need for action.

# Learning from operations

Routes with critical punctuality and stability are subjected to an in-depth analysis.

Korridor: // ZOER-ZUE-ZWIE-ZEN-ZWOL-KIL-RUES-TW-HG-WAE-PF // 02.03.2015 - 27.04.2015 // Zugnummern, -gruppen: 1-20999 // Zusatzzugnum  
Zürich Oerlikon - Pfäffikon SZ  
| MO | DI | MI | DO | FR | SA | SO | | 17.00 - 18:30 | | 02.03.2015 - 27.04.2015

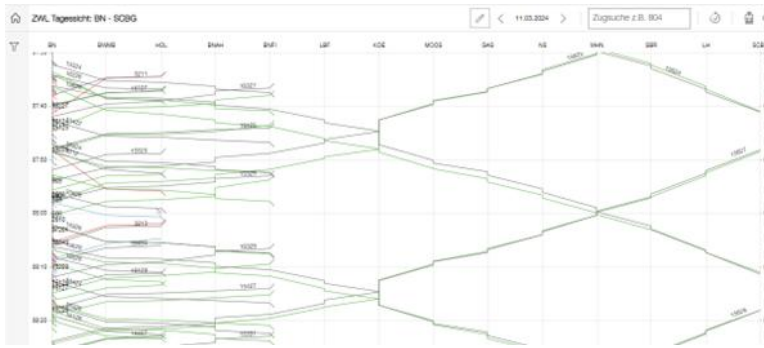


Cronos  
17:05

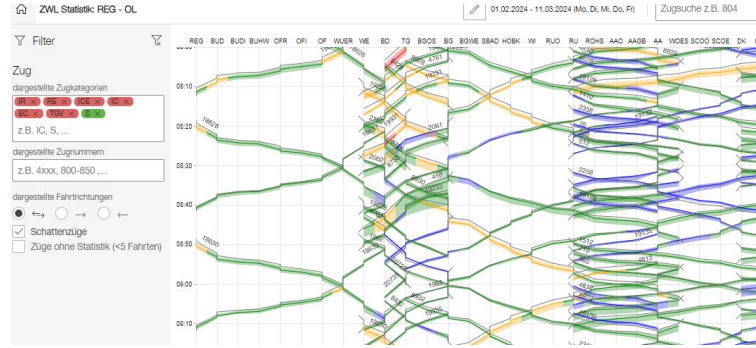
- Example of a **line with critical punctuality**.
- Mean delay at almost 3 min (red coloured areas).
- Huge spreading of train runs (large coloured areas).
- Delays are transferred onto other trains.
- Root-cause-analysis needed.

# Analytics tool CRONOS

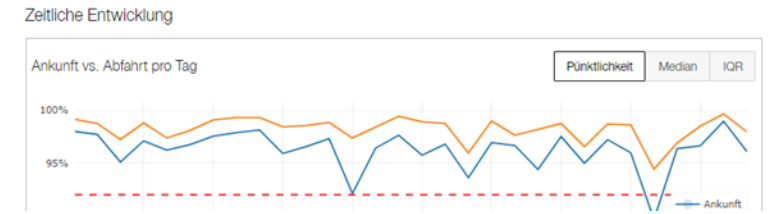
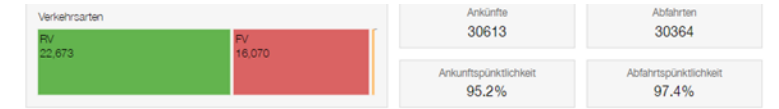
# Live demonstration



**Daily view** Assessment of individual days on selected corridor.



**Train statistics** Recognition of systematics with cover area and colored median value.



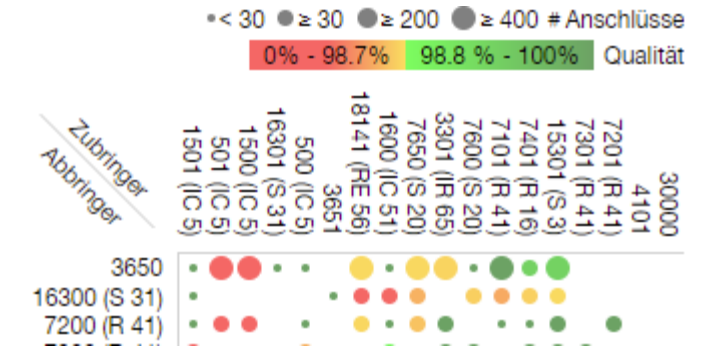
**Station** Detailed information for the selected freight and passenger node.



