Technological and economic factors on the maximum design speed of high speed trains

International Congress on High Speed Rail, Ciudad Real, 2017

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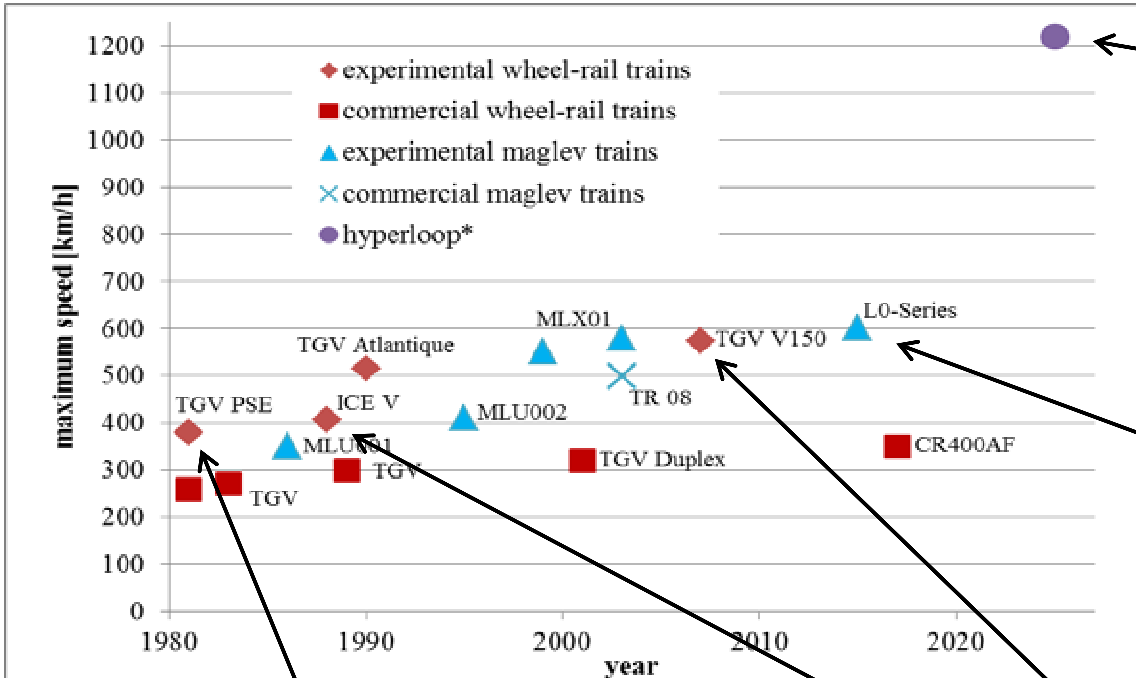
Overview

- Development of Speed in the Railway Sector
- Project Next Generation Train
- Increasing speed up to 600 km/h:
  - Operational aspects
  - Vehicle- and Aerodynamics
  - Signalling and Train Control
- Conclusion

