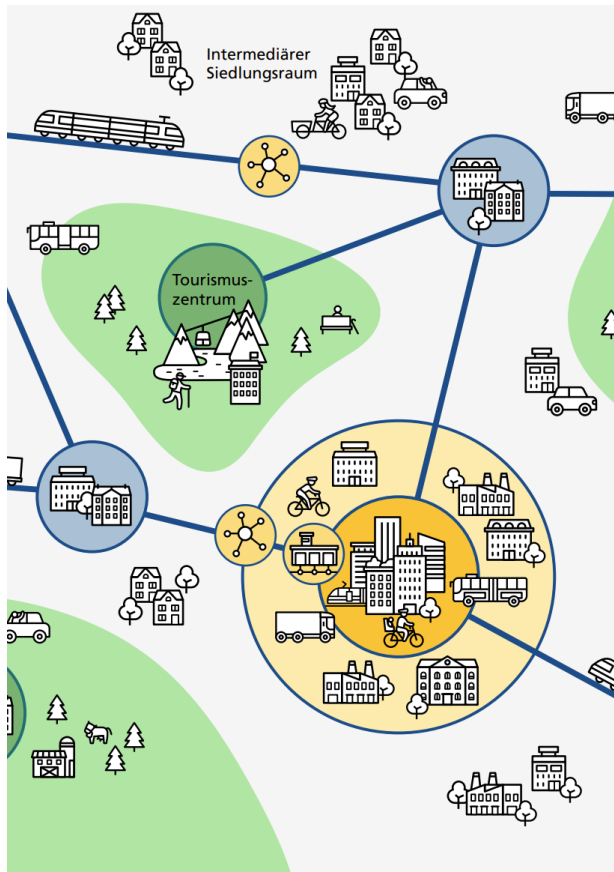


Railway systems and their transition
Lecture 2

Transport systems and the role of the railway.

Peter Kummer
EPFL, Autumn Semester 2025
September 16, 2025

Preparatory reading for the lecture.



Rail Perspective 2050 of the Swiss Federal Government

Based on a vision and six objectives, the Rail Perspective 2050 defines the direction for the further expansion of the rail system. The vision is to efficiently utilise the strengths of the railways and contribute to the climate goal of 2050 by increasing the share of rail in passenger and freight transport. Additionally, it aims to enhance the living environment and economic location of Switzerland and align the development of the rail system with the objectives of spatial development.

Preparatory reading:

Rail Perspective 2050 of the Swiss Federal Government.

Short version on moodle

More information (voluntary reading)

In German:

[Perspektive BAHN 2050 - BAV](#)

In French:

[Perspective RAIL 2050 - OFT](#)

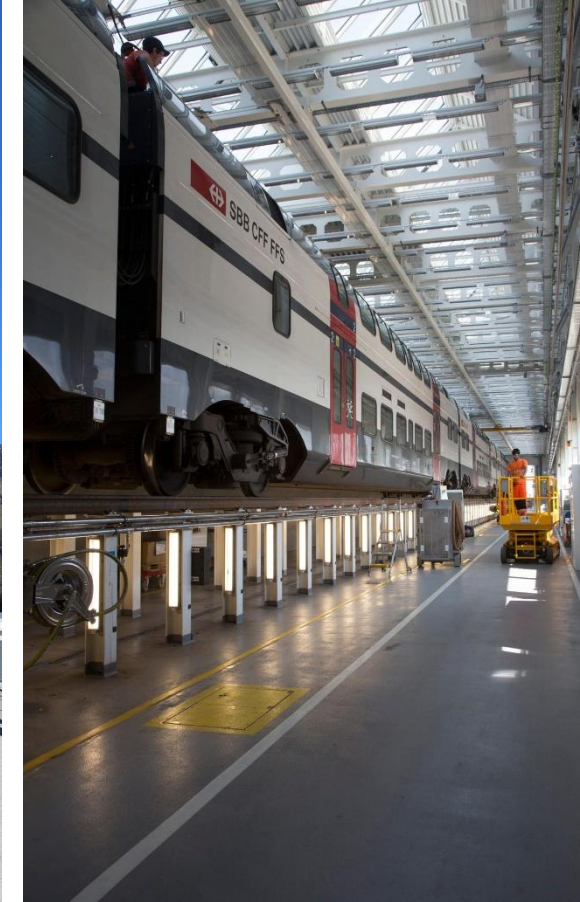
Agenda.

1. Efficiency of Rail-Based Mass Transit Systems
2. Modal Split
3. Measures and challenges to increase the modal split for rail
4. Case study and semester report



Efficiency of Rail- Based Mass Transit Systems.

Area use, energy consumption, CO2 emissions and safety.

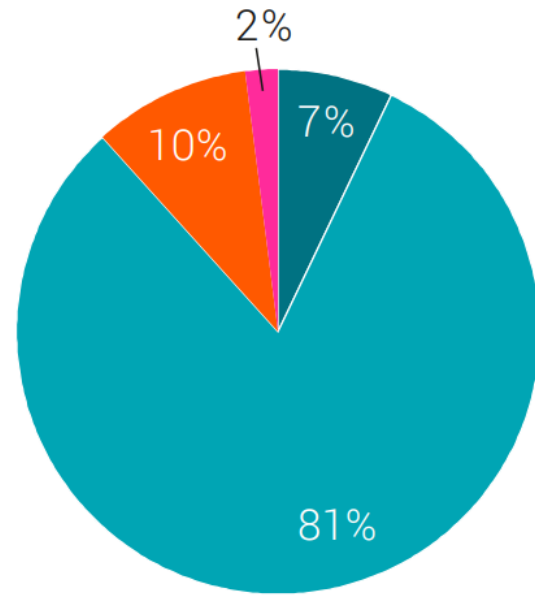


Source: SBB Media Center

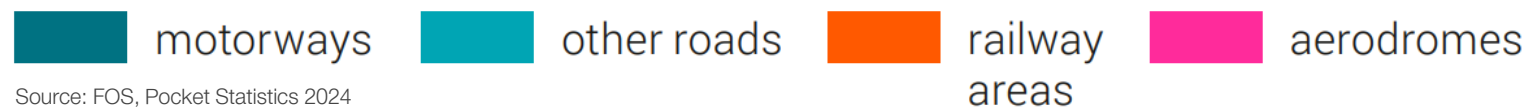
Area used for transportation.

Railway only occupies 10% of the total transportation area in Switzerland.

Transportation area
according to survey 2013/18

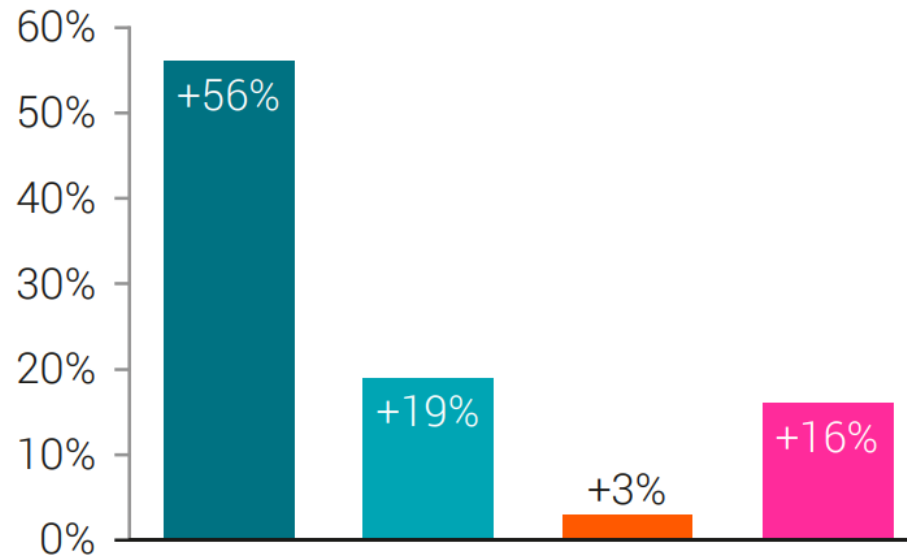


Total: 983 km²



Source: FOS, Pocket Statistics 2024

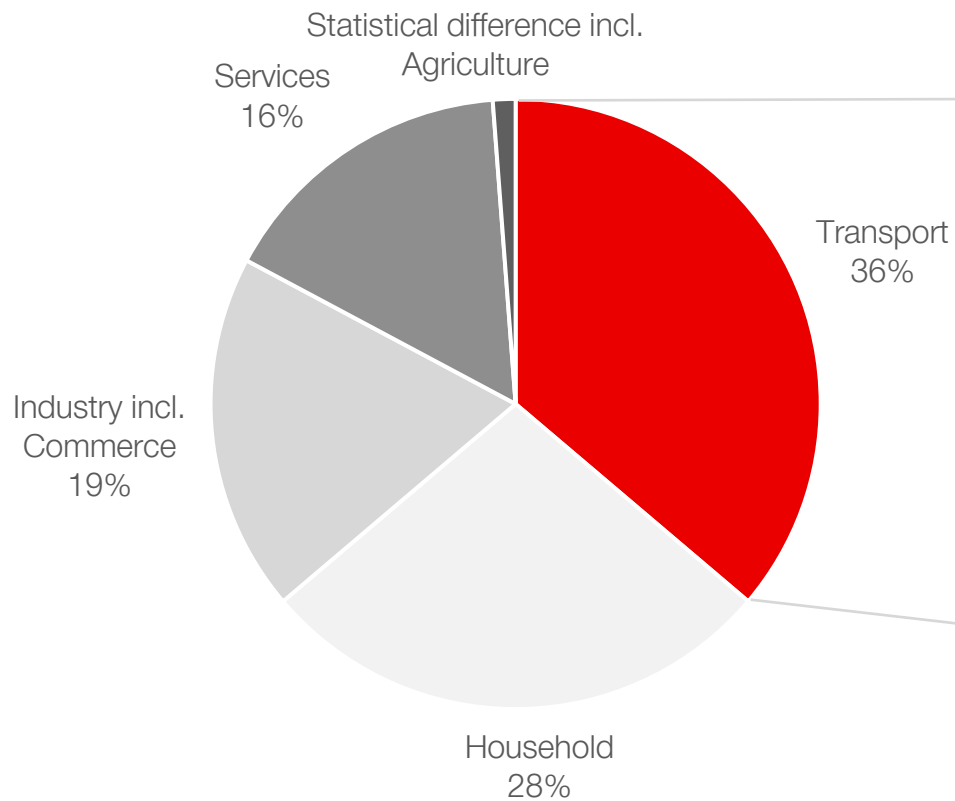
Increase
since survey 1979/1985



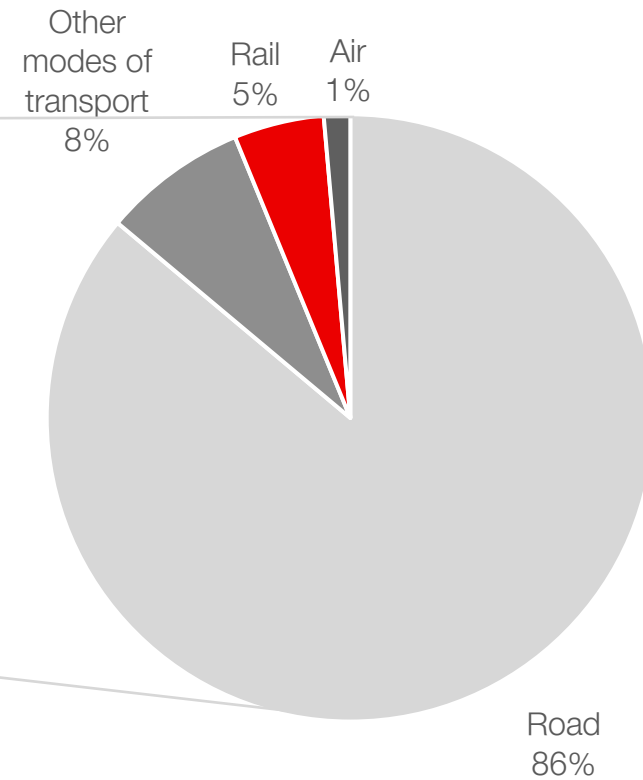
Energy consumption.

Transportation is responsible for more than one third.