**Train family (passenger)** Details on temporal development, corridor and train number level.



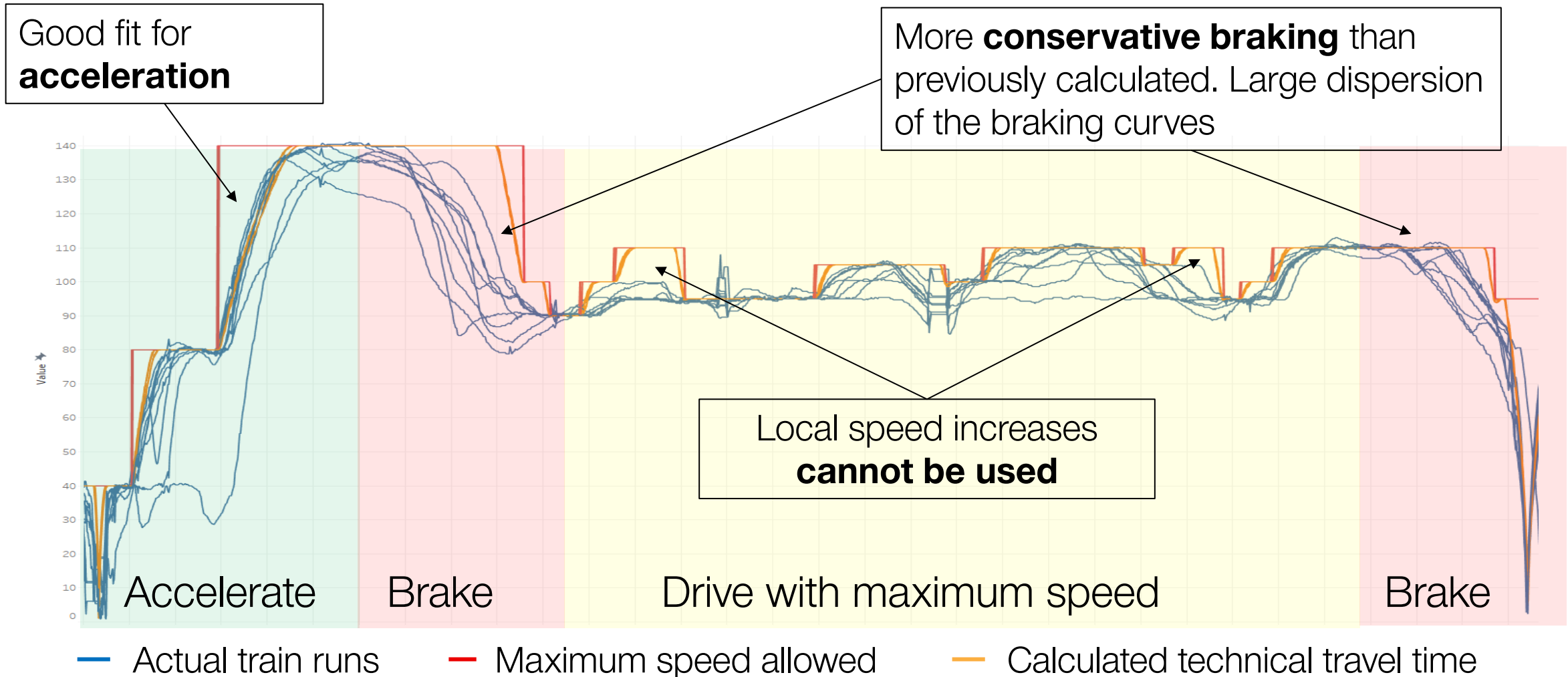
**Single train journey** Train run in one day including connection achievements.



