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KTH Railway Group

Status Report 2011





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RV RAIL VEHICLES		RV RAIL VEHICLES		RV RAIL VEHICLES		SB STRUCTURAL ENGINEERING AND BRIDGES	
RV1	Running gear for freight wagons	RV10	Gröna Tåget – Programme Management	RV19	Technology opportunities and strategies toward climate-friendly transport (TOSCA)	SB1	Loads and Load Influence on Structures
RV2	Simulation of wheel-on-rail deterioration phenomena	RV11	Gröna Tåget – Track-friendly bogies	RV20	Lightweight carbody for high-speed trains	SB2	Long-term Monitoring and Assessment of Bridges
RV3	Modelling of rail vehicles dynamics	RV12	Gröna Tåget – High-speed vehicles with carbody tilt	RV21	Wheel profile for freight wagons in Sweden	SB3	A study of the dynamic interaction between train and bridge and the long-term changes in the dynamic properties of the new Årsta bridge
RV4	Track stiffness, irregularities and maintenance	RV13	Gröna Tåget – Sound quality of external railway noise	RV22	Modelling contact in the wheel-rail interface	SB5	Sustainable bridges
RV5	Dynamic instability and discomfort of high-speed trains due to aerodynamics in tunnels	RV14	Gröna Tåget – Energy consumption	RV23	Make Rail The Hope for protecting Nature (MARATHON)	SB6	Soil-Structure Interaction for Integral Bridges and Culverts
RV6	Robust safety systems of trains	RV15	Gröna Tåget – Active lateral suspension	RV24	The sustainable freight railway (SUSTRAIL)	SB7	Dynamic response of railway bridges subjected to high-speed trains
RV7	Simulation of energy consumption and running time of trains	RV16	Gröna Tåget – Overhead power systems for operation of high-speed trains in Sweden			SB8	Bridge Weigh-in-motion for railway bridges
RV8	Train formation management and monitoring (TIMM)	RV17	Collaboration in research and development of new curriculum in sound and vibration (CIRCIS)			SB9	BRIDCAP – Increased load capacity of existing bridges on corridors
RV9	Crosswind stability and unsteady aerodynamics in vehicle design	RV18	Railway vehicle dynamics and track interactions: Total regulatory acceptance for the interoperable network (dynoTRAIN)			SB10	Enhanced Fatigue Evaluation of Old Steel Railway Bridges

SB
STRUCTURAL ENGINEERING
AND BRIDGES

EP
ELECTRIC POWER
ENGINEERING

ME
MACHINE ELEMENTS
(DEPT OF MACHINE DESIGN)

ToL
TRANSPORTATION
AND LOGISTICS

SB11
Development and Implementation of Monitoring Systems for Increased Safety and Improved Operation and Maintenance of Railway Bridges

EP1
New converter topologies for electric railway traction

ME1
Track-vehicle interaction (SAMBA 6) – Wheel rail wear mechanisms and transitions

ToL1
Model for supply and costs for freight transport by rail

SB12
Development of Methodology for LCC and LCA of Railway Bridges

EP2
Dual system locomotives for rail freight transportation/ Drive cycles for freight locomotives

ME2
Adhesion between railway wheel and rail

ToL2
Evaluation of intermodal transport chains

SB13
Efficient Assessment Methods of the Dynamic Response of Existing Railway Bridges to High-speed Trains

EP3
System aspects of Permanent magnet traction motors

ME3
Airborne particles generated from train-track interaction

ToL3
Intermodal small-scale liner trains

EP4
Train information Management and Monitoring (TIMM)

ToL4
Regional freight transport systems

EP5
Dynamic maintenance, Planning and Scheduling for Train Operation, DUST

ToL5
TESS – Intermodal Solutions for Trans European Temperature Sensitive Shipments

ToL6
MINT – Model and decision Support System for Evaluation of Intermodal Terminal Networks

ToL7
FTCS – Freight Transport Corridor Study

ToL8
SCANDRIA – Scandinavian-Adriatic Corridor for Growth and Innovation

ToL9
Bothnian Green Logistic Corridor (BGLC)

ToL
TRANSPORTATION
AND LOGISTICS

ToL
TRANSPORTATION
AND LOGISTICS

MW
MARCUS WALLENBERG
LABORATORY FOR
SOUND AND VIBRATION
RESEARCH

ToL10 The VEL wagon – efficient and longer wagons for future freight transportation

ToL19 Future infrastructure and train run quality

MW1 Gröna Tåget – noise and vibration part

ToL11 Gröna tåget – market and services

ToL20 Congested infrastructure

ToL12 High-Speed Trains in Sweden – Supply and demand

ToL21 Timetable planning with simulation

ToL13 Competition and interaction between rail and air

ToL22 Cost-benefit analysis of capacity measurements

ToL14 Evaluation of new train systems

ToL23 Gröna tåget – capacity analysis of higher speed for express trains

ToL15 Deregulation of passenger traffic – a case study of the West Coast Main Line

ToL24 Capacity analysis of the rail network in Sweden

ToL16 Development and forecast models

ToL25 Stockholm Central 2050 – Forecast of demand and capacity needs

ToL17 TOSCA – Energy consumption and emissions from transportation

ToL26 Simulation and capacity analysis

ToL18 Database of supply and prices for railway-lines in Sweden

ToL27 Evaluation of track fees



KTH Railway Group in 2011

KTH Railway Group was formed in 1988 as an informal organization to support and coordinate expertise in the area of railway technology at KTH. Since 1996, the Railway Group is a formal research and development centre in rail technology at KTH. The main tasks are research, higher education at undergraduate and postgraduate level, and training for employees in the railway field. The funding is regulated by an agreement between KTH, the Swedish Transport Administration (Trafikverket), Bombardier Transportation, Stockholm Public Transport (SL), the Swedish Train Operators (Tågoperatörerna) and Interfleet Technology.

Thus KTH Railway Group has more than 20 years of experience of working multidisciplinary. It consists today of nine research groups of which each group represents one or more disciplines, i.e. in principle all competencies in the railway area are covered. This makes KTH Railway Group quite unique and has throughout the years enabled us to successfully carry out several major research programmes with a broad approach – covering not only technique but also e.g. market analysis – together with our partners. The concept for the Regina train running in Sweden, Norway and China is a product of one of these programmes. At the time this report is printed the “Gröna Tåget” programme is about to be finished. It has accomplished a further development of the Regina train to run at speeds up to 303 km/h. KTH Railway Group is also an important voice in the discussions on how to increase transport capacity on a more and more crowded Swedish railway network and on whether new high-speed lines in Sweden should be built. This spring we have started a co-operation with the Rail Transportation and Engineering Center of the University of Illinois at Urbana-Champaign, to further broaden our research network especially on heavy freight traffic.

In September 2011 I participated on a large conference on Railway Vehicles in Graz in Austria. The most important conclusion as well from presentations as from discussion is that it has to be pointed out again and again that Railways are an integrated system. To only look at one part inevitably leads to sub-optimization that does not minimize the cost for the whole system. Infrastructure managers for example would like to see more track friendly vehicles. However, there are no incentives for operators today to use vehicles that perform better than just fulfilling existing standards. Also the

introduction of the new European train control system ETCS was discussed lively. Instead of blaming each other all parties should agree on common strategies for the best of the whole. Centers like KTH Railway Group have as one of their main tasks to take a holistic view to get the most for the railway sector.

This status report gives an impression of the diversity of activities in research and education that are carried out. In our opinion the importance of railway research is only increasing. In an EU white paper from 2011, for example, it is said that “30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050”. This is not possible without a dramatic development of both railway infrastructure and rolling stock. We are looking forward to contribute to a positive development of railway traffic together with our partners also in the coming years. If you have any questions do not hesitate to contact me or any other member of the KTH Railway Group.

Professor Sebastian Stichel
Director

September 2011



**Professor
Sebastian Stichel,
Director of the KTH
Railway Group**

The Board 2011

The KTH Railway Group is organized as an independent unit within the School of Engineering Sciences. The board of the Railway Group consists of representatives from companies or organizations that have signed the general agreement.

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Not present on photo: Marcin Tubylewicz

Research groups 2011

SCHOOL OF ENGINEERING SCIENCES

Rail Vehicles – Professor Mats Berg

Vehicle Dynamics – Assistant Professor Lars Drugge

MWL (Sound and Vibrations) – PhD Ulf Carlsson

Lightweight Structures – PhD Per Wennhage

SCHOOL OF ARCHITECTURE AND BUILT ENVIRONMENT

Traffic and Logistics – Adj Professor Bo-Lennart Nelldal

Structural Engineering and Bridges – Professor Raid Karoumi

Highway and Railway Engineering – PhD Elias Gebretsadik

SCHOOL OF INDUSTRIAL ENGINEERING AND MANAGEMENT

Machine Design – Professor Ulf Olofsson

SCHOOL OF ELECTRICAL ENGINEERING

Electrical Machines and Power Electronics – Professor Stefan Östlund

The Board members 2011



Henrik Tengstrand



Sara Paulsson



Raid Karoumi



Mats Berg



Stefan Östlund



Hugo von Bahr



Malcolm Lundgren



Peder Wadman



Bo-Lennart Nelldal



Rickard Nilsson



Sebastian Stichel

Not present on photo: Marcin Tubylewicz

Railway Education at KTH Railway Group

In five of the KTH Railway Groups divisions are given courses in the Railway sector. This is done from the divisions for Rail Vehicles, Transport & Logistics, Road and Railway Engineering, Structural Engineering and Bridges, and in Electric Power Engineering. Our courses are carried out in three different forms of training.

These program courses are part of the Master (or Civilingenjör) Educations here at KTH. It is also possible to make Bachelor or Master Thesis at our divisions.

There are also courses for independent students including courses within further education here at KTH. That is some of the program courses that are also open to external and the teaching is carried out together with the KTH students. These courses are presented and are searchable by www.studera.nu.

The third course form is Education for company development. They are given on request from companies by our Divisions. Please contact the Professor or Director of Studies of the Division.

Division of Rail Vehicles

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Division of Road and Rail Engineering

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Division of Structural Engineering and Bridges

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Division of Electrical Machines and Power Electronics

Stefan Östlund 08-790 77 45 stefan.ostlund@ee.kth.se

Railway Courses in 2011-2012

Division of Rail Vehicles

SD2221 Fordonssystemteknik (8 hp)

Vehicle System Technology

SD2307 Spårfordonsteknik (7,5 hp)

Rail Vehicle Technology

SD2313 Spårfordons dynamik (8 hp)

Rail Vehicle Dynamics

Rail Operation Group at Division for Transportation and Logistics

AH2026 Tågtrafik, marknad och planering, gk (7,5 hp)

Railway Traffic - Market and Planning, Basic Course

AH2028 Tågtrafik, marknad och planering, fk (7,5 hp)

Railway Traffic - Market and Planning, Advanced Course

AH2029 Järnväg signalteknik – signalsystem (7,5 hp)

Railway Signalling System, Basic Course

AH2030 Järnväg Systemsäkerhet, tillförlitliga system (7,5 hp)

Railway Signalling System – Reliability

AH2031 Järnväg signalteknik – projektering (7,5 hp)

Railway Signalling System - Project Planning

AH2032 Simulering av tågtrafik (7,5 hp)

Train Traffic Simulation

Division for Road and Rail Engineering

AF2901 Väg- och banteknik gk (7,5 hp)

Road- and Railway Track Engineering

AH2906 Drift och underhåll av järnväg (7,5 hp)

Operation and maintenance of railways

Division for Structural Design and Bridges

AF2011 Structural Dynamics for Civil Engineers (7,5 hp)

AF2201 Brokonstruktion (7,5 hp)

Bridge Design

AF2203 Brokonstruktion fk (7,5 hp)

Bridge Design, Advanced Course

Division for Electric Power Engineering

EJ2400 Elektrisk traktion (7,5 hp)

Electric Traction

More information on the web-site for KTH Railway Group at www.railwaygroup.kth.se



PhD theses at the KTH Railway Group 1995–2011

1. Anders Nordborg: Vertical rail vibrations - Noise and structure-born sound generation, 1995.
2. Raid Karoumi, Response of Cable-Stayed and Suspension Bridges to Moving Vehicles, Analysis methods and practical modeling techniques, 1998,
3. Karl Kottenhoff: Evaluation of passenger train concepts – methods and results of measuring travellers' preferences in relation to costs, 1999.
4. Eckart Nipp: Permanent magnet motor drives with switched stator windings, 1999.
5. Johan Förstberg: Ride comfort and motion sickness in tilting trains – Human responses to motion environments in train and simulator experiments, 2000.
6. Pelle Carlbom: Carbody and passengers in rail vehicle dynamics, 2000.
7. Romain Haettel, Vibration Transmission in Plate Structures - Special Application to Train Car Bodies, 2000
8. Björn Kufver: Optimisation of horizontal alignments in railways – Procedures involving evaluation of dynamic vehicle response, 2000.
9. Robert Hildebrand: Countermeasures Against Railway Ground and Track Vibrations, 2001
10. Piotr Lukaszewicz: Energy consumption and running time for trains – Modelling of running resistance and driver behaviour based on full scale testing, 2001.
11. Peter Kjellqvist: Modelling and design of electromechanical actuators for active suspension in rail vehicles, 2002.
12. Gerard James, Analysis of Traffic Load Effects on Railway Bridges., 2003,
13. Tanel Telliskivi: Wheel-Rail Interaction Analysis, 2003
14. Oskar Fröidh: Introduction of regional high-speed trains – A study of the effects of the Svealand line on the travel market, travel behaviour and accessibility, 2003.
15. Staffan Norrga: On soft-switching isolated AC/DC Converters without Auxiliary Circuit, 2005.
16. Rickard Nilsson: On wear in rolling/sliding contacts, 2005
17. Jerker Sundström: Difficulties to read and write under lateral vibration exposure – Contextual studies of train passengers' ride comfort, 2006.
18. Ben Diedrichs: Studies of two aerodynamic effects on high-speed trains: Crosswind stability and discomforting car body vibrations in tunnels, 2006.
19. Roger Enblom: On simulation of uniform wear and profile evolution in the wheel-rail contact, 2006.
20. Nizar Chaar: Wheelset structural flexibility and track flexibility in vehicle-track dynamic interaction, 2007.
21. Per-Anders Jönsson: Dynamic vehicle-track interaction of European standard freight wagons with link suspension, 2007.
22. Dan Brabie: On derailment-worthiness in rail vehicle design – Analysis of vehicle features influencing derailment processes and consequences, 2007.
23. Eric Berggren: Railway track stiffness – Dynamic measurements and evaluation for efficient maintenance, 2009.
24. Gerhard Troche: Activity-based rail freight costing – A model for calculating transport costs in different production systems, 2009.
25. Tommy Kjellqvist: On design of a compact primary switched conversion system for electric railway propulsion, 2009.
26. Esra Bayoglu Flener, Static and dynamic behaviour of soil-steel composite bridges obtained by field testing, 2009.
27. Johan Wiberg, Railway bridge response to passing trains. Measurements and FE model updating, 2009.
28. Jon Sundh, On wear transitions in the wheel-rail contact, 2009.
29. Andreas Andersson, Capacity assessment of arch bridges with backfill: Case of the old Årsta railway bridge, 2011.
30. Rickard Persson: Tilting trains – Enhanced benefits and strategies for less motion sickness, 2011.
31. Olov Lindfeldt: Railway operational analysis. Evaluation of quality, infrastructure and timetable on single track and doubletrack lines with analytical models and simulation. 2011.



Rail Vehicles – RV

The activities at the Division of Rail Vehicles mainly focus on rail vehicles and their dynamic interaction with the track. Research is also carried out on pantograph-catenary interaction, energy consumption and running

times. In addition, the division is responsible for two undergraduate courses and also external courses. A Master Programme on Vehicle Engineering, covering both rail and road vehicles, started in the autumn of 2010.



Professor Mats Berg

RESEARCH PROJECTS

RV1. Running gear for freight wagons

Project leader Sebastian Stichel
 Scientists Per-Anders Jönsson
 Sebastian Stichel
 Evert Andersson
 Nebojsa Bogojevic

Sources of funding: Banverket/Trafikverket, Bombardier Transportation, SL AB, Tågoperatörerna, Interfleet Technology, LKAB.

The project is firstly aimed to study and learn how freight wagons behave dynamically on track. This is made both for standardised running gear and for novel designs. The second step is to analyse and test possible improvements in the designs, in particular the standardised designs now dominating in Europe. In the project special attention is given

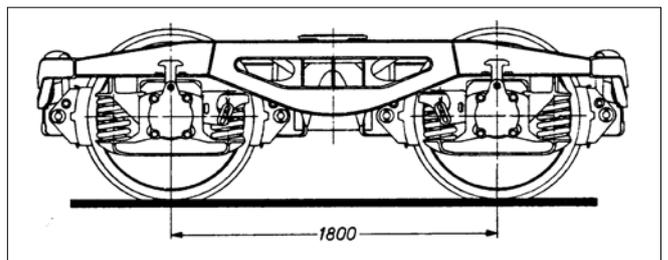
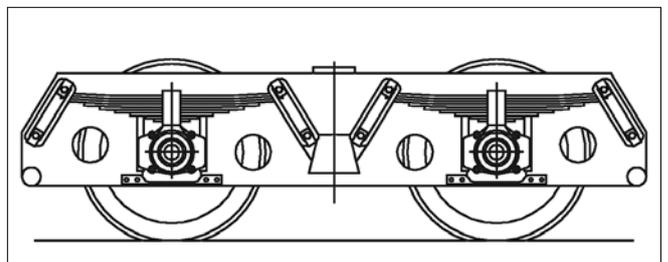
to the very common link suspensions, their characteristics and the possible effects on variations in the characteristics. Substantial improvements by means of additional hydraulic dampers have been suggested and tested on modified two- and four-axle wagons on track. Speeds up to 170 km/h have been tested. In 2007 Per-Anders Jönsson defended his dissertation on the topic "Dynamic Vehicle-Track Interaction of European Standard Freight Wagons with Link Suspension".

A third part of this project is to investigate the causes of track deterioration and to propose mathematical models for prediction of deterioration.

In 2010 work on modelling the latest iron ore wagon from MTAB/LKAB with so called three-piece bogies started. The aim of this part of the project is to be able to study different types of phenomena with help of multibody simulation



A two-axle wagon with different damper arrangements was successfully tested at speeds up to 176 km/h.



Examples of running gear investigated.

instead of only with on-track tests to save time and money. One of the major difficulties when modelling three-piece bogies is a correct mathematical description of the friction damping.

Jönsson P-A and Stichel S: Improving Ride Comfort in Freight Wagons with Link Suspension Running Gear using Hydraulic Dampers. ZEV+DET Glas. Annalen 131, Juni, p. 230-240, 2007.

Jönsson P-A and Stichel S: On the Influence of Freight Traffic Operational Conditions on Track Deterioration cost. Proceedings of International Heavy Haul Conference, p 445-452, Kiruna, June 11-13, 2007.

Jönsson P-A: Dynamic Vehicle-Track Interaction of European Standard Freight Wagons with Link Suspension, Ph.D. Thesis, Report TRITA AVE 2007:36, KTH Rail Vehicles, 2007. ISBN 978-91-7178-727-9.

Jönsson P-A, Persson I and Stichel S: New Simulation Model for Freight Wagons with UIC Link Suspension. Vehicle System

Dynamics, Volume 46, Supplement, pp 695-704, 2008.

Jönsson P-A and Stichel S: On the Influence of Freight Traffic Operational Conditions on Track Deterioration Cost. International Journal of COMADEM, 12(2), pp 3-9, April 2009.

Stichel S and Jönsson P-A: Is there a Future for Freight Wagon with Link Suspension? Proc. of the 9th International Heavy Haul Conference, IHHA'09. Shanghai, China, June 22 - 24, 2009.

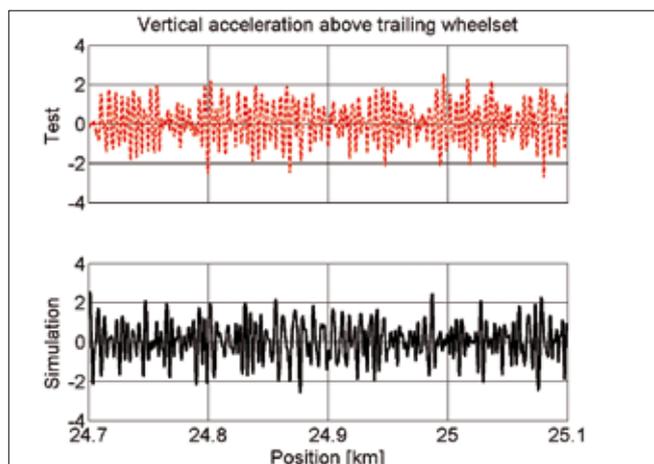
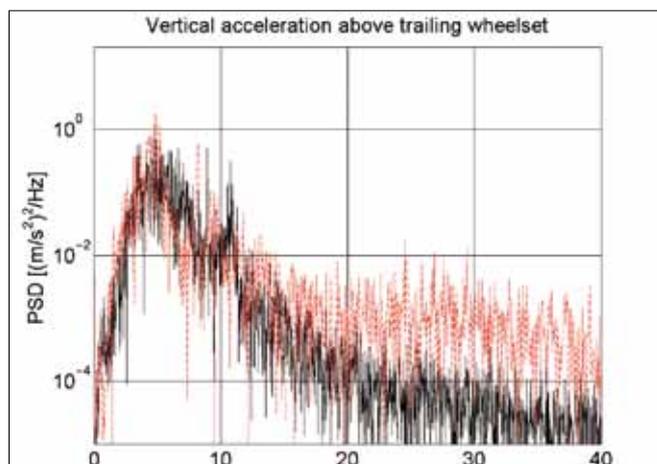
Andersson E and Öberg J: Models for infrastructure costs related to the wheel-rail interface. Chapter 21 in Wheel-rail interface handbook, Woodhead Publishing Ltd, Cambridge, England, 2009.