Final energy consumption in Switzerland 2022



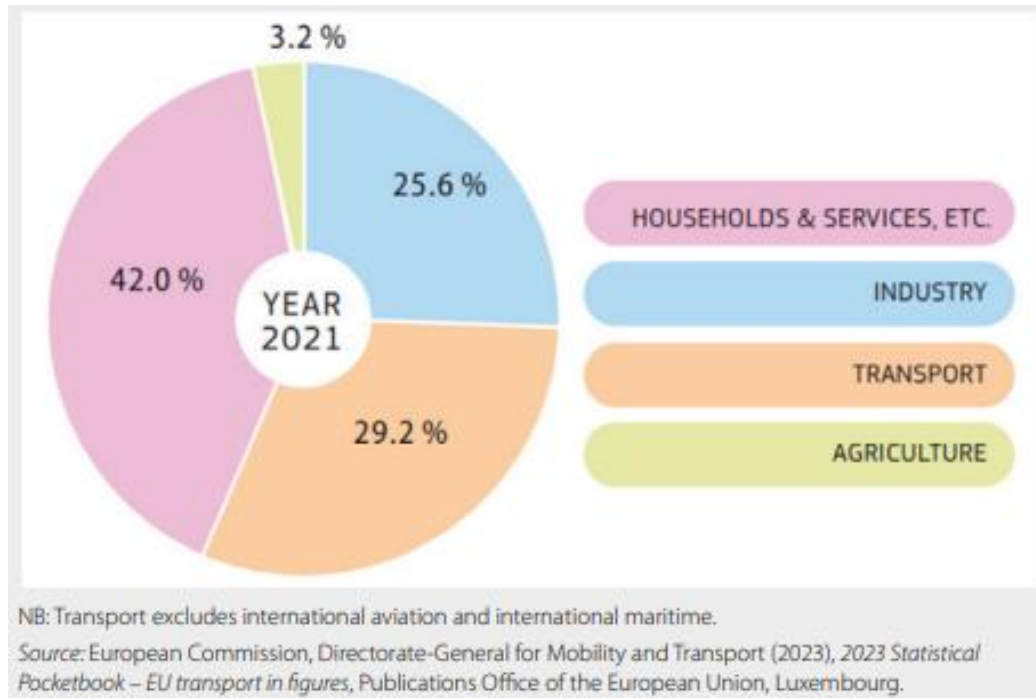
Share of total energy consumption in transport 2022



Source: Litra Verkehrszahlen 2024

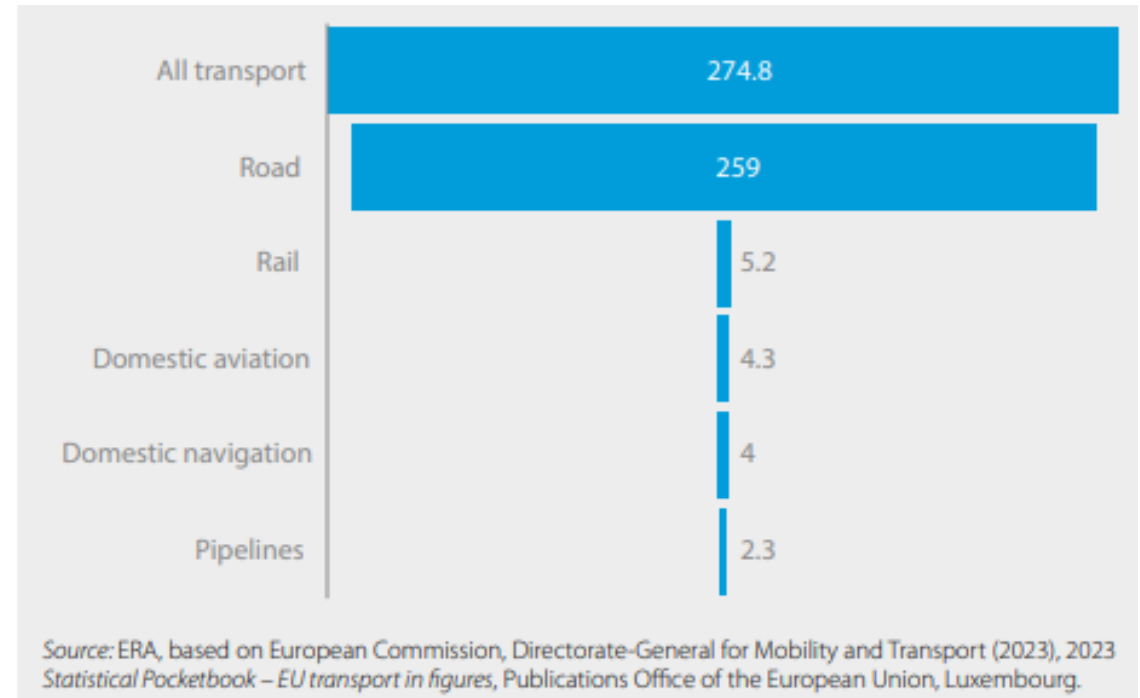
Energy consumption in the EU.

Transportation is responsible for 30 percent – similar to Switzerland.



million tonnes of oil equivalent (Mtoe)

Source: Rail Environmental Report 2024



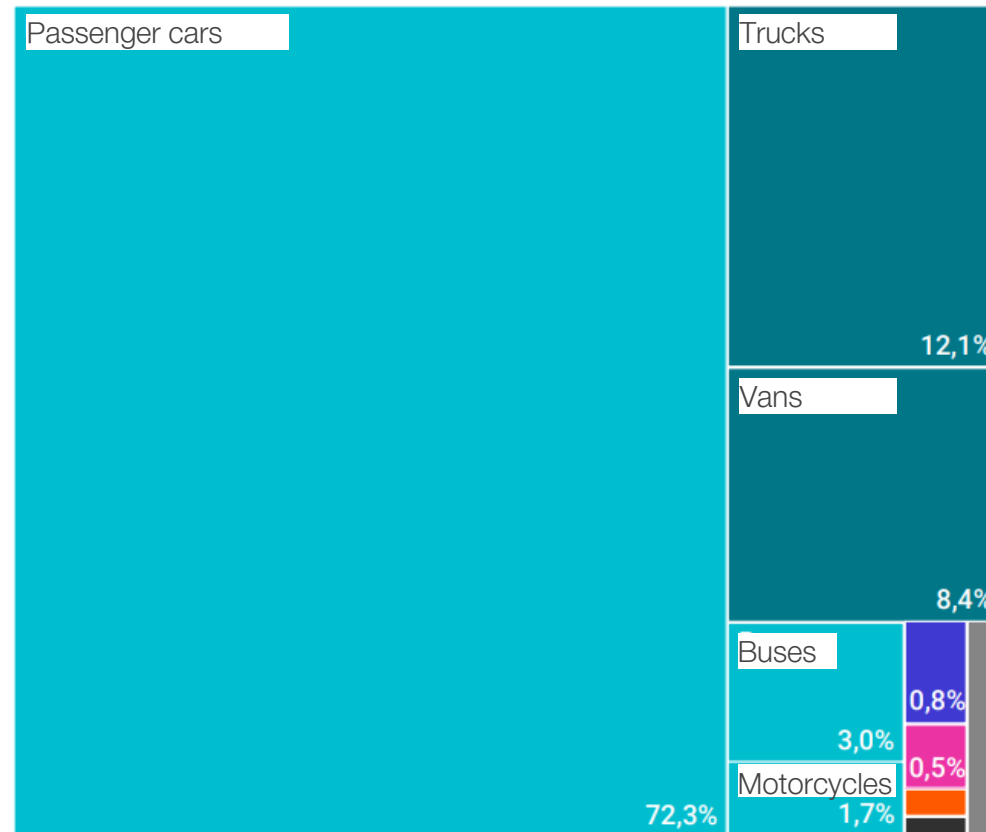
million tonnes of oil equivalent (Mtoe)

CO2 emissions from transport by mode of transport.

Railways responsible for 0.2%.

■ shipping 0,2% ■ domestic aviation 0,5% ■ railways 0,2% ■ pipelines 0,2%
■ other 0,9%

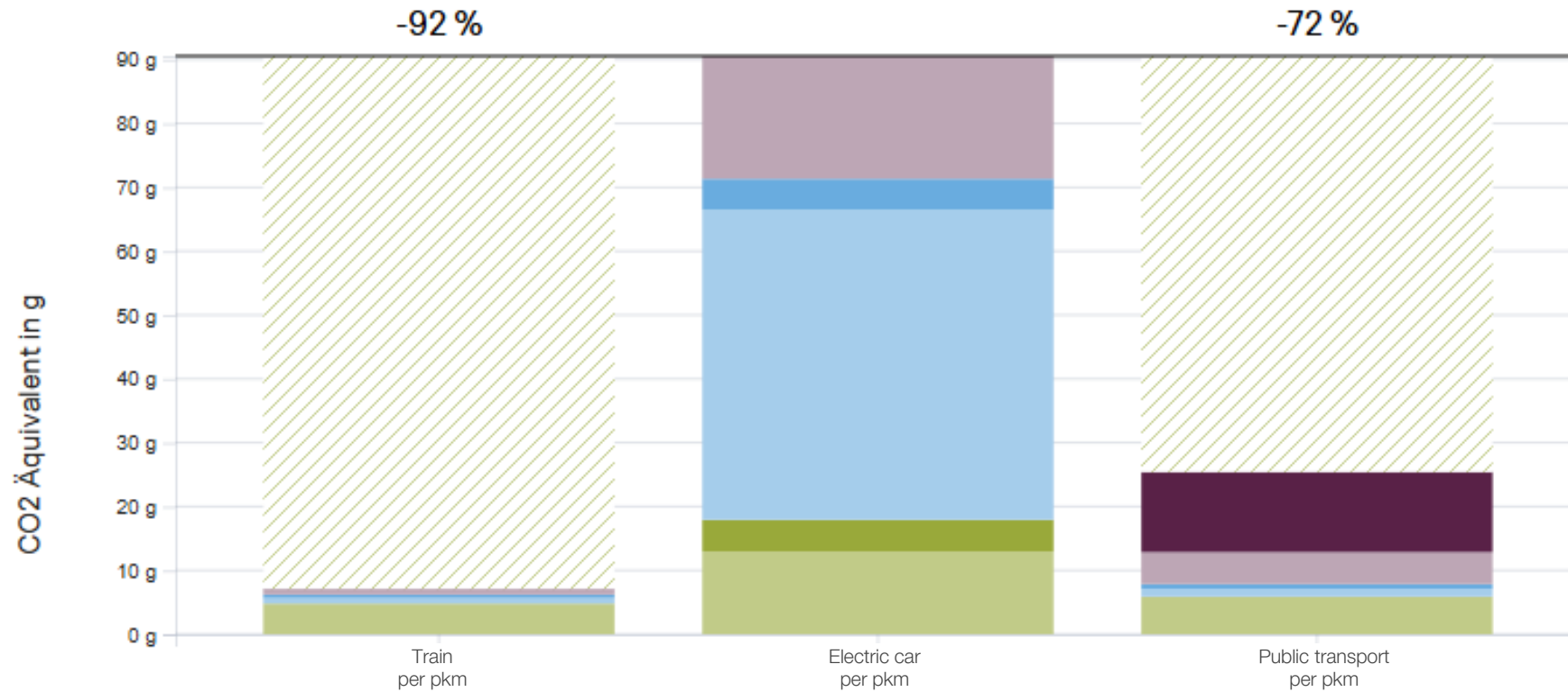
Total 13.6 million tonnes (including fuel tourism and statistical discrepancies)



Source: 11 Mobilität und Verkehr, Die Schweiz in Zahlen – Statistisches Jahrbuch 2024, BFS

CO2 emissions:

A comparison of electric cars, public transport and rail.