**Connection** Connection quality from train family to train family on a node basis.

# Timetable reality check

The (previously) calculated technical travel times are not feasible.



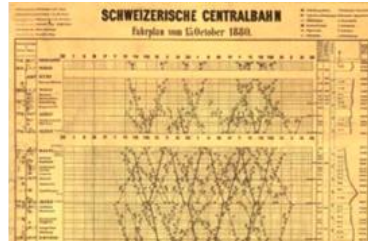
# Tools, processes and people

Efficiency, digital support, automation and complexity handling ...

# Connecting people, data and systems:

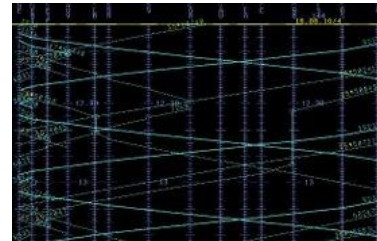
Planners „drawing in NeTS“ is put into operation in the command centers and drivers cabins.

Papier & Bleistift



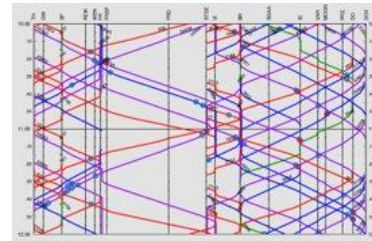
1847

Syfa



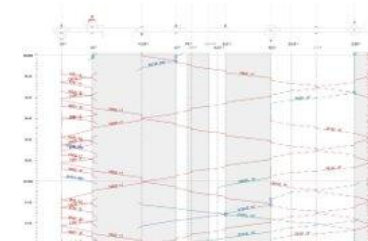
1988

Viriato



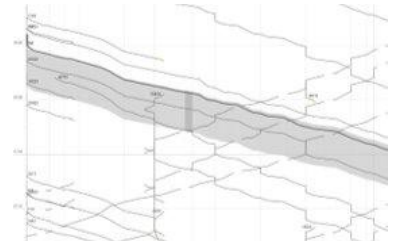
2005

NeTS bis Fpl. 2027



2007

TMS



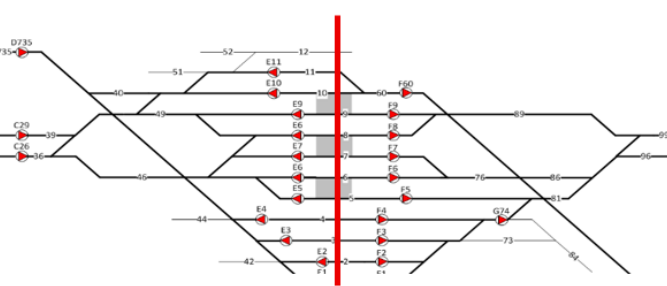
2030/31 TMS go live

2025 train timetable trips are **still planned manually** by experts with the planning **knowledge in their heads**.

Capacity planners master more than **700 specifications** and identify and resolve conflicts.

Two hours before departure a detailed driving profile (vPRO) for the driver is automatically generated.

