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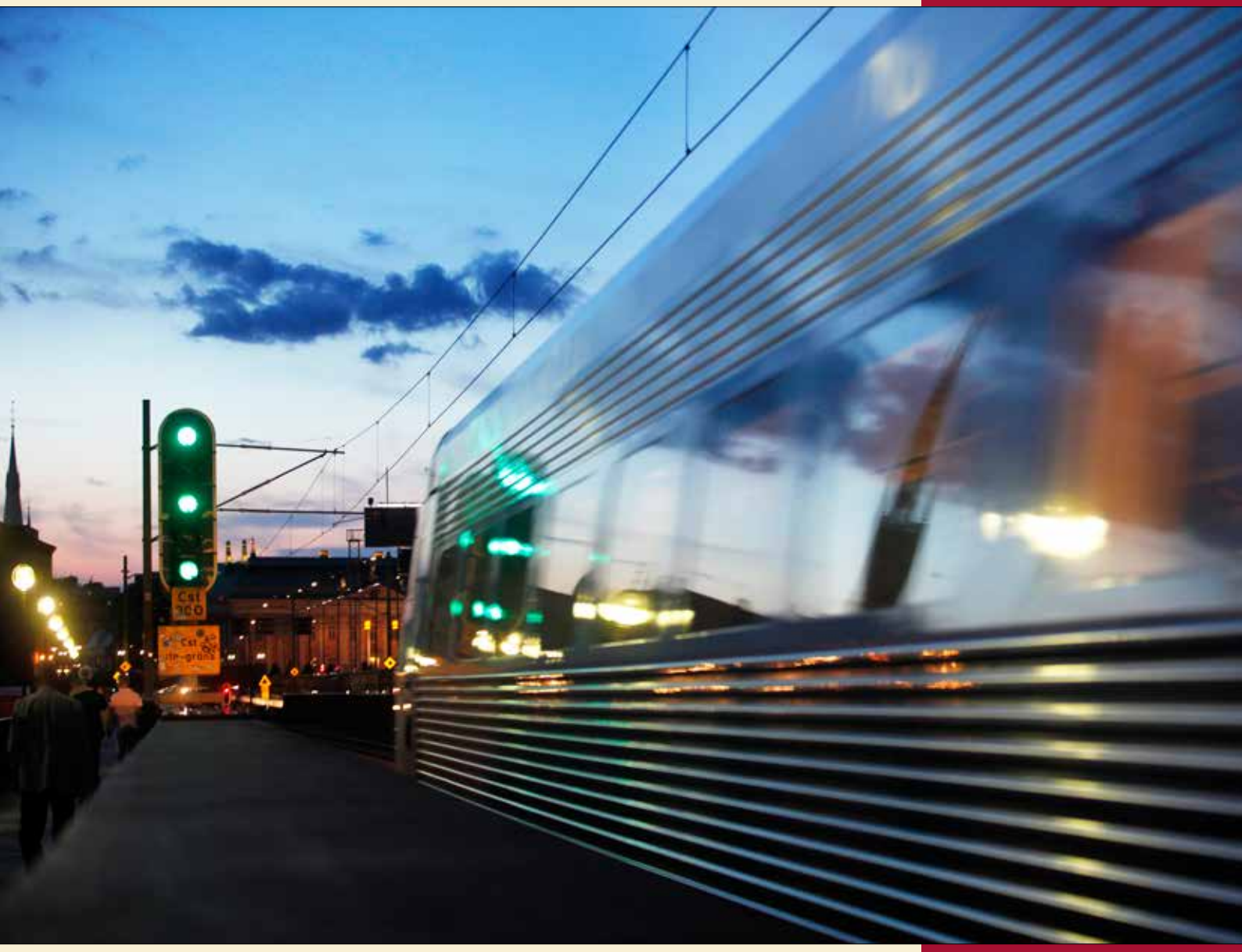
KTH Railway Group

Status Report 2015



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Cover photo: X2000 on Centralbron in Stockholm,
Source Bombardier

RV
RAIL VEHICLES

RV 1	Running gear for freight wagons
RV 2	Simulation of wheel-on-rail deterioration phenomena
RV 3	Modelling of rail vehicles dynamics
RV 4	Track stiffness, irregularities and maintenance
RV 5	Dynamic instability and discomfort of high-speed trains due to aerodynamics in tunnels
RV 6	Robust safety systems of trains
RV 7	Simulation of energy consumption and running time of trains
RV 8	Train formation management and monitoring (TIMM)
RV 9	Crosswind stability and unsteady aerodynamics in vehicle design