Development of railway speed records



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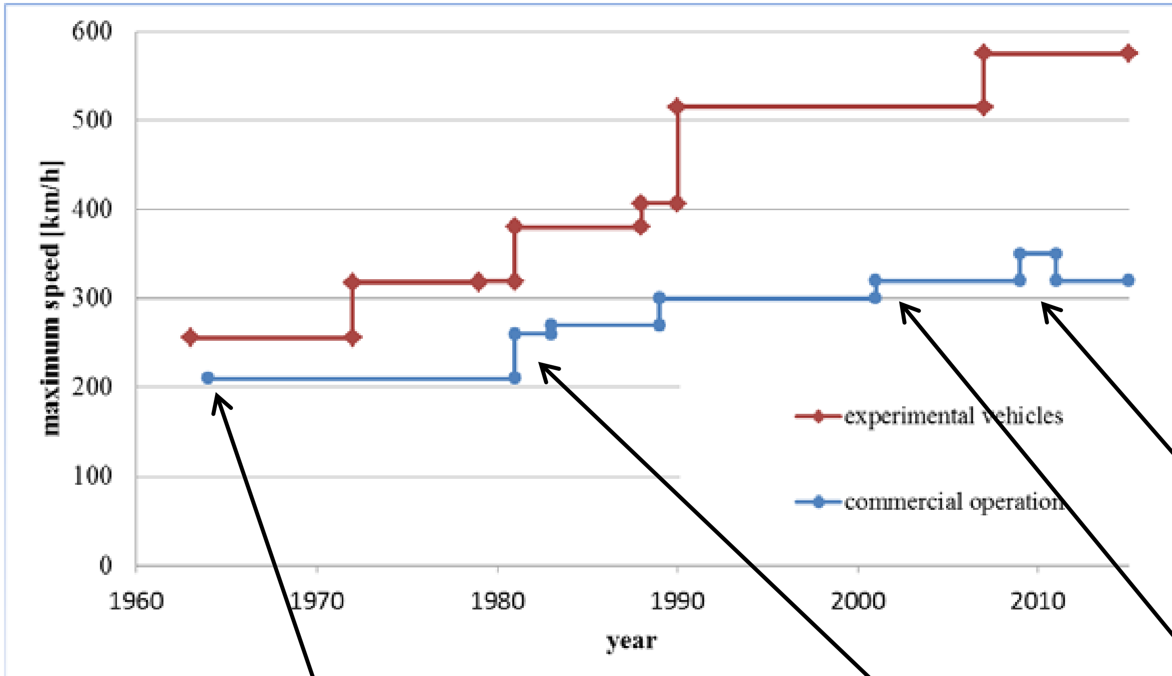
Development of commercial speed