BP	Gleis	Fahrtweg	betrAn	betrAb	F...	frühAb	kommAn	kommAb	betrfz	tfz
BSD	3	BSD53-BS033-212-BS023-BS0413-B...	18:28.0	18:28.8		18:28.0	18:27	18:27	1.5	1.4
DORF	13	210-209-208-207-ZFH83-ZFH73-ZF...	18:30.3	18:30.3		18:30.3			2.2	2.1
ZFH	4	ZFH4-ZFH34-ZFH23-ZFH13-205	18:32.5	18:34.3		18:34.0	18:32	18:34	2.0	1.9
OP	204	204-OP34	18:36.3	18:36.3		18:36.3			0.4	0.4
OPS	14	203-202-201-ZOER773-ZOER753	18:36.7	18:36.7		18:36.7			0.9	0.8
ZOER	733	ZOER733-ZOER723-ZOER713-ZOER3	18:37.6	18:37.6		18:37.6			0.7	0.7
ZOER	3	ZOER893-ZOER883-ZOER873-ZOER...	18:38.3	18:39.5		18:39.0	18:38	18:39	0.8	0.7
ZBST	663	ZOER631-ZWIP404-ZWIP32-ZWIP2...	18:40.3	18:40.3		18:40.3			1.6	1.5
ZWIP	2	ZWIP2-ZWIP53-ZWIP42-ZWIP402-Z...	18:41.9	18:42.7		18:41.7	18:41	18:41	1.6	1.5
ZVIA		401-ZUEP76	18:44.3	18:44.3		18:44.3			0.6	0.6
ZLST		ZUEP56-ZUEB1-ZUEB11-ZUEA4	18:44.9	18:44.9		18:44.9			1.8	1.6
ZUE	A4	ZUEA4-ZUEY10-ZUEP12-ZUEP52-Z...	18:46.7	18:51.3		18:51.0	18:46	18:51	1.4	1.3
ZLST	T62	ZLST072-ZLST082-101-ZWIE11	18:52.7	18:52.7		18:52.7			0.8	0.8
ZAU	11-21	ZWIE21-ZWIE31-ZWIE41-ZWIE1	18:53.5	18:53.5		18:53.5			0.9	0.9
ZWIE	1	ZWIE81-103-ZEN11-ZEN1	18:54.4	18:55.2		18:54.5	18:54	18:54	1.4	1.3
ZEN	1	ZEN41-ZEN61-104-ZWOL14-ZWOL...	18:56.6	18:57.6		18:57.0	18:57	18:57	1.9	1.8
ZWOL	4	ZWOL4-ZWOL74-ZWOL84-ZWOL9...	18:59.5	19:00.3		18:59.3	18:59	18:59	2.6	2.4
KIL	1	KIL51-KIL61-KIL71-107-RUES11	19:02.9	19:03.7		19:02.2	19:03	19:03	2.0	1.9
RUES	1	RUES1-RUES61-RUES71-108-TW13	19:05.7	19:06.5		19:04.6	19:05	19:05	1.1	0.9



Station	Time	Block	Speed
Unterzosen	10:15	Block	100
Walensdorf	10:20	Block	100
Mels	10:25	Block	100
Sargans	10:30	Block	100
Bad Ragaz	10:35	Block	100
Märschfeld	10:40	Block	100
Landquart	10:45	Block	100



NeTS: Planning with seconds accuracy, visualised in decimal minutes

conflict resolution «midpoint railway station building» - vPRO driving profile in 5 kmh steps