Öberg J and Andersson E: Determining the deterioration cost for railway tracks. Proc. IMechE Vol 223 No F2, J. Rail and Rapid Transit, pp. 121-129, 2009.

Bogojevic N., Jönsson P-A and Stichel S: Iron Ore Transportation Wagon with Three-Piece Bogies – Simulation Model and Validation. HEAVY MACHINERY - HM 2011, ISBN 978-86-82631-45-3.



Three-piece bogie.



Comparison between measured and simulated results...

... for two-axle vehicle with link suspension.

RV2. Simulation of Wheel-On-Rail Deterioration phenomena (SWORD)

Project leader Roger Enblom
Scientists Babette Dirks
Roger Enblom
Mats Berg

Sources of funding: Trafikverket, Bombardier Transportation, SL AB, Tågoperatörerna, Interfleet Technology.

The project was started in May 2008 with the employment of Babette Dirks as Ph.D. student.

The research focus is on damage prediction in the wheel–rail interface. The contact patch is small and subjected to high stresses and wear. Two common modes of deterioration, causing significant maintenance costs, are wear and fatigue. In addition the vehicle–track interaction may be influenced in the direction of decreasing dynamic performance. The prevailing mode of deterioration is determined by load and operating conditions. The challenge is to develop and integrate methods for prediction of wear and rolling contact fatigue (RCF) – in reality mutually dependent phenomena. Initiated cracks may be worn away and the contact geometry may be altered, changing the rate of crack propagation.

The objective is to create a model for prediction of the total expected life of wheels or rails with respect to both fatigue cracking and wear, practically applicable and resting on a firm scientific foundation. For model validation, access to results in terms of real damage investigations and laboratory tests, mainly carried out by other research projects or the industry, is anticipated.

The prediction methodology is based on recent achievements in wear and RCF modelling. Multi-body simulations (MBS) of the interaction between vehicle and track by using commercially available software provide input to the tribological models. The real operation conditions are emulated by defining an adequate set of simulations.

For a successful simulation of the wear – fatigue trade-off it is believed that adequate models for contact stress, local slip, material loss, fatigue damage, and possibly plastic material flow are needed.

- In the area of contact mechanics the intended starting point is investigation and adaptation of available non-Hertzian models, able to describe the typical geometry of the wheel-rail contact.
- When it comes to material loss modelling, the path forward may be further development and validation of the Archard approach with emphasis on lubricated contacts and poor adhesion conditions.
- For assessing the fatigue damage, a quantitative damage accumulation rate is needed. The purpose is to determine the prevailing damage mechanism for actual contact conditions.
- If found critical, some model for plastic material relocation should be considered.

In the first Florence paper available models for prediction of rolling contact fatigue are evaluated and some trial

simulations and parameter studies are reported. In the Cape Town paper further parametric studies and accumulated damage comparisons related to the Stockholm commuter service are carried out. The performance of two vehicle concepts, two wear models, and two RCF models is evaluated and vehicle related as well as model related differences are addressed. The objective of the ongoing work is to arrive at a calibrated RCF model, using crack and rail profile measurements on the iron ore line in northern Sweden. The next step is recording of wear and RCF development on wheels and rails of the Stockholm commuter operation, selected as the reference application.

Papers

Dirks B and Enblom R: Prediction model for wheel profile wear and rolling contact fatigue. Proceedings of the 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Florence, September 15-18, 2009.

Enblom R and Stichel S: Industrial implementation of novel procedures for prediction of railway wheel surface deterioration. Proceedings of the 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Florence, September 15-18, 2009.

Iwnicki S, Björklund S and Enblom R: Wheel-rail contact mechanics. Chapter 3 in Wheel-rail interface handbook, Woodhead Publishing Ltd, Cambridge, England, 2009.

Dirks B and Enblom R: Prediction of wheel profile wear and rolling contact fatigue for the Stockholm commuter train. Proceedings of the 16th International Wheelset Congress, Cape Town, March 14-19, 2010.

Enblom R: Getting to the root of wheel wear. Railway Gazette, March 2010.

Dirks B and Enblom R: Prediction model for wheel profile wear and rolling contact fatigue. Accepted for publication in Wear. Wear 271, issues 1-2, pp. 210-217, May 2011. (Available online October 16, 2010).

Enblom R and Stichel S: Industrial implementation of novel procedures for prediction of railway wheel surface deterioration. Wear 271, issues 1-2, pp. 203-209, May 2011. (Available online October 12, 2010)

Papers related to the preceding project in this area, "Wear on wheels and rails" (SAMBA 2):

Enblom R: On Simulation of Uniform Wear and Profile Evolution in the Wheel-Rail Contact, Ph.D. Thesis, Report TRITA AVE 2006:83, KTH Rail Vehicles, 2006. ISBN 978-91-7178-605-3.

Since then, the following papers have been published:

Enblom R and Berg M: Impact of non-elliptic contact modelling in wheel wear simulation, Wear, vol 265, pp 1532-1541, 2008.

Enblom R and Berg M: Proposed procedure and trial simulation of rail profile evolution due to uniform wear, Proc. IMechE Vol 222/1 Part F: J. Rail and Rapid Transit, pp. 15-25, 2008.

Enblom R: Deterioration mechanisms in the wheel-rail interface with focus on wear prediction - A literature review, Vehicle System Dynamics, Vol 47/6, pp 661-700, 2009.

RV3. Modelling of rail vehicle dynamics

Project leader Mats Berg
Scientists Nizar Chaar
Mats Berg

Sources of funding: Banverket, Bombardier Transportation, SL AB, Tågoperatörerna, Interfleet Technology.

This project aimed at developing improved mathematical models for analysing the vehicle-track dynamics interaction. The work was focused on wheelset structural flexibility and track flexibility, and in particular with respect to wheel-rail forces up to say 200 Hz. Simulated results were compared with measured ones, both on component level and on the global vehicle-track level. Two case studies were selected for the studies: An Rc locomotive and the Green Train running on two different straight tracks. Track flexibility was measured at both sites and the wheelset structural flexibility was measured in laboratory. It is concluded that both types of flexibility have a significant influence on the vehicle-track dynamics and should be properly modelled and included in vehicle-track interaction simulations.

Chaar N and Berg M: Experimental and numerical modal analyses of a loco wheelset, Proceedings of the 18th IAVSD Symposium on dynamics of vehicles on roads and on tracks, Vehicle System Dynamics Supplement, 41 (2004), pp. 597-606.

Chaar N and Berg M: Vehicle-track dynamic simulations of a locomotive considering wheelset structural flexibility and comparison with measurements, Proc IMechE Part F: Journal of Rail and Rapid Transit, Vol. 219, pp. 225-238, December 2005.

Claesson S: Modelling of Track Flexibility for Rail Vehicle Dynamics Simulation, Master Thesis, Report TRITA AVE 2005:26, Division of Railway Technology, Department of Aeronautical and Vehicle Engineering, Royal Institute of Technology (KTH), Stockholm 2005.

Polach O, Berg M and Iwnicki S: Simulation. Chapter 12 in Handbook of Railway Vehicle Dynamics, Taylor & Francis, 2006.

Chaar N and Berg M: Simulation of vehicle-track interaction with flexible wheelsets, moving track models and field tests, Proceedings of the 19th IAVSD Symposium on dynamics of vehicles on roads and on tracks, Vehicle System Dynamics Supplement, 44 (2006), pp. 921-931.

Chaar N: Wheelset Structural Flexibility and Track Flexibility in Vehicle-Track Interaction, Ph.D. Thesis, Report TRITA AVE 2007:17, KTH Rail Vehicles, 2007. ISBN 978-91-7178-636-4.

Chaar N and Berg M: Dynamic wheel-rail force measurements and simulations of a high-speed train running on two tracks with different flexibility and irregularities, submitted for publication.

RV4. Track stiffness, irregularities and maintenance

Project leader Mats Berg and Eric Berggren
Scientists Eric Berggren (Banverket)
Mats Berg et al.

Sources of funding: Banverket/Trafikverket.

The overall aim of this project was to use measurement results of vertical track stiffness along the track to improve the track maintenance, in particular with respect to track irregularities. The track stiffness was measured by a special-purpose rebuilt two-axled freight wagon running on the track at speeds up to 50 km/h and exciting one of the axles by harmonic or "white noise" loading. To some extent results from ground penetrating radar was also used to suggest proper track maintenance actions or soil reinforcements. The project was partly integrated with the EU project INNOTRACK, for instance by using the test wagon above on tracks in France and Germany.

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Irregularities to Detect Short Waved Support Conditions, Proceedings of International Conference on Railway Track Foundations, Birmingham, 11-13 September, 2006. ISBN 0-704426-00-5.

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Berggren E, Kaynia A and Dehlbom B: Identification of Substructure Properties of Railway Tracks by Dynamic Stiffness Measurements and Simulations, Journal of Sound and Vibration, Vol. 329, pp. 3999-4016, 2010.

RV5. Dynamic instability and discomfort of high-speed trains due to aerodynamics in tunnels

Project leader Mats Berg
Scientists Ben Diedrichs
Sinisa Krajnovic
Mats Berg

Sources of funding: Banverket

In this project high-speed train aerodynamics inside tunnels was mainly studied. Through computational fluid dynamics and multibody vehicle simulations it has been found that the rear coaches of high-speed trains can start oscillating laterally when negotiating tight and long tunnels. This has also been confirmed in Japanese measurements. The oscillations are annoying and discomforting. Careful design of the train tail geometry can mitigate the discomfort. Crosswind stability of rail vehicles was also studied through simulations and wind tunnel measurements, for instance considering track embankments.

Diedrichs B: On computational fluid dynamics modelling of crosswind stability for high-speed rolling stock. *Proc. Instn Mech. Engrs, Part F: J. Rail and Rapid Transit* 217(F3), 203–226, 2003.

Diedrichs B, Ekequist M, Stichel S and Tengstrand H: Quasi-static modelling of wheel–rail reactions due to crosswind effects for various types of high-speed rolling stock. *Proc. Instn Mech. Engrs, Part F: J. Rail and Rapid Transit*, 218 (F2), 133–148, 2004.

Diedrichs B, Berg M and Krajnovic S: Large eddy simulations of a typical European high-speed train inside tunnels. *SAE 2004-01-0229*, 2004.

Diedrichs B, Berg M and Krajnovic S: Large eddy simulations of the flow around high-speed trains cruising inside tunnels. *European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS*. P. Neittaanmäki, T. Rossi, S. Korotov, E. Oñate, J. Périaux, and D. Knörzer (eds.) Jyväskylä, 24–28 July, 2004.

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RV6. Robust safety systems for trains

Project leader Evert Andersson
Scientists Dan Brabie
Evert Andersson

Sources of funding: Banverket, Bombardier Transportation, SL AB, Tågoperatörerna, Interfleet Technology, Vinnova.

This research project aimed at systematically studying the possibilities of minimizing devastating consequences of high-speed derailments by appropriate measures and features in the train design. In particular the cause of events immediately after a mechanical failure on axles, wheels, rails or similar was studied, e.g. whether the train stays upright close to the track centre or deviates laterally with probably serious consequences. Conclusions were drawn from an interactive process where multi-body computer simulations were performed and compared with real incidents and accidents. Different train design parameters were systematically investigated by means of in this way validated simulation models. The vehicle behaviour associated with derailments was taken into consideration through a newly developed multi-body system post-derailment module, capable of predicting the dynamic motion of wheelsets rolling and bouncing on concrete sleepers. The project continued until January 2008, but publications are available also after that.

Brabie D: Wheel-Sleeper Impact Model in Rail Vehicle Analysis, *Journal of System Design and Dynamics*, Vol. 1, Nr. 3, pp 468–480, On-line ISSN 1881–3046, 2007.

Brabie D and Andersson E: Post-derailment dynamic simulations of rail vehicles - Methodology and applications, Presented at the 20th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks, Berkeley, CA, 13–17 August, 2007. Also In *Vehicle System Dynamics*, Vol 46, Supplement, pp 289–300, 2008.

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Brabie D: On Derailment-Worthiness in Rail Vehicle Design - Analysis of Vehicle Features Influencing Derailment Processes and Consequences, Ph.D. Thesis, Report TRITA AVE 2007:78, KTH Rail Vehicles, 2007. ISBN 978-91-7178-828-3.

Brabie D and Andersson E: High-speed Train Derailments - Minimizing consequences through innovative design. *World Congress of Railway Research (WCRR'08)*, Seoul, Korea, May 18–22, 2008.

Brabie D and Andersson E: Vehicle features minimizing consequences of a train derailment. 15:e Nordiska seminariet för Järnvägsteknik, Hook, 22–23 maj 2008.

Brabie D and Andersson E: Analysis of vehicle features

influencing train derailment processes and consequences. 38. Tagung Moderne Schienenfahrzeuge, Graz, September 2008. Also published as proceedings in ZEVrail, Vol 132 (2008), Tagungsband SFT.

Brabie D and Andersson E: An overview of some high-speed train derailments - means of minimizing consequences based on empirical observations. Journal of Rail and Rapid Transit, Vol 222, p 441-463, 2008.

Brabie D and Andersson E: On minimizing derailment risks and consequences of passenger trains at higher speeds. Journal of Rail and Rapid Transit, Vol 223, p 543-566, 2009.

RV7. Simulation of energy consumption and running time of trains

Project leader Piotr Lukaszewicz
Scientists Piotr Lukaszewicz
 Evert Andersson
 Mats Berg

Sources of funding: Banverket/Trafikverket.

This project was partly based on measurements of running resistance of different passenger and freight trains. A software was developed to calculate train energy consumption and running time for selected trains and railway lines. Emphasis has been put on driver style and how it can effect the energy consumption and running time; a number of different driver models have been formulated for that purpose promoting so-called eco driving. The project has been integrated with the EU project Railenergy in the context of energy efficient timetabling.

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Lukaszewicz P: Energy Saving Driving Methods for Freight Trains. Computers in Railways IX. Advances in Transport Vol. 15. ISBN 1-85312-715-9. Presented in Dresden, Germany, 2004.

Andersson E and Lukaszewicz P: Energy consumption and related air pollution for Scandinavian electric passenger trains. Report TRITA AVE 2006:46, KTH Rail Vehicles, 2006.

Lukaszewicz P: Impact of train model variables on simulated energy usage and journey time. Computers in Railways X. WIT Transactions on The Built Environment, Vol. 88, 2006. ISBN 1-84564-177-9.

Lukaszewicz P: Running resistance - results and analysis of full-scale tests with passenger and freight trains in Sweden. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, Vol 221, No 2, pp 183-192, 2007.

Lukaszewicz P: A simple method to determine train running resistance from full-scale measurements. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, Vol 221, No 3, pp 331-337, 2007.

Lukaszewicz P: Running Resistance of Ore Trains in Sweden. High Tech in Heavy Haul. Proceedings of IHHA 2007, pp 111-120, Kiruna, Sweden, 2007. ISBN 978-91-633-0607-5.

Lukaszewicz P: Energy and Power Efficient Timetabling - Results from Information Search. Railenergy deliverable NRG-KTH-D-2.3-001.003. December 2007.

Lukaszewicz P: Energy Consumption of Future High Speed Trains. Estrategias de Ahorro y Eficiencia Energetica en el Transporte Ferroviario. (2nd Spanish Conference for Energy Efficiency in Railways). Sitges, Spain, 5-6 June 2008.

Lukaszewicz P: Methods and Models for Energy Efficient Driving - Algorithms. Railenergy deliverable NRG-KTH-D-2.3-005. June 2008.

Lukaszewicz P: Projekt SimERT- Fas 2, Sammanfattande slutrapport för perioden 2005-01--2008-12. Report TRITA AVE 2008:72, KTH Rail Vehicles, 2008.

Lukaszewicz P: Running resistance and energy consumption of ore trains in Sweden. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit. Special Issue. Vol 223, No 2, pp 189-197, 2009.

RV8. Train Information, Management and Monitoring (TIMM)

Project leader Stefan Östlund
Scientists Tobias Forsberg
 Mats Berg
 Sebastian Stichel et al.

Sources of funding: Vinnova, Banverket/Trafikverket, Bombardier Transportation.

This project focused on vehicle-track dynamic interaction and how it can be monitored, in particular from vehicle based systems. Phenomena that may vary along the track, for

instance ride instability and ride discomfort, were of special interest. A case study with a Regina EMU train has been studied in this context.

Forsberg T: Condition monitoring of railway mechanics with focus on train ride stability, M.Sc. Thesis, Report TRITA AVE 2006:107, KTH Rail Vehicles, 2006.

Forsberg T, Berg M, Stichel S and Andersson E: Condition monitoring of train ride stability. BOGIE'07, Budapest, 3-6 September, 2007. Proceedings of the 7th International Conference on Railway Bogies and Running Gears, pp 271-280.

RV9. Crosswind stability and unsteady aerodynamics in vehicle design

Project leader Mats Berg
Scientists Dirk Thomas
Mats Berg
Ben Diedrichs
Sebastian Stichel et al.

Sources of funding: KTH, Vinnova, Scania, Volvo, Saab, Bombardier, A2Zound, VTI, Trafikverket. This is a project within the Vinnova Centre for ECO² Vehicle Design.

This project comprises both vehicle aerodynamics and vehicle dynamics, and is applied to both rail and road vehicles. A significant challenge is to carry out unsteady fluid dynamics simulations, supporting the vehicle dynamics studies including overturning risk. A case study selected for the rail application is the Green Train, making use of the field tests carried out in recent years to investigate the lateral dynamics in more detail. Wind gusts have then been introduced in the simulations to investigate various overturning scenarios. Further on a stand-still vehicle has been subjected to lateral carbody loads imitating crosswind and evaluating the vehicle response, both through measurements and simulations. The overall goal of the project is to suggest less wind sensitive vehicle designs, mainly through the external shaping as well as the vehicle mass and suspension properties.

Favre T and Thomas D: Transient Crosswind Stability of Vehicles – A Literature Survey, Report TRITA AVE 2007:60, Centre for ECO² Vehicle Design, KTH, 2007.

Diedrichs B: Aerodynamic Calculations of Crosswind Stability of a High-Speed Train using Control Volumes of Arbitrary Polyhedral Shape, VI International Colloquium on Bluff Bodies Aerodynamics & Applications (BBAA), Milan, 20-24 July, 2008. A corresponding paper has also been published.

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Diedrichs B: Unsteady Aerodynamic Crosswind Stability of a High-Speed Train Subjected to Gusts of Various Rates, Euromech Colloquium 509: Vehicle Aerodynamics – External Aerodynamics of Railway Vehicles, Trucks, Buses and Cars, Berlin, 24-25 March 2009. A corresponding paper has also been accepted.

Favre T, Diedrichs B and Efraimsson G: Detached-Eddy Simulations applied to Unsteady Crosswind Aerodynamics of Ground Vehicles, 3rd Symposium on Hybrid RANS-LES Methods, Gdansk, June 2009.

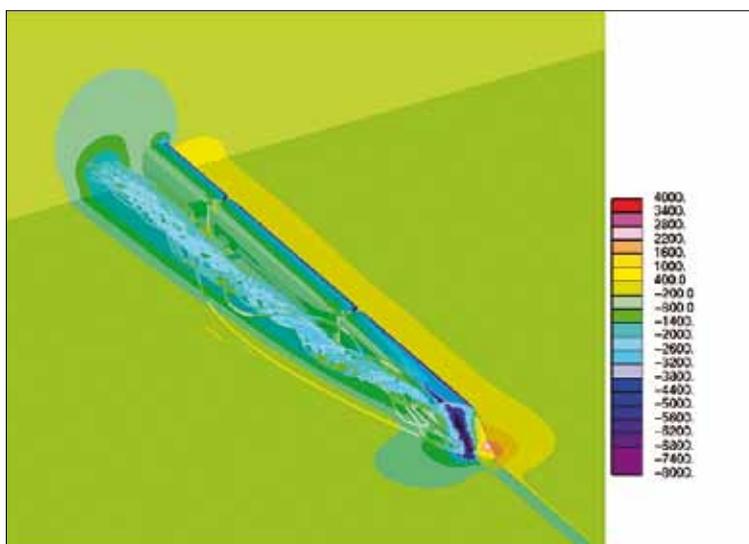
Thomas D, Diedrichs B, Berg M and Stichel S: Dynamics of a High-Speed Rail Vehicle Negotiating Curves at Unsteady Crosswind, paper presented at 21st International Symposium on Dynamics of Vehicles on Roads and Tracks (IAVSD'09), Stockholm, 17-21 August 2009.