CRH400 - Source: Wikimedia/N509FZ


CRH3 - Source: Wikimedia/Brücke-Osteuropa


Shinkansen 0 - Source: Wikimedia/Nadate

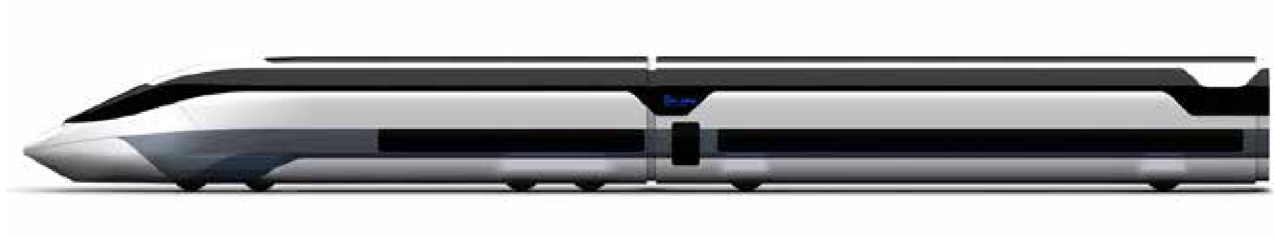

TGV PSE - Source: Wikimedia/Falk2


TGV Duplex - Source: Wikimedia/PS-2507

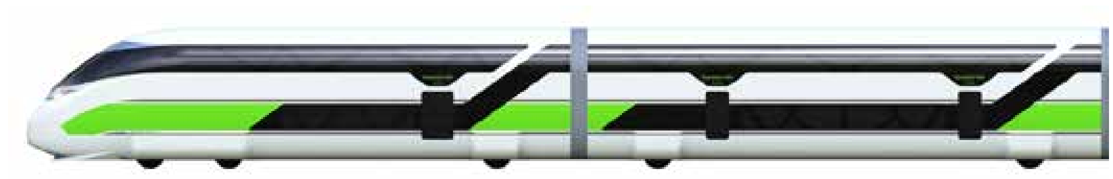
Project Next Generation Train

Since 2007, 11 DLR Institutes, current phase until 2018

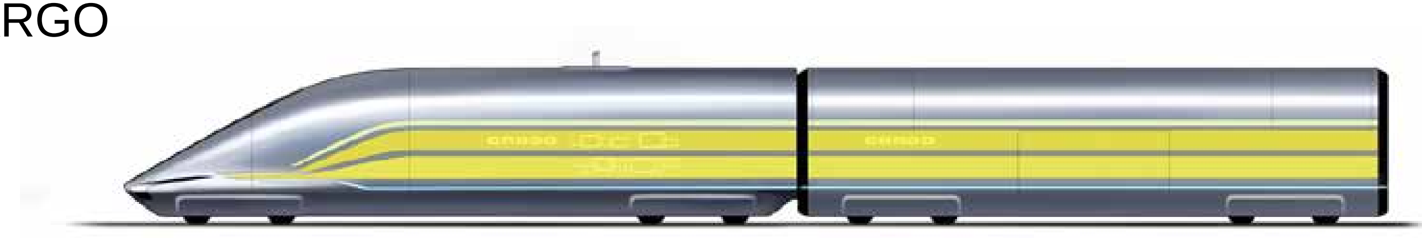
- Ultra-high-speed train (400 km/h, 202m, 800 seats, double-deck, 16 MW)
  NGT HST



- High-speed regional train (230 km/h, 120m, 480 seats, double deck)
  NGT LINK



- High-speed Cargo train (up to 400 km/h, currently in design process)
  NGT CARGO