RV
RAIL VEHICLES

RV 10	Gröna Tåget – Programme Management
RV 11	Gröna Tåget – Track-friendly bogies
RV 12	Gröna Tåget – High-speed vehicles with carbody tilt
RV 13	Gröna Tåget – Sound quality of external railway noise
RV 14	Gröna Tåget – Energy consumption
RV 15	Gröna Tåget – Active lateral suspension
RV 16	Gröna Tåget – Overhead power systems for operation of high-speed trains in Sweden
RV 17	Collaboration in research and development of new curriculum in sound and vibration (CIRCIS)
RV 18	Railway vehicle dynamics and track interactions: Total regulatory acceptance for the interoperable network (dynoTRAIN)

RV
RAIL VEHICLES

RV 19	Technology opportunities and strategies toward climate-friendly transport (TOSCA)
RV 20	Lightweight carbody for high-speed trains
RV 21	Wheel profile for freight wagons in Sweden
RV 22	Modelling contact in the wheel-rail interface
RV 23	Make Rail The Hope for protecting Nature (MARATHON)
RV 24	The sustainable freight railway (SUSTRAIL)
RV 25	Planning tool for energy-saving loading strategy for intermodal freight trains
RV 26	Track irregularities and vehicle response
RV 27	Towards an affordable, rsilient, innovative and high-capacity European Railway System för 2030/2050 (Capacity4Rail)

RV
RAIL VEHICLES

RV 28	New dependable rolling stock for a more sustainable, intelligent and comfortable rail transport in Europe (Roll2Rail)

GREY BOXES INDICATE TERMINATED PROJECTS

SB
STRUCTURAL ENGINEERING AND BRIDGES

- SB 1 Loads and Load Influence on Structures
- SB 2 Long-term Monitoring and Assessment of Bridges
- 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
- SB 5 Sustainable bridges
- SB 6 Soil-Structure Interaction for Integral Bridges and Culverts
- SB 7 Dynamic response of railway bridges subjected to high-speed trains
- SB 8 Bridge Weigh-in-motion for railway bridges
- SB 9 BRIDCAP – Increased load capacity of existing bridges on corridors
- SB 10 Enhanced Fatigue Evaluation of Old Steel Railway Bridges

SB
STRUCTURAL ENGINEERING AND BRIDGES

- SB 11 Development and Implementation of Monitoring Systems for Increased Safety and Improved Operation and Maintenance of Railway Bridges
- SB 12 Development of Methodology for LCC and LCA of Railway Bridges
- SB 13 Efficient Assessment Methods of the Dynamic Response of Existing Railway Bridges to High-speed Trains
- SB 14 Train-track-bridge interaction
- SB 15 Controlled dynamic field tests for accurate assessment of railway bridges to higher train speeds

EP
ELECTRIC POWER ENGINEERING

- EP 1 New converter topologies for electric railway traction
- EP 2 Dual system locomotives for rail freight transportation/ Drive cycles for freight locomotives
- EP 3 System aspects of Permanent magnet traction motors
- EP 4 Train information Management and Monitoring (TIMM)
- EP 5 Dynamic maintenance, Planning and Scheduling for Train Operation, DUST
- EP 6 Railway Power Supplies with new converter and system topologies
- EP 7 AC/AC Modular Multilevel Converters for Railway Applications (EP7)

GREY BOXES INDICATE TERMINATED PROJECTS

ME
MACHINE ELEMENTS (DEPT OF MACHINE DESIGN)

- ME 1 Track-vehicle interaction (SAMBA 6) – Wheel rail wear mechanisms and transitions
- ME 2 Adhesion between railway wheel and rail
- ME 3 Airborne particles generated from train-track interaction
- ME 4 Block brakes during winter conditions
- ME 5 Quiet track
- ME 6 Models for rail traffic emission factors (ME4)

TET
TRANSPORT PLANNING, ECONOMY AND ENGINEERING

TET F1	Model for supply and costs for freight transport by rail
TET F2	Regional Intermodal Transport Systems – Analysis and Case Study
TET F3	Efficient rail freight transportation and production systems
TET F4	Rail Freight Corridors
TET F8	TRANSFORUM – Possibilities to realise the goals in the EU's White Paper
TET F9	Major traffic interruptions on Sweden's railways 2000-2014 and their impact for customers
TET F10	Freight transportation by rail – stage 2 measures
TET F11	Transportation by rail for the forest industry
TET F12	Green Freight Train - Roadmap for rail and intermodal freight transportation

TET
TRANSPORT PLANNING, ECONOMY AND ENGINEERING

TET F13	Capacity 4 Rail (C4R)
TET F14	Sustainable and energy efficient regional logistics in the Mälardalen area
TET P1	Green Train market prerequisites, passenger valuations and service concepts
TET P2	High-Speed Rail in Sweden – Supply and demand
TET P3	Development of passenger forecast models
TET P4	Database of supply and prices for railway lines in Sweden
TET P5	Evaluation of the deregulation and competition in interregional rail services
TET P6	Peripherally located railway stations – effects for train travel and society
TET C1	Congested infrastructure