Thomas D: Lateral stability of high-speed trains at unsteady crosswind, Licentiate Thesis, Report TRITA AVE 2009:79, KTH Rail Vehicles, 2009. ISBN 978-91-7415-473-3.

Diedrichs B: Aerodynamic crosswind stability of a regional train model, Proc. IMechE Journal of Rail and Rapid Transit, Vol 224, pp 580-591, November 2010.

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Thomas D., Berg M., Diedrichs B. and Stichel S.: Rail Vehicle Response to Lateral Carbody Excitations Imitating Crosswind, 22nd International Symposium on Dynamics of Vehicles on Roads and Tracks (IAVSD'11), Manchester, UK, 15-19 August 2011.



CFD calculation of train in strong crosswind.

RV10. Gröna Tåget (Green Train) : Programme management

Research leader Evert Andersson

Sources of funding: Banverket/Trafikverket

The “Green Train” is a multi-disciplinary research and development program involving several members of the KTH Railway Group. KTH is performing research on selected topics and is also appointed as total programme manager. The programme also involves several other members of the Swedish railway sector, such as Banverket, Bombardier Transportation, Tågoperatörerna (The Association of Swedish Train Operators), Transitio, VTI and CHARMEC, as well as some consultants as Interfleet Technology, Transrail and Ferroplan. The public funded part constitutes some 50 MSEK (5 MEUR) besides still higher contributions from industry (as decided at the end of 2007). The duration is from 2005 to 2011.

The overall aim is to safeguard and further develop knowledge and technologies required for specification and development of a new generation high-speed train for Swedish (Nordic) conditions – fast and attractive, economically viable and still friendlier to the environment. The top speed is aimed for 250-300 km/h, running both on the existing Swedish rail network and on future high-speed lines.

Andersson E: Vad är grönt i Gröna Tåget – vårt framtida attraktiva snabbtåg? Transportforum, Linköping, 2007.

Andersson E: Vad gör vi – och varför? Nordic Rail, Jönköping, okt 2007.

Andersson E and Fröidh O: Goda tider kan ge snabbare resa. Nordisk Järnbane tidskrift, Nr 11 2008

Andersson E: Gröna Tåget: Varför? Krav och mål. Vad har vi gjort? Preliminära resultat hittills. Vad planerar vi? 15:e Nordiska seminariet för järnvägsteknik, Hook, 22-23 maj 2008.

Andersson E: Gröna Tåget: Varför? Krav och mål. Vad har vi gjort? Preliminära resultat hittills. Vad planerar vi? Föredrag för NJS Stockholm, 12 nov, 2008.

Andersson E: Gröna Tåget: Varför? Krav och mål. Vad har vi gjort? Preliminära resultat hittills. Vad planerar vi? Föredrag för Swedish Rail Industry Group (SWERIG), Stockholm, 2 dec 2008.

Andersson E: Gröna Tåget - för konventionella banor och framtida höghastighetsbanor. Nordic Rail, Jönköping (Sweden), October 2009.

Gröna Tåget - Trains for tomorrow's travellers. KTH, Banverket and Bombardier Transportation, Information brochure 16 p, Stockholm, December 2010.

RV11. Gröna Tåget: Track-friendly bogies

Project leader Evert Andersson

Scientists Anneli Orvnäs
Rickard Persson
Evert Andersson

Sources of funding: Banverket/Trafikverket

Investigation and specification of appropriate suspension parameters for radial self-steering high-speed bogies. The aim is to contribute to the development of bogies allowing a high degree of passenger comfort, dynamic stability at high speed, moderate track forces and a low wheel-rail wear in curves. This is made by an extensive set of multi-body simulations taking a large number of possible track conditions into account. During summers 2006-08 these developments were successfully tested on various straight and curved tracks in Sweden. A Swedish speed-record of 303 km/h was set in Sep 2008, on a conventional Swedish track for 200 km/h.

Orvnäs A, Andersson E and Persson R: Development of Track-Friendly Bogies for High Speed – A Simulation Study, Publ 0703 KTH Railway Group, 2007. ISBN 978-91-7178-726-2.

Andersson E, Orvnäs A and Persson R: Radial Self-Steering Bogies – Development, Advantages and Limitations, ZEV+DET Glasers Annalen, June 2007 (Proceedings from “Moderne Schienenfahrzeuge”, Graz, April 2007).

Andersson E, Orvnäs A and Persson R: Radial Self-Steering Bogies - Recent Developments for High Speed, BOGIE'07, 3-6 September 2007, Budapest. Proceedings of the 7th International Conference on Railway Bogies and Running Gears.

Orvnäs A: Development of Track-Friendly Bogies for High Speed, SIMPACK News, Vol.11, Second Issue, November 2007.

Persson R: Spårvänliga fordon principer och fördelar, Nordic Rail, Jönköping, October 2007.

Andersson E, Orvnäs A and Persson R: On the Optimization of a Track-Friendly Bogie for High Speed, Proceedings of the 21st International Symposium on Dynamics of Vehicles on Roads and Tracks, IAVSD'09, Stockholm, August 17-21, 2009.



The Regina prototype train.

Photo: Bombardier Transportation

RV12. Gröna Tåget: High-speed vehicles with carbody tilt

Project leader Evert Andersson
Mats Berg

Scientists Rickard Persson
Evert Andersson
Mats Berg
Björn Kufver (Ferroplan)

Sources of funding: Banverket/Trafikverket, Bombardier Transportation, SL AB, Tågoperatörerna, Interfleet Technology, Vinnova, VTI.

This project aims at investigating possibilities for improved performance of rail vehicles equipped with a carbody tilt system. Firstly a review was made on state-of-the-art in this field, followed by an analysis of suitable cases for tilted rail vehicles. At the second stage a thorough analysis was made on possible causes for motion sickness in tilting trains, presently being a major limitation of tilted vehicles. Suitable improvements in the vehicle technology have been investigated as well as suggestions for suitable track geometry parameters. In particular a more advanced choice of tilting angle is studied. Field tests, including test subjects, was carried out in 2010 and a PhD thesis presented in 2011.

Kufver B and Persson R: On enhanced tilt strategies for tilting trains, Proceedings of Comrail 2006, pp 839-848. WIT Press, Southampton 2006.

Persson R: Spårvänliga boggiar och korglutning, Transportforum 2007.

Persson R: Tilting Trains – A description and analysis of the present situation. Publ 0702, KTH Railway Group, 2007. ISBN 978-91-7178-608-1.

Persson R: Identification of areas where the competitiveness of tilting trains can be further improved, Proc of Railway Engineering 2007, Engineering Technical Press, Edinburgh 2007.

Persson R: Research on the competitiveness of tilting trains, Proc of Railway Engineering 2007, Engineering Technical Press, Edinburgh 2007.

Persson R: Korglutning - behövs det? Nordic Rail, Jönköping, October 2007.

Persson R: Åksjuka i korglutande tåg. Transportforum, Linköping 2008.

Persson R: Motion sickness in tilting trains – Description and analysis of the present knowledge. Publ 0801, KTH Railway Group, 2008. ISBN 978-91-7178-680-3.

Persson R: Tilting trains – Technology, benefits and motion sickness. Licentiate Thesis, Report TRITA AVE 2008:27, KTH Rail Vehicles, 2008. ISBN 978-91-7178-972-3.

Persson R: Motion sickness in tilting trains, Proc of the 43rd UK Conference on Human Response to Vibration, Leicester 2008.

Persson R: Motion sickness on-track test evaluation, Proc of the 43rd UK Conference on Human Response to Vibration, Leicester 2008.

Persson R, Goodall R M and Sasaki K: Carbody tilting - Technologies and benefits. State-of-the-Art Paper of the 21st IAVSD Symposium, Vehicle System Dynamics, Vol 47, No 8, pp 949-981, August 2009.

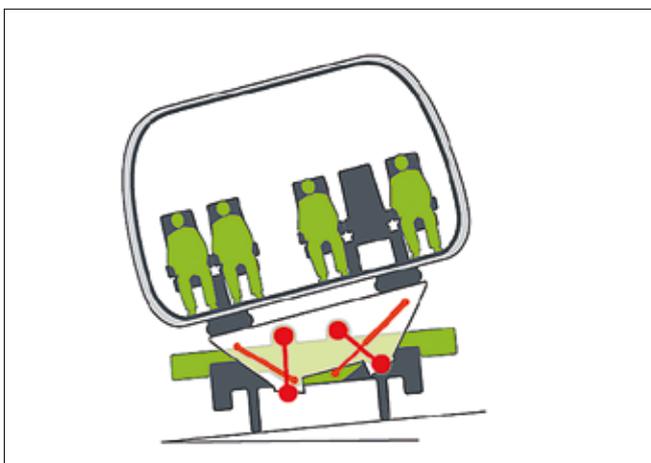
Persson R: Weighting curves to motion sickness, Proc of the 44th UK Conference on Human Response to Vibration, Loughborough 2009.

Persson R: Tilting trains - benefits and motion sickness, Proc. IMechE Journal of Rail and Rapid Transit, Vol 224, pp 513-522, November 2010.

Persson R, Kufver B: Strategies for less motion sickness on tilting trains, Proceedings of Comrail 2010, pp 581-591. WIT Press, Southampton 2010.

Persson R: Tilting trains – Enhanced benefits and strategies for less motion sickness. Doctoral Thesis, Report TRITA AVE 2011:26, KTH Rail Vehicles, 2011. ISBN 978-91-7415-948-6.

Persson R, Kufver B and Berg M: On-track test of strategies for less motion sickness on tilting trains, submitted for international publication.



Principle of car body tilt

RV13. Gröna Tåget: Sound quality of external railway noise

Project leader Shafiq Khan
Scientists Shafiq Khan
Jerker Sundström
Evert Andersson

Sources of funding: Banverket and VTI

In this project a study was made on human annoyance of different characters of railway noise, as radiated to the surrounding environment. This was made by recording

sound (noise) from different types of trains and subsequently exposing these noises to human test subjects in a laboratory. The latter noises were normalized with respect to duration and A-weighted sound pressure level. The results show that there are significant differences in human annoyance from different characters of railway noise, although all these noises have the same A-weighted sound pressure level.

Khan S: Sound quality of railway noise with and without barrier – a laboratory study, Proceedings of 19th International Congress on Acoustics (ICA), September 2007.

RV14. Gröna Tåget: Energy consumption

Project leader Piotr Lukaszewicz
Scientists Piotr Lukaszewicz
Evert Andersson

Sources of funding: Banverket/Trafikverket

Possible levels of energy consumption - per seat-km or per passenger-km - have been estimated for future high-speed trains, in particular for the Green Train concept. The study shows that appropriate train design makes it possible to

reduce energy consumption by 25 – 40 % both on the existing railway network and on future high-speed lines - despite of shorter travel time and higher speeds.

Andersson E: Gröna Tåget, morgondagens snabbtåg. Hur kan energiförbrukning och CO₂-utsläpp reduceras? Invited speaker, NJS konferens "Jernbaner og CO₂", Köpenhamn, 31 okt 2008.

Lukaszewicz P and Andersson E: Green Train energy consumption - Estimations on high-speed rail operations, Publication 0901, KTH Railway Group, 2009. ISBN 978-91-7415-257-9.

RV15. Gröna Tåget: Active lateral suspension

Project leader Sebastian Stichel
Scientists Anneli Orvnäs
Rickard Persson
Sebastian Stichel

Sources of funding: Banverket/Trafikverket

At increased rail vehicle speed, it may be difficult to maintain acceptable passenger ride comfort with conventional passive secondary suspension. Within this project, in co-operation with Bombardier Transportation, it is investigated whether active technology is able to maintain good passenger comfort although vehicle speed is increased and track conditions are worse.

The possibility of reducing travel in the lateral suspension – and thus allowing a wider carbody within the prescribed dynamic envelope – is also investigated. After design studies with help of computer simulation, on-track tests have been performed with an active lateral secondary suspension concept implemented in a two-car Regina train during the summers of 2007 and 2008. The evaluated measurement results are encouraging and the device has been implemented in long-term tests in service operation. A Regina train with active lateral suspension has now been operating since March 2009. In June 2009, Anneli Orvnäs presented her licentiate thesis within the project. Since the summer 2009, work has been concentrating on improvements of the control algorithms, e.g.

by testing H-infinity control instead of sky-hook control.

The next step in the project was to perform simulations with active vertical secondary suspension. Finally, active lateral (ALS) and active vertical (AVS) secondary suspensions are combined to improve ride comfort in both lateral and vertical direction.

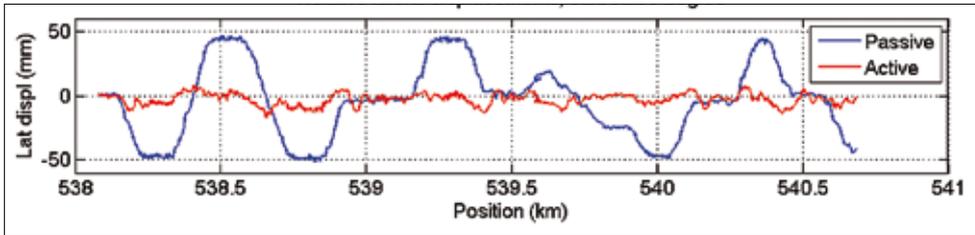
Orvnäs A, Stichel S and Persson R: Improving Ride Comfort in Trains with Active Suspension. 15:e Nordiska Seminariet i Järnvägsteknik, Jönköping, May 23, 2008.

Orvnäs A, Stichel S and Persson R: On-Track Tests with Active Lateral Secondary Suspension: A Measure to Improve Ride Comfort, ZEV rail Glasers Annalen 132, No 11-12, pp. 469-477, 2008.

Orvnäs A: Active Secondary Suspension in Trains – A Literature Survey of Concepts and Previous Work, Publ 0803, KTH Railway Group, 2008. ISBN 978-91-7415-144-2.

Orvnäs A: Active lateral secondary suspension in a high-speed train to improve ride comfort, Licentiate Thesis, KTH Rail Vehicles, 2009. ISBN 978-91-7415-300-2.

Orvnäs A, Stichel S and Persson R: Ride Comfort Improvements in a High-speed Train with Active Lateral Suspension. Proc. of the International Symposium on Speed-Up, Safety and Service Technology for Railway and Maglev Systems, STECH'09, Niigata, Japan, 16-19 June, 2009. Also in Journal of Mechanical Systems for Transportation and Logistics (JSME), Vol. 3, No. 1, pp. 206-215, 2010.



Relative lateral displacement between carbody and bogie with and without active lateral suspension.

Orvnäs A, Stichel S and Persson R: Development and Test of Active Secondary Suspension in a High-Speed Train. Proc. of the 21st International Symposium on Dynamics of Vehicles on Roads and on Tracks, IAVSD'09, Stockholm, Sweden, 17-21 August, 2009.

Stichel S, Persson R, Himmelstein G, Andersson E and Orvnäs A: Development of Next Generation High-speed Trains for Scandinavia. Proc. of 12th International Conference on Civil, Structural and Environmental Engineering Computing CC2009, Madeira, Portugal, September 1-4, 2009.

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Orvnäs A, Stichel S and Persson R: Ride Comfort Improvements of a REGINA Train with Active Lateral Secondary Suspension, Proceedings of the 8th International Conference on Railway Bogies and Running Gears, BOGIE '10, Budapest, Hungary, September 13-16, 2010.

Orvnäs A, Stichel S and Persson R: Active Lateral Secondary Suspension with H_∞ control to Improve Ride Comfort: Simulations on a Full-Scale Model, Vehicle System Dynamics, online publication (DOI: 10.1080/00423114.2010.527011), 2011

RV16. Gröna Tåget: Overhead power systems for operation of high-speed trains in Sweden

Project leader Sebastian Stichel
 Scientists Per-Anders Jönsson
 Sebastian Stichel
 Lars Drugge
 Mats Berg

Sources of funding: Banverket/Trafikverket

The overhead power system has been identified as one of the critical areas when increasing train speed.

Several questions cannot be answered today:

- Which performance do pantograph, catenary and traction system need to have - especially in case of multiple units?

- Does the maximum speed need to be limited in case of more than one pantograph with short distance between each other?

The issue does not exist in the same way for other European high speed traffic since the trainsets and thus the distance between pantographs are significantly longer e.g. in Germany or France.

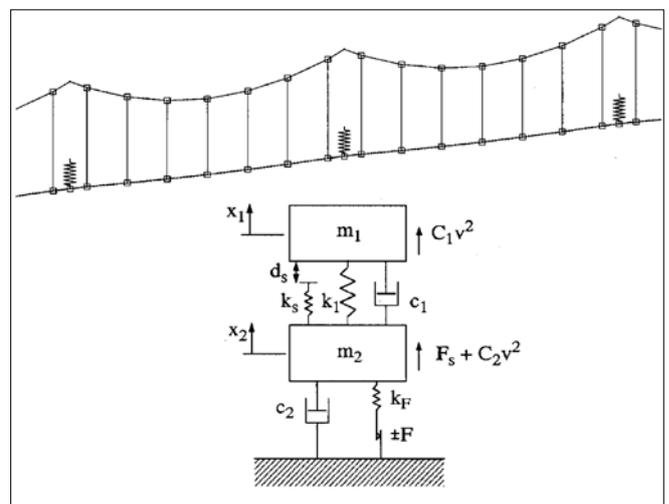
- Could active pantographs work at the desired speed without changing the catenary system?

Within the project the dynamic interaction pantograph/catenary will be studied mainly by use of computer simulation. An existing 2-D model will be extended to a 3-D model. Existing measurement results shall be used as long as possible.

The criterion for satisfying interaction is the variation in the contact force. Therefore the contact force will be studied in the first place. A validation of the existing programmes

that shall be used in the project will be done and necessary improvements will be implemented. After that parameter studies will be started. Type of catenary resp. pantograph, speed, number of and distance between pantographs are examples of parameters that will be examined. Finally the potential improvement of active pantographs will be evaluated.

Bucca, G., Carnevale, M., Collina, A., Facchinetti, A Drugge, L., Jönsson, P.-A., Stichel, S.: Differentiation of pantograph's preloads as a mean to improve multiple collection and speed up existing lines. Accepted for presentation at IAVSD conference in Manchester, August 2011.



Modelling pantograph catenary interaction with ANSYS.

RV17. Collaboration In Research and development of new Curriculum In Sound and vibration (CIRCIS)

Project leader Mats Berg
Scientists Shafiq Khan
Mats Åbom
Hans Bodén et al.

Sources of funding: European Commission (FP6), SIDA (Swedish Research Link Programme)

This was a collaboration between two European universities, KTH and Loughborough University, and two Indian universities, Indian Institute of Technology in Delhi respectively in Roorkee. The overall project goal was twofold: Curriculum development in sound and vibration, and research work on the influence of low frequency vibrations on activity comfort while travelling by railway vehicles. An important project element was also student mobility (exchange). The description and references below focus on the research part, for which extensive field and laboratory measurements have been carried out. For the latter part a test chamber was developed with a platform vibrating in different directions and on which seated test subjects are evaluated with respect to activity performance, for instance reading and writing/sketching.

Narayanmoorthy R, Khan S, Berg M, Goel V K, Saran V H and Harsha S P: Determination of Activity Comfort in Swedish Trains. Presented at World Congress on Railway Research, Seoul, South Korea, May 2008.

Harsha S P, Saran V H, Goel V K and Berg M: Nonlinear Vibration Signature Analysis of Rail Bearing Systems. 12th Nonlinear Vibration, Dynamics and Multi-body Systems, Virginia Tech, Blacksburg (USA), June 1-5, 2008.

Khan S, Ulhas M and Goel V K: Synthesis of Passby Railway Noise. Acoustics-08 Congress, Paris, June 29 - July 4, 2008.

Bhiwapurkar M K, Saran V H, Goel V K and Berg M: Influence of multi-axis random vibrations on reading activity. Presented at the 4th International Conference on Whole Body Vibration Injuries, Montreal, Canada, June 2-4, 2009.

Bhiwapurkar M K, Saran V H, Goel V K, Mansfield N and Berg M: Study of Human Comfort under Thermal and Vibratory Environment using Physiological Indices. Presented at 16th International Congress on Sound and Vibration, Krakow, 5-9 July 2009.

Bhiwapurkar M K, Singh G, Choudhary S, Saran V H, Goel V K and Berg M: Influence of whole body vibrations on sketching performance. Presented at 21st International Symposium on Dynamics of Vehicles on Roads and Tracks, 17 - 21 August 2009, Stockholm.