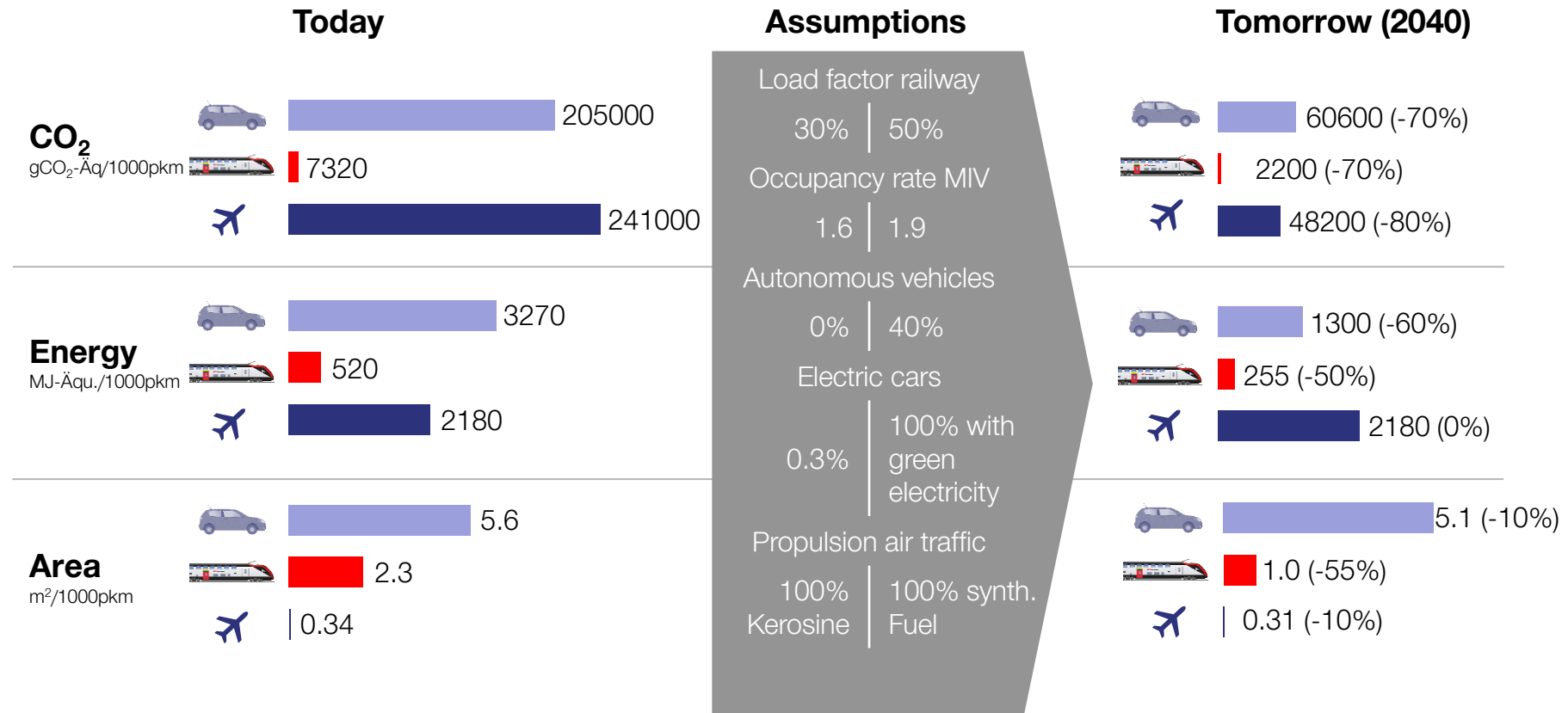
Source:

<https://www.mobitool.ch/>



What are the predictions for 2040.

Railways will be able to maintain/ expand their environmental lead in the future, provided they can realise assumptions regarding load factor and technological development.



Source: Infrac 2015

Rail also outperforms other modes in freight transport in terms of energy consumption, land use and emissions.



Source: <https://blog.sbbcargo.com/>

- Due to the lower rolling resistance of wheels and rails, the railway is three times more energy-efficient than a car and **five times more energy-efficient than trucks**.
- Freight transport by **rail emits 80 percent less CO2 per tonne-kilometre** compared to the average truck.
- An **average freight train can replace 52 trucks**. On a similar transport area (road and rail), railways can carry significantly more at once.
- Rail freight transport requires approximately **five times less space for the same quantity** than road transport.

Rail is the safest means of transport in Switzerland.

Risk comparison of selected land transport modes, 2013–2022

	One fatality per:	Death risk per distance travelled, measured relative to the safest of the compared transport modes, railway (=1)
Railway	190,86 bn passenger-km	1 time
Passenger car	1,13 bn passenger-km	169 times
Bicycle (excl. e-bike)	0,10 bn passenger-km	1985 times
Motorcycle	0,04 bn passenger-km	4732 times

Rail journeys are the safest in terms of distances travelled: on average, there has been **one death per 191 billion passenger-kilometres** (equivalent to 4.8 million circumnavigations of the world) in the last ten years (2013 to 2022).

Source: 11 Mobilität und Verkehr, Die Schweiz in Zahlen – Statistisches Jahrbuch 2024, BFS





Modal split.

Definitions.

Public transport

Public transport includes transport services with regular trips according to a defined timetable, which can be used by all persons based on specified transport regulations. In Switzerland, public transport not only includes transport services by train, tram and bus, but also by boat and cable car.

Modal split passenger transport

The modal split represents the market share of the various means of transport. It can be expressed in two ways:

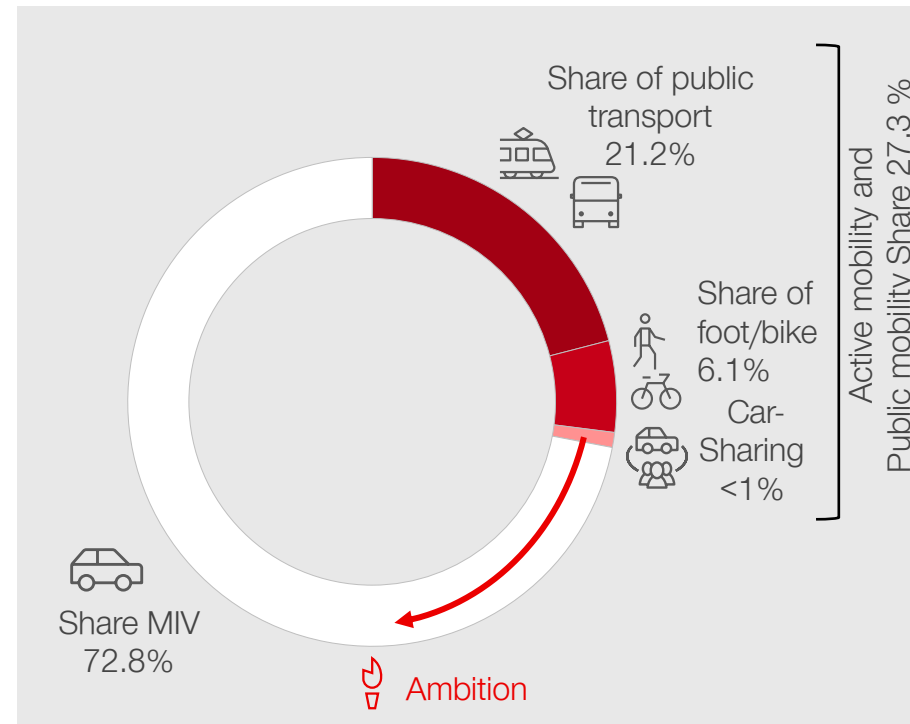
- Depending on **the totality of journeys**: This type of calculation has the advantage of taking into account all modes of transport, including short distances on foot or by bike.
- Depending **on the distance**: This method of calculation provides a more accurate overview of the distances covered by each mode of transport. It is about the distances that an individual travels in total. This method focuses more on the means of transport that are used to cover long distances.

Modal split freight transport

The modal split is the distribution of transport performance among different modes of transport, such as trucks, shipping or planes, in tonne-km.

The share of active mobility and public mobility in 2023 was 27.3%

Modal split 2023

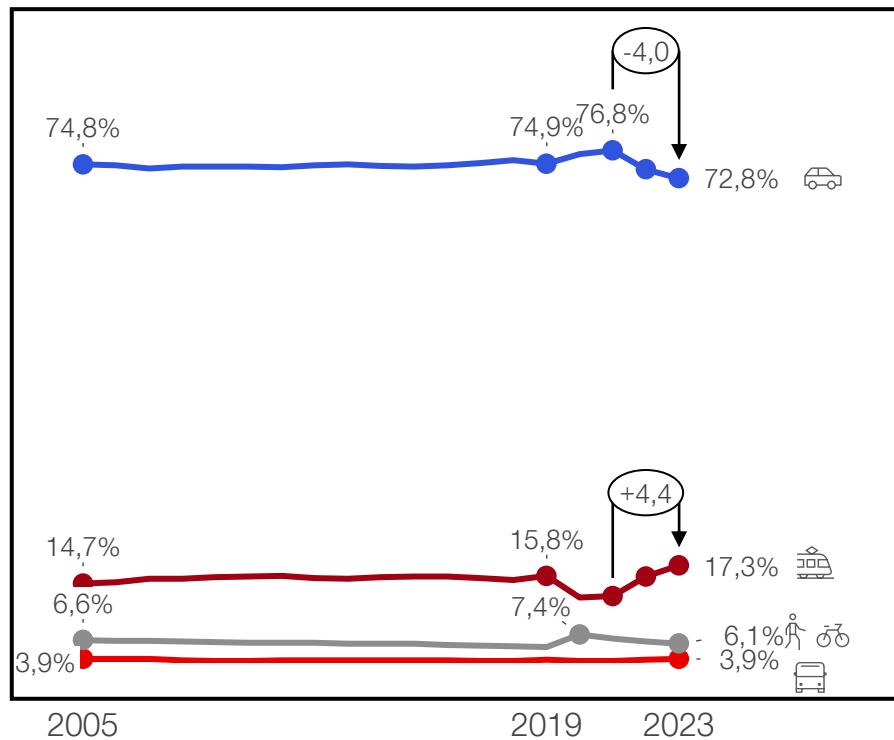


Modal Split Pkm
Source: Verkehrsleistungen im Personenverkehr 2023 vom Bundesamt für Statistik

Modal Split for Railway.





The modal split share of the railway is increasing at a low level.

Development of modal split share in Pkm



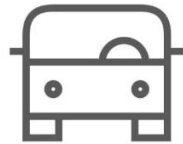
Source: BfS – Transport Performance Passenger Transport

Main developments / changes

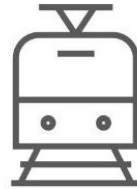
-  **Motorised private transport (MIV):** The share of private transport in the modal split fell again by -1.8% points in 2023 compared to 2022.
-  **Railway:** In 2023, railway was able to increase its modal split share by +4.4% points compared to 2021. At 17.3%, the Railway's share of the modal split was at a new record high.
-  **Public transport, cycling & walking:** The share of the modal split for public transport increased only slightly (0.1% points).
-  **Bicycle and pedestrian traffic:** The share of the modal split for cycling and walking decreased by 0.3% points to 6.1% (2022: 6.4%) compared to the previous year.

Modal split.

Modal split is an important KPI. SBB has its own continuous mobility panel (CMP) to track mobility in almost real time based on a sample population.



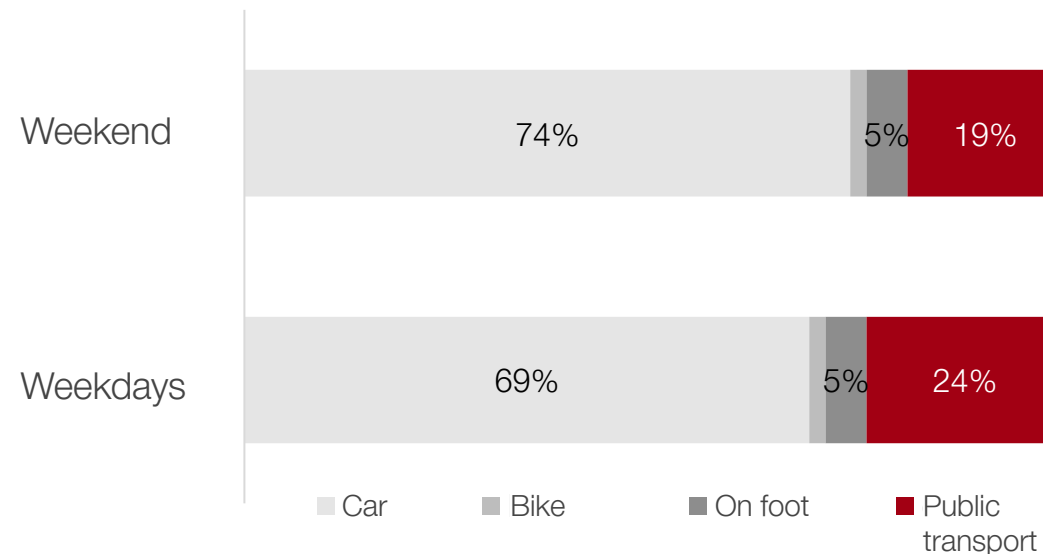
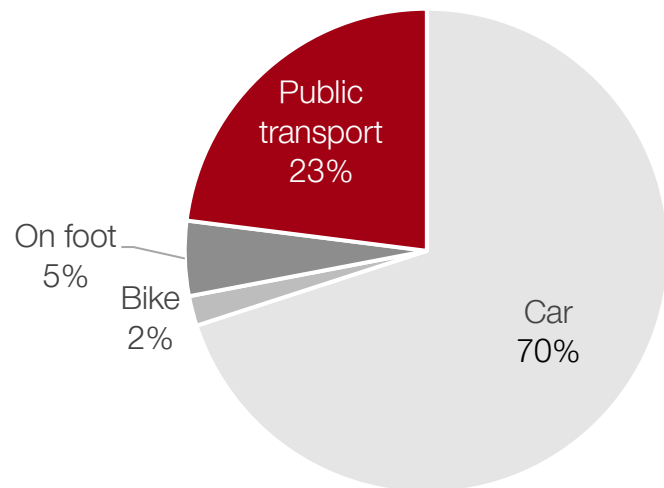
24.7 km by car per day
(9'000 km per year)



7.9km by public transport per day
(2'890 km per year)