TET
TRANSPORT PLANNING, ECONOMY AND ENGINEERING

TET C2	Timetable planning with simulation
TET C3	Development of time-table strategies
TET C4	Analysis of capacity and punctuality 2008-2012
TET C5	Development of methods for capacity analysis
TET C6	Analysis of track access charges and the rail market
TET C7	Future rail vehicle maintenance and depots – research road map
TET C8	Capacity analysis in a network perspective
TET C9	Prestudy – Cause and effects for the maintenance of railways
TET C10	Program for research and innovation in signalling systems

TET
TRANSPORT PLANNING, ECONOMY AND ENGINEERING

TET C11	Procurement and implementation of complex signalling systems – work processes and tools

MW
MARCUS WALLENBERG LABORATORY FOR SOUND AND VIBRATION RESEARCH

MW 1	Gröna Tåget – noise and vibration part
MW 2	Electromagnetic noise generation

GREY BOXES INDICATE TERMINATED PROJECTS

KTH Railway Group in 2015

The 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 graduate and postgraduate level, and training for employees in the railway field. The funding is today regulated by an agreement between KTH, the Swedish Transport Administration (Trafikverket), Bombardier Transportation, Stockholm Public Transport (SLL), the Swedish State Railways (SJ) and the consultant companies Interfleet Technology and SWECO.

KTH Railway Group is a multidisciplinary research center with a holistic approach. It consists of eight research groups, each of them representing one or more disciplines which together, in principle, cover all competencies in the railway area. This unique organization is able to carry out major research programs with a broad approach in collaboration with our partners, covering not only technical aspects but also commercial ones, e.g. market analysis. Throughout the years, KTH Railway Group has improved railway systems and carried out high-impact concept studies, like for example Gröna Tåget. All these projects aim to increase the efficiency of railway transport and the competitiveness of the railway industry compared to other means of transport.

By the very close contact to our external partners our research in many cases does not only lead to scientific publications but is directly implemented in new vehicle designs, infrastructure upgrades or train operating strategies. In June 2015 KTH and Bombardier Transportation signed a strategic partnership agreement with the aim to further intensify the co-operation between both organizations.

Throughout the last years the Railway Group has also become more international. While in the early years of the Railway Group most of the projects where financed within Sweden, today more and more funding comes from the EU. Also the amount of scientific exchange with partner universities in Europe and non-European universities for example in USA, China and Indonesia is continuously increasing.

The KTH Railway Group is also very active in Railway education. We teach railway students in mechanical, civil and electrical engineering. We have a two-year master program in Vehicle Engineering (Road and Railway), which is fully taught in English. Probably in fall 2017 a new multi-institutional master program in Railway Engineering in cooperation with the University of Illinois in Urbana Champaign will start. The railway group is also regularly arranging courses for engineers in industry and railway operators/infrastructure managers as continued education.

This status report gives an impression of the diversity of activities in research and education that are carried out. We hope you find some interesting projects. 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 2015

Professor Sebastian Stichel, Director of the KTH Railway Group

The Board 2015

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: Sven Ödéen, Michael Than, Henrik Engströmer, Stefan Östlund, Björn Westerberg and Uday Kumar

Research groups 2015

SCHOOL OF ENGINEERING SCIENCES

Rail Vehicles – Professor Mats Berg
Vehicle Dynamics – Associate Professor Lars Drugge
MWL (Sound and Vibrations) – PhD Ulf Carlsson
Lightweight Structures – Associate Professor Per Wennhage

SCHOOL OF ARCHITECTURE AND BUILT ENVIRONMENT

Transport Planning, Economics and Engineering – PhD Oskar Fröidh
Structural Engineering and Bridges – Professor Raid Karoumi

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 2015


Henrik Tengstrand


Susanne Rymell


Raid Karoumi


Mats Berg


Stefan Östlund


Oskar Fröidh


Roger Lundén


Sara Paulsson


Jon Sundh


Rickard Nilsson


Tohmmy Bustad


Sebastian Stichel

Not present on photo:
Sven Ödéen, Michael Than, Henrik Engströmer, Stefan Östlund, Björn Westerberg and Uday Kumar

Railway Education at KTH Railway Group

In four of the KTH Railway Groups divisions education and courses in the Railway sector are given, i.e. from the divisions for Rail Vehicles, Transport Planning Economics and Engineering, Structural Engineering and Bridges, and Electric Power Engineering. Our courses are carried out in three different forms of training.

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

There are also courses for external students including courses within further education here at KTH. That is some of the program courses that are also open to external applications and the teaching is carried out together with the KTH students. These courses are presented and are searchable by www.studera.nu (SD2307, SD2313 and EJ2400 below).

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

We also have an educational co-operation with the University of Illinois in Urbana Champaign with on-line education and in 2017 we will together start the Master program of Railway Engineering.