Bhiwapurkar M K, Saran V H, Goel V K and Berg M: Influence of Whole Body Random Vibrations on Reading Activity. 44th UK Conference proceedings on Human Response to Vibration, Loughborough, 7- 9 September 2009.

Bhiwapurkar M K, Singh G, Khare D, Saran V H, Goel V K, Berg M and Mansfield N: Evaluation of drawing ability while exposing to multi axis whole body random vibrations. 44th UK Conference proceedings on Human Response to Vibration, Loughborough, 7- 9 September 2009.

Bhiwapurkar M K, Saran V H, Harsha S P, Goel V K, Berg M and Mansfield N: Effect of magnitudes and directions (mono-axis and multi-axis) of whole body vibration exposures and subject postures on the sketching performance. Proc IMechE Journal of Rail and Rapid Transit, Vol 225, pp 71-83, January 2011.

Bhiwapurkar M K, Saran V H, Goel V K, Mansfield N and Berg M: Evaluation of human comfort using physiological indices under random whole body vibration, acoustic and thermal stressors. Submitted to International Journal of Acoustic and Vibration.

RV18. Railway vehicle dynamics and track interactions: Total regulatory acceptance for the interoperable network (DynoTrain)

Project leader UNIFE
Scientists From 25 partners
(KTH: Mats Berg and Sebastian Stichel)

Sources of funding: European Commission (FP7).

The certification of a rail vehicle in Europe represents a significant element of both vehicle cost and time to market. The objective of DynoTrain, dealing with vehicle-track interaction, is to propose an innovative methodology via a computer simulation / virtual homologation that will allow multi-system network and route approval in Europe to become a faster, cheaper and better process for all involved

stakeholders. KTH is participating in three work packages: Track geometry quality (WP2), Contact geometry (WP3) and Model building and validation (WP5). There are two parallel projects to DynoTrain: Aerodynamics (AeroTrain) and Pantograph-Catenary Interaction (PantoTrain). These three projects form the TrioTrain cluster.

DynoTrain D5.1: State-of-the-art of railway vehicle modelling and validation, WP5 - Model building and validation, December 2010.

Bruni S, Vinolas J, Berg M, Polach O and Stichel S: Modelling of suspension components in a rail vehicle dynamics context, State-of-the-Art Paper of the 22nd IAVSD Symposium. Vehicle System Dynamics, 2011.

RV19. Technology opportunities and strategies toward climate-friendly transport (TOSCA)

Project leader Andreas Schäfer, University of Cambridge
 Scientists (KTH) Evert Andersson, WP leader of Rail Transport
 Mats Berg
 Bo-Lennart Nelldal
 Oskar Fröidh

Sources of funding: European Commission (FP7).

The EU has committed to reduce GHG (Green-House Gas) emissions by at least 20% based upon the 1990 level by 2020 and further reductions are expected beyond that timeframe. However, realizing this and subsequent targets may become increasingly challenging, given the past growth and future projections of transportation GHG emissions.

TOSCA was an 18-month EU Framework 7-funded project, beginning in September 2009, that aimed at investigating the potential for technologies and fuels to reduce the environmental impact of transport within the EU to 2050. The work was carried out by a consortium of seven organisations across Europe with expertise in a wide range of areas related to transportation and the environment. The activity enables the EU to obtain a better strategic perspective as to what contribution future transportation technologies and fuels could make to reduce GHG emissions.

The TOSCA project's main objective was to identify the most promising technology and fuel pathways that could help reduce transport-related greenhouse gas emissions both over the short term (2020) and beyond (2050). To better understand the policy interventions that are necessary to push (potentially expensive) technologies and fuels into the market, a further

objective was to assess the penetration of these options under different future scenario and policy conditions. These scenario outputs were then evaluated with regard to their technical feasibility, economic affordability, and overall likelihood of realisation. TOSCA operated on a total transport sector basis, with work packages devoted to road traffic, aircraft, shipping, rail traffic, infrastructure capacity and fuels, as well as scenarios and policies.

For preparation of this strategic document for the EU commission a number of European research institutes were involved:

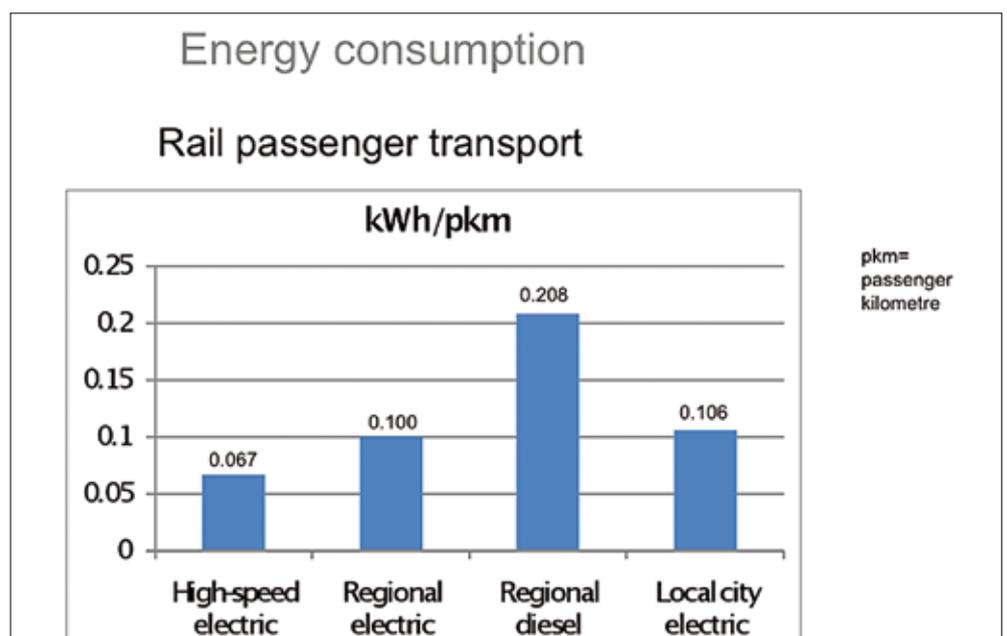
- University of Cambridge, UK
- German Biomass Research Centre (DBFZ), Germany
- Ecorys, The Netherlands
- Swiss Federal Institute of Technology (ETHZ), Switzerland
- Royal Institute of Technology (KTH), Sweden
- National Technical University of Athens, Greece
- Paul Scherrer Institute, Switzerland

TOSCA is planned for working reports, final report and seminar in spring 2011.

A final report and a large number of subreports are available on www.toscaproject.org

Andersson E, Berg M: Greenhouse gas emissions from rail services – Present and future. Proceedings of Railways and Environment, Delft, 16-17 December 2010.

Average new rail vehicles 2009 at mixed operation.



RV20. Lightweight Carbody for High Speed Trains

Project leader Peter Göransson/Sebastian Stichel
 Scientists David Wennberg
 Per Wennhage
 Sebastian Stichel

Sources of funding: KTH, Vinnova, Scania, Volvo, Saab, Bombardier, A2Zound, VTI, Trafikverket. This is a project within the Vinnova Centre for ECO² Vehicle Design.

The carbody structure in railway vehicles is heavy in comparison to road vehicles. Weight per seat is significantly higher than in buses for example. In addition the price per kilogram is high. Reasons are partly short series and individual design for each customer. Conservative load assumptions in railway standards are another contributor. In metros and suburban trains a low mass is important due to frequent stops and in turn frequent acceleration and braking of the train. In high-speed trains with larger station intervals the energy saving potential by reduced mass is due to high mileages – up to 500 000 km per year. For high speed trains, however, it is equally important to limit axle load as weight per passenger. At speeds above 250 km/h a maximum axle load of 17 tons is permitted according to European legislation. High speeds with high dynamics forces in combination with high axle loads cause severe fatigue damage on wheels and rails.

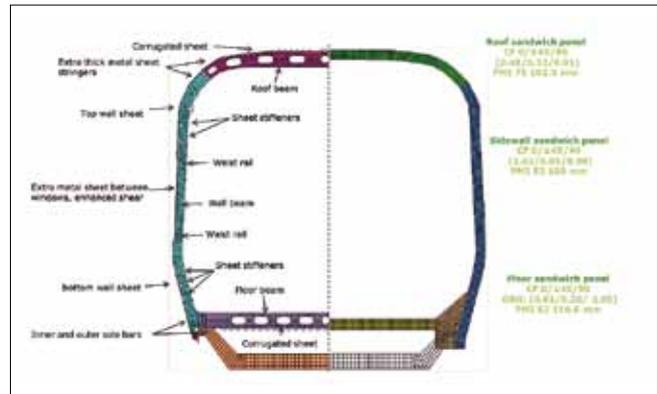
Today there is quite a lot of knowledge existing about properties and manufacturing possibilities of sandwich structures. Therefore a sandwich carbody or a combination of a steel/aluminium carbody with sandwich design is considered to be a realistic alternative to conventional steel or aluminum designs. Some applications in rail vehicles as well as busses already exist. The long term goal of the proposed project is to design and test a prototype carbody for the Green train (next generation high speed trains for Scandinavia) using at least partly modern sandwich/composite techniques. A

weight reduction of 30% in relation to comparable existing carbodies and a cost reduction per kilogram of 10% should be possible.

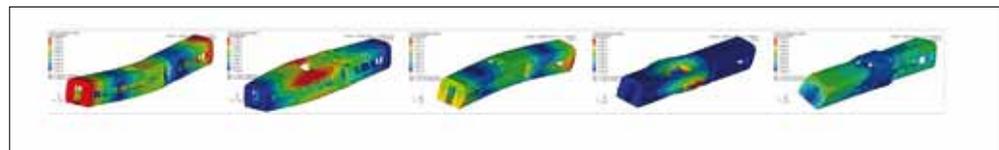
Wennberg D: A light weight car body for high-speed trains - Literature study. Report TRITA AVE 2010:16, Centre for ECO² Vehicle Design, KTH, 2010. ISBN 978-91-7415-591-4.

Wennberg, D., Wennhage P. and Stichel S.: Orthotropic Models of Corrugated Sheets in Finite Element Analysis, International Scholarly Research Network ISRN Mechanical Engineering Volume 2011, Article ID 979532.

Wennberg D, Stichel S and Wennhage P: Cutting the Weight of High-Speed Trains, Railway Gazette International, pp. 30-32, January 2011.



Cross-section comparison between original steel body (left) and a sandwich alternative (right). Number of parts reduced by over 90% for sandwich alternative.



Typical carbody eigenmodes.

RV21. Wheel profile for freight wagons in Sweden

Project leader Sebastian Stichel
 Scientists Carlos Casanueva
 Per-Anders Jönsson
 Sebastian Stichel

Sources of funding: KTH, Trafikverket, Green Cargo AB, Tikab, Kockums Industrier AB.

Freight wagons in Sweden use the S1002 wheel profile, developed in a benchmark back in the 70s. This profile

is quite common in European countries. It is originally developed for rail inclination 1:40 and it is not a specific wheel profile for Swedish conditions. Today many operators use their own modified profile. Thus, the freight vehicle fleet has high maintenance costs due to wheel reprofiling and has some low-frequency instability related problems. Wear and rolling contact fatigue can be a major issue as its cost can reach up to 30M SEK per year. Some wagon types are more critical than others, with re-profiling intervals of sometimes less than 1000km.

There is a lack of knowledge about the relationship between the dynamic behaviour of different freight vehicles and their wheel damage, and thus this is usually studied case by case. The output is usually some modifications in the vehicle design which are not applicable to all types of running gear. Thus, the purpose of this research project is to create a wheel profile suitable for freight transport in Sweden, which reduces the reprofiling costs and improves the low-frequency instability behaviour of the vehicles. This profile should especially reduce the uniform wear and the material to be removed in each reprofiling, and increase the critical speed of empty vehicles. The first reduction generates a higher running distance between reprofilings, and the second one ensures more reprofilings for each wheelset before it can no longer be used.

In the first phase of the project, the wear calculation methodology developed at the Division of Rail Vehicles at KTH is being validated for freight transport. The wear predicted by computer models will be validated with experimental results. The vehicles that are being used for this validation are two:

- Smmnps wagons with Y25 running gear, leased by AAE to SSAB, that transport steel slabs from Luleå to Borlänge and go back to Luleå empty. These vehicles only run through this line, which simplifies track characterization. Also, the load of the vehicles is easy to model.

- Laaps wagons with Unitruck running gear that transport timber by Trätåg timber logistic company around Gävle, Borlänge and Hällefors. The operational case model is more complicated as there are several locations where they run.

As a future work, after the methodology has been validated the wheel profile will be optimized. This new profile shall be used in future freight vehicles, so first of all the future freight train fleet will be investigated. The wheel profile will be optimized using a genetic algorithm for each of the vehicles included in this future vehicle fleet.

The next step will be to install wheelsets with this new profile in some freight vehicles and do a follow up in order to detect further improvements and validate experimentally the benefits of this optimized profile.

RV22. Modelling contact in the wheel-rail interface

Project leader Roger Enblom
 Scientists Matin Shahzamanian Sichani
 Roger Enblom
 Mats Berg

Sources of funding: Trafikverket, Bombardier Transportation, SL AB, Tågoperatörerna, Interfleet Technology.

The project started in Jan 2011 with the employment of Matin Shahzamanian Sichani as Ph.D. student. The aim of this research is to arrive at a wheel-rail contact model practically applicable in the context of vehicle dynamics simulation, resting on a firm scientific foundation and answering to modern requirements regarding precision and numerical efficiency. Limitations related to traditional methods, for instance geometrical constraints, elastic identity, or half space assumption, are expected to be overcome.

The small and highly stressed contact patch is the interface to the infrastructure to be evaluated at each time step in a transient analysis. Thus the model has to be numerically efficient. Traditional methods often used in this context are Hertz' method for the normal contact and Kalker's simplified model for the tangential solution. The starting point of this project is a survey of recent pertinent research and related modelling ideas. Evaluation of approaches like multiple ellipses, discretisation by strips, various amendments to Kalker's methods, Winkler-type elastic foundations, and more is anticipated. The feasibility of modern numerical methods like boundary element discretisation should be investigated as well.

Some important steps are believed to be:

- Determination of the shape and size of the contact patch and the contact pressure distribution. With the traditional half space assumption, the normal contact becomes well defined. In case of small radii or close to conformal contact, this condition may be violated. Thus an improved model shall be able to handle non-elliptic contact areas on curved surfaces.
- Assessment of the shear stress distribution. With the traditional assumptions of quasi-identical contacting bodies, the normal and tangential problems can be solved independently. Analysis of more general contacts may however require simultaneous solution.
- Selection of numerical algorithm and implementation. With modern computer power, more sophisticated numerical methods than traditionally may be realistic. A competing consequence of the improving computer capacity is however increasing expectations on model size.
- Validation. Since the research target is some kind of simplified model it is possible to verify it by more detailed calculations like finite element analysis. Experimental verification is desirable and ultrasound measurements may be an option.

Ongoing work is literature survey and evaluation of candidate modelling approaches. The aim is to report on this work at the 9th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Chengdu, August 27-30, 2012.

RV23. Make Rail The Hope for protecting Nature (MARATHON)

Project Co-ordinator D'Appolonia
Scientists from 16 partners
(KTH: Mats Berg, Sebastian Stichel)

Sources of funding: European Commission (FP7).

MARATHON is a three-year project, starting in April 2011, that will investigate the possibilities of making European rail freight transport more efficient through running longer trains. The focus is put on the scenario of merging two 750

m long trains, keeping the traditional pneumatic braking system. Radio communication between the two (groups of) locomotives is to be developed for a reliable and safe train operation. KTH will study the risk of train derailment at poorly synchronized braking conditions between the two halves of the long train. Multibody dynamics simulations are to be carried out for various train braking conditions, both on tangent and curved track. In particular derailment through wheel flange climbing, related to train buckling and/or buffer climbing, will be studied.

RV24. The sustainable freight railway (SUSTRAIL)

Project Co-ordinator Train Consortium
Scientists from 29 partners
(KTH: Sebastian Stichel, Stefan Östlund, Mats Berg)

Sources of funding: European Commission (FP7).

The rail industry is lagging in its adoption of state of the art techniques and technologies that are gaining traction in air, shipping, and roadway transport. These include performance-based design, the use of lightweight and high performance materials, the use of structural health monitoring technologies, and the trend toward condition based maintenance. Within this context, SUSTRAIL will increase the SUSTAINABILITY, COMPETITIVENESS, and AVAILABILITY of European railway networks. The SUSTRAIL approach takes into account Methodology, Implementation Timeframe, and Means of Application. SUSTRAIL employs an integrated approach. Contributions from the different topic areas (vehicles, track, and operations) will be demonstrated on real routes. Four routes that offer geographic dispersion as well as differences in type (freight vs. passenger), mixed traffic vs. freight only routes, speed, and frequency of traffic have been made available. In specific, SUSTRAIL will conduct the following activities:

- Benchmarking to establish existing state of the art for comparison activities, including correlation of track damage levels with vehicle design parameters on three real routes in the EC (WP1);

- Duty requirements for current and future freight traffic flows. An innovative “smart embankment” concept is considered for the monitoring of the effect of high speed freight vehicles on the rail infrastructure (WP2);
- The business case for the freight vehicle-track system for higher delivered tonnage (WP5).
- Track design requirements for reduced maintenance time and whole life cost based on optimised vehicle characteristics (WP4);
- Wheelset design requirements, including consideration of unsprung mass and fatigue life (WP2 and WP3);
- Suspension design requirements, including the need for acceptable dynamic performance in tare (empty) and fully laden conditions (WP2 and WP3);
- Novel design and materials for lightweight high performance freight vehicles, including the body structure, bogies and brake systems. A new concept of lightweight will be studied using a range of advanced materials/technology (WP3);
- Recommendations for whole-system implementation, including strategies for the equitable redistribution of whole-system savings (WP5);
- A practical demonstration of potential technological solutions (WP6);



Structural Engineering and Bridges – SB

The division is conducting research and education within railway engineering including bridges and tunnels. They are also responsible for co-ordination of issues concerning the

railway infrastructure. More information on the research performed at the division and the publications are available on www.byv.kth.se/avd/bro.



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RESEARCH PROJECTS

SB1. Loads and Load Influence on Structures

Researchers Raid Karoumi
 Gerard James

weigh-in-motion systems including interpretation of statistical results are developed.

Source of Funding: KTH, Swedish National Road Administration (Vägverket), Swedish National Rail Administration (Banverket) and Johnson Foundation.

James G, Karoumi R, Kullberg C and Trillkott S, Measuring the Dynamic Properties of Bridges on the Bothnia Line, TRITA-BKN Report 92, Brobyggnad, 2005.

The project deals with studies of the dynamic response of bridges subjected to moving vehicles. Measurement methods for loading on railway and road bridges are examined. Bridge

Guidelines for Railway Bridge Dynamic Measurements and Calculations, UIC leaflet, Union Internationale des Chemins de Fer, Version 1, January, 2006. (Edited by Karoumi R.)

SB2. Long-term Monitoring and Assessment of Bridges

Researchers Håkan Sundquist
 Merit Enckell
 Richard Malm

Malm R., Predicting shear type crack initiation and growth in concrete with non-linear finite element method, doctoral thesis, 2009.

The aim of the project is the long-term monitoring of railway bridges. The project is designed to compare traditional monitoring techniques with the relatively new fibre optic measuring systems and assess their behaviour over long measuring periods. The project is also intended to increase the understanding of the dynamic behaviour of railway bridges. Source of Funding: KTH, Swedish Rail Administration (Banverket), Formas and KTH Railway Group.

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Enckell M., Structural Health Monitoring of Bridges in Sweden. The 3rd International Conference on Structural Health Monitoring of Intelligent Infrastructure (SHMII-3), November 14-16, 2007, Vancouver, Canada.

Malm R, James G, Sundquist H, Monitoring and evaluation of shear crack initiation and propagation in webs of concrete box-girder sections, The International Conference on Bridge Engineering – Challenges in the 21st Century , November 1–3, 2006, Hong Kong.

Malm R, Analys av sprickbildning och sprickbredd vid plant spänningstillstånd i balkliv av armerad betong, TRITA-BKN, Rapport 88, Brobyggnad 2005.

Malm R, Andersson A, Field testing and simulation of dynamic properties of a tied arch railway bridge, Engineering Structures 28(1), 143-152, January 2006.

Enckell M, Structural Health Monitoring using Modern Sensor Technology – Long-term Monitoring of the New Årsta Railway Bridge, Licentiate thesis, TRITA-BKN. Bulletin 86, Brobyggnad, 2006.

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Andersson A, Gamla Årstabron, FEM-beräkning av förstärkningsåtgärders inverkan på betongbågarna, TRITA-BKN, Rapport 101, Brobyggnad, 2006.