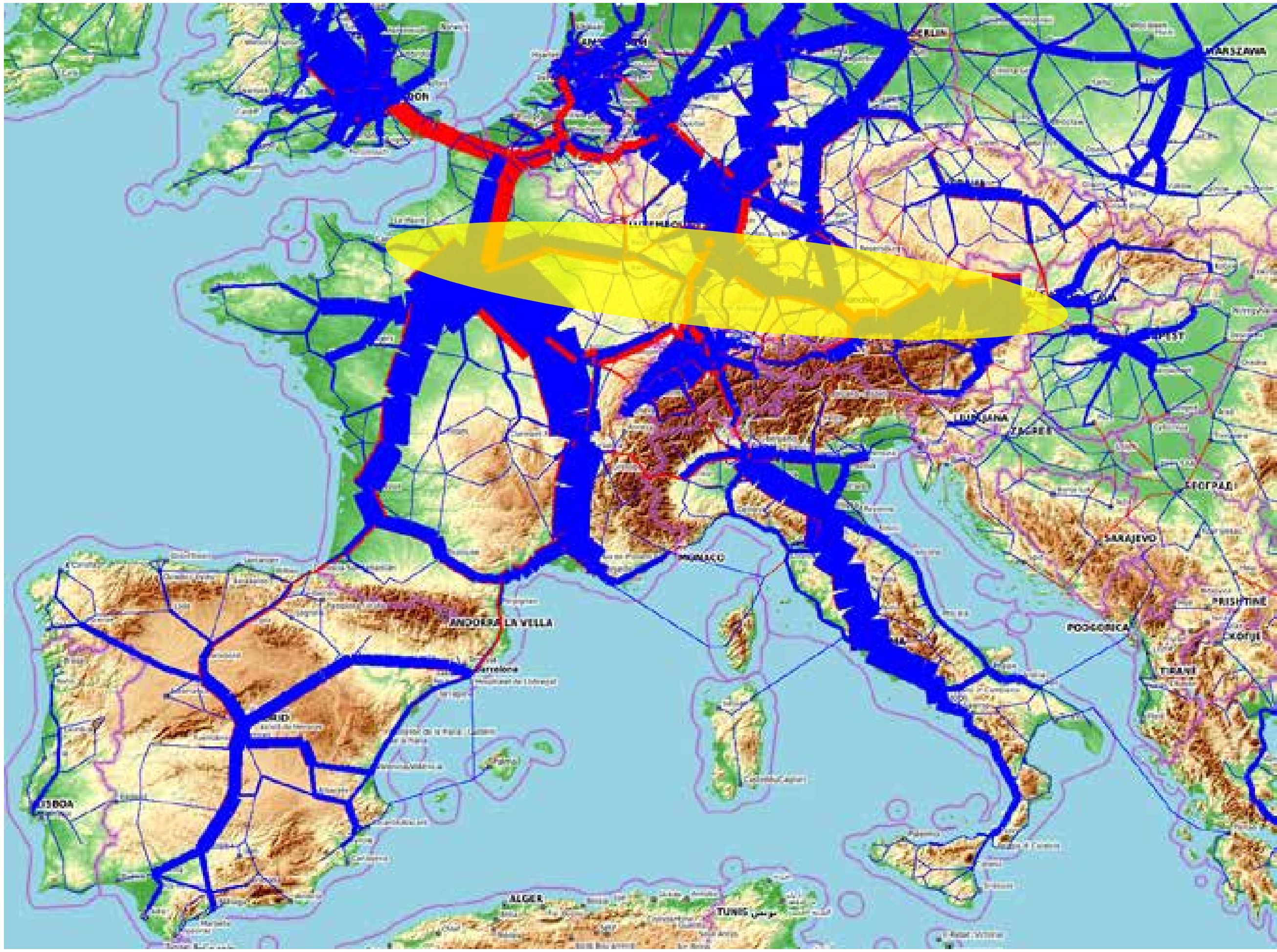


Operational aspects of a commercial speed of 600 km/h

Passenger demand on reference line Paris-Vienna

- Usage of the NGT European Rail Passenger Model
- Gravity model with population and economy data
- Calibrated with 2010 Eurostat data

- 2 700 cities
- 2 000 train routes
- 20 100 km HSR
- 80 000 km Intercity
- 80 000 km regional
- 10.2m train-km/day



NGT Model for 2025 (Thickness: rail passenger demand) BaseMap: OpenTopoMap / OpenStreetMap Contributors

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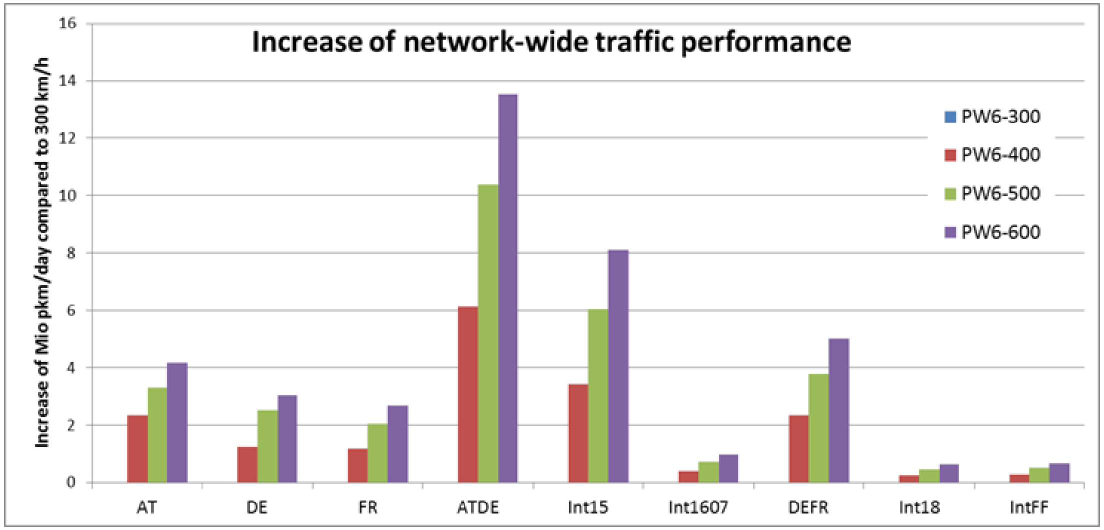
Operational aspects of a commercial speed of 600 km/h