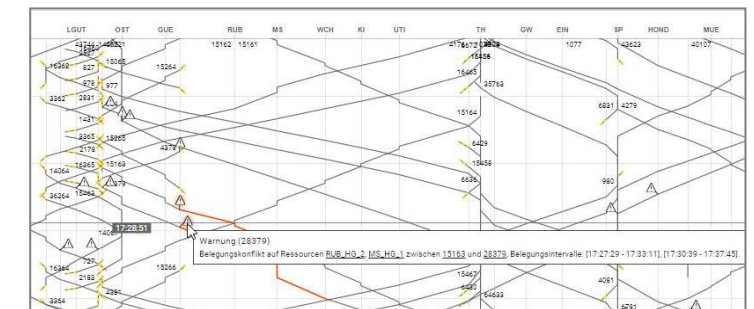
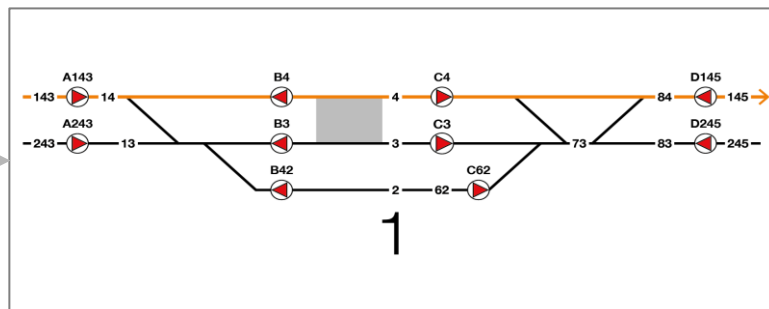
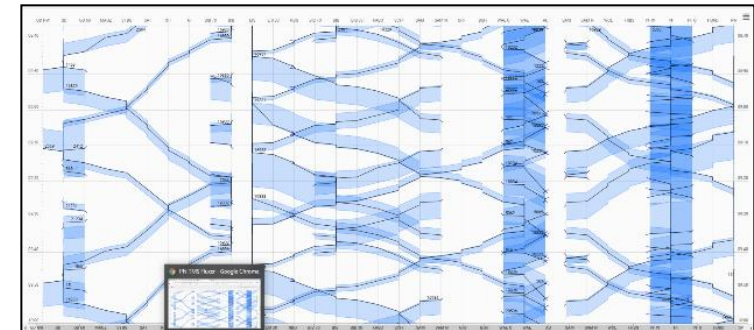
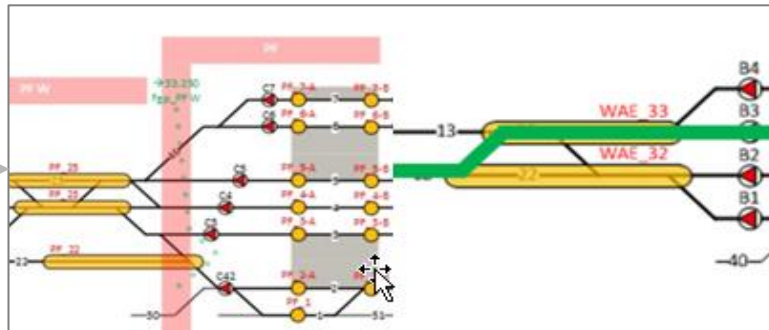
Punctuality deviation PüA in seconds

# The complexity of automated timetable planning

Automated, rule-based planning holds special challenges and many surprises.



Vorgaben	Ort	An	Ab	Min.Halt	Gleis	Haltzweck	Formation