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SB 3. A study of the dynamic interaction between train and bridge and the long-term changes in the dynamic properties of the new Årsta bridge

Researcher Raid Karoumi
 Johan Wiberg
 Ignacio González

The New Årsta Railway Bridge in Stockholm is a slender and a very complex prestressed concrete structure. Over 80 sensors, e.g. traditional strain gauge and fibre optic sensors, are embedded into the concrete section to monitor strains that arise from curing concrete, dead load, traffic, wind.

The Swedish National Railway Administration (Banverket) initiated the measuring program to follow up stresses and deformations during construction and operation of the bridge. The dynamic and static behaviour of the bridge is investigated through inspection and supervision via internet connection to the sensors, which will give a unique opportunity for research on railway bridges and particularly the interaction between trains and the bridge.

The objective is to verify uncertainties in the structure, during construction and 10 years of service, leading to knowledge and



updated codes which, in turn, will give economical and safe solutions concerning similar structures in the future. The aim is to:

- Evaluate the fundamental frequencies, modes and damping ratios
- Evaluate the dynamic effects of trains crossing the bridge
- Evaluate the long-term changes in the bridge's dynamic properties.

Source of Funding: KTH, Swedish Rail Administration (Banverket) and KTH Railway Group.

Wiberg J., Railway bridge response to passing trains. Measurements and FE model updating, doctoral thesis, 2009.

González I., Dynamic Behaviour of the New Årsta Bridge to Moving Trains - Simplified FEM Analysis and Verifications. TRITA-BKN Master Thesis 262, 2008.

Wiberg J., Karoumi R., Monitoring dynamic behaviour of a long-span railway bridge. *Journal of Structure and Infrastructure Engineering*, Taylor & Francis, vol.5, 2009.

Wiberg J., Railway bridge dynamic characteristics from output only signal analysis. 2nd International Conference on Experimental Vibration Analysis for Civil Engineering Structures (EVACES'07), 24-26 October 2007, Porto, Portugal

Karoumi R, Wiberg J, Olofsson P: Monitoring traffic loads and traffic load effects on the New Arstaberg Railway Bridge. In: International Conference on Structural Engineering, Mechanics and Computation (SEMC 2004), Cape Town, South Africa, 2004.

Wiberg J, Bridge Monitoring to Allow for Reliable Dynamic FE Modelling: A Case Study of the New Årsta Railway Bridge, Licentiate thesis, TRITA-BKN. Bulletin 81, Brobygggnad, 2006.

SB5. Sustainable bridges

Researchers Raid Karoumi
 Gerard James
 Axel Liljencrantz

The project is a European Community funded project that involves the cooperation between many partners from universities, railway infrastructure owners and industry around Europe and is part of the sixth framework programme.

The aim of the project is to produce guidelines and research papers to assist engineers in the evaluation of existing railway bridges. Much of the railway bridge stock in Europe is coming to an end of its originally planned service life. However, the demands on our railway bridges are constantly increasing with railway operators requiring increased allowable axle loads and increased train speeds. There is a common European need to establish new and improve existing methods for the evaluation of this ageing railway bridge stock.

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James G, Karoumi R, Considerations for Traffic Loads in the Assessment of Existing Railway Bridges, IABMAS 2006, Porto, Portugal, July 16-19, 2006.

Jensen J S, Karoumi R, Melbourne C, Casas J R, Gylltoft K, Patrón A, Development of a Guideline for Load and Resistance Assessment of Existing European Railway Bridges, IABMAS 2006, Porto, Portugal, July 16-19, 2006.

SB6. Soil-Structure Interaction for Integral Bridges and Culverts

Researchers Håkan Sundquist
 Esra Bayoglu
 Mahir Ülker-Kaustell
 Raid Karoumi

The behaviour of integral concrete bridges and steel culvert bridges are investigated considering soil-structure interaction and dynamic effects from passing trains. The project is financed by KTH, Trafikverket (the Swedish Transport Administration) and Viacon.

Bayoglu E. och Karoumi R., Dynamic testing of a soil-steel composite railway bridge, *J. of Engineering Structures*, Vol.21, 2009.

Ülker-Kaustell M., Some aspects of the dynamic soil-structure interaction of a portal frame railway bridge, Licentiate thesis, 2009.

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Ülker-Kaustell M., Karoumi R., Uppskattning av upplagsstyheter och effekter av jord-bro interaktion genom dynamisk mätning - steg 1. TRITA-BKN. Rapport 123, 2008.

Bayoglu E, Karoumi R, Sundquist H, Field Testing of a Long-span Arch Steel Culvert during Backfilling and in Service, *Structure & Infrastructure Engineering*, Taylor & Francis, Vol. 1, No. 3, June 2005, pp. 181-188.

Bayoglu E, Field testing of a long-span arch steel culvert railway bridge over Skivarpsån, Sweden - Part III, TRITA-BKN Rapport 91, Brobygggnad 2005.

SB 7. Dynamic response of railway bridges subjected to high-speed trains

Researchers

Raid Karoumi

Johan Wiberg

Mahir Ülker -Kaustell

The project investigates the dynamic response of railway bridges on high-speed lines such as those for the new Bothnia line. The bridges on this line have to be designed for train speeds up to 300 km/h. Such high speeds may cause excessively high stresses and vibrations, if the bridge is excited at one of its natural frequencies. Another problem to be studied is that of ballast instability where the accelerations of the bridge deck cause the ballast to lose its resistance properties to transverse forces.

Battini J-M, Ülker-Kaustell M., A simple finite element to consider the non-linear influence of the ballast on vibrations of railway bridges. (Accepted for publication in *J. Engineering Structures* 2011)

Ülker-Kaustell M., The dynamic properties of two concrete railway bridges during the testing of Gröna Tåget. TRITA-BKN. Rapport 117, 2007.

Lorieux L., Analysis of train-induced vibrations on a single-span composite bridge. Master thesis, 2008.

Ülker-Kaustell M., Övervakning av accelerationer i broar vid passage av Gröna Tåget, Teknisk Rapport 2006:11, Brobyggnad, 2006.

Karoumi R, Wiberg J, Kontroll av Dynamiska Effekter av Passerande Tåg på Botniabanans Broar – Sammanfattning, TRITA-BKN Rapport 97, Brobyggnad, KTH, Stockholm, 2006.

James G, Karoumi R, Kullberg C, Trillkott S, Measuring the Dynamic Properties of Bridges on the Bothnia Line, TRITA-BKN Report 92, Brobyggnad, 2005.

Monitoring the response of the Lögdeälv Bridge during the Gröna Tåget test on the Bothnia line.



SB 8. Bridge Weigh-in-motion for railway bridges

Researchers

Raid Karoumi

Axel Liljencrantz

This is a project financed by the Swedish rail administration (Banverket) and KTH.

The project aim is to develop, implement and test methods for weighing trains by means of instrumented bridges.

Karoumi R., Fredrik C., Liljencrantz A., Assessment of actual traffic loads using B-WIM. Background document SB D4.3.2, Sixth framework programme Sustainable Bridges, 2007.

Liljencrantz A, Karoumi R, Twim – a MATLAB toolbox for real-time evaluation and monitoring of traffic loads on railway bridges, *J. of Structures and Infrastructure Engineering*, vol.5, 2009.

Liljencrantz A, Karoumi R, Olofsson P, Implementing Bridge Weigh-in-Motion for railway traffic, *Computers and Structures*, vol.85, 2007.

Liljencrantz A., Monitoring railway traffic loads using Bridge Weight-in-Motion, Licentiate thesis, 2007.

Liljencrantz A, Karoumi R, Olofsson P, Implementation of Bridge Weigh-in-Motion for Railway Traffic, ICWIM4, The Fourth International Conference on Weigh-In-Motion, Taipei, Taiwan, February, 2005.

Karoumi R, Wiberg J, Liljencrantz A, Monitoring traffic loads and dynamic effects using an instrumented railway bridge, *Engineering Structures*, Elsevier, No. 27, 2005, pp. 1813–1819.

O'Brien EJ, Quilligan M, Karoumi R, Calculating an Influence Line from Direct Measurements, *J. Bridge Eng., Proc. Inst. Civil Eng.*, 159(1), March 2006, pp. 31–34.

SB 9. BRIDCAP – Increased load capacity of existing bridges on corridors

Researchers

Raid Karoumi

This is a project financed by the International Union of Railways (UIC). The project started in 2005 and ended in 2006. The project's main objective is to develop a guideline for railway bridge dynamic measurements and calculations in order to improve the use of existing railway bridges.

Guidelines for Railway Bridge Dynamic Measurements and Calculations, UIC leaflet, Union Internationale des Chemins de Fer, Version 1, January, 2006. (Edited by Karoumi R.)

Karoumi R, Simple bridge/vehicle models for studying the behaviour of bridges under dynamic traffic loads, In UIC seminar on Dynamic Effects of Railway Traffic on Bridges, Frankfurt, Germany, March, 2002.

SB 10. Enhanced Fatigue Evaluation of Old Steel Railway Bridges

Researchers

Raid Karoumi

John Leander

Andreas Andersson

This project is financed by Trafikverket (the Swedish Transport Administration) and KTH. The project started in 2008 and will continue until 2011. The project's main objective is to study the remaining fatigue life of railway bridges by response monitoring combined with advanced analysis methods. The project focuses mainly on the Söderström Bridge in central Stockholm which is one of Sweden's most important railway bridges.

Leander J., Andersson A., Karoumi R., Monitoring and enhanced fatigue evaluation of a steel railway bridge, J. of Engineering Structures, vol.32, 2010.

Andersson A., Utmattningsanalys av järnvägsbroar, en fallstudie av stålbroarna mellan Stockholm Central och Söder Mälarstrand, baserat på teoretiska analyser och töjningsmätningar. Licentiate thesis, TRITA-BKN. Bulletin 97, 2009.

Leander J., Andersson A., Karoumi R., Enhanced Assessment of the Remaining Service Life of a Steel Railway Bridge. DAMAS, China, 2009.

Leander J., Bro över Söderström, mätning och utvärdering m.a.p. utmattning. Report, Royal Institute of Technology, TRITA-BKN. Rapport 126, 2008.

SB 11. Development and Implementation of Monitoring Systems for Increased Safety and Improved Operation and Maintenance of Railway Bridges

Researchers

Raid Karoumi

Ignacio González

This project is financed by Trafikverket (the Swedish Transport Administration) and KTH. The project started in 2009 and will continue until 2012. The project's main objective is to investigate available structural health monitoring techniques and to develop a bridge monitoring system which can assist railway owners in the operation and maintenance processes for bridges.

The project has produced an extensive state-of-the-art literature review on the latest development in Structural Health Monitoring relevant to bridge structures. Monitoring systems have been developed, implemented and tested on the

High Coast suspension bridge and the Söderström railway bridge. Emphasis has been placed on monitoring the traffic loads acting on bridges as these are the main contributor to wear and damage in bridges. In the next step, the feasibility of wireless monitoring techniques and their applicability to bridges will be investigated. The project has so far resulted in the following publications which will be submitted in 2011 to international journals for publication:

González I. and Karoumi R., Recent Developments in Structural Health Monitoring of Bridges.

González I. and Karoumi R., Continuous Monitoring of Bearing Forces and Displacements on the High Coast Suspension Bridge.

González I. and Karoumi R., Long-term Traffic Monitoring using Bridge Weight-in-Motion.

SB 12. Development of Methodology for LCC and LCA of Railway Bridges

Researchers Raid Karoumi
 Mohammed Safi
 Guangli Du

This project is financed by Trafikverket (the Swedish Transport Administration) and KTH. The project started in 2009 and will continue until 2012. The project is focused on 1) the implementation of LCC and LCA for railway bridges via the case studies of actual performed construction, maintenance and repairs, and end of life scenarios; 2) the development of LCC and LCA calculation tools for bridges; 3) the development of guidelines for LCC and LCA evaluation of railway bridges.

The project aims at enhancing the bridge investment and management decisions by Integrating the LCC and LCA with the decision making process. This will ensure that the society's needs are optimally met and assist in providing more sustainable bridges. Two simplified standalone computer tools were developed for this propose supported with real case studies and implementation examples.

Safi M., Sundquist H., Racutanu G., Life-Cycle Costing Integration with Bridge Management Systems, J. ICE-Bridge Engineering. (Submitted on 16 April 2011)

Safi M., Sundquist H., Karoumi R., Racutanu G., LCC applications for bridges & Integration with BMSs- case study whether to repair or to replace a bridge, J. ASCE-Bridge Engineering. (To be submitted 2011)

Safi M., Sundquist H., Karoumi R., Guangli Du., Integrated Bridge Life Cycle-Cost Approach for Extended Bridge

Sustainability, J. Structure and Infrastructure Engineering, Maintenance, Management, Life-Cycle Design & Performance. (To be submitted 2011)

Racutanu G., Safi M., Sundquist H., LCC applications for bridges & Integration with BaTMan. Technical Report for Trafikverket, Royal Institute of Technology. (to be submitted 2011)

Thirbault V., Du G. L., Karoumi R., Design of railway bridges considering LCA, accepted to be published by the journal of ICE Bridge Engineering.

Du G. L., Karoumi R., Life cycle assessment approach for comparing railway bridge designs, to be submitted to the Journal of Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance.

Du G. L., Karoumi R., A guideline for the life cycle assessment of railway bridge infrastructures, to be submitted to the Journal of Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance.

Du G. L., Life cycle assessment for railway bridge infrastructure: a case study of Bollstaån Bridge, COST Action C25: Proceedings of the international conference sustainability of constructions-towards a better built Environment. Innsbruck, Austria, 2011.

Rossi, B., Lukic I., Iqbal N., Du G. L., Cregg D., Borg R. P., Haler P., Life cycle impacts assessment of steel, composite, concrete and wooden columns, COST Action C25: Proceedings of the international conference sustainability of constructions-towards a better built Environment. Innsbruck, Austria, 2011.

Du G. L., A Literature review of life cycle assessment for bridge infrastructure, COST Action C25: Sustainability of Constructions: An Integrated Approach to Life-time Structural Engineering". Malta, 2010.

SB 13. Efficient Assessment Methods of the Dynamic Response of Existing Railway Bridges to High-speed Trains

Researchers Raid Karoumi
 Costin Pacoste
 Christoffer Johansson

This project is financed by Trafikverket (the Swedish Transport Administration) and KTH. The project started in 2010 and will continue until 2014. The purpose with this project is to develop simplified and efficient analysis tools that will allow the decision makers (Railway administration for instance) to quickly analyze a large number of bridges and identify the ones that are likely to exhibit unacceptable acceleration levels if subjected to high speed train passages.

The bridges in this latter category can then be subjected to more refined analyses partly based on the probabilistic methods that will be developed within the project.

The project has resulted in the following publications:

KTH-Brobyggnad rapport, 2010. Höghastighetsprojekt – Bro Delrapport 1, Befintliga krav och erfarenheter samt parameterstudier avseende dimensionering av järnvägsbroar för farter över 200 km/h, KTH Brobyggnad, TRITA-BKN Rapport 139.

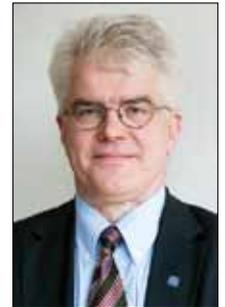
Johansson, C., Pacoste, C., Karoumi, R., 2011. Simplified analysis of continues bridges for high-speed trains. (To be submitted 2011)



Electric Power Engineering – EP

The laboratory for Electrical Machines and Power Electronics at the School of Electrical Engineering carries out research and education in the field of electric

railway traction. That includes traction motors, transformers, converters and electromechanical devices.



**Professor
Stefan Östlund**

RESEARCH PROJECTS

EP1. New converter topologies for electric railway traction

Researchers Stefan Östlund
 Staffan Norrga,
 Tommy Kjellqvist

topology allows full four-quadrant operation and galvanic isolation by a transformer that can operate at arbitrary frequency. All valves can operate under zero-voltage or

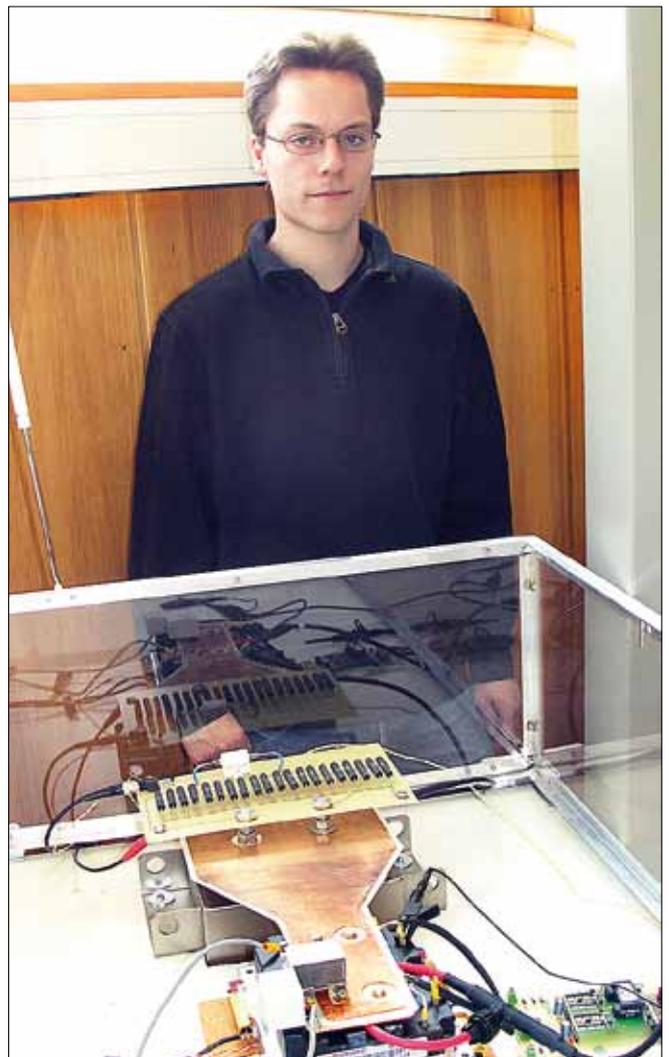
Period: Stage 1 00-05, Stage 2 05-11

Source of funding/partners: Banverket/Trafikverket

PhD degree: Staffan Norrga "On Soft-Switching" Isolated AC/DC Converters without Auxiliary Circuit", May 2005

PhD degree: Tommy Kjellqvist "On Design of a Compact Primary Switched Conversion System for Electric Railway Propulsion". June 2009

The project is concerned with a new soft-switched medium frequency converter topology for railways. The proposed



PhD Tommy Kjellqvist, Researcher in EP1.



Prototype of medium frequency transformer for 200 kVA, 4 kHz.

EP 4. Train Information Management and Monitoring (TIMM)

Researchers Stefan Östlund KTH, stefan.ostlund@ee.kth.se
Mats Berg KTH, mabe@kth.se
Fredrik Carlsson KTH
Martin Bohlin SICS
Anders Holst SICS
Martin Aronsson SICS

Source of funding/industrial partners: Vinnova, Bombardier Transportation, SKF, Tågoperatörerna

This is a two-year project (2006-2007) carried out by KTH and Swedish Institute of Computer Science (SICS).

Today the European railways are being deregulated and massive sums are invested in new infrastructure thus rail transportation is expected to increase considerably. The pressure on the railways to provide more flexible and efficient rail transportations makes it necessary to develop tools for

common status information, deviation detection, prognoses, dynamic re-planning and optimisation. Such tools facilitate e.g. condition monitoring of vehicles and infrastructure via sensors in the vehicle or in the infrastructure. The proposed project deals with the process of designing a platform for information management and monitoring of trains. The project consists of four work packages: WP1 Condition Monitoring, WP2 Diagnosis and deviation detection, WP3 Dynamic re-planning, WP4 Information platform issues. The work of the laboratory for electrical machines and power electronics is mainly within WP1 and deals with monitoring of the propulsion and in particular the current collection. Up to now the dynamics of train ride stability has been investigated.

Östlund S, Gustafsson A, Buhrkall L and Skoglund M: Condition Monitoring of Pantograph Contact Strip, 3rd Railway Condition Monitoring Conference, Derby UK, 2008

EP 5. Dynamic maintenance, Planning and Scheduling for Train Operation, DUST

Researchers Stefan Östlund KTH
Mats Berg KTH
Tommy Kjellqvist KTH
Martin Bohlin SICS
Anders Holst SICS
Martin Aronsson SICS
Kivanc Doganay SICS

Source of funding/partners: Vinnova, Euromaint Rail, Bombardier Transportation, Green Cargo

Period 2008-2011

The DUST project is a continuation of the TIMM project focusing on issues regarding Condition based maintenance

in train operations, and its consequences for production planning and control. The focus is on how cooperation between different players can contribute to a more reliable and punctual operation through efficient and dynamic maintenance connected to planning and control.

The purpose is to develop methods that link the whole chain from condition monitoring to planned actions that is useful in real operation. That includes further development of methods for deviation detection, diagnosis, life-time analysis, dynamic re-planning and optimization, as well as assessing the methods in a common real scenario.