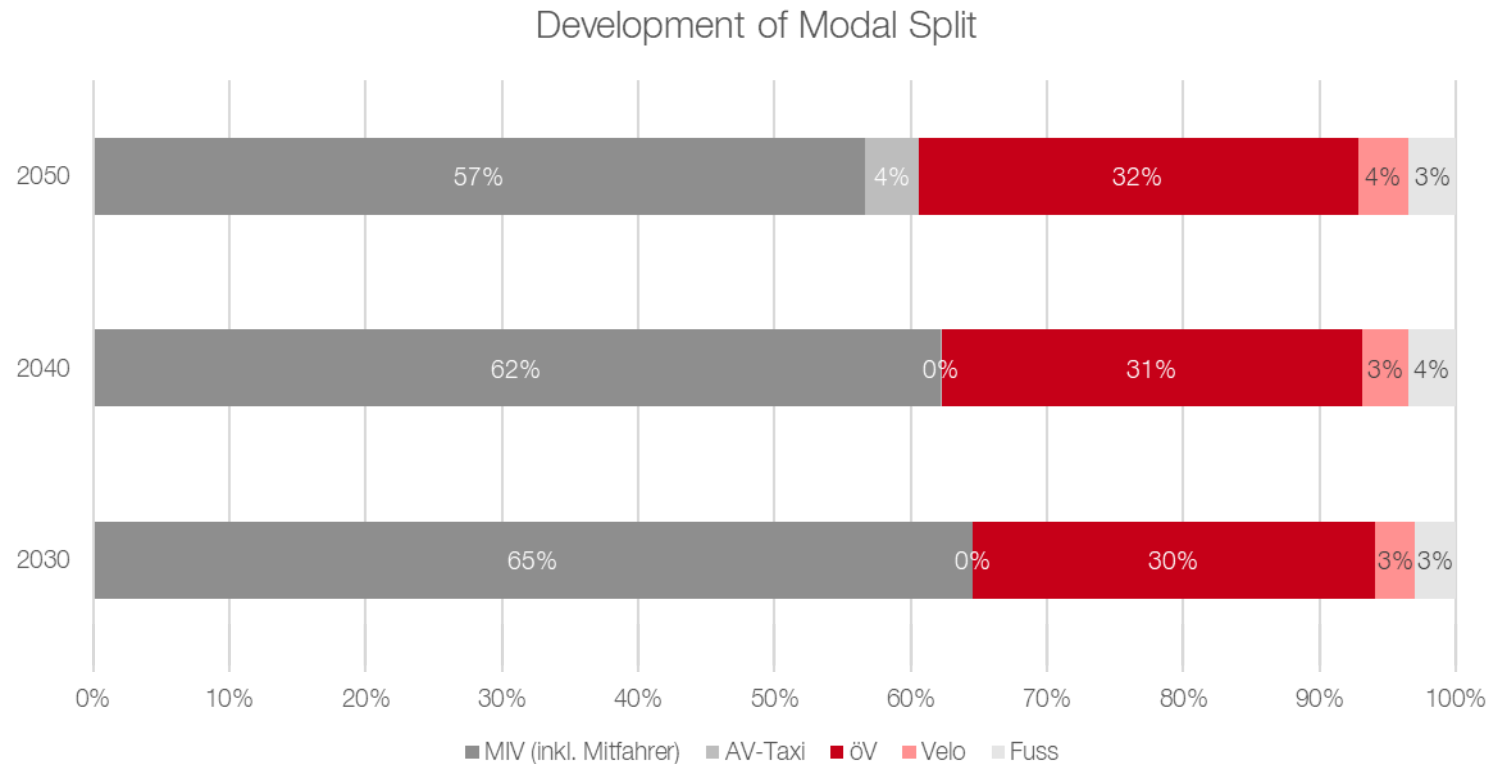


1.7km on foot per day
(630 km per year)



Forecast modal split share rail based on data from SBB.

Densification in cities and development of rail services have a positive effect.



Source: SBB, Simba



Densification in cities



Customer-oriented expansion of services



have a positive effect on rail demand



MIV offer (expansion of national roads)



Autonomous Vehicles (AV)



have a negative impact on rail demand

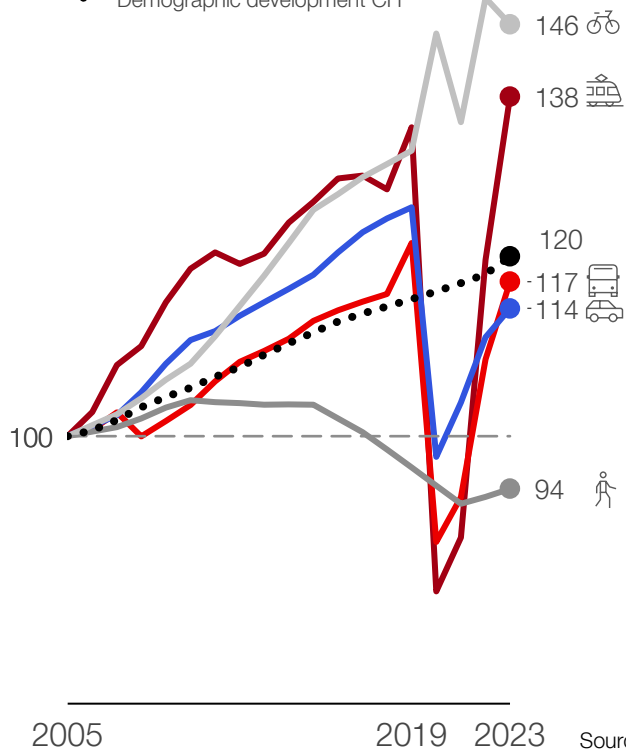
Transport Performance.

Rail and Bike are the big winners in recent years.

Indexed development of transport performance

in Pkm

• Demographic development CH



Main developments / changes

Motorised private transport (MIV): increase in transport volume in Pkm in 2023 compared to 2022 (+3%).

Rail: The transport performance in Pkm of the railway increased by +18% in 2023 compared to 2022. 2023 was the first complete financial year without Corona restrictions (home office and mask requirement).

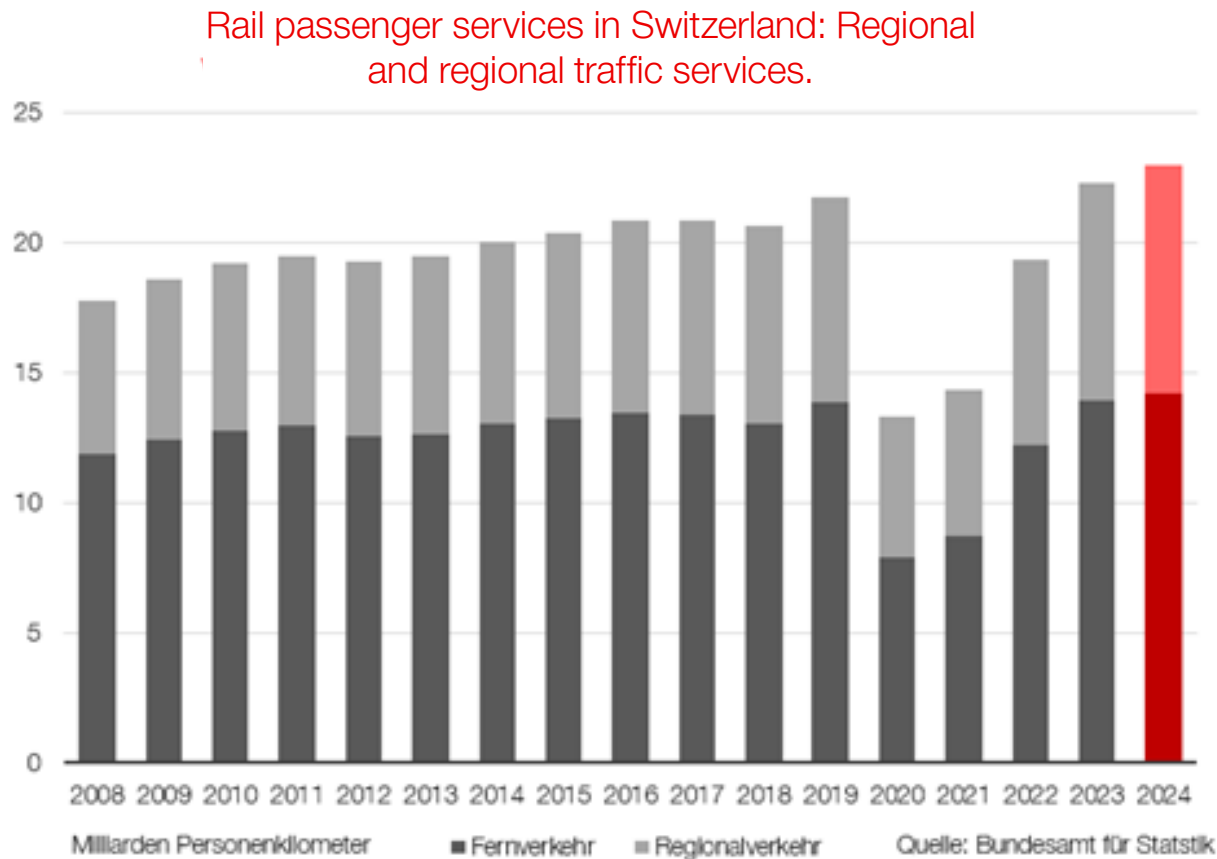
Public transport: Public transport performance also increased by +8% compared to the previous year.

Bicycle: Slight decline in bicycle transport performance compared to 2022 (-3%). This is probably due to increased amount of wet weather in quarter 2 + 3.

Pedestrian traffic: Pedestrian traffic improved slightly for the first time in several years (+2% compared to 2022) but was 6% lower than in 2005 despite strong population growth over the past 20 years (+>1 million more inhabitants / +20%).

SBB Transport Performance.

The increase in demand that occurred in 2004 with Bahn 2000 has continued in recent years.



- In 2024, Swiss rail passenger traffic grew by +3.1% compared to the previous year to 22.98 billion passenger kilometres.
- Regional traffic grew by +4.8% and long-distance traffic by +2.1%.
- At 214.9 million train kilometres, the mileage of all passenger trains in Switzerland also exceeded the previous year's peak by +1.1%.

Source: BFS – Öffentlicher Verkehr im Jahr 2024 – Eisenbahn-Personenverkehr.

Rail freight comparison train and truck.

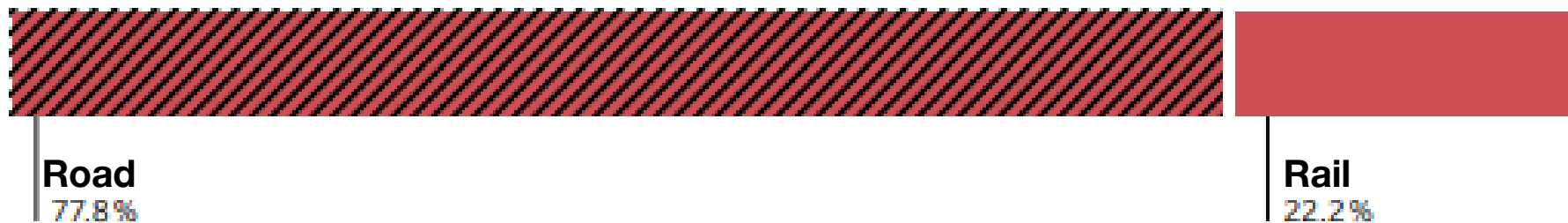
Significant modal split difference between transit and domestic transport.

Comparison of tonne-kilometres between rail and heavy road vehicles, 2022 (in %).

