



#### **Gröna Tåget** (the Green Train)

#### Train for tomorrow's travellers



Evert Andersson Sebastian Stichel Prof, Programme co-ordinator Prof, Director KTH Railway Group

**KTH = Royal Institute of Technology, Stockholm** 



Gröna Tåget (Green Train)

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







### **Partners**

Most main actors in the Swedish railway sector



Total budget ≈ 15 MEUR



FLASH · HTM



Gröna Tåget (Green Train)

#### 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?

Gröna Tåget (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.





### **Attractiveness and cost**

Gröna Tåget (Green Train)

- 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.** 



# Additional requirements to European standards (TSI, EN)

Gröna Tåget (Green Train)

- **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

Gröna Tåget (Green Train)

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.





Gröna Tåget (Green Train)



According to Gröna Tåget studies:

Total operating cost per pass-km

when different factors are changed by 20 % (not combined)







Gröna Tåget (Green Train)

#### **Opportunity** According to EN 15 273

- 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 => 2+3; 2+1 => 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
- Best European
- Japan Shinkansen
- 2.2 (but some <2.0)
  - 2.6 (double-decker)
- 3.3 (wide-body + other features)



Gröna Tåget (Green Train)

# 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)



#### 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

Gröna Tåget (Green Train)

#### 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



RAILWAY GROUP Centre for Research and Education

in Railway Engineering

# Attractive passenger environment

Gröna Tåget (Green Train)

#### Functionality and comfort for useful travel time





# 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.



Gröna Tåget (Green Train)

#### **Testing** Bogies, noise, aerodynamics, propulsion, winter protection

Prototype and certification testing 2006 – 2008: Modified "Regina" wide-body EMU train





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





Gröna Tåget (Green Train)

- **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)







Gröna Tåget (Green Train)

# Track friendly technology (1)

#### 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.









Gröna Tåget (Green Train)

Track friendly technology (2) For acceptable track deterioration (Sweden)

- 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.







Gröna Tåget (Green Train)

... still ensuring stability up to 300 km/h

# Stability requirements according to UIC 518 are fulfilled

Measured equivalent conicity on high-speed test track

Equivalent conicity Sk-T- U-track axle 1 and 3







## Active lateral suspension (1)

Gröna Tåget (Green Train)

## **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  $\Rightarrow$  reduced bumpstop gap

- $\rightarrow$  wider carbody profile possible
- $\rightarrow$  improved cross wind stability



 $\Rightarrow$  allowing higher speed in curves

KTH vetenskap och konst RAILWAY GROUP Centre for Research and Education in Railway Engineering

Gröna Tåget (Green Train)

# Active lateral suspension (2) Results from UIC 518 test runs

#### Lat acceleration (m/s<sup>2</sup>) (ISO-weighted)





Similar comfort improvements are predicted with active vertical suspension but not yet verified with on-track tests.



# Further testing and studies 2006 – 2008 (– 2011)

Gröna Tåget (Green Train)

- 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







Gröna Tåget (Green Train)

#### **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/s<sup>2</sup>.







### **Travel time performance**

Gröna Tåget (Green Train)

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

Performance property Cant deficiency	<b>X 2000</b> 245 mm	<i>Gröna Tåget</i> 275 mm
Short-term tractive power	3.9 MW	6.0 MW
Starting acceleration	0.44 m/s <sup>2</sup>	0.6 m/s <sup>2</sup>
Running time	3:07	2:51





Gröna Tåget (Green Train)

#### **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.





Gröna Tåget (Green Train)



It is expected that **energy use** (per pass-km) will be **reduced by 25-35 %,** compared with present X 2000, despite higher speed





#### This because of

- Improved **aerodynamics** + **permanent magnet** motor drives
- More energy regeneration and eco-driving
- Improved space utilization + higher load factor



#### RAILWAY GROUP

Centre for Research and Education in Railway Engineering



Gröna Tåget (Green Train)

Environmental performance, reliability, lower cost and passenger attractiveness can be improved in parallel with higher speed.

Thanks for Your attention! everta@kth.se, stichel@kth.se www.gronataget.se