Aronsson M, Bohlin M, Doganay K, Holst A, Kjellqvist T and Östlund S: 'An Integrated Adaptive Maintenance Concept' Proceedings of International Conference on Condition Monitoring and Diagnosis, Sept. 6-11, 2010, Toyosu, Tokyo





Machine Elements (Dept of Machine Design) – ME

KTH Machine Design is performing research and education in the area of tribology of the wheel-rail contact. That includes the adhesion, wear and lubrication of the wheel-rail contact. In contrast to other well-investigated machinery, such as roller bearings, the wheel-rail contact is an open system. It is exposed to dirt and particles and natural lubrication, such as high humidity,

rain and leaves, all of which can seriously affect the contact conditions and the forces transmitted through the contact. A handbook published by Woodhead Publisher Limited and entitled Wheel/rail interface handbook has been edited by Roger Lewis Sheffield University UK and Ulf Olofsson Railway Group, KTH.



**Professor
Ulf Olofsson**

RESEARCH PROJECTS

ME 1. Track-vehicle interaction (SAMBA 6)–Wheel rail wear mechanisms and transitions

Project leader Ulf Olofsson
Graduate student Jon Sundh
Research engineer Peter Carlsson

Sources of funding: Banverket and KTH Railway Group
An observation that can be made about wear is that an increase of the severity of loading at some stage leads to a sudden change in the wear rate. Wear transitions are identified using wear maps and are defined in terms of sliding velocity and contact pressure. Wear regimes are related to expected wheel rail contact conditions and contact points (tread/flange). Such wear assessments are becoming more significant as train speeds are increasing and new specifications are being imposed relating to safety and reliability. It can also help in determining more efficient maintenance schedules on particular routes; where different track profiles may be needed to reduce the severity of the wheel rail contact and where application of lubrication or change of material may be necessary to reduce wear problems. The transitions between the different wear mechanisms were studied with special emphasis on the transition between mild and severe wear. Jon Sundh Defended his PhD thesis on the 11th of December 2009.

Sundh J: An experimental study on wear transitions in the wheel rail contact, Licentiate thesis in machine Design, KTH, Stockholm, Sweden 2007.

Sundh J, Olofsson U, Olander L, and Jansson A: Wear rate testing in relation with airborne particles generated in a wheel-rail contact. Nortrib 08, June 2008, Tampere Finland, also submitted to Tribotest.

Sundh J, Olofsson U and Sundvall K: Seizure and wear rate testing of wheel/rail contact under lubricated conditions using a transient and a standard ball-on-disc test method, *Wear*, Vol. 265, Issues 9-10, (2008) 1425-1430.

Sundh J and Olofsson U: Seizure mechanisms of wheel/rail contacts under lubricated conditions using a transient ball-on-disc test method, *Tribology International*, Vol. 41, Issues 9-10, (2008) 867-874.

Sundh J, Olofsson U, Olander L, and Jansson A., Wear rate testing in relation with airborne particles generated in a wheel-rail contact, *Tribotest*, vol 21 issue 4, p. 135-150.

Sundh J, and Olofsson U, Relating contact temperature and weartransitions in a wheel-rail contact, Presented on the 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems (CM2009), Firenze, Italy, September 15-18, 2009, Submitted to *Wear*.

Sundh J. On wear transitions in the wheel rail contact, Doctoral thesis Department of Machine Design, KTH (2009).

ME 2. Adhesion between railway wheel and rail

Project leader Ulf Olofsson
Graduate student Zhu Yi
Research engineer Peter Carlsson

Sources of funding: Banverket, SL and KTH Railway Group

The wheel rail contact operates with the limitations imposed by the friction existing between steel surfaces. Poor adhesion in braking is a safety issue as it leads to extended stopping distances. In traction, however, it is also a performance issue. If a train experiences poor adhesion when pulling away from a station and a delay is enforced the train operator will incur costs. Similar delays will occur if a train passes over areas of poor adhesion while in service. Fallen leaves can disrupt rail services all over Europe. A mature tree has between 10 000 and 50 000 leaves. There are estimations that thousands of tonnes of leaves fall onto railway lines every year. The leaves are usually swept onto the track by the slipstream of passing trains. While conditions leading to poor adhesion have been well investigated, methods for addressing the problems have not. The purpose of this project is firstly to develop a test

method where friction modifiers can be evaluated in contact conditions and an environment that correspond to the wheel rail contact. Secondly, the research aims to develop new environmentally friendly friction modifiers and, furthermore, to develop adhesion models for the railway wheel rail contact including contaminants.

Olofsson U: Adhesion and friction modification, Wheel/rail interface handbook, ed. R. Lewis and U. Olofsson, Woodhead Publisher Limited 2009.

Olofsson U: A multilayer model of low adhesion between railway wheel and rail, Proceeding of IMECHE part F, vol.221 (2007) 385-389.

S.R. Lewis, U. Olofsson, R. Lewis, J. Cotter U., A study on top of rail friction. Influence of temperature, humidity, biological material and top rail modifiers. 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Firenze, Italy, September 15-18, 2009.

Olofsson U., A study of top of rail contaminants on a local traffic track, Nordtrib Norrforsen, June 2010.

ME 3. Airborne particles generated from train-track interaction

Project leader: Ulf Olofsson
Graduate student Saeed Abbasi
Research engineer Peter Carlsson

Source of funding: KTH Railway Group

A well known problem for the rail road industry is that the railway wheel and rail are worn. The profile change of rail on curves makes a large contribution to track maintenance cost. The profile change on wheels can also be significant, especially on a curved track. Another problem is that the material loss from the wheel, rail, brakes and pantograph generate airborne loose debris. Recent studies in underground systems and in stations placed in tunnels shows large numbers of airborne particles. The number and mass of airborne particles less than 10 μm usually exceed acceptable levels in the different countries and cities. There also exist EU guidelines for PM₁₀ (dir 96/62/EG), which often is exceeded (PM₁₀ refers to particles less than 10 microns, which are defined as small enough to enter into the alveoli of the human lung and be potentially dangerous). The purpose of this project is firstly

to develop a test method where generated airborne particles can be evaluated in contact conditions and an environment that correspond to the wheel rail contact. Furthermore, the project aims to develop simulations models for the generation of airborne particles from train track interaction with the aim to include them into simulation software's for train track interaction.

Olofsson U: A study of airborne wear particles generated from the train traffic – block braking simulation in a pin-on-disc machine, 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems (CM2009), Firenze, Italy, September 15-18, 2009.

Olofsson U, Olander L, Jansson A: Towards a model for the number of airborne particles generated from a sliding contact, Nordtrib 08, 11-13 June 2008 Tampere Finland, also Wear (2008), doi:10.1016/j.wear.2009.05.002

S. Abbasi S, Wahlstrom J, Olander L, Larsson C, Olofsson U, Sellgren U, A study of airborne wear particles generated from railway organic brake pads and brake discs, Nordtrib Norrforsen, June 2010.



Transportation and Logistics – ToL

The Group has special competence in the areas of traffic planning such as cost models, customer preference evaluations, forecast models, logistic and transportation models as well as capacity and simulation models. The group has special competence in the areas

of traffic planning, customer preference evaluations, models for explaining the number of passengers, capacity simulation models, logit models and travel time evaluations.



**Professor
Bo-Lennart
Nelldal**

RESEARCH PROJECTS

FREIGHT AND LOGISTICS

ToL1. Model for supply and costs for freight transport by rail

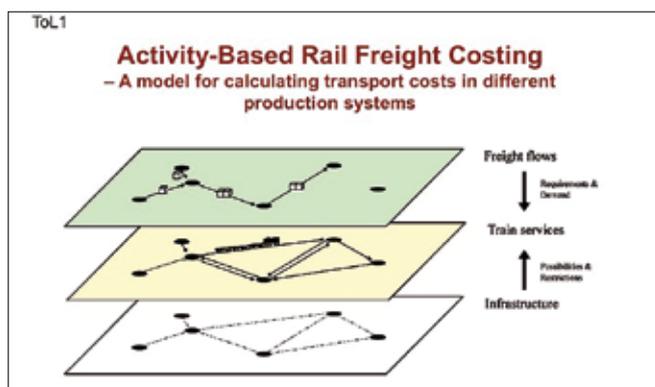
Researchers Bo-Lennart Nelldal
Gerhard Troche

Sources of funding: Swedish National Rail Administration (Banverket) and Green Cargo (Swedish State Freight Railways) Duration: 1998-2008.

The aim of the project is to develop a supply-model for production and cost-structure of rail freight transportation. With the model it will be possible to predict the consequences of new railway production systems, changes in cost-structure and to get input data for forecast-models and for calculations of new transport-systems. The model is an activity based cost model (ABC) that also increase understanding of how costs is generated and of cost-drivers.

With the model it will be possible to calculate the effects of new transport systems and changes in performance in the railway system. Examples are higher axle-loads, wider structural gauge, longer trains, automatic couplers and new traffic patterns. The model has among others been used to evaluate new train concepts in the project “Efficient train systems for rail freight transportation”.

Activity-Based Rail Freight Costing – A model for calculating transport costs in different production systems, Doctoral Thesis, KTH Railway Group, TRITA-TEC-PHD 09-002. Gerhard Troche, 2009



ToL2. Evaluation of intermodal transport chains

Researchers: Bo-Lennart Nelldal
Gerhard Troche
Robert Sommar (KTH)
Ulf Carlsson (KTH-MWL)
Peter Andersson (Mariterm)
Peter Bark (TFK) et al.

Sources of funding: Swedish National Road Administration (Vägverket) and Swedish National Rail Administration (Banverket) by SiR-C (Swedish Intermodal Transport Research Center. Duration: 2006-2009.

KTH Railway Group is participating in the virtual research center SiR-C (Swedish Intermodal Transport Research Center) together with Chalmers University of Technology (CTH), School of Business Economics and Law at Gothenburg University (HGU), Transport Research Institute (TFK), MariTerm, Transek-WSP and BMT Transport Solutions. KTH is responsible for the project "Evaluation of intermodal transport chains", described below. KTH is also participating in the following studies (project leader): Strategic modelling of combined transport between road and rail (HGU), Intermodal transports of commodities (TFK) and Intermodal urban distribution – prospects and barriers Transek-WSP). The last project deals with freight transports by tram and metro.

Intermodal transport chains consist of several mode of transport and terminal handling that are linked to a certain time, cost and stresses on the freight. The purpose of this project is to monitor a number of intermodal transport chains and map each link in the chain as regards time consumption, costs, administrative routines and any stresses on the freight.

A number of different transport chains will be selected with varying modes of transport, terminal handling and length. Measurements can be taken by equipping a container, swap-body or trailer with measuring apparatus that registers time, jerks and jolts, temperature, etc that can be saved or possibly transmitted via mobile telephony equipment. At the same time the administrative process is followed up at the transport

company's and the customer's sites to obtain a holistic picture of the transport assignment in question.

The aim is to identify the weakest link in an intermodal transport chain that may be critical for increasing intermodal transportation. When the weakest link has been identified, an investigation can be undertaken to determine whether the transport chain can be improved so that the weakest link is eliminated.

The following reports were published during 2010:

Huvudrapport: Utvärdering av intermodala transportkedjor, Bo-Lennart Nelldal och Robert Sommar (red) 2010-06-01

Underlagsrapporter:

Utvärdering av intermodala transportkedjor – Kartläggning av transportkedjor, Robert Sommar (red) 2010-04-13

Utvärdering av intermodala transportkedjor – Kostnadsmodeller, Robert Sommar 2010-04-12

Utvärdering av intermodala transportkedjor – Mätningar av accelerationer vid hantering och transport av lastbärare, Mariterm 2009-06-18

Utvärdering av intermodala transportkedjor – Analys av mätdata, skaktester, 62 sidor, Marcus Wallenberg laboratoriet för Ljud och vibrationsforskning, KTH, 2010-04-27

Utvärdering av intermodala transportkedjor – Djupanalys av Skadestatistik från Stora-Enso-Fors, Nils Anderson, Mariterm, 2009-06-10

Utvärdering av intermodala transportkedjor – Riskanalys, 217, Nils Andersson, Sven Sökjer-Petersen, Mariterm, 2009-06-09

The following papers are also available in English:

Evaluation of intermodal transport chains, Bo-Lennart Nelldal, paper at 7th European Congress on ITS, Geneva, 2008

Evaluation of intermodal transport chains, Bo-Lennart Nelldal, Robert Sommar, Gerhard Troche paper at Congress on ITS, New York, 2008

Measures to make intermodal transport smarter from a transport chain perspective, Robert Sommar paper at World Congress for ITS Stockholm., 2009.



ToL3. Intermodal small-scale linear train

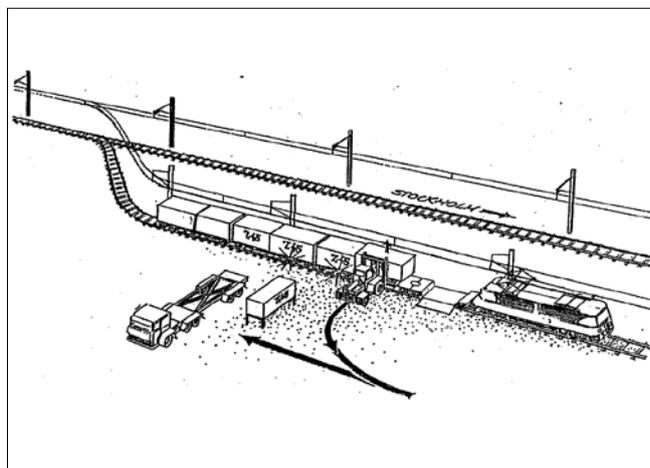
Researchers Bo-Lennart Nelldal
Gerhard Troche
Robert Sommar (KTH)
Jakob Wajsman (Trafikverket)

Sources of funding: Swedish National Traffic Administration (Trafikverket) by SiR-C (Swedish Intermodal Transport Research Center. Duration: 2008-2011.

Liner train system with many small terminals can widen the market for inter-modal radically if the system is restricted to swap-bodies and containers of a maximum length of 10,7m and weight of 25 tonnes. Then ordinary and cheap forklifts can be used and the train can use many terminals under their way at a side-tracks and containers can be lift-off and lift-on at a 15-30 minutes stop.

The aim of this project is to investigate the prerequisites for a demonstration project with a light-kombi system in Sweden (or between Sweden and another country) and after that put it into service and evaluate the demonstration project. The

project includes market analysis integrated with the Sir-C project 1, 2 and 3 and cost model calculation by KTH-model and contacts with potential customers and operators.



ToL4. Regional freight transport systems

Researchers Bezadh Kordnejad (KTH)

Sources of funding: Swedish National Traffic Administration (Trafikverket) by SiR-C. Duration 2010-2013.

The major metropolitan areas account for a growing proportion of Sweden's population. At the same time, the regions are expanding geographically as the possibilities for fast transportation extend both people's and companies' action radius. Despite a growth in service production the metropolitan areas nonetheless need transportation.

The railway's market share for transportation to/from the Stockholm region has steadily decreased at the same time as the total need for transportation has increased. In order to obtain a transport system that is sustainable in the long term a larger proportion of intermodal transport solutions is

desirable, where the railways play a bigger role.

The purpose is, based on a case study in the Lake Mälaren valley, to analyse the possibilities to create a regional freight transport system around Lake Mälaren. The project aims to investigate the market, suitable terminal locations, what frequency is required and the economic viability of such a system. It may later result in a demonstration project.

ToL5. TESS – Intermodal Solutions for Trans European Temperature Sensitive Shipments

Researchers Gerhard Troche
Robert Sommar
Francesco Radano (KTH)
Jonas Flodén (HGU)
Tayssa Rytter (TfK Borlänge)
Herwig Schöbel (Büro Herry, Wien)
Philipp Schmidt (ETH Zürich)

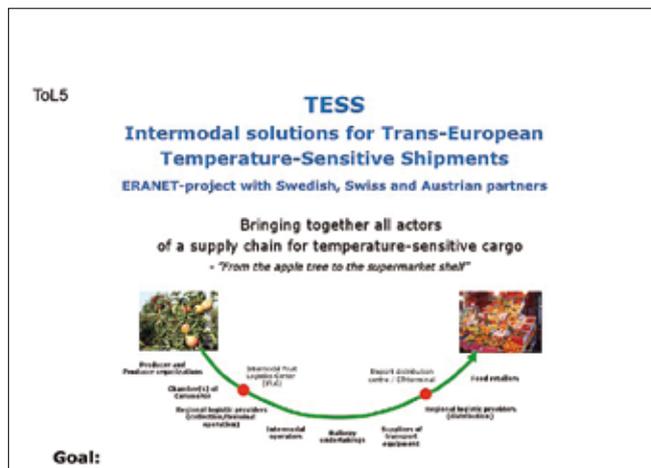
The project is being conducted within the scope of the ERANET programme and will run between 2008 and 2010.

Five parties from three countries are collaborating on the project: KTH Traffic & Logistics, the School of Business, Economics and Law at the University of Gothenburg, and TFK Transport Research Institute in Borlänge from Sweden, HERRY Consult from Vienna in Austria and the ETH Zürich Institute of Technology in Switzerland. The project is funded by the research authorities in the respective countries, in Sweden by the Vägverket (the National Road Administration) and Banverket (the National Rail Administration) through Sir-C (the Swedish Intermodal Transport Research Centre).

The need to transport temperature-sensitive goods, in

particular food, has grown markedly in recent decades. The railways have almost completely lost this market to the truck, first and foremost in international traffic. Customers have adapted their logistics to road transport. Ever increasing fuel prices, the introduction of road tolls, congestion problems on the central European motorways, greater awareness on the part of both companies and not least consumers of the climatic effects of transportation, mean that convenience goods suppliers are once again seeking transport solutions.

The bearing concept in the TESS project is to bring together players and their knowledge from the whole transport chain in order to develop a model case for international intermodal transport solutions for temperature-sensitive freight transport. The aim is to develop a transport solution for a pilot route that will be able to be implemented in connection with the project.



ToL6. MINT – Model and decision Support System for Evaluation of Intermodal Terminal Networks

Researchers Gerhard Troche
Fredrik Hagelin (KTH)
Fredrik Bärthel (TfK Borlänge)
Jonas Flodén (HGU)
Hans Häuslmeyer (BOKU, Wien)
Hans Rüsç (RAPP, Zürich).

The project is being conducted within the scope of the ERANET programme and will run between 2008 and 2010. Five parties from three countries are collaborating on the project: KTH Traffic & Logistics, the School of Business, Economics and Law at the University of Gothenburg, TFK Transport Research Institute in Borlänge from Sweden, the University of Natural Resources and Life Sciences (BOKU) from Vienna in Austria and the RAPP consulting firm from Zürich in Switzerland. The project is funded by the research authorities in the respective countries, in Sweden by the National Road Administration and Banverket (the National

Rail Administration) through Sir-C (the Swedish Intermodal Transport Research Centre).

The proposed project is a joint strategic and tactic trans-national project researching a new and improved model and decision support system for evaluation of intermodal terminal networks – MINT. The result will be a model and decision support system of compatible and integrated models and methods to investigate, evaluate and analyse costs and benefits for terminal networks as well as single terminals.

The system is based on a number of models on different system levels and by combining these models some of their individual weaknesses are overcome. Together they form an excellent basis for improved system or terminal network design, investigation and evaluation. To integrate the models an information exchange structure will be developed. Finally an additional deepening network analysis complements the models system - to integrate other non-modelling aspects in the analysis. This model and decision support system, will be the result of the MINT project

ToL7. FTCS - Freight Transport Corridor Study

Researchers Sharin Nasir (KTH)

Sources of funding: Malaysian Government. Duration: 2006–2010.

Malaysia container trade is expected to grow more than 60% by the year 2020 from 2005. 90% of the local shipments to the hinterland are handled by road haulage and only 10% handled by rail freight. By looking at the dominance of road haulage, the opportunities for modal shift from road to rail to improve container movement to the hinterland can be further explored. The government and the industry players are looking at the idea of modal shift from road to rail as one of the main solution in order to reduce the pressure on roads and port congestion.

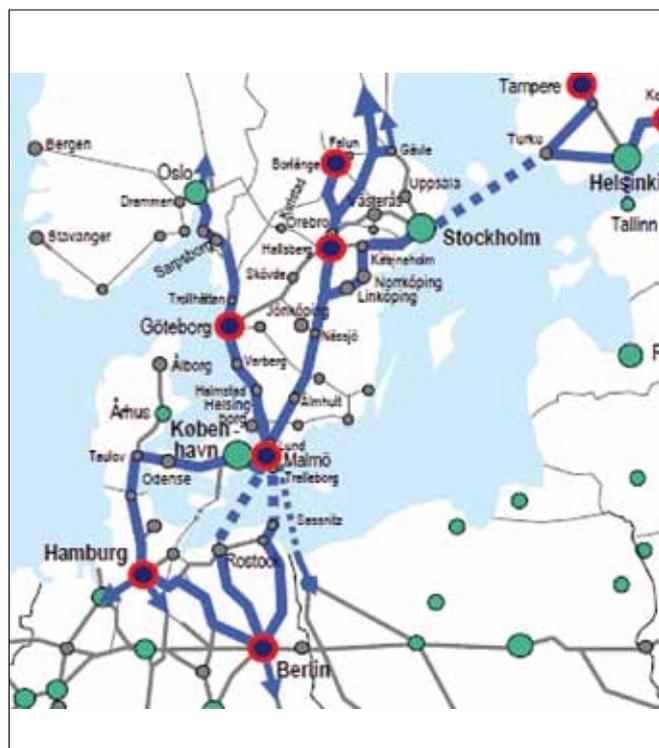
The main aim of the study is to analyze the factors that influence the development of rail freight services for container traffic from port to the hinterland in Malaysia perspective. This study will focus on the container movement from port to the hinterland of Malaysia. In developing a new service, the actors or players involve in organizing and implementing the services has to identify.