Passenger demand on reference line Paris-Vienna

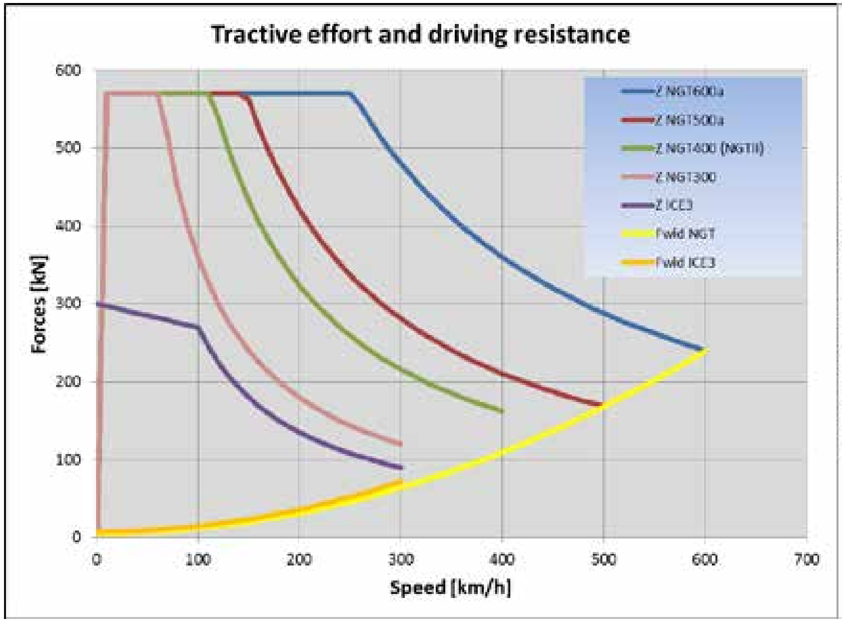
- Speed 300 à 600 km/h: Increase of demand from 19 to 31 bn Pkm/year
- International traffic profits the most (especially Austria-Germany and France-Germany)

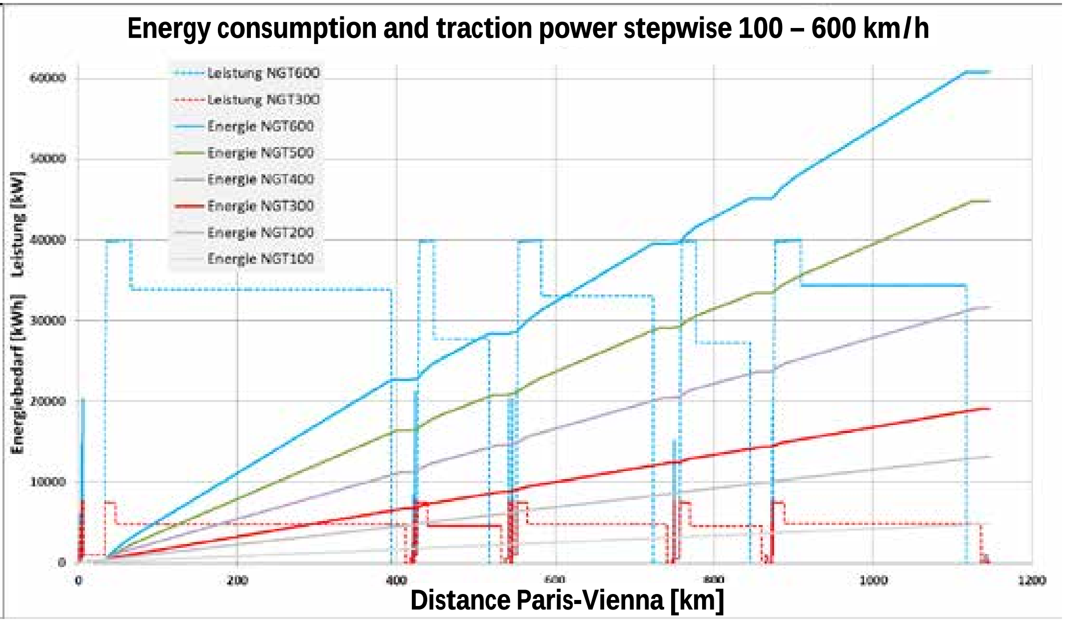


Reference line Paris-Vienna	300 km/h	400 km/h	500 km/h	600 km/h
Travel time (hours)	4:42	3:51	3:23	3:03
Passengers (mio/year)	55.3	69.1	77.2	83.0
Passenger-km (bn. Pkm/year)	19.00	24.84	28.38	30.99
Energy consumption (at wheel) (MWh/run)	19.2	31.6	44.8	60.8