Transit Traffic

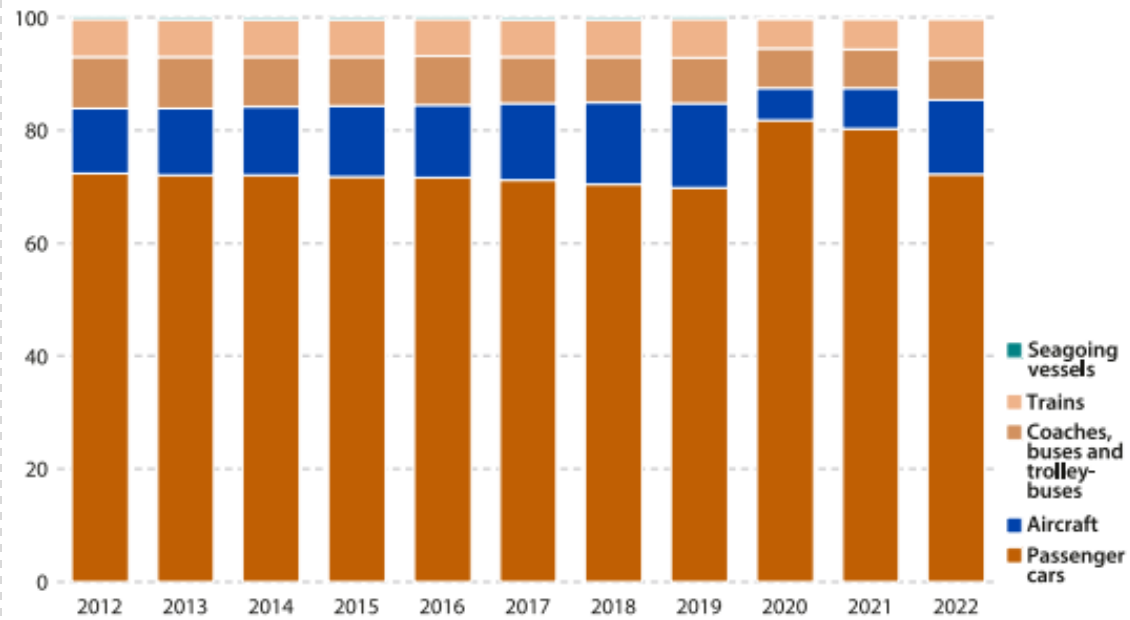


Swiss traffic (domestic, import and export traffic)



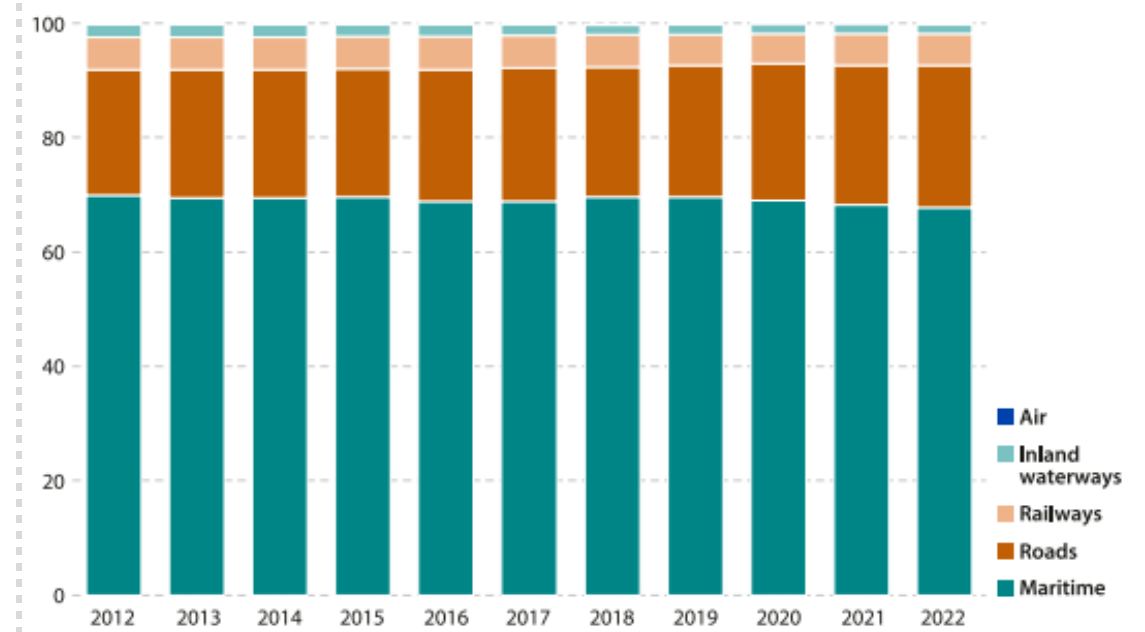
Modal split: passenger and freight transport in the EU.

Change in the modal split of **passenger transport**
% based on passenger-kilometres 2012-2022.



Source: Eurostat (online data code: [tran_hv_ms_psmod](#))

Change in the modal split of **freight transport** in Europe
% based on tonne-kilometres 2012-2022.

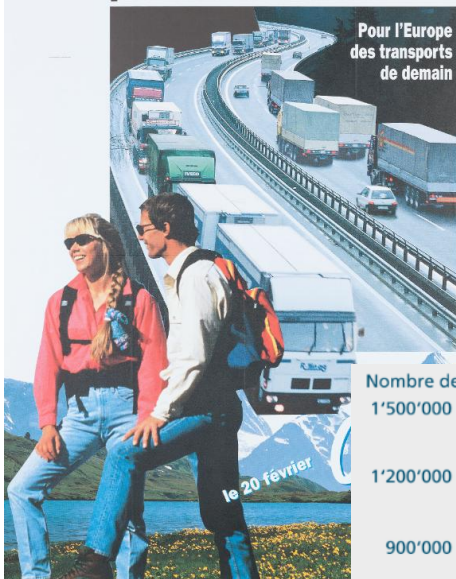


Source: Eurostat (online data code: [tran_hv_ms_fmmod](#))

New Rail Link through the Alps NRLA.

Swiss transport policy aims to shift goods traffic across the Alps from road to rail.

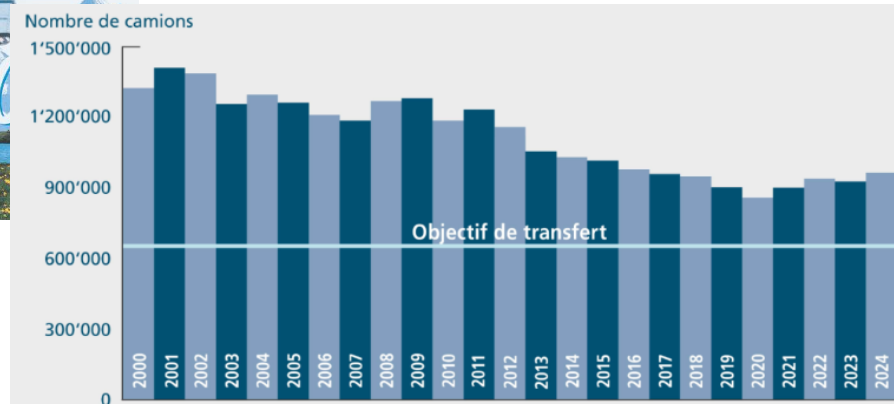
Et si les camions en transit prenaient le train ?



Source: Alptransit Portal



Source: railway-technology.com

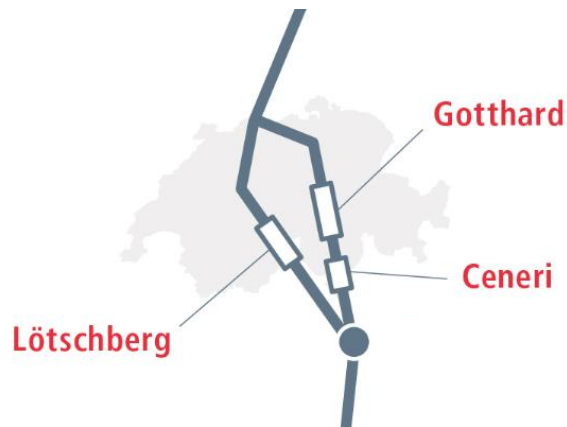


Source: Number of goods trucks crossing the Alps. (Federal Office of Transport)

- In the **1990s**, the **Swiss population** voted several times to shift goods transport across the Alps from road to rail, responding to **growing traffic, environmental concerns, and European integration**.
- In **1992**, approval of the building of a **New Rail Link through the Alps (NRLA)**.
- In **1994**, approval of the **constitutional article on the protection of the Alps**.
- In **1998**, approval of a law on a heavy vehicle fee and the **financing plan for major railway projects**.
- The **goal** is to reach a maximum of **650'000 heavy goods vehicles crossing the Swiss Alps**.

New Rail Link through the Alps NRLA.

A project involving three new base tunnels: Lötschberg, Gotthard and Ceneri.



	Lötschberg	Gotthard	Ceneri
Length	34.6 km	57.1 km <i>World record!</i>	15.4 Km
Main tube excavation start	Sep. 2000	Nov. 2002	Mar. 2010
Commissioned	2007	2016	2020
Costs	5.3 Bil. CHF	12.2 Bil. CHF	3.6 Bil. CHF

(Federal Office of Transport)

Between 2000 and 2020

Whole project 22.8 Bil. CHF

Many challenges !

Examples for the Gotthard Base Tunnel:

High **temperatures**

See left Y-axis in the figure

High **thickness** of the rock above the tunnel

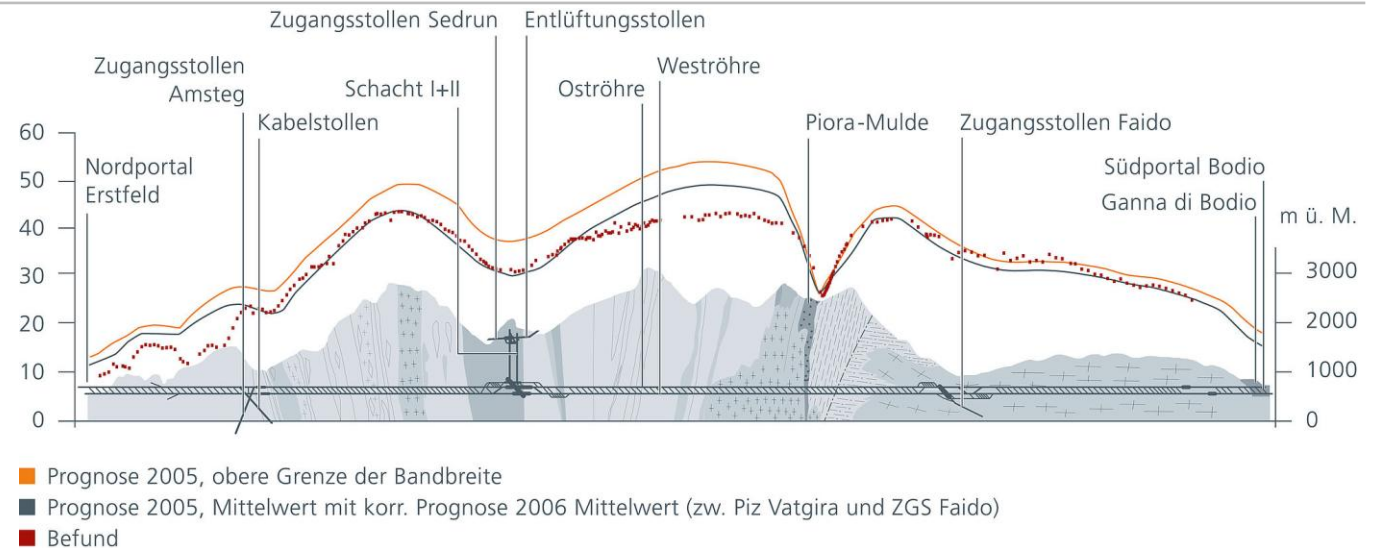
See right Y-axis in the figure

Multiple **geological fault zones**

See grey zones in the figure

...

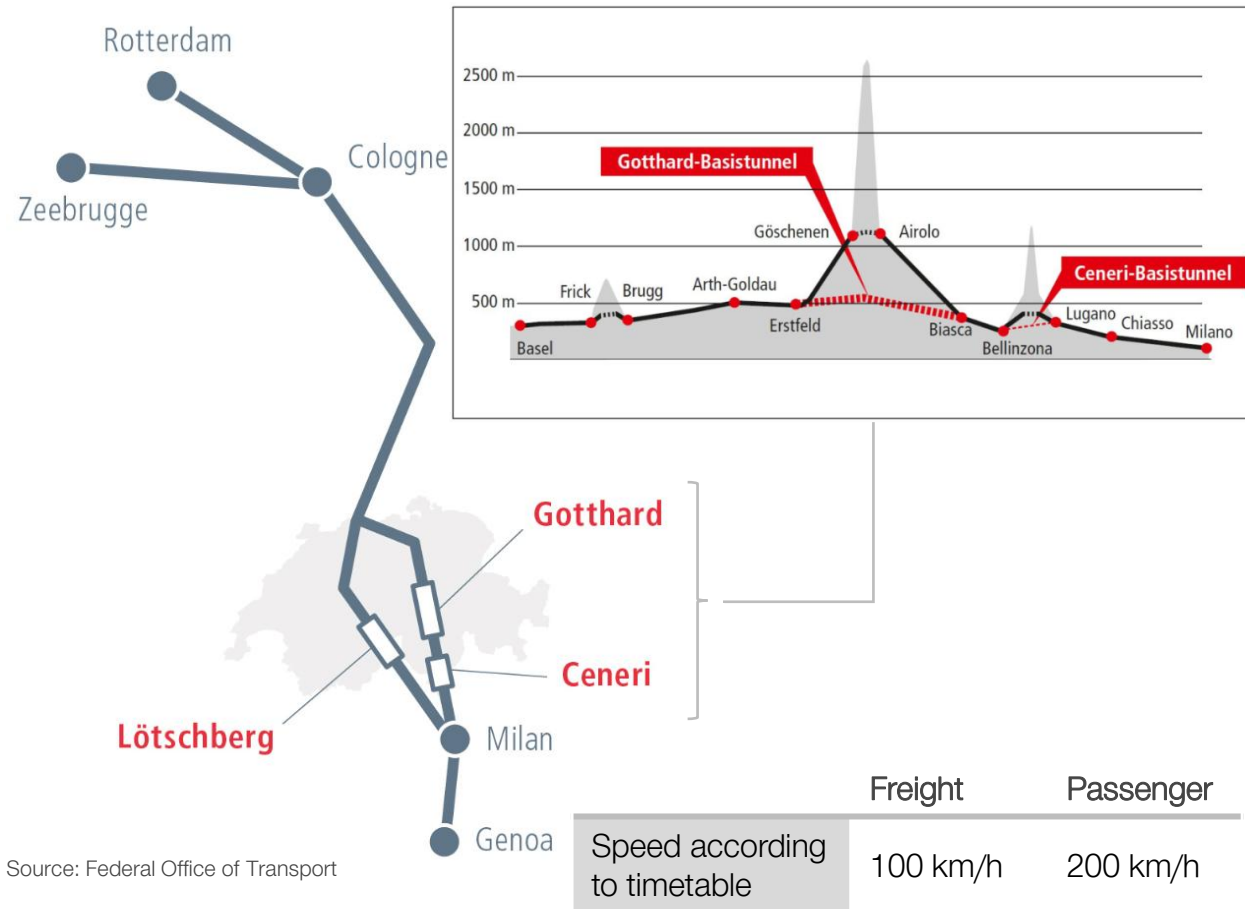
More information: [Video](#)



Rock temperature in the Gotthard Base Tunnel (left Y-axis). (Source: Alptransit Portal)

New Rail Link through the Alps NRLA.