	TW - Thalwil	09:50:00	09:55:00		Ein-/Aussteigen		1052,3006,3006,3006,3006,3006,1052
	ZG - Zug	10:10:00	10:12:00		Ein-/Aussteigen		
	EBI - Eblikon	10:30:00			Ein-/Aussteigen		



Which of the possible routes\* make sense and which do not?

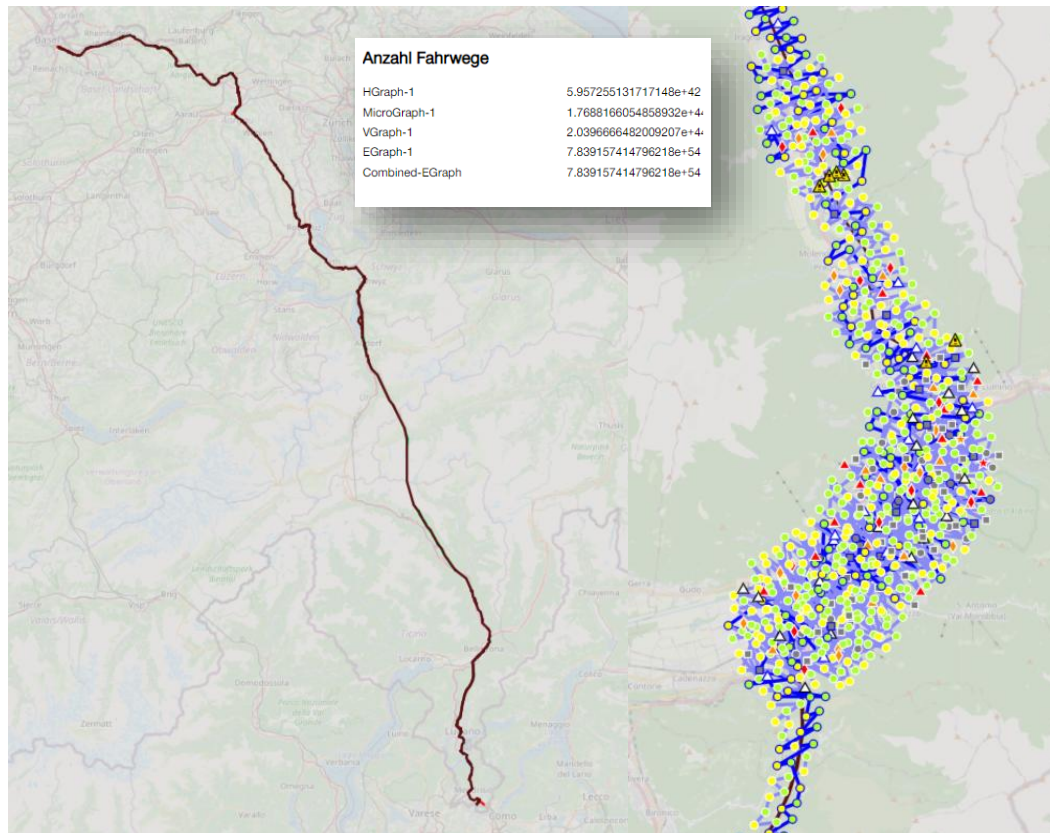
\*Example: There are  $10^{19}$  possible routes between Zurich main station and Lucerne.