Operational aspects of a commercial speed of 600 km/h
Energy consumption

- Energy consumption increases by factor 3 from 300 to 600 km/h
- One run from Paris to Vienna: 20 à 60 MWh
- For very high speed: renunciation of traction force buffer à speed decrease in slopes à travel time increase hardly noticable

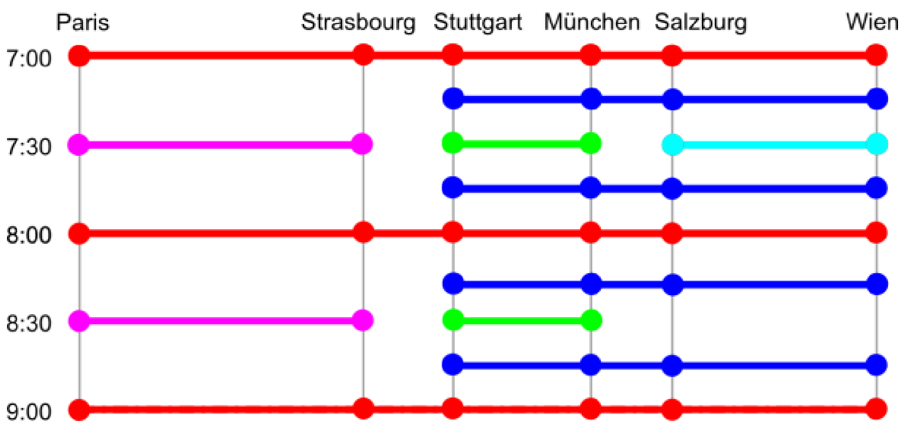


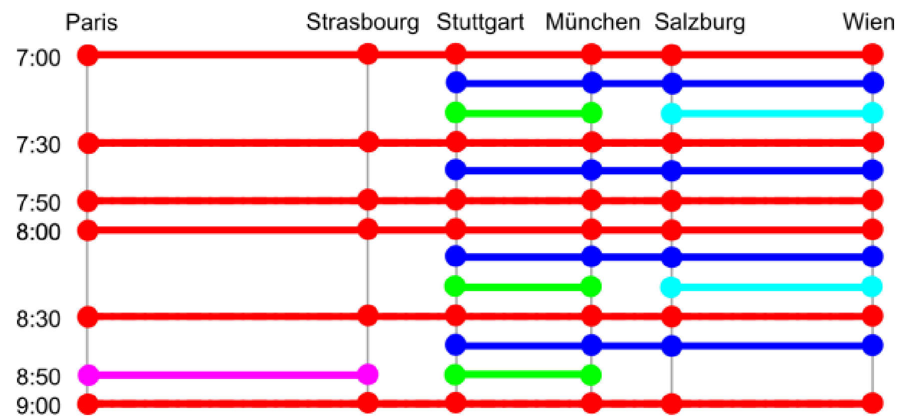


Operational aspects of a commercial speed of 600 km/h

Reference Timetable

Reference line Paris-Vienna	300 km/h	400 km/h	500 km/h	600 km/h
Average speed (km/h)	244	297	338	375
Average speed of all passengers using the line at least for a part of the journey including dwell times (km/h)	119	130	138	146
Specific energy consumption at wheel level (Wh/(km * seat))	21.0	34.5	48.9	66.4
Number of NGT trainsets (incl. 10% operational buffer)	37	40	42	44
Operational performance (Mio trainset-km/year)	29.4	36.3	40.7	46.3
Average operational performance of one NGT trainset (km/year)	786 000	916 000	973 000	1 052 000
Seat utilization (reservation compulsory)	81%	86%	87%	84%





