Gröna Tåget (the Green Train)

Train for tomorrow’s travellers

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KTH = Royal Institute of Technology, Stockholm
What is Gröna Tåget? (Green Train)

- A Swedish research and development programme aiming at
  - **defining a concept** for the next generation HS trains for long-distance and fast regional service
  - developing appropriate **technology** suitable for Northern European countries (SE, N, DK, SF)
- Programme carried out 2005-2011
- Involves most stakeholders in Swedish rail business
RAILWAY GROUP
Centre for Research and Education in Railway Engineering

Gröna Tåget (Green Train)

Partners
Most main actors in the Swedish railway sector

Gröna Tåget

Regina 250

BOMBARDIER

BANVERKET

TRAFIKVERKET

vti

Interfleet

transrail

CHALMERS

Vinnova

Total budget $\approx 15$ MEUR
Gröna Tåget is not a physical train! The programme should serve as a bank of ideas, proposals and technical solutions, for increased market share, improved profitability, still better environmental performance.

Also infrastructure upgrading is necessary.

What is a "Green" Train?

- Improved **environmental performance**:  
  - **Energy** use (per pass-km) should be reduced.  
  - No higher **noise level** at higher speeds (cf. 200 km/h).

- However, the most important “green” effect is that the train has a **high market share**, because of electric train’s superior environmental performance.  
Passenger attractiveness, cost and ticket price are therefore most important issues.
• **Short travel time** (on upgraded and new infrastructure);
  - Top speed **250 (-320) km/h**.
  - **Tilting carbody** is needed on old main lines:
    curve radii (250-600-) 1000-1600 m
  Travel time to be reduced by approx 10 % on conventional lines, compared with today´s tilting reference trains.

• Improved **passenger comfort** and **functionality**
  (seating and working ability, noise & ride, pressure tightness, reduced motion sickness, pass with reduced mobility).

• **Low cost** per pass-km.
  - **Space efficient** = Large number seats per m train
  - To efficiently **compete with low-cost carriers** (car, bus, air)

On a competitive market low cost will result in **lower ticket prices**.
• **Mixed traffic** with heavy freight trains, as well as **frost upheaval** would produce larger track defects. Requires **track-friendly trains** (low track deterioration, smooth ride on non-perfect track)

• The **modest population density**, and varying traffic demands, requires **flexible trains** (4 – 12 cars). This means 2 or 3 pantographs (current collectors) at short distance in between.

• High requirements for **disabled passengers** (preferably level entrances and/or convenient lift facilities within the train).  
  Note: normal platform height 0.55-0.75 m.

• High **braking deceleration** (short pre-signalling distance)

• Reliable operation also under harsh **winter conditions**.

All this is **compliant to the European standard**, but is not specifically required in TSI and EN.
The climate challenge in Nordic European countries

3-6 months average below zero
Occasionally -40°C
Heavy snowfall

A lot of measures must be applied compared to a “standard” high-speed train, in order to be able to operate in the low temperatures and snow conditions.

Many of these measures must be considered early in the design phase.
According to Gröna Tåget studies:
Total operating cost per pass-km
when different factors are changed by 20 % (not combined)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Cost Reduction</th>
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<tbody>
<tr>
<td>Reduced travel time</td>
<td>- 8 %</td>
</tr>
<tr>
<td>Higher load factor</td>
<td>- 16 %</td>
</tr>
<tr>
<td>Improved space utilization</td>
<td>- 11 %</td>
</tr>
<tr>
<td>Reduced purchase price</td>
<td>- 6 %</td>
</tr>
</tbody>
</table>
The Swedish (and Nordic) rail network allows wider trains than continental Europe (in Sweden+Norway approx 0.6 m). Nordic interoperability with wide-body trains is investigated.

- One more seat abreast. $2+2 \Rightarrow 2+3$; $2+1 \Rightarrow 2+2$
- Can be made comfortable if properly arranged.
- Important for economic efficiency, energy use (per passenger) and capacity!
- Double-decker trains deliver about the same, but are not suitable for carbody tilt.

Benchmark: Number of seats per metre train (high-speed)

- European average 2.2 (but some <2.0)
- Best European 2.6 (double-decker)
- Japan Shinkansen 3.3 (wide-body + other features)
Gröna Tåget concept

Quite small units (~300 seats) to run in multiple by demand (600-1000 seats)
- Capacity according to need (higher load factor)
- Different destinations by coupling/uncoupling (avoiding train change)

Wide body Gröna Tåget
~300 seats

Continental width

Present X 2000, 309 seats

Wide body (~3,5 m exterior) allowing one more comfortable seat abreast will alone reduce cost (per seat-km) by about 13%.