A modern flat-track railway for the major north-south rail freight transport route.

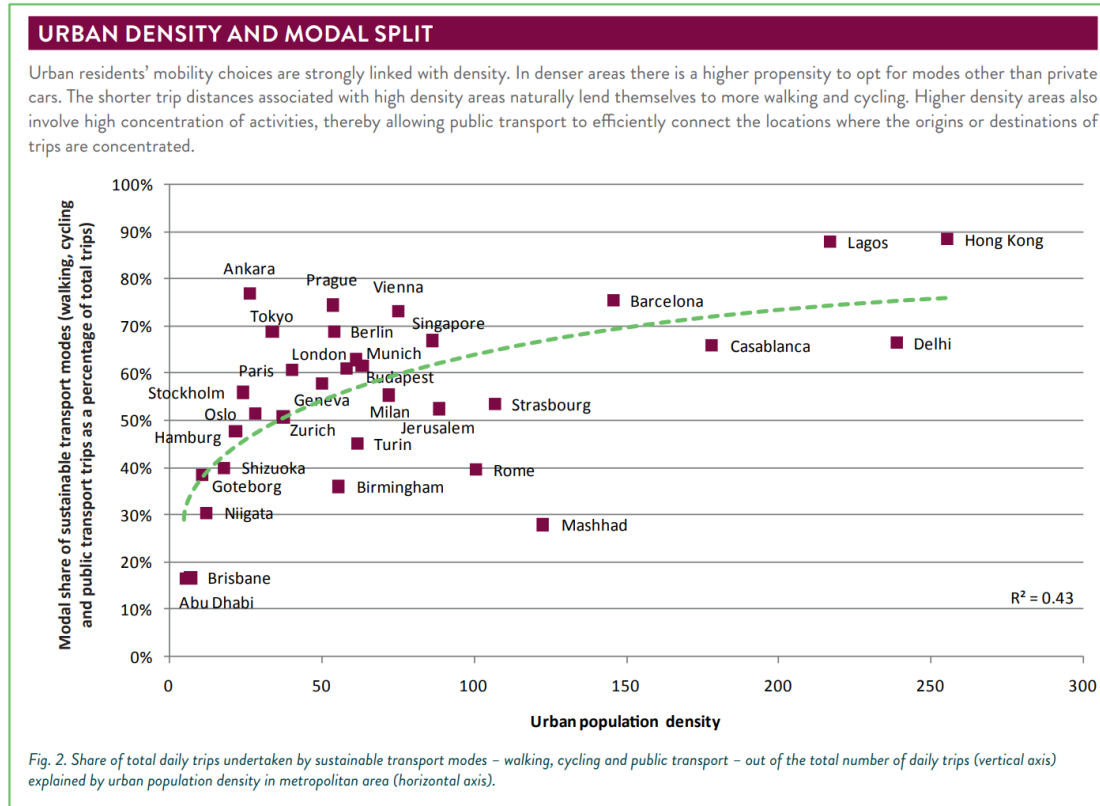
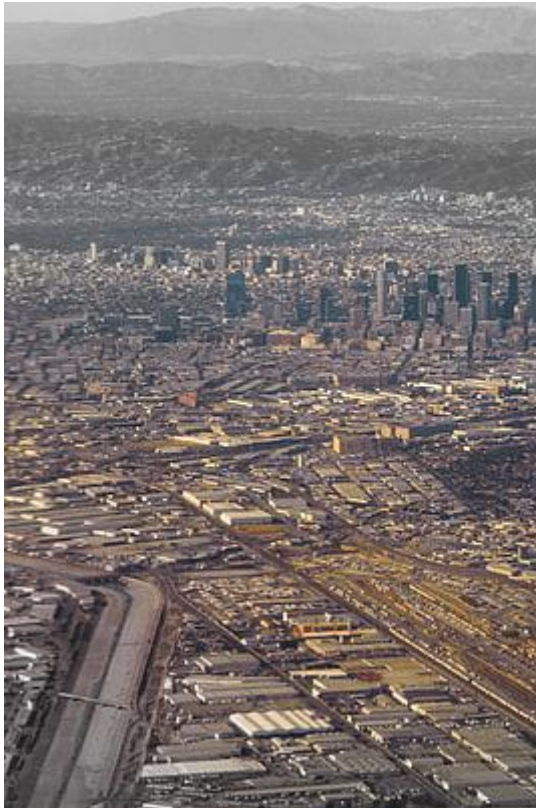


Source: Federal Office of Transport

- Advantages for the **passenger transport**
 - Improved **connections** for peripheral cantons and **tourist destinations** Ticino and Valais
 - **Shorter journey times** to several European destinations Examples of time gains:
 - Zurich-Lugano: approx. 45 mn (1:53 hrs vs 2:38 hrs)
 - Lugano-Locarno: approx. 25 mn (30 mn vs 55 mn)
- Advantages for **freight transport**
 - Increase in available transport options (i.e. **capacity**)
 - **Driving time gains**
 - Journeys with **heavier and longer trains** possible
 - **Energy savings**
- The NRLA is the centrepiece of the European rail freight **corridor between Rotterdam and Genoa.**
- To realise its **full potential, the access routes in Germany and Italy** also need to be expanded.

Mobility in Cities.

Modal share of public transport correlates with the population density.



Source: UITP Mobility in cities database, June 2015 (data used 2012)

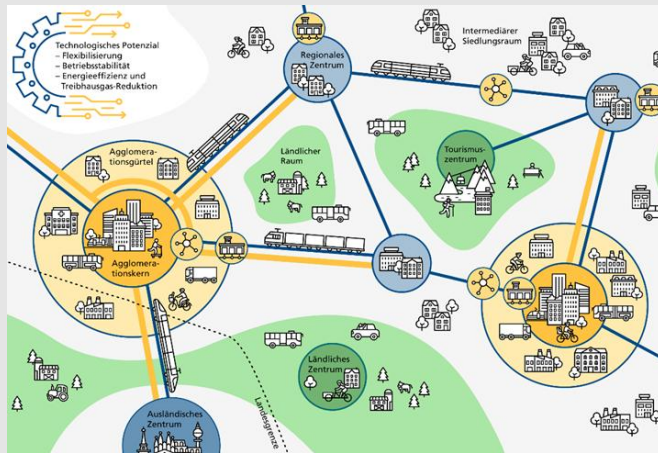


Measures and
challenges to increase
the modal split for rail.

The strategy of the Swiss Federal Government to increase modal split railway by 2050.

One Vision

The '**Perspective Rail 2050**' of the Federal Government is a long-term strategy aimed at planning and promoting the development and expansion of rail transport in Switzerland until the year 2050.



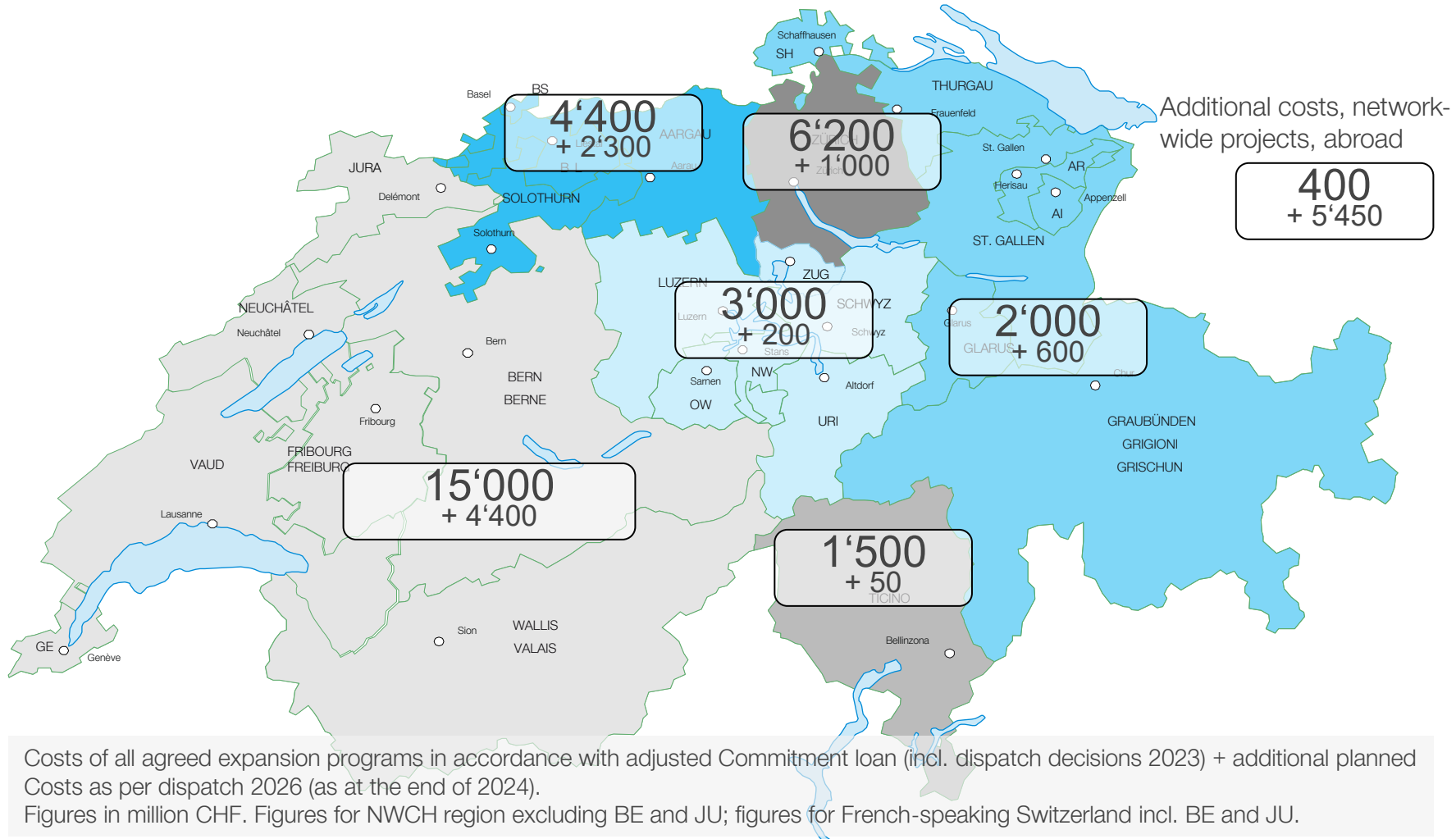
Source (in French): [Perspective RAIL 2050 - OFT](#)

Six Objectives

1. The development of the railway is aligned with the objectives of **spatial development**.
2. The railway service is part of **overall mobility**. It is flexible and optimally integrated with other transport services and carriers.
3. The share of rail in **the modal split** for passenger and freight transport increases significantly.
4. Rail operations are **climate-neutral**, and new railway infrastructures are designed to be land- and resource-efficient, as well as well-integrated into the landscape and settlements.
5. Rail operations are **safe, punctual, reliable, and flexible**.
6. Efficiency gains through automation and **new technologies** are consistently utilized.