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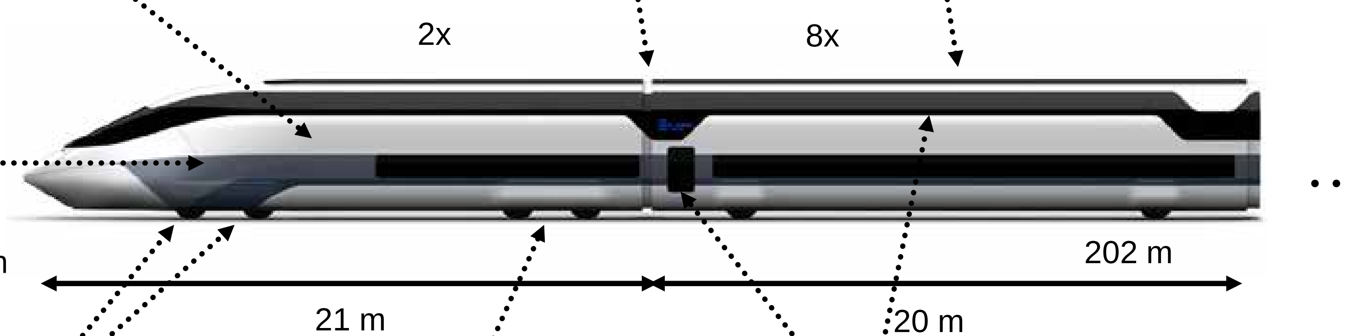
Vehicle – Components to have a look at

Car body
- Dynamic Forces
- Aerodynamic Forces

Interchange of cars
- Pressure resistance
- Air flow (Noise, Resistance)

Energy supply
- Pantograph
- Noise

Propulsion
- Installed Power
- Energy consumption

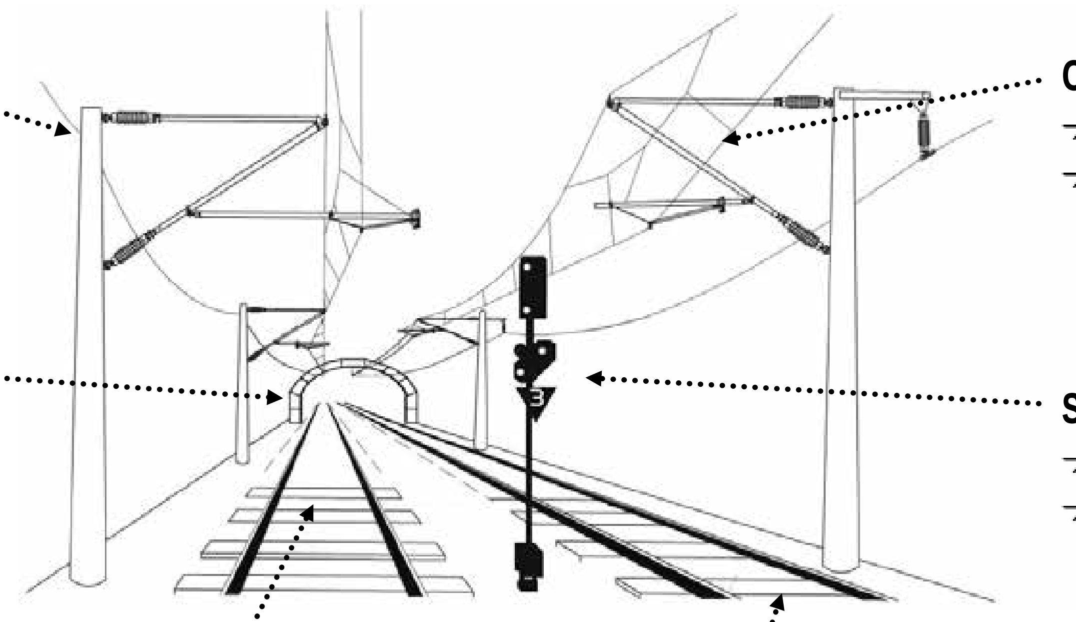


Chassis
- Track condition
- Wheel wear

Brakes
- Pneumatic
- Alternative Brake systems

Doors & Windows
- Pressure resistance

Infrastructure – Components to have a look at



Energy supply
- Substations

Civil engineering
- Tunnels, Bridges
- Air flow (noise, resistance)