The study area will focus on the North Port as the main gateway to Malaysia and Port of Gothenburg as the comparison port. Port of Gothenburg has been successfully implementing a comprehensive rail freight service for container movement. 40% of its container movement to logistics centre in Sweden is through rail freight.

ToL 8. SCANDRIA – Scandinavian-Adriatic Corridor for Growth and Innovation

Researchers Bo-Lennart Nelldal
Hans Boysen (KTH)

Sources of funding: European Union. Duration: 2010–2012.
SCANDRIA is an EU-funded project that aims to improve transport possibilities and increase the exchange between Scandinavia and northern Germany in a manner that is sustainable in the long-term. Scandria stands for "Scandinavian-Adriatic Corridor for Growth and Innovation" that is a corridor stretching from Scandinavia via Germany and down to the Adriatic. The northern section between Scandinavia and Germany is being analysed in the Scandria project while the southern section between Germany and the Adriatic will be studied in the SoNorA (South-North-Axis) project.



The aim is to increase the use of the railways instead of trucks and to increase the competitiveness of the ports along the South-North-Axis compared to the North Sea ports. The idea is to create an alternative route that will pass through the Suez Canal. Freight will be transported by the fastest land route by train through Europe instead of touring Europe by ship.

Scandria is a collaborative project with 19 parties from Germany, Sweden, Denmark, Norway and Finland participating. They are regional authorities and other organisations, ports, and universities and other institutions of higher education, among them KTH.

KTH Railway Group is contributing analyses of a transport corridor from Sweden, Norway, Denmark and Finland to Germany. These include a review of terminals, marshalling yards, train routes, and infrastructure in order to identify bottlenecks and propose measures to establish a corridor with a common standard that is sufficiently high to be able to provide an alternative to road transport. Different alternative routes with ferries and fixed connections will be analysed. The project will collaborate with the Ministry of Enterprise, Energy and Communications' "Green freight corridors" project, in which KTH Railway Group is participating.

On the passenger traffic side, an analysis is also included of how passenger traffic can be improved, among other things by means of a high-speed network via the fixed links at the Fehmarn Belt that are due for completion in 2018 according to the present schedule. The question is how these can be designed so as to increase accessibility between the different countries.

Report "Railway Corridor Performance between Scandinavia and Northern Germany - An investigation for the Scandria project" by Bo-Lennart Nelldal and Hans Boysen, published 2010-08-29.

"Pushing the limits of European Rail Freight – how to develop trans-European rail freight corridors" by Gerhard Troche. Paper to the EURO-Zel conference the 18th International Symposium at Zilina, SK the 26-27th of May 2010.

"Development in Railway freight transportation between Scandinavia and Germany" by Hans Boysen. Paper to the 6th Sonora Think Tank conference eské Bud jowise the 15th of October 2010.

ToL 9. Bothnian Green Logistic Corridor (BGLC)

Researchers Bo-Lennart Nelldal
Hans Boysen (KTH)

Sources of funding: European Union. Duration: 2011–2014.
The overall objective of the proposed Bothnian Corridor project is to increase the integration between northern Scandinavia and Barents, with its vast natural resources and increasing industrial production, and the industrial

chain and end markets in the Baltic Sea Region and central Europe. This will be done by improved planning, use and utilisation of the infrastructure in the Bothnian Corridor, by practicing green corridor concepts, promoting smooth inter modal solutions and increasing collaboration between society, industry, transport and logistics stakeholders. Members are regions, transport administrations, seaports and universities of Finland, Germany, Poland, Norway and Sweden, in total 29 organisations.

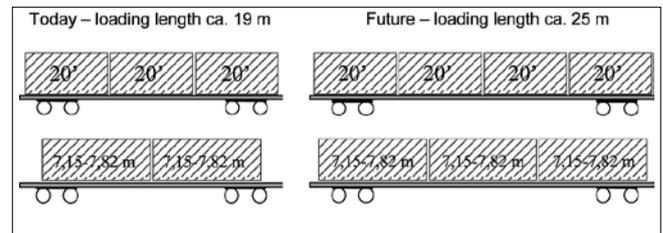
ToL10. The VEL wagon – efficient and longer wagons for future freight transportation

Researchers Hans Boysen (KTH)

Sources of funding: EU. Duration: 2011–2012.

VEL stands for Versatile, Efficient and Longer Wagon for European Transportation and aims to develop more efficient freight wagons for future freight transportation in Europe. The aim is to strengthen the railway's competitiveness compared to truck traffic. The project is funded by the EU and is a collaborative project between TU-Berlin, who is the project leader, KTH and the University of Žilina (UNIZA), and wagon manufacturer Tatravagónka a.s. Poprad (TVP) in Slovakia.

One of the fundamental ideas today is an approximately 25-metre long freight wagon that can load four 20-foot containers instead of three, which is the usual number today. It will be a multipurpose platform that can be used both for intermodal as well other kinds of transportation.



PASSENGER TRANSPORT AND CUSTOMER PREFERENCES

ToL11. Gröna tåget – market and services

Researchers Oskar Fröidh
Bo-Lennart Nelldal
Hans Sipilä

Source of funding: Swedish National Rail Administration (Banverket). Duration: 2005–2011.

The aim of the research program Gröna tåget (Green train) is to strengthen the Swedish competence in developing and procuring the future generation of high-speed trains, according to Swedish requirements and special conditions. The aim is also to strengthen possibilities to participate in and influence the all-European program of railway research and standardisation.

Market and services for the Gröna tåget will be a frame for many technical and economic issues. One important task is to set a platform for an internationally viable knowledge-base of train concept design. The market and services section has the aim to design a concept for the new train with high customer values, i.e. to identify new market segments for services and to work out a suitable performance specification and layout with respect to customer valuations and travel demand.

An important factor is to examine the customers demand for shorter travelling times and make simulations for different specifications of vehicles and track parameters to try to find

an optimum. This will be made by different top speed and tractive effort, with or without tilting, different track lay-out and different stopping patterns.

Running time calculations for Gröna Tåget. In this project, Railsys is used to calculate running times for trains with different performance on a number of typical lines of varying standard. It concerns a number of different variables such as top speed, with and without overspeed and carbody tilting at different inclinations, with different cant deficiency and track geometry and output in KW/ton (acceleration). Simulations will also be conducted to analyse combinations of different trains with different performance.

Fröidh, Oskar (2008): Perspectives for a future high-speed train in the Swedish domestic travel market. *Journal of Transport Geography* 16, 268-277

Sipilä, Hans (2008): *Körtidsberäkningar för Gröna tåget*. KTH Järnvägsgruppen publikation 0802.

Fröidh, Oskar (2010) *Resande och trafik med Gröna tåget*, KTH Järnvägsgruppen publikation 1001.



The Regina prototype train. Photo: Bombardier Transportation



Researcher
PhD Oskar Fröidh

ToL 12. High-Speed Trains in Sweden – Supply and demand

Researchers Bo-Lennart Nelldal
Oskar Fröidh
Kjell Jansson
Josef Andersson
Gerhard Troche (KTH)
Chris Halldin (ÅF)

High-speed trains have existed in Japan since 1964 and in France since 1981. Sweden has had a vision of the Götaland Line and the Europa Line. This involves the construction of a completely new railway line from Stockholm (Södertälje) to Norrköping-Linköping via Nyköping-Skavsta (the East Link) and from there to Jönköping and on to Borås and Göteborg (The Götaland Line). From Jönköping a southward branch is planned to Helsingborg/Malmö and on to Helsingör-Copenhagen and via the fixed link at the Fehmarn Belt to Hamburg.

The fundamental characteristic of high-speed trains is that they travel fast, between 300 and 350 km/h, and thus give extremely short journey times. As examples can be mentioned Stockholm-Linköping with a journey time of 1:00, Stockholm-Göteborg 2:00, Stockholm-Copenhagen 2:45, and Stockholm-Hamburg 4:25. They increase capacity substantially both on high-speed lines and conventional lines. When the fast trains are removed from the conventional lines, capacity is freed up for freight trains and regional trains on the main lines and the fast trains can travel on the high-speed lines with both high capacity and high punctuality.

KTH Railway Group has participated in several studies and research projects concerning high-speed trains. The first study “Europakorridoren – ett bredband för fysiska transporter” (The European Corridor – a broadband for physical transportation) was conducted in 2001 and comprised networks of lines and journey times for a high-speed network in Sweden. The second, “The European Corridor: Supply, forecasts and socioeconomic” also contained forecasts and socioeconomic calculations and international comparisons, and was conducted in 2003.

KTH Railway Group also conducted the research project ”Höghastighetståg – affärsmässighet och samhällsnytta” (High-speed trains – business viability and public benefit) in collaboration with WSP between 2006 and 2008. The aim of the project was to increase knowledge of which high-speed standard and train type would be suitable in a long-term perspective for a high-speed network in the whole of Sweden and its neighbours. The project also looked at travellers’ demands as regards quality of service and business-economic and socioeconomic aspects.

In 2008 the Government assigned Banverket (the National Rail Administration) to make a study of high-speed lines in Sweden- KTH Railway Group was commissioned to draw up a sub-report for Banverket on ”Höghastighetsbanor i Sverige-Götalandsbanan och Europabanan” (High-speed

lines in Sweden – the Götaland Line and the Europa Line). KTH Railway Group also participated in a 2008 study of the market, funding and implementation of a high-speed network in Sweden, ”Nya tåg i Sverige” (New trains in Sweden) that was funded by SJ AB (Swedish Rail), Green Cargo, Alstom, Jernhusen and the Nordic Investment Bank. In 2008 a study was conducted on ”Godstrafikens utvecklingsmöjligheter som följd av en satsning på Europakorridoren” (Development opportunities for freight traffic as a consequence of the establishment of the European Corridor). During 2009 KTH Railway Group participated in the commission on high-speed trains appointed by the Government, resulted in the following reports from KTH:

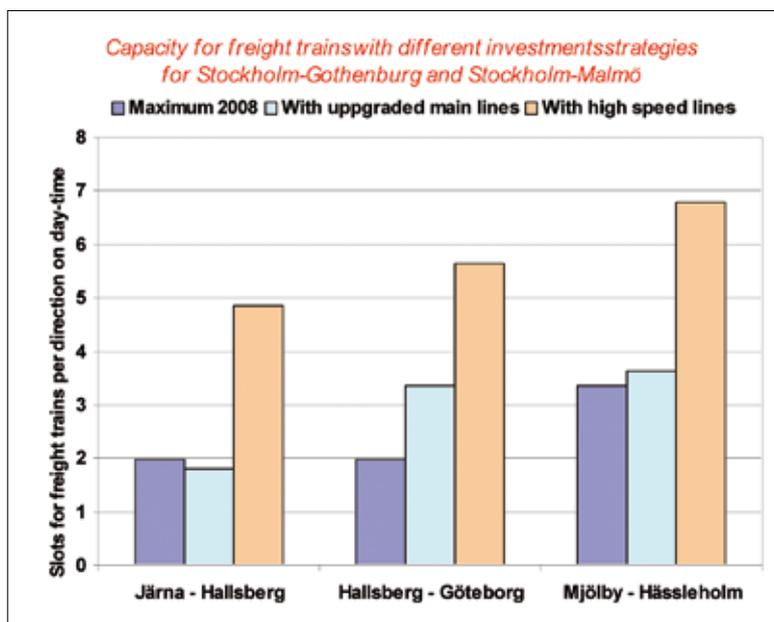
Prognoser och samhällsekonomiska kalkyler för Götalandsbanan – Underlagsmaterial till Banverket, Bo-Lennart Nelldal och Kjell Jansson KTH, Chris Halldin ÅF Infrateknik, KTH-rapport 2009-04-27 (pdf)

Regeringsutredning om höghastighetsbanor N 2008:14: Delrapport 0 - Nulägesanalys 2009-06-30.

Regeringsutredning om höghastighetsbanor N 2008:14: Delrapport 7 – Marknad, trafiksystem och prognoser 2009-09-10.

KTH Järnvägsgrupp: Höghastighetsbanor i Sverige: Trafikprognoser och samhällsekonomiska kalkyler med Samvipsmetoden för utbyggda stambanor och separata höghastighetsbanor. Rapport till Banverket 2010-02-20. Incl: High-speed lines in Sweden Traffic forecasts and socioeconomic calculations using the Samvips method for expanded main lines and separate high-speed lines – Summary in English.

“High-speed trains in Sweden – a good idea?” by Kjell Jansson and Bo-Lennart Nelldal, Royal Institute of Technology (KTH), Stockholm, Sweden. Paper at WCTR 12th congress in Lisbon, 11-15th July 2010.



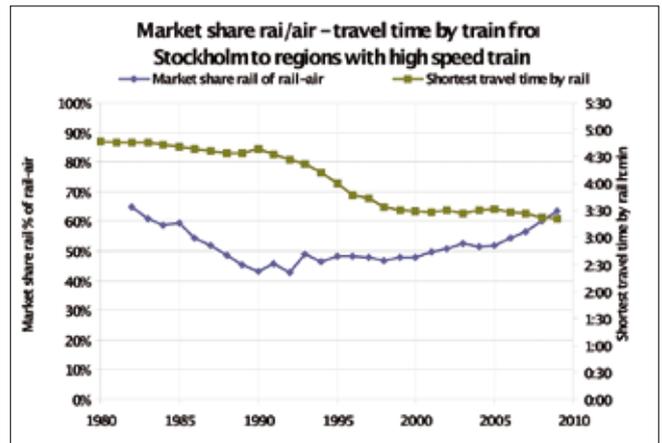
ToL13. Competition and interaction between rail and air

There is a strong correlation between the train's travelling time and its market share of the rail-air market. This has been shown in many different studies and analyses. The purpose of this project is to compile relevant up-to-date data for Europe and other countries in the world and estimate a correlation. The work also includes compiling data for domestic train and air journeys in Sweden over an extended period in the form of a time series. An outline study of the interaction between air and rail was also made.

Bo-Lennart Nelldal: Möjligheter för tåget att konkurrera med och ersätta flyget. Rapport utarbetad på uppdrag av Banverket 2007 (pdf).

Konkurrens och samverkan mellan tåg och flyg, Del 1: Internationell jämförelse. Rapport TRITA-TEC-RR 11-001. Anna-Ida Lundberg, 2011. (pdf). Incl: Competition and interaction between rail and air, Part 1: International comparison -Summary in English.

Konkurrens och samverkan mellan tåg och flyg, Del 2: Tidsserieanalys i Sverige. Rapport TRITA-TEC-RR 11-002. Anna-Ida Lundberg, Bo-Lennart Nelldal 2011. (pdf). Incl: Competition and interaction between rail and air, Part 2: Time series analysis in Sweden - Summary in English.



ToL14. Evaluation of new train systems

Researchers Oskar Fröidh
Karl Kottenhoff

Traffic on the newly constructed Svealand Line was evaluated by Oskar Fröidh in his doctoral thesis in 2003. The project was conducted as a post ex ante study of supply and travelling habits before and after the line was built. A later study analysed the development of travel (demand) and the train traffic (supply; train type, timetable, fare) during the Svealand Line's first ten years of existence from 1997 to 2007 in order to give examples of difficulties in the train traffic and learn lessons for the future. A report was published in 2008.

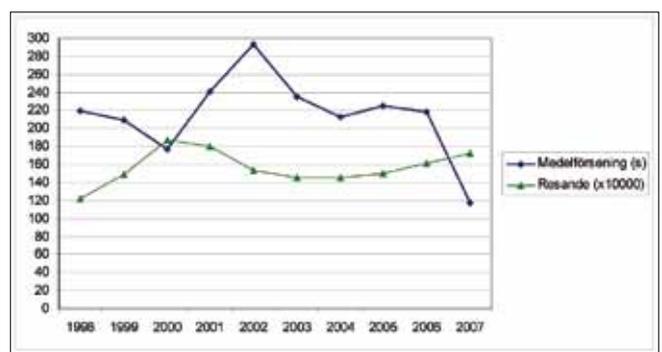
Blekinge kustbana (the Blekinge Coastal Line) between Karlskrona and Kristianstad was evaluated for the first time in 1992 when traffic was radically improved. The line was later electrified and during the electrification work traffic was operated with comfortable coaches that replaced the diesel-powered trains. The line was again operated with direct regional trains to Malmö when electrification was completed in 2007.

In connection with this, a case study of the line was conducted of the line before and after the introduction of electric regional trains. The study comprises both passenger interviews using

combined RP and SP and collection and analysis of supply and demand data. The results are linked to forecast models' characteristics when major changes occur in the supply.

Oskar Fröidh and Bo-Lennart Nelldal: Regional high-speed trains on the Svealand line: Evaluation of effects. 2008. Chapter in Bruinsma, F., Pels, E., Priemus, H., Rietveld, P., van Wee, B. (eds.): Railway development. Impacts on urban dynamics, 295-314. Physica-Verlag, Heidelberg

Oskar Fröidh och Olov Lindfeldt, 2008; Svealandsbanans första 10 år - erfarenheter för framtiden av tågtrafiken och resandet. TRITA-TEC-RR 08-002. Rapport utarbetad på uppdrag av Svealandsbanans intressenter.



ToL15. Deregulation of passenger traffic – a case study of the West Coast Main Line

On the West Coast Line between Copenhagen/Malmö and Göteborg, SJ AB (Swedish Rail) and three cooperating county traffic companies (Skånetrafiken, Hallandstrafiken and Västtrafik have been operating competing services with separate rail traffic concepts since January 2009. This is the

first time in Sweden that long-distance train traffic across county borders is being operated in competition on the same track, with the exception of night services. A step-wise deregulation of all long-distance passenger traffic by train began in July 2009.

Not enough is known about how travellers choose from the supply of train services and operators. Both SJ and the county traffic companies say that they have experienced good demand, despite the fact that the supply has been increased with several trains. The improved supply can be assumed to consist partly of new travel and partly travel that has switched

from cars and coaches. Train travellers can be interviewed about their present and earlier travel habits on the West Coast Line in a follow-up survey. The train travellers' valuations of the supply will be analysed using a combined RP and SP method. The results will be able to be used to predict effects of competing train traffic supply and plan future train traffic.

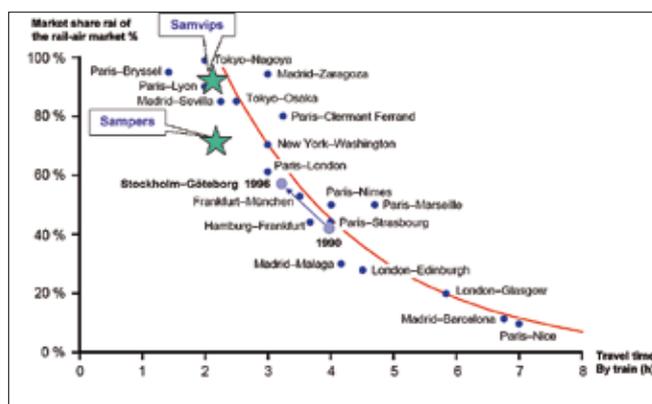
ToL16. Development of forecast models

Together with, among others, ÅF infrateknik, KTH Railway Group has been working for a long time on developing the Samvips forecast model. The background is that the Swedish national forecasting system, Sampers, does not function satisfactorily for forecasts of, principally, interregional public transport, which became particularly apparent in connection with major system changes like the introduction of high-speed trains. A method has been developed where Sampers' matrices are distributed over transport modes, routes and lines using the Vips forecasting tool.

No earmarked research funds have been available for this but the work has primarily been carried on in connection with different assignments. However, a research project to develop an international model has begun. In connection with this, a program called Visum and that will eventually supersede Vips is being used. KTH has also participated in this development work.