In total: About 25% reduced cost (per pass-km), compared X 2000
Attractive passenger environment

For comfort, functionality and space utilization (examples)

Individual armrests very important for comfort

New **under-seat design** and **thin seatbacks** allows some 15% more seats with the same passenger acceptance
Attractive passenger environment

Functionality and comfort for useful travel time

- Adjustable neck rest
- Lumbar support
- Head rests
- Table design
- Adjustable depth

And a lot of other useful features
- for clothes
- for luggage
- etc

Space for lap-top.
Adjustable table depth.
Edges to prevent fall-off.
Cup-holders.
Prototype and certification testing 2006 – 2008: Modified "Regina" wide-body EMU train

**Step 1**
2006-07

- Improved radial steered bogies (self-steering)
- Bogie noise shield

**Step 2**
2007-08

- Modified radial steered bogies with Active Lateral Suspension (ALS) and Permanent magnet motors
- Mechatronic bogies with Active Radial Steering (ARS)
- Bogie noise shield

Endurance & reliability testing in revenue service (2009-2011)
Propulsion

- **Permanent Magnet (PM) Motors** are successfully tested (performance and endurance). Benefits are
  - Reduced losses, **higher energy efficiency**
  - **Reduced need for cooling** (forced cooling via air ducts eliminated; no rotor cooling)
  - **Reduced mass** and size; improved power/mass ratio.

- **Improved pantograph** for multiple operation on medium-quality catenary at high speed (tested up to 303 km/h on catenary for 200)
2005 – 2008 (-2011) particular focus on

- **Track-friendly bogies** (passive self-steering + mechatronic)
  
  **Track forces** + running stability
  measured by instrumented wheels

- **Ride quality** on non-perfect track, including **active suspension**

Simulation, hardware, certification testing, endurance testing.
- The **axle load** of the train should not exceed 14.5 tonnes. (without passengers)
- **Cant deficiency** should normally be limited to 275 mm.
- **Wheelset guidance as soft as possible** still ensuring hunting stability; i.e. in the order of 8-10 MN/m per axle box.

**Track friendly technology (2)**

For acceptable track deterioration (Sweden)

![Graph](image)

- **Wear number** (energy dissipation) outer leading wheel

![Graph](image)
... still ensuring stability up to 300 km/h

Stability requirements according to UIC 518 are fulfilled

Measured equivalent conicity on high-speed test track
Active lateral suspension (1)

Objectives

• **Dynamic vibration control**
  to improve lateral vibration comfort
  Goal: Same ride comfort at 250 km/h as without active suspension at 200 km/h

• **Hold-Off Device (HOD)**
  to keep carbody in centred position in curves
  ⇒ reduced bumpstop gap
    → wider carbody profile possible
    → improved cross wind stability
  ⇒ allowing higher speed in curves
Active lateral suspension (2)
Results from UIC 518 test runs

Similar comfort improvements are predicted with **active vertical suspension** but not yet verified with on-track tests.
Further testing and studies 2006 – 2008 (– 2011)

- Aerodynamics
- Winter climate protection at high-speed operation
- Carbody tilt systems performance & measures to reduce motion sickness.
- Noise reduction (external + internal)
- Market, economy, capacity in mixed traffic
- Travel time and energy use

Winter testing
Carbody tilt

Risk for motion sickness – can be reduced by improved tilt control

Results from on-track tests with test subjects.
Case 1 is the reference case with passenger lateral acceleration 0.6 m/s².

More non-tilting like
Simulated running time benefit on typical Swedish main lines is about 10%. Example: Stockholm–Gothenburg, 4 intermediate stops
Gröna Tåget 6 car average, including time margin

<table>
<thead>
<tr>
<th>Performance property</th>
<th>X 2000</th>
<th>Gröna Tåget</th>
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</thead>
<tbody>
<tr>
<td>Cant deficiency</td>
<td>245 mm</td>
<td>275 mm</td>
</tr>
<tr>
<td>Top speed</td>
<td>200 km/h</td>
<td>250 km/h</td>
</tr>
<tr>
<td>Short-term tractive power</td>
<td>3.9 MW</td>
<td>6.0 MW</td>
</tr>
<tr>
<td>Starting acceleration</td>
<td>0.44 m/s²</td>
<td>0.6 m/s²</td>
</tr>
<tr>
<td>Running time</td>
<td>3:07</td>
<td>2:51</td>
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External noise

Installing high noise barriers is costly and visually intrusive. Instead the following measures are proposed:

- **Bogie skirts.**
- Careful design of the **front area.**
- Shielding and careful design of **pantograph** and other **on-roof equipment.**
- **Smooth surfaces,** including closure of **inter-car gaps.**
- **Rail absorbers** and **low track-side barriers** – at least in sensitive areas along the line.
It is expected that energy use (per pass-km) will be reduced by 25-35%, compared with present X 2000, despite higher speed. This is because of:

- Improved aerodynamics + permanent magnet motor drives
- More energy regeneration and eco-driving
- Improved space utilization + higher load factor
Environmental performance, reliability, lower cost and passenger attractiveness can be improved in parallel with higher speed.

Thanks for Your attention!
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