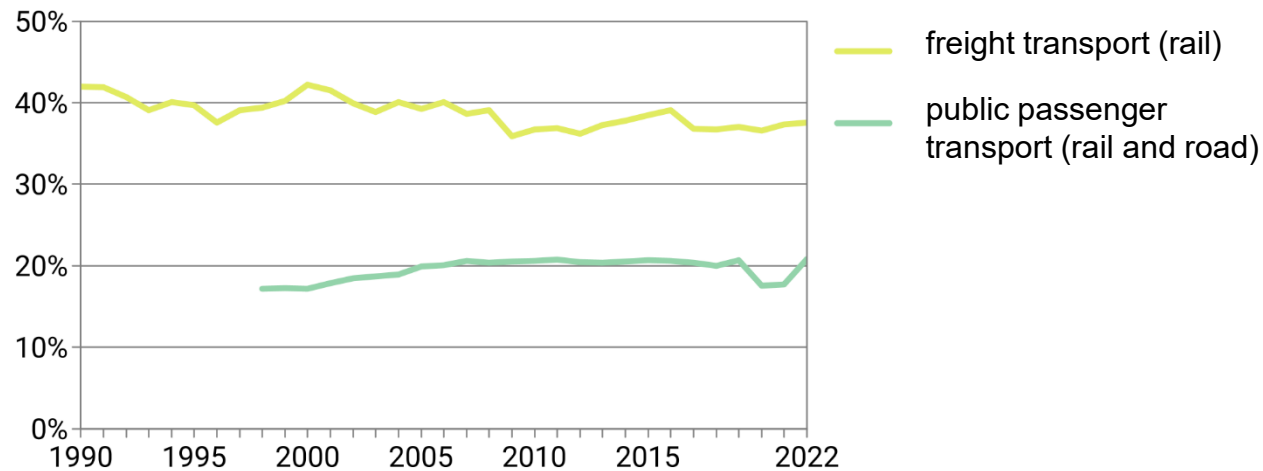
The Federal Rail Perspective 2050 is not just about rail expansion; it is about creating a robust and sustainable transport network that supports our climate objectives, enhances connectivity, and strengthens Switzerland's position as a leader in sustainable mobility.

Total volume of infrastructure investments (decided and planned)



Stagnation of the modal split of public transport in passenger traffic in Switzerland since 2005.

Modal split in passenger and freight transport



¹ Anteil am gesamten terrestrischen Güterverkehr (Strasse und Schiene), in % der Tonnenkilometer

² Anteil am gesamten Personenverkehr (Strasse und Schiene), in % der Personenkilometer

Source: BfS

© BFS 2024



Public transport makes an important contribution to the implementation of Switzerland's climate and energy strategy.



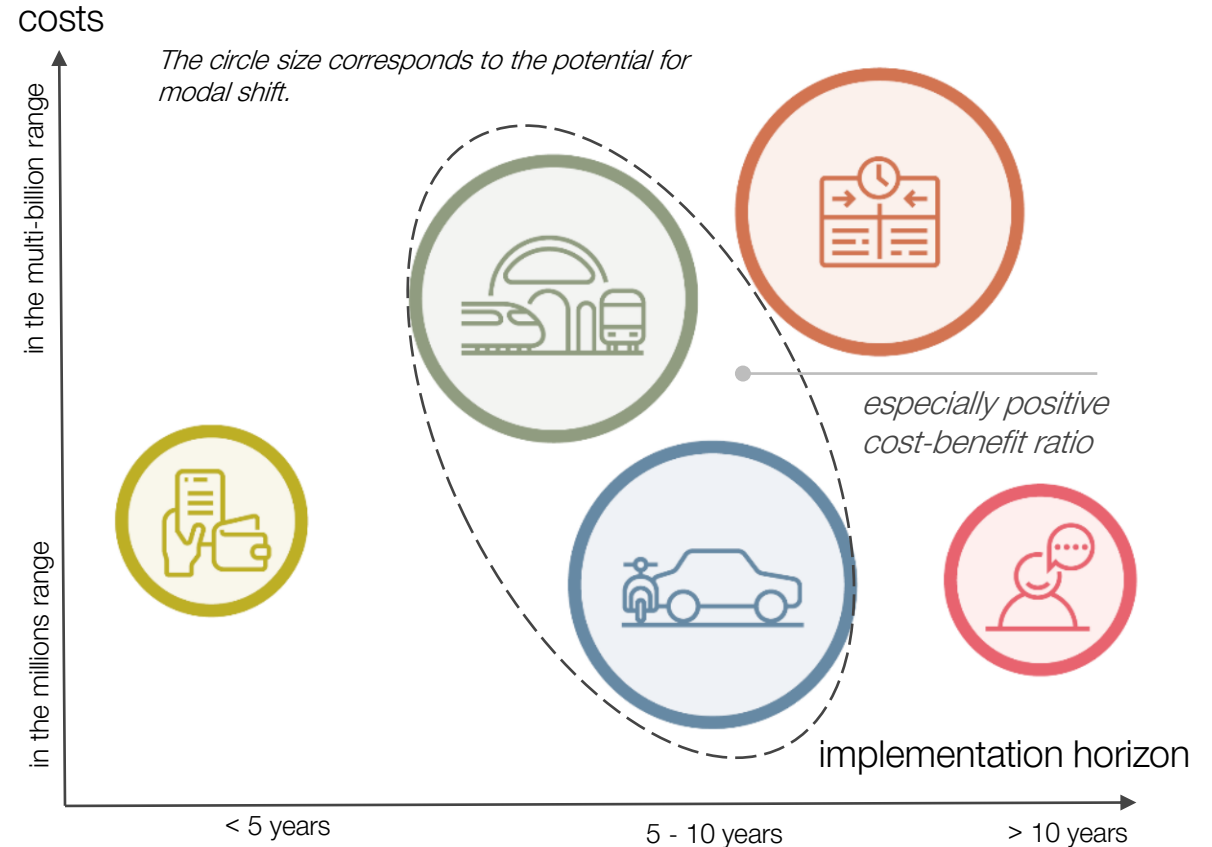
It is largely free of CO₂ emissions and is extremely energy-efficient and space-efficient compared to motorised individual transport.

The modal split of public passenger transport has stagnated, despite political will and substantial investment in rail and road infrastructure.

To increase the modal split, complementary measures are necessary in addition to expansion of infrastructure.

Precondition: integrated planning of land use and mobility

- Field of action 1: Mobility Hubs**
Strengthen access to public transport and intermodal mobility chains.
- Field of action 2: Pricing**
Provide segment-specific discounts for public transport and enhance user-friendliness.
- Field of action 3: Quality and availability**
Improvement of reliability, travel comfort, travel time, and operating hours.
- Field of action 4: Regulation**
Regulate and manage motorised individual transport.
- Field of action 5: Social norms**
Influence attitudes and social/personal norms towards public transport.



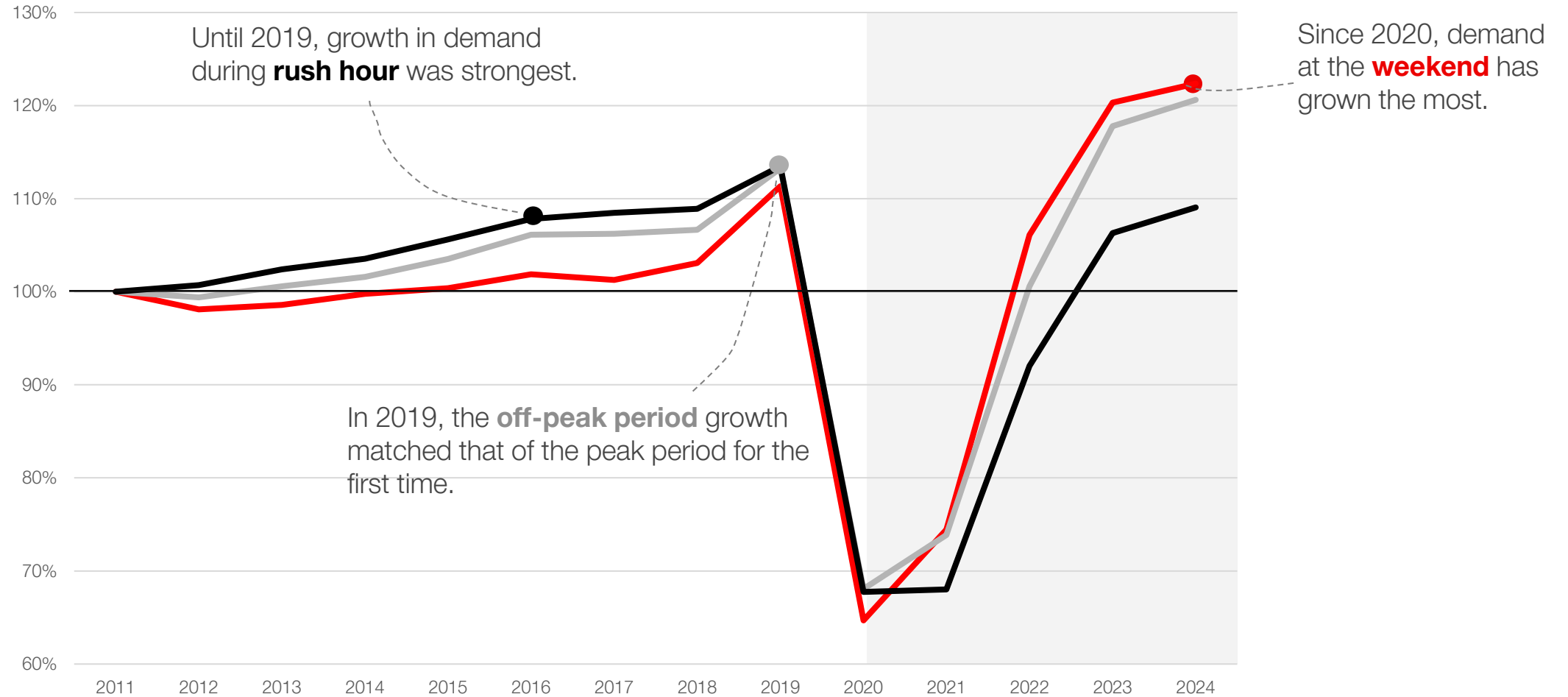
Source: Federal Office of Transport (FOT): [Studie zur Steigerung des öV-Anteils am Gesamtverkehr \(2025\)](#).

These complementary measures aim to improve access and availability of public transport, leading to behavioural changes among travellers in their daily lives.

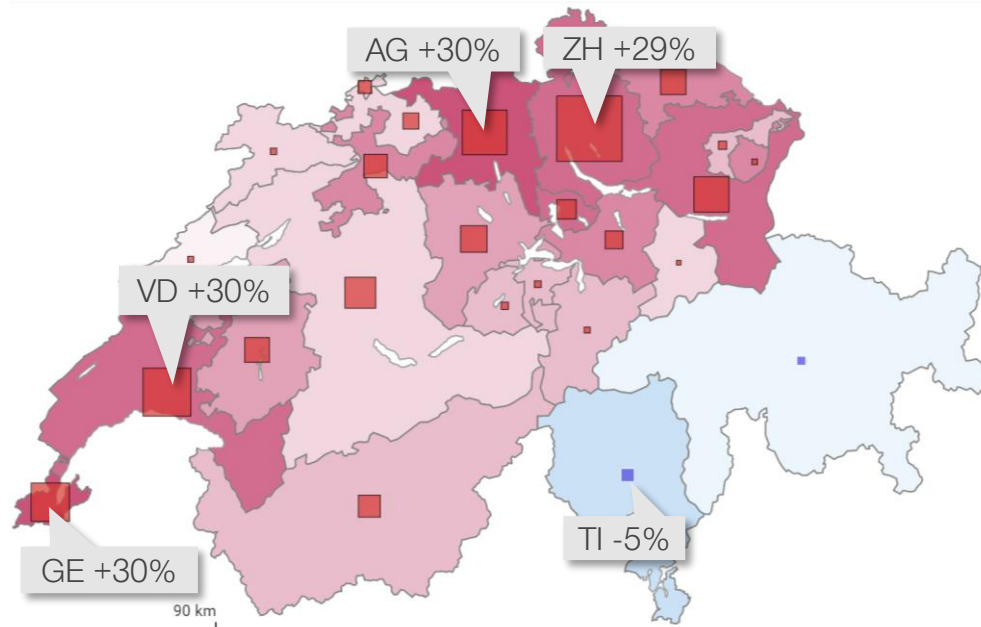
Travel behaviour has changed.

Demand at weekend and off-peak times has grown faster than peak times since 2020.

Indexed growth in passenger kilometres since 2011



Increasing the modal split for a growing population will cause conflicts of objectives.