Division of Rail Vehicles

Mats Berg 070-652 24 41 mabe@kth.se

Railway Traffic Planning at division of Transport Planning, Economics and Engineering

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Division of Structural Engineering and Bridges

Raid Karoumi 08-790 90 84 raid.karoumi@byv.kth.se

Division of Electrical Machines and Power Electronics

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

Railway Courses in 2015-2016

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

Railway Traffic Planning Group at division of Transport Planning, Economics and Engineering

AH1025 Kollektivtrafiksystem, bussar och spårtrafik, gk (7,5 hp)
Public Transport Systems, Buses and Rail, BC

AH2026 Tågtrafik, marknad och planering, gk (7,5 hp)
Railway Traffic - Market and Planning, Basic Course

AH2029 Järnväg signalteknik – signalsystem (7,5 hp)
Railway Signalling System, Basic Course

AH2031 Järnväg signalteknik – projektering (7,5 hp)
Railway Signalling System - Project Planning

Division for Road and Rail Engineering

AF2901 Väg- och banteknik gk (7,5 hp)
Road- and Railway Track Engineering

AH1907 Anläggning 1. Väg-, järnväg och VA-teknik (7,5 hp)
Installation1. Road, Railways and Wastewater Networks

AH1908 Anläggning 2. Byggande drift och underhåll av vägar och järnvägar (7,5 hp).
Installation2. Construction, Management and Maintenance of Roads and Railways

Division for Structural Engineering 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 1995–2015

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. Olov Lindfeldt: Railway operational analysis. Evaluation of quality, infrastructure and timetable on single track and doubletrack lines with analytical models and simulation. 2010.

30. Andreas Andersson: Capacity assessment of arch bridges with backfill: Case of the old Årsta railway bridge, 2011.

31. Rickard Persson: Tilting trains – Enhanced benefits and strategies for less motion sickness, 2011.

32. Anneli Orvnäs: On Active Secondary Suspension in Rail Vehicles to Improve Ride Comfort, 2011.

33. Lars Abrahamsson: Optimal Railroad Power Supply System Operation and Design, 2012.

34. David Wennberg: Multi-Functional Composite Design Concepts for Rail Vehicle Car Bodies, 2013.

35. Dirk Thomas: On rail vehicle dynamics in unsteady crosswind conditions - Studies related to modelling, model validation and active suspension, 2013.

36. Saeed Abbasi: Towards Elimination of Airborne particles from rail traffic, 2013.

37. Yi Zhu: Adhesion in the Wheel-Rail Contact, 2013.

38. Mahir Ülker-Kaustell: Essential modelling details in dynamic FE-analyses of railway bridges, 2013.

39. John Leander: Refining the fatigue assessment procedure of existing steel bridges, 2013.

40. Mohammed Safi: Life-Cycle Costing - Applications and Implementations in Bridge Investment and Management, 2013.

41. Ignacio Gonzalez: Application of monitoring to dynamic characterization and damage detection in bridges, 2014.

42. Shahrin Nasir: Intermodal container transport logistics to and from Malaysian ports – Evaluation of customer requirements and environmental effects, 2015

43. Hans Sipilä: Simulation of rail traffic. Methods for timetable construction, delay modeling and infrastructure evaluation, 2015.

44. Guangli Du: Life cycle assessment of bridges, model development and case studies, 2015.

45. Babette Dirks: Simulation and measurement of wheel on rail fatigue and wear, 2015.

46. Anders Lindfeldt: Railway capacity analysis – Methods for simulation and evaluation of timetables, delays and infrastructure, 2015

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 graduate 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

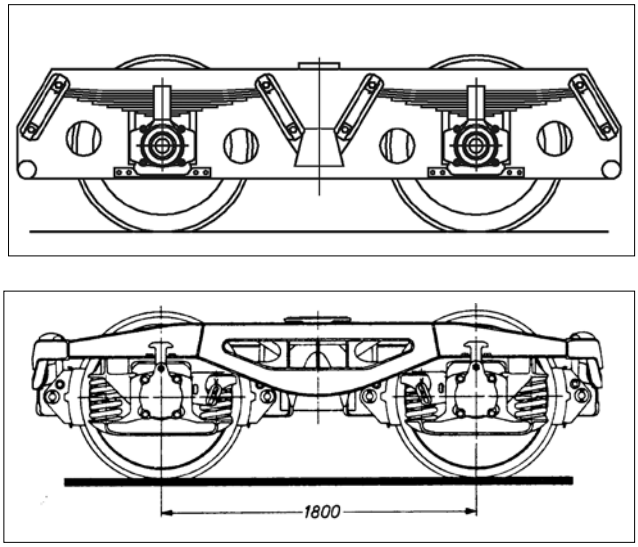
Project leader	Sebastian Stichel
Scientists	Per-Anders Jönsson
	