Differences between manual (implicit knowledge) planning and explicit, automated algorithmic planning?

# Automated timetable planning

Remains a challenge purely because of the computing capacity.

Above a certain planning area size, the many route alternatives lead to a problem complexity no longer to be solved in a useful time. Accordingly, no railway in the world has yet been able to automatically generate a timetable nationwide.



In theory, a freight train from Basel to Chiasso has  **$10^{54}$  possible paths.**

Challenge:  
Solution must **scale** for the whole of Switzerland.

I wouldn't have thought so. Between the exit of the Basel shunting yard to the Südbahn and GBT the number of possible route combinations explodes: There are  $10^{54}$ !

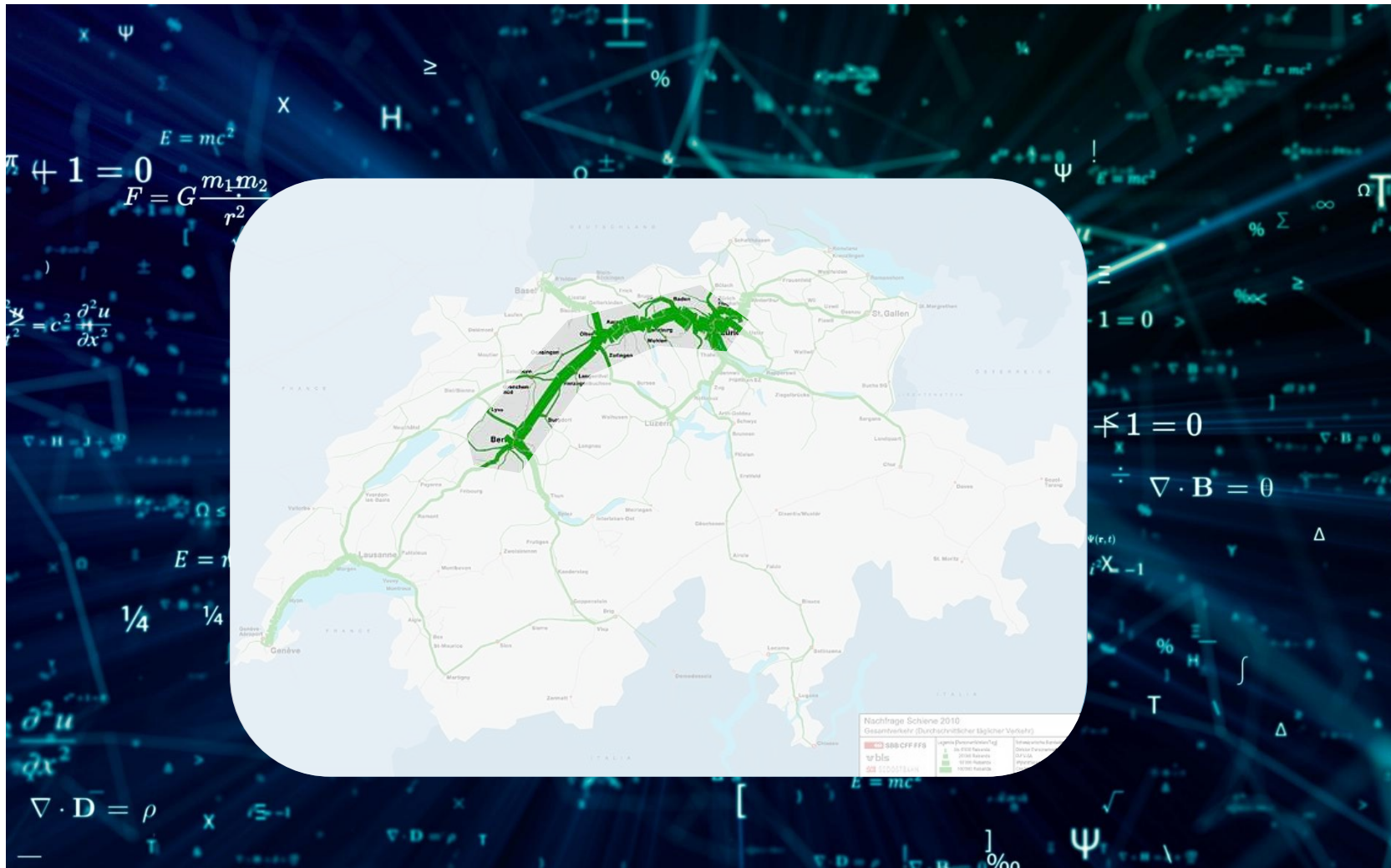


## Linear Computing – an example



- A phone book with **6 million entries**
- Sorting in about **5 sec** with laptop.

# Mixed Integer Linear Programming – an example



## Route **Bern – Zürich:**

- Time period **5 min** (ca. **300 trains**)  
calculating time about **5 seconds** too.
- Time period **12h** (ca. **3'000 trains**)  
calculating time **5 hours**  
(increasing exponentially)

# Timetable for the whole of Switzerland



Switzerland (entirely)

– Time period  
**1h** (system hour,  
ca. **1'000 trains**)  
calculating time about  
**one day**

– Time period  
**1 year**  
(ca. **3'650'000 trains**)  
calculating time  
**longer than the age  
of the universe**

# Planning the timetable to the operational detail level

There are many people involved and interactions to be managed.

7'900 passenger trains daily



**Customer-facing offer**

30'000 yearly track closures for works on the network



**Construction & Maintenance**

30 Mio. passengers yearly



**Events**

Mastering the timetable complexity



~700 Employees in planning



Safeguarding the people's expertise



Efficiency gain with data usage

## Production plan

- Rolling stock
- Infrastructure
- ...