Catenary
- Contact wire cross section
- Contact wire tension

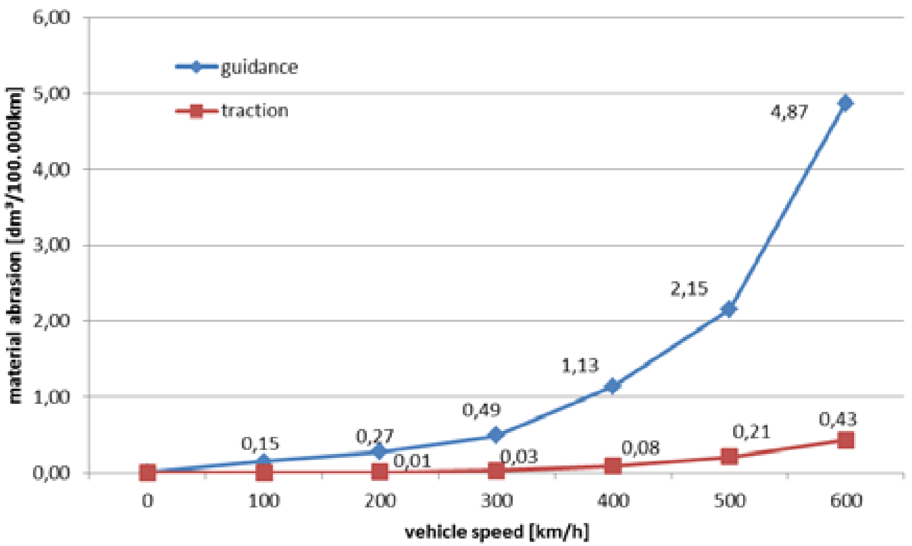
Signalling
- Train protection
- Train guidance

Line routing
- Curve- & Rounding off radii
- Track spacing
- Line width

Super structure
- Ballast, Slab track
- Dynamic additional forces due to track geometry faults

Vehicle dynamics

- Sub-Tasks of the transportation task are: Load bearing, Guidance, Traction
- Guidance is depending on hunting motion, whose stability depends strongly on speed
- Measures: adjust stiffness of primary suspension, low equivalent conicity, additional yaw dampers, long wheel-base (everything solvable)
- Wear: Sliding friction, speed dependency is difficult to quantify
- Exemplary calculation with standard HSR configuration shows a progressive increase of abrasion due to guidance forces à
- Traction potential drops with incr. speed, according to Curtius and Kniffler, friction coefficient μ = 0.1
- Aerodynamical drag causes the equipment of as much wheels as possible to be powered



Aerodynamics

- Aerodynamic drag exceeds mechanical friction at higher speeds and increases with the square of driving speed
- Measures: long nose, plane surface, plane wagon interchange

- Also important: Crosswind stability especially with the lightweight construction (NGT as example)
- Measures: specific devices for active control of stability, wind (and noise) fences

- Noise problem: over 300 km/h aeroacoustic emissions dominate
- Pantograph sound scales with U^6 à measures for a noise-optimization such as the Shinkansen pantograph

Signalling and Train Control

- Braking distance grows approximately by square of the speed
- Current high-speed train control systems (e.g. ERTMS) could solve speeds up to 600 km/h without significant problems
  - Cab signalling instead of trackside signals
  - Radio connections capable of working with high-speeds
  - Balise message transmission capable of working with high-speeds
- Due to long braking distances the Moving Block promises higher capacity (fixed obstacles like junction switches can be found in areas with lower speed)

Conclusions

- Many technical aspects can be solved (like speed records show)
- The problem will be the economic side: effort grows progressive, the benefit (travel time reduction) decreases, energy consumption is only a small part