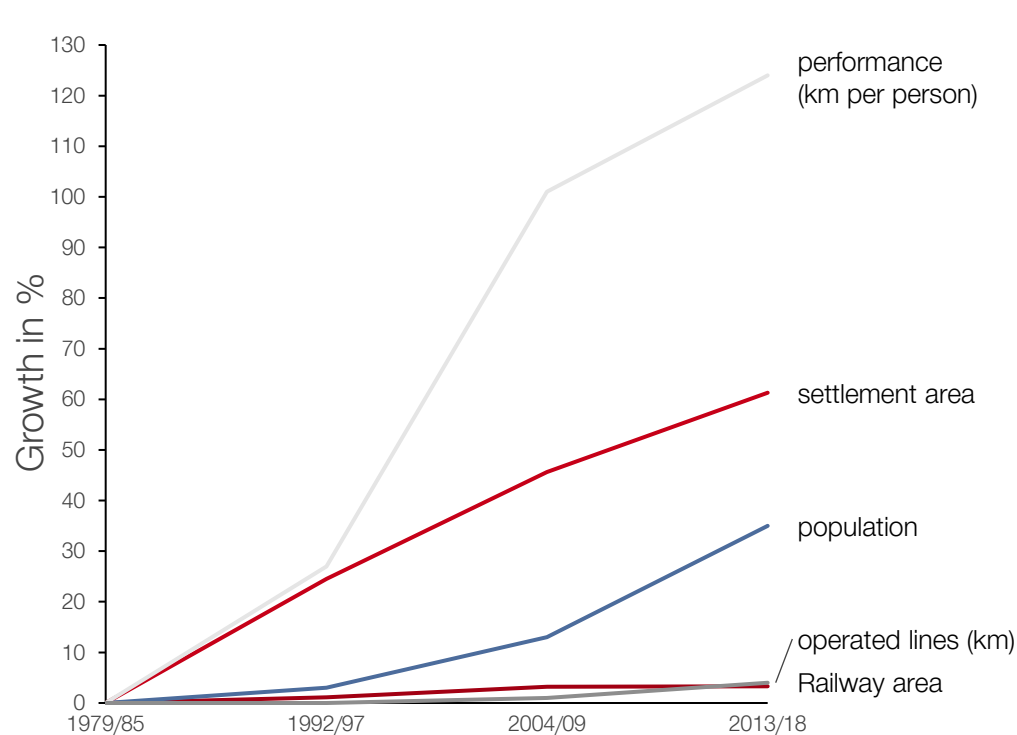


- Settlement and urban areas 8%
 - Agricultural areas 35%
 - Wooded areas 32%
 - Unproductive areas 25%
- Total Area Switzerland: 41'285 km²**

Sources:
FSO – Switzerland's Land Use Statistics (AREA) © FSO 2024
The Federal Council 2021: [Swiss National Soil Strategy](#)

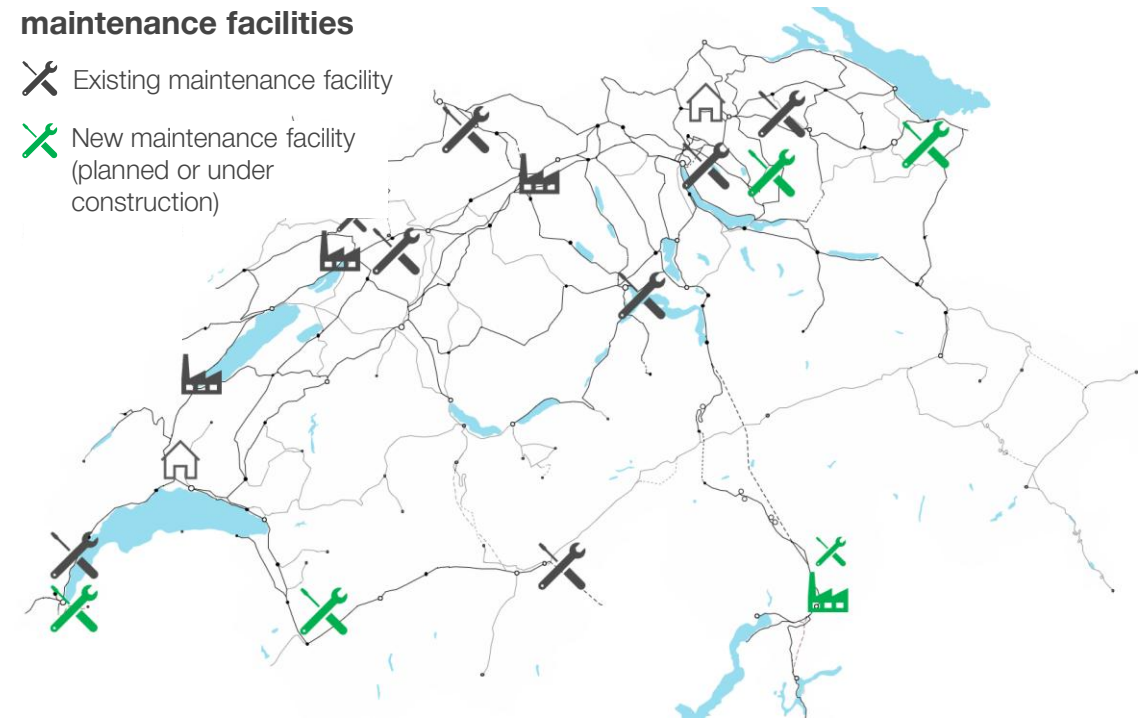
A significant increase in the modal share of public transport is needed to meet the demands of significant population growth in Switzerland. However, in line with the Swiss National Soil Strategy, this needs to be implemented without any additional land consumption, causing a conflict in objectives.

Railway network expansion can reach a limit due to lack of sites for maintenance facilities.



maintenance facilities

- Existing maintenance facility
- New maintenance facility (planned or under construction)



Since 1979, the areas for railway operational uses have hardly grown, while the kilometres travelled by train have more than doubled. To ensure the planned and financed railway service, new maintenance facilities will be needed by 2032.

Source: Bundesamt für Statistik Bfs 2023, Konzernstatistik SBB 2024



The capacity of train paths* and railway operational areas is becoming exhausted.
 In the future, will we need to make some concessions regarding both the expansion of services and land use?

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.»



Take home
messages.

Transport systems and the role of railway.

Efficiency of Rail-Based Mass Transit Systems.

The **main advantages** of rail-based mass transit are **land-use efficiency**, low energy consumption, **reduced CO2** emissions, and **improved safety**.

Modal split.

The modal split is **an important KPI** as it reveals **how individuals choose to travel**. It helps to prioritise infrastructure, target interventions to shift trips to cleaner or safer modes, estimate emissions and energy use, and monitor the effectiveness of mobility measures over time.

Measures and challenges to increase the modal split for rail.

The modal split of public passenger transport in Switzerland **has stagnated** since 2005, **despite political will and substantial investment** in rail and road infrastructure.

To increase the modal split, **complementary measures are necessary** leading to **behavioural changes among travellers**.

Rail **network expansion can reach a limit** due to **lack** of railway **operational areas**.

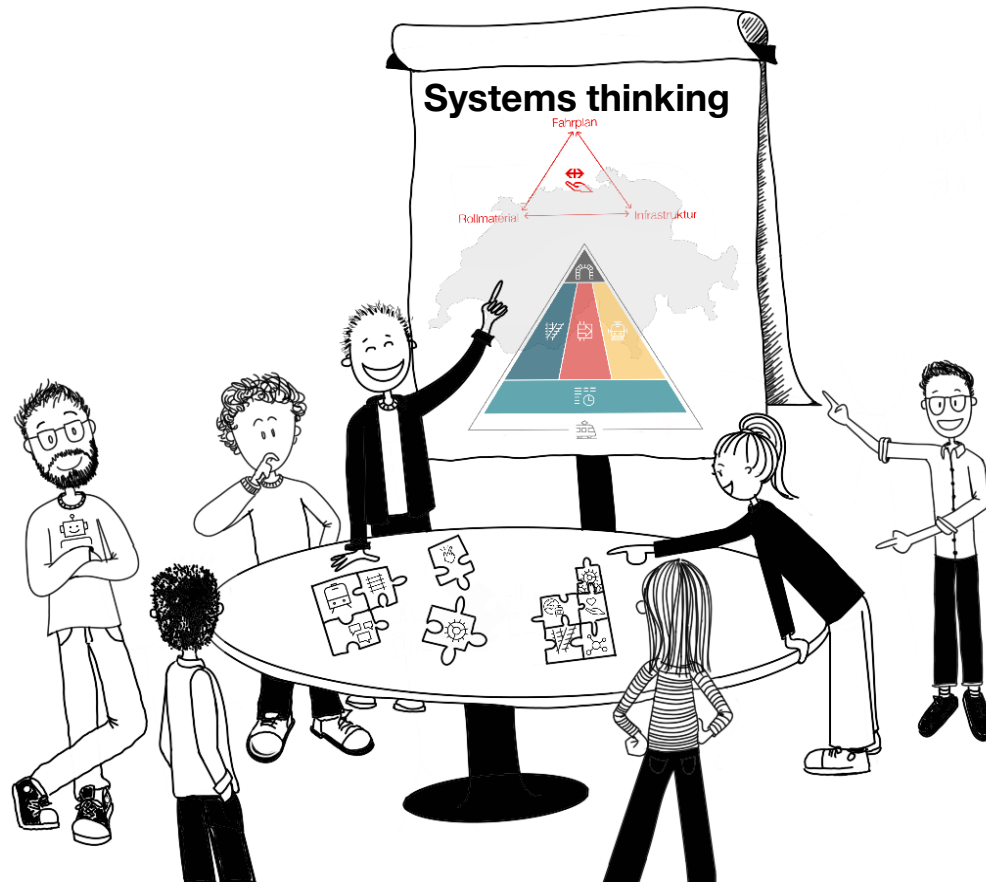
Transport systems and the role of railway.

Case study.

Autumn 2025



Information about the Case Study.



Organisation and Preparation

- Group Size: 3-4 members, ideally the same as for the semester report.
- Case Study Selection: Each group selects one case study per semester.
- Preparation Time: Time allocated is preparation during the exercise class plus a maximum of 3 hours outside of class.

Presentation

- Duration: A pitch of a maximum of 5 minutes.
- Format: No formal requirements, but a maximum of 3 slides, with no additional documents or handouts.
- Discussion: Input and discussion facilitated by the professor.

Evaluation

- Non-graded

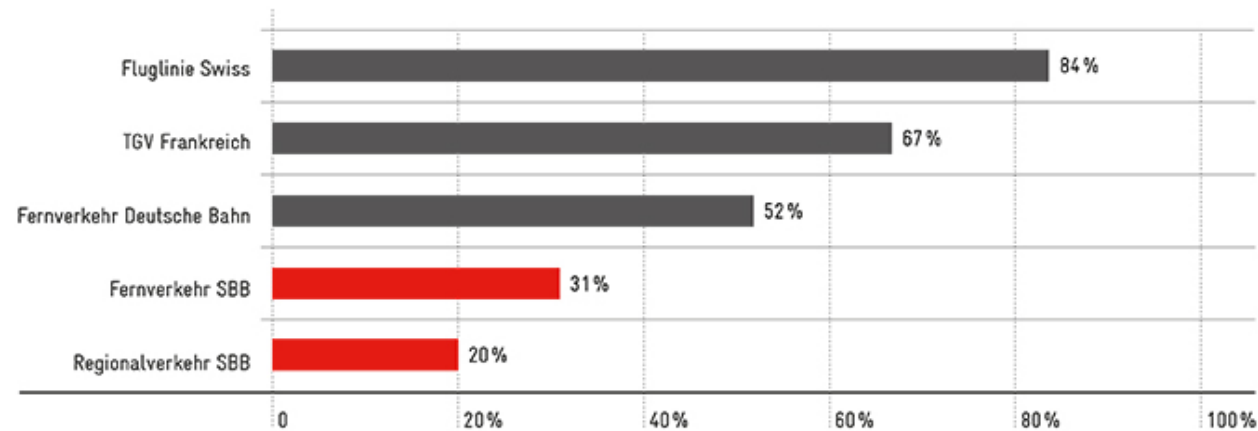
Case: Efficiency of means of transport.

Today we have dealt with the modal split to compare rail and public transport with other means of transport. For the economic management of a railway, the key figure of utilization is highly relevant.

Premise

- Considerations detached from political framework conditions / restrictions

Seat occupancy rates of selected modes of transport in comparison.



Your Role

- In-house Consultant, Strategy Expert

Specific questions

- What do the numbers tell us – why are there differences?
- What are the differences between air travel and rail as a public service
- What are possible measures to increase the seat occupancy rate/load factor of the railway?
- Approx. 3 measures including assessment of feasibility and impact.

Additional information

- Link [Tagesanzeiger](#)



Semester report.

Information on group semester project.

- Study a specific question related to transport systems and produce a final **report of 15 pages**.
 - The groups will consist of **3 to 4 students** each.
 - We will **provide topics** and possible questions.
 - No more than two groups can work on the same topic.
 - There is no presentation of your work. But questions regarding your report **will be part of the final oral exam**.
- **Tuesday 16.09.2025 Discussion of research questions possible during the exercise hour.**
 - **Monday 23.09.2025: Groups sign up on Moodle with defined research topic question.**
 - **Tuesday 07.10.2025: Deadline for the validation of the table of content.**
 - **Tuesday 16.12.2025: Final report delivery.**

Please refer to the moodle information sheet!