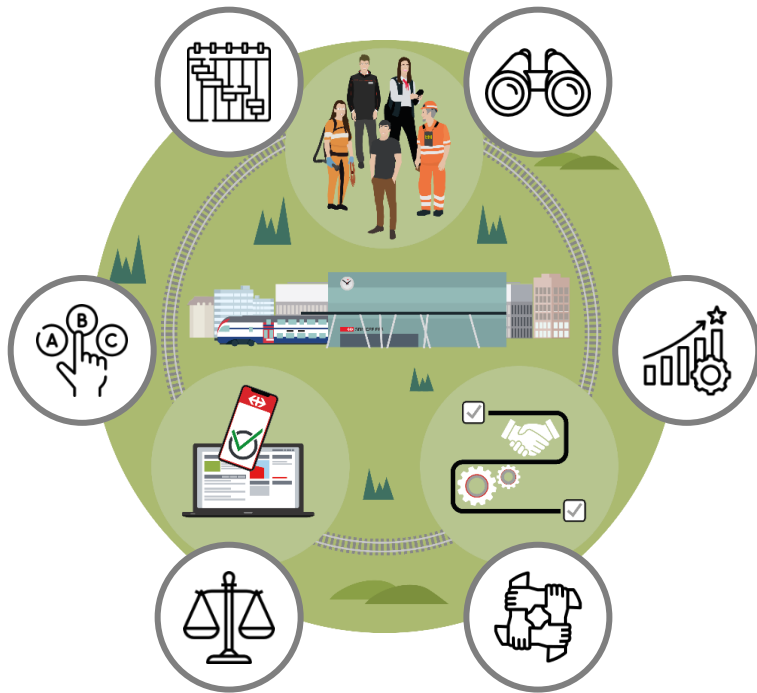
## Customer information

## Resource plan

- Workforce
- Sidings
- Workshops
- ...

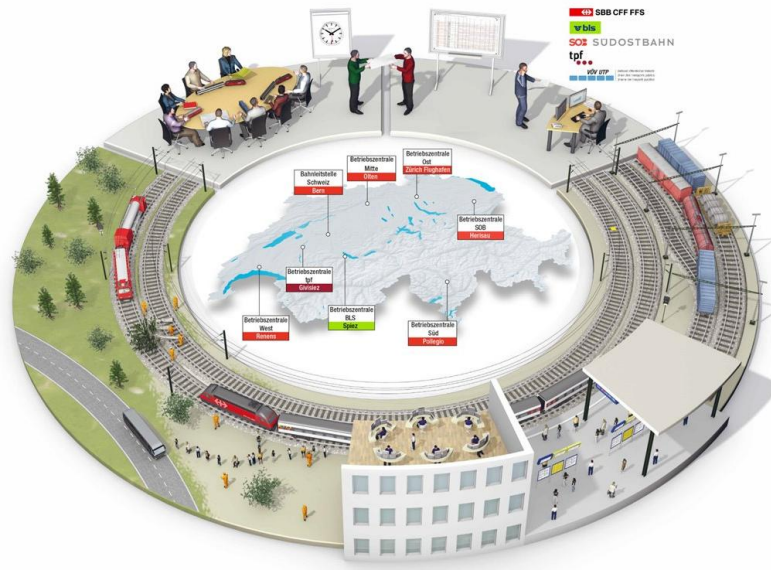
# Optimisation: Processes, Tools and People!

Medium term interdependencies are a complex but interesting field.



## Integrated production planning

Algorithm based variants and constant live prognostics on availability and requirements for all resources (→ IPP)



## Traffic management system(s)

Request, plan, optimize and manage (infra) capacity. Driving assistance and track access charges (→ TMS).



## OpenRail Association

Opensource, collaborative approaches to use community knowledge and contribution. (→ [openrailassociation.org](https://openrailassociation.org))



# Summary

# Summary of medium term planning



- The integral clock-face timetable is the DNA of the railway system and the key work object.
- The resources required (rolling stock, staff, track requirements, sidings, etc.) are planned in an iterative process.
- With intervals we plan for appropriate time to work on the railway system.
- We learn with feedback loops and increase robustness through intelligent analysis of production.
- It only works if the puzzle pieces fit together.
- The experienced people doing this planning work today are critical for success.

# Further reading.

# Glossary.

Abbreviation used	English	German
AS 2035 / AS 2025 / ZEB	Expansion phases AS 2025/2035 and ZEB (Programmes)	Ausbauschnitt 2025/2035 (AS) Zukünftige Entwicklung Bahn (ZEB)
AK 2035	Service concept 2035	Angebotskonzept 2035
CHF	Swiss francs	Schweizer Franken
FOT	Federal Office of Transport	Bundesamt für Verkehr (BAV)
IM	Infrastructure manager	Infrastrukturbetreiberin (ISB)
RUs	Railway undertakings	Eisenbahnverkehrsunternehmung (EVU)
STEP	Strategic Development Program (STEP)	Strategisches Entwicklungsprogramm (STEP)
TVS	Capacity allocating body (CH)	Schweizer Trassenvergabestelle

## Further reading.



OpenRailAssociation yearly report 2024 with a foreword by the current SBB CIO Jochen Decker

You can find it on



«learning journey» redacted for the SBB board of executives (same as after lecture Traffic Management Systems)