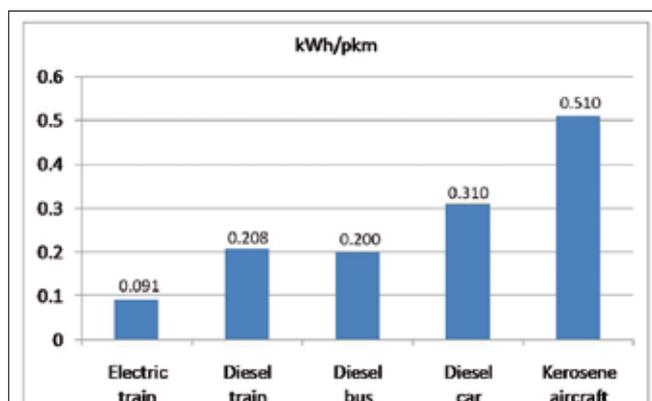
Car ownership model. Access to a car is an important factor as regards individuals' choice of transport mode when they travel. An older car ownership model was implemented in Sampers which proved to give less than satisfactory results.

The aim of the research project is to develop a new car ownership model. A number of new car ownership models have been estimated that take differences and changes in accessibility and the standard of public transport into consideration. These were based partly on calculated data from Sampers and partly on aggregated data on public transport and accessibility. The models proved to be able to explain regional differences in car ownership very well.



ToL17. TOSCA – Energy consumption and emissions from transportation

TOSCA stands for Technology Opportunities and Strategies towards Climate-friendly transport. It is an EU project that aims to analyse how energy consumption and emissions from transportation in Europe can be reduced by 2050. The University of Cambridge is project manager and at KTH Spårfordon (the Division of Rail Vehicles) is project manager. The Railway Group at Traffic and Logistics is responsible for statistics processing, forecasts and capacity analyses.



ToL18. Database of supply and prices for railway-lines in Sweden

On behalf of Banverket the department of Transportation and Logistic has continuously built up a database of supply and prices for 56 railway lines in Sweden. The database now consists of the years 1990-2009 and will be updated every year. The content is facts about travel times, frequency and prices for relations for different products (i.e. high-speed, InterCity, commuter trains) for SJ-traffic, regional authorities' traffic,

state subsidized traffic and private traffic. A report will be published every year that also include some special analysis for Banverkets yearly report "Swedish Rail Sector".

Nelldal B-L, Troche G, Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2009 samt utvecklingen av persontrafiken i ett långsiktigt perspektiv. KTH 2010, pdf.

ToL19. Future infrastructure and train run quality

Researchers Olov Lindfeldt

Source of funding: Swedish National Traffic Administration (Trafikverket)

Duration: 2004-2010.

Capacity dimensioning of single-track railways – Partial double-track vs. single track with only crossing stations

The project began in 2005 and was concluded in 2007. Partial double-track holds both advantages and disadvantages compared to normal crossing stations. In order to realise the advantages (short journey time and less disruption) the timetable must be constructed in the right way, while the disadvantages (higher investment cost and/or lower track capacity) are independent if the timetable.

The purpose of the project is to develop mathematical capacity models and compare the results of mathematical models and simulations and to compare capacity between a uniform model line and an actual line. The function, value and potential of partial double-track on single-track sections will be described and a comparison made between a single-track line with partial double-track and with only normal crossing stations.

Using the results from these analyses it will be possible to determine how a new single-track line must be designed or how an existing single-track line can be expanded to reduce sensitivity to disruptions and running time.

Olov Lindfeldt: Quality on single-track railway lines with passenger traffic - Analytical model for evaluation of crossing stations and partial double-tracks. Licentiate Thesis. TRITA-TEC-LIC 07-003, 2007.

Olov Lindfeldt: Effekter av partiella dubbelspår och fler mötesstationer på enkelspår TRITA-TEC-RR 07-009, 2007. (Effects of partial double-track and more crossing stations on single-track lines).

Analysis of capacity and sensitivity to disruption of double-track lines, applied to the Western Main Line Stockholm-Göteborg

Double-track lines have considerably higher capacity than single-track lines and since the trains do not need to meet, the problem is the mix of different trains where faster trains catch up slower ones. The traffic pattern and overtaking opportunities instead become limiting factors as regards theoretical capacity. Punctuality, on the other hand, has a greater effect on capacity than on single-track lines. The practical capacity is often overestimated unless punctuality is taken into consideration in capacity allocation and timetable planning. The traffic management function is also of importance.

This project aims to analyse how infrastructure, traffic pattern and disruptions affect capacity and punctuality on a double-track line. This is done by means of a systematic analysis of a large number of variables for a typical line using simulation. This is then applied to a real line, the Western Main Line Stockholm-Göteborg.

The result can form the basis for determining practical capacity as a function of theoretical capacity depending on the level of disruption and choice of optimum traffic pattern and expansion of the infrastructure in a longer perspective.

Olov Lindfeldt: Railway operational analysis. Evaluation of quality, infrastructure and timetable on single track and doubletrack lines with analytical models and simulation. Doctoral thesis TRITA-TEC PHD 10-001.

Några slutsatser av fem års forskning på kapacitet och kvalitet i järnvägstrafik, eller Doktor Lindfeldts recept. PM KTH-Cst 2010-05-28. Olov Lindfeldt 2010.

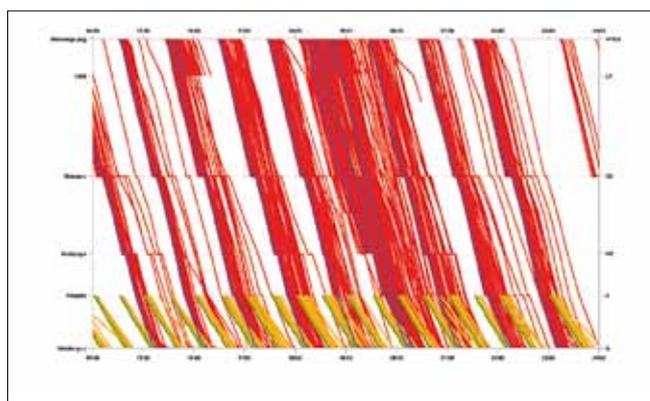
ToL20. Congested infrastructure

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2009-2013.

The load on the Swedish rail network is increasing and Banverket has declared parts of the rail network to be overloaded. The purpose of the project is to analyse what the capacity limit for rail traffic is under different prerequisites. One approach is to analyse how the load on the rail network affects the risk of delay. Another approach is to try to find a "volume-delay"-function for train traffic, i.e. the limit where the infrastructure becomes so loaded that delays increase, causing capacity to fall. This makes it possible to determine the limit for a robust timetable with different prerequisites.

First, a database of the Swedish rail network was created, with data on the infrastructure, the number of trains, the timetables and the delays. A general analysis is made of the



capacity utilisation on various railway lines in Sweden with the aim of finding correlations between different variables and what the capacity limit is with different prerequisites. The analysis is made for lines with single-track and double-track

with different types of traffic. The next step is to construct an analytical model of an actual station with several connecting lines. The model is used to analyse how departure delays are affected by different arrival delays and choice of timetable structures, etc. A large number of simulations are then made in a simulation tool. The simulation results are validated against actual research statistics and compared with the results from the analytical model.

The results will for example be able to be used to calculate how many train paths can be permitted without punctuality falling below a set limit, given a certain type of arrival delay.

ToL 21. Timetable planning with simulation

Researcher Hans Sipilä

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2009-2013.

As railway traffic increases, the infrastructure is being used more and intensively and after deregulation more and more players want to use the tracks, which increases complexity at the same time as demands for flexibility in the timetables are growing. This project aims to analyse if it is possible to improve timetable planning by drawing up timetables with the help of simulation. The purpose is to study whether it is possible in the long term to speed up the planning process and raise the quality of the timetables by being able to simulate the effects of different proposed timetables in advance.

A further purpose of this project is to try to find timetable designs that give better punctuality for the X2000 traffic. Both adjustments of time additions and margins between the trains in today's timetable and major structural changes in the traffic designs that can be made in the long term are being studied. The intention is also to try to create simple, usable guidelines for timetable planning.

The project is being run alongside the timetable planning process one year at a time for the Western Main Line Stockholm-Göteborg, the Southern Main Line Stockholm-Malmö and the East Coast Line Stockholm-Sundsvall. A researcher at KTH, planners at SJ (Swedish Rail) and

Papers:

A study of the performance and utilization of the Swedish railway network. Paper in: Lakušić, S. (editor): Proceedings of the First International Conference on Road and Rail Infrastructure (CETRA 2010), pp 889–895. Opatija, Croatia. Anders Lindfeldt 2010

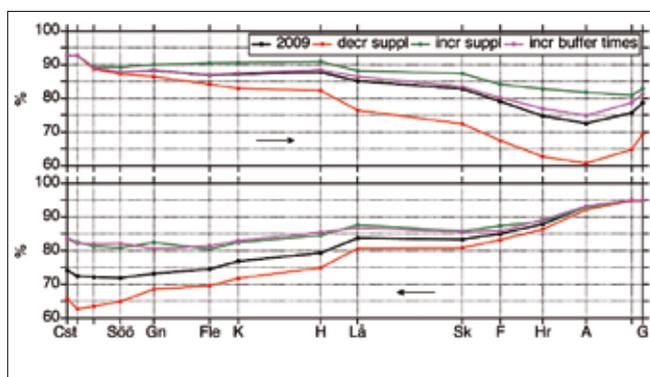
Investigating the impact of timetable properties on delay propagation on a double-track line using extensive simulation. Paper in: Forde, M. C. (editor): Proceedings of Railway Engineering 11th International Conference, London, UK. Anders Lindfeldt 2011.

planners at Banverket work in parallel with timetable construction and simulation. A doctoral student project is also going on where the outcome of the planning is followed up.

Hans Sipilä: Tidtabellsläggning med hjälp av simulering. Effekter av olika tillägg och marginaler på X2000-tågen Stockholm-Göteborg. Forskningsrapport TEC-RR 09-007

Simulation of modified timetables for high speed trains Stockholm-Göteborg. Paper in: Lakušić, S. (editor): Proceedings of the First International Conference on Road and Rail Infrastructure (CETRA 2010), pp 575–581. Opatija, Croatia. Hans Sipilä 2010.

Calibration of simulation model on the southern main line in Sweden. Paper in: Forde, M. C. (editor): Proceedings of Railway Engineering 11th International Conference, London, UK. Hans Sipilä 2011.



ToL 22. Cost-benefit analysis of capacity measurements

KTH Railway group at the department of Transports and Logistics has developed several models to analyse the effects of different infrastructure investments. Some of them are published in Olov Lindfeldts thesis "Railway Operation analysis". I.e. it can be the effects of more crossing stations instead of partial double track sections on a single track line or more overtaking stations on a double track line.

The aim is that these models will be completed with costs to build the infrastructure at one hand and the benefit for travellers, freight customers and operators at the other hand

of different investment strategies. In this way it will be possible to calculate the benefit and choose between different measurements. The aim is that the models can be used in the future planning process.

From the benefit there is experience from research at KTH of the customers stated preferences of travel time, frequency and delays. There is also experience from the business economics of operators by the cost models developed in "Gröna Tåget" and freight costs models. Also there it is possible to use results from the passenger forecast model "Samvips".

ToL 23. Gröna tåget – capacity analysis of higher speed for express trains

The aim of the project is to analyse the effects of higher speeds for express trains on the western and southern main lines. If the express trains are to run faster on existing lines, capacity will fall due to the greater differences in speed. The faster trains will catch up the slower ones and can not overtake just

anywhere because there are not a great number of overtaking stations. The long-term solution is to build dedicated high-speed lines. If this takes to long, it may be interesting to analyse how capacity problems can be handled on the existing track.

ToL 24. Capacity analysis of the rail network in Sweden

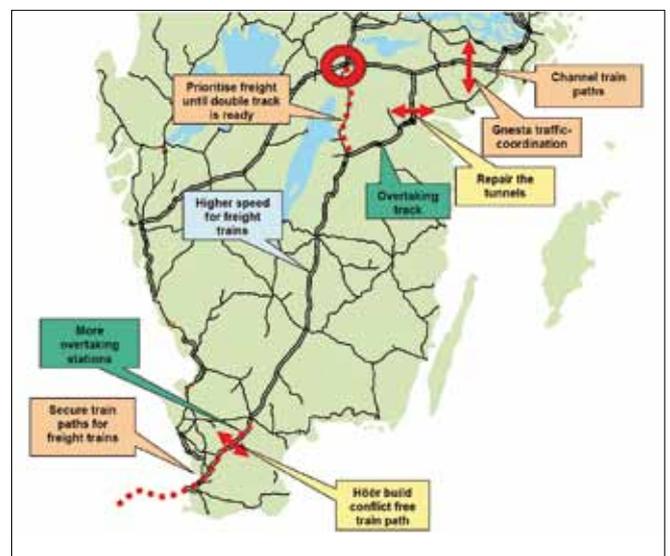
The Swedish rail network is heavily utilised in many places. Demand for journeys and freight transportation by rail has increased quickly in recent years. Operators and customers can not get the train paths desired. Banverket (the National Rail Administration) has been forced to declare some sections of the rail network overloaded. This means that the demand that exists today for journeys and transportation can not be completely satisfied. There is also a much greater potential demand than the timetable applications show.

Continued deregulation means that more operators will enter the arena, which further increases the demand for capacity. Environmental issues have also had a tangible effect on the choice of transport mode in recent years. If this is to be solved, considerably greater capacity utilisation than today is needed. Investment in increased capacity takes time, even if the decisions have been taken and are funded. KTH Railway Group have therefore been commissioned by Banverket to make a capacity analysis of the rail network in Sweden. The “Capacity analysis of the Swedish rail network” project published three sub-reports in Swedish with summary in English in 2009:

1. How many trains can be operated? An analysis of theoretical and practical capacity. TRITA-TEC-RR-10-002

2. Processing and analysis of a database of infrastructure, traffic, timetables and delays. TRITA-TEC-RR-10-003

3. Proposed measures to increase capacity in the short term. TRITA-TEC-RR-10-004.

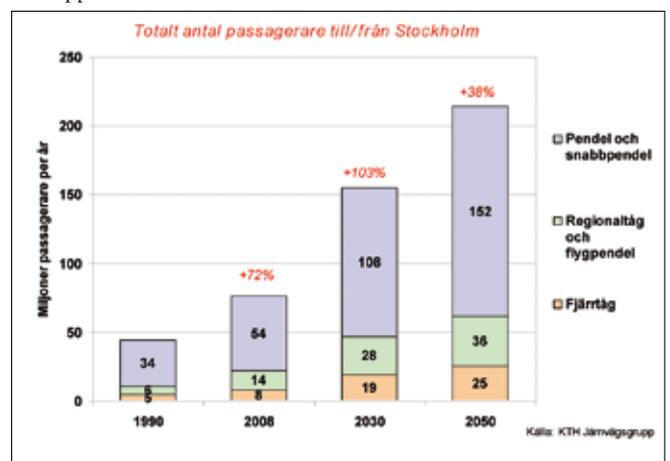


ToL 25. Stockholm Central 2050 – Forecasts of demand and capacity needs

In 2005 KTH Railway Group conducted a study entitled “Framtida marknad, tågtrafik och kapacitet inom Stockholm Central med perspektivet 2015-2030” (Future market, train traffic and capacity at Stockholm Central for 2015-2030). Since then, demand has further increased for both passenger and freight traffic. Banverket therefore initiated a project to ensure that the planned design of Stockholm C after the opening of the City Line is sustainable in a long-term perspective.

The initial situation was updated by KTH in 2008 as regards numbers of trains, travellers and capacity utilisation on the railway lines approaching Stockholm. Against the background of population forecasts KTH Railway Group produced new forecasts for the rail traffic where the supply was also defined and the degree of utilisation on the trains and on the lines were checked against the earlier model.

Bo-Lennart Nelldal, Oskar Fröidh och Olov Lindfeldt: Stockholm Central 2050 - Prognoser över efterfrågan och kapacitetsbehov. Rapport TRITA-TEC-RR 10-006.



ToL 26. Simulation and capacity analysis

As a result of cooperation with IVE (The Institute of Transport, Railway Construction and Operation) at the University of Hannover KTH has availability to the simulation software Railsys. This model has been developed with great efforts in many years and is used in many countries around the world. Railsys is commercially handled by RMCon (Rail Management Consultants).

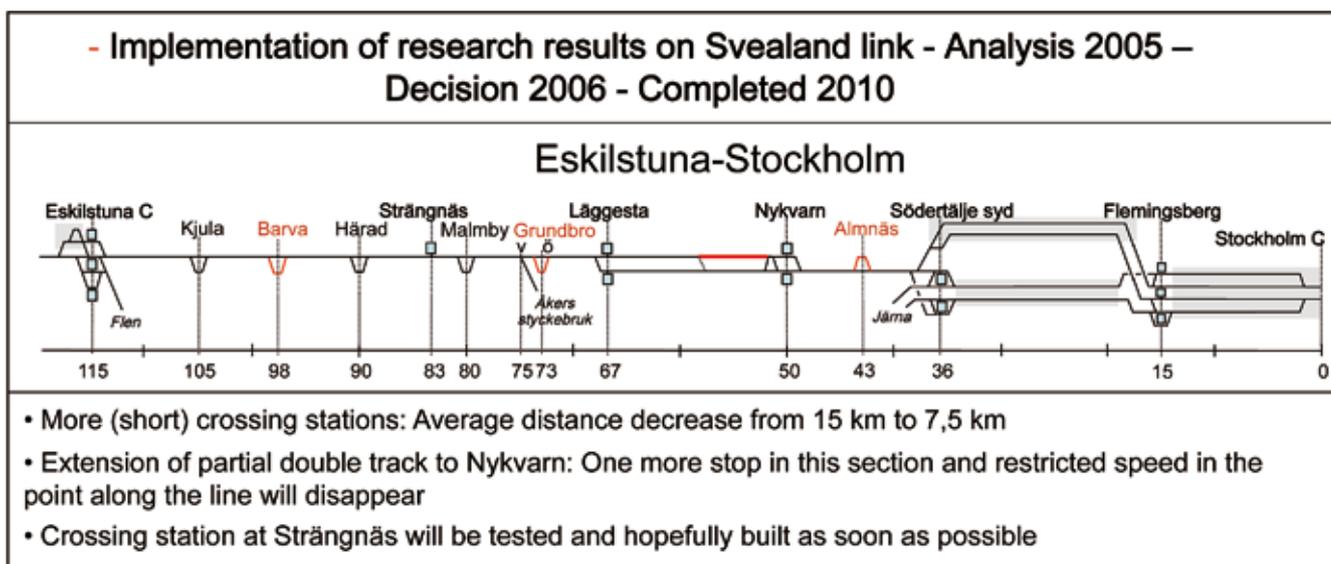
In the simulation model the infrastructure with all tracks and signalling blocks will be defined as well as the time table and the vehicles (trains). The result shows how a given line and time-table will handle e.g. delays.

Banverket has in 2006 chosen Railsys for their future work.

The Railway Group is also sub-contractor of Railsys in Sweden and offer support and education of Railsys in Sweden. A user group will be formed to exchange experience.

The Railway Group also offers commissions in capacity analysis and simulation. Simulation has been carried out of the following railway lines: "Ostlänken" Stockholm–Linköping, "Svealandsbanan" Stockholm–Eskilstuna, "Nynäsbanan" Västerhaninge–Nynäshamn, "Västra stambanan" Stockholm–Järna.

Bo-Lennart Nelldal, Olov Lindfeldt, Hans Sipilä och Johannes Wolfmaier: Förbättrad punktlighet på X2000 - analys med hjälp av simulering Uppdragsrapport TRITA-TEC-RR 08-001, 2008



ToL 27. Evaluation of track fees

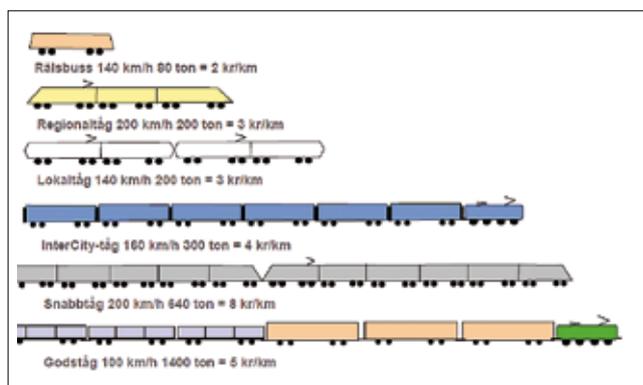
Railway Group KTH has together with Trafikverket evaluated different alternatives for changes in track fees in Sweden. Database s and models has been built up for this purpose and has been used for several studies.

Effekter av höjda banavgifter - Utvärdering av Banverkets förslag till banavgifter för 2011. Jakob Wajsman och Bo-Lennart Nelldal 2009:09-30.

Effekter av höjda banavgifter - Analys av olika modeller för kapacitetsavgifter. Jakob Wajsman och Bo-Lennart Nelldal 2009-08-28

Effekter av höjda banavgifter - Utvärdering av Banverkets förslag till banavgifter för 2010. Jakob Wajsman och Bo-Lennart Nelldal 2008-10-13

Effekter av höjda banavgifter - Utvärdering av kraftigt höjda dieslavgifter. Jakob Wajsman och Bo-Lennart Nelldal 2007-05-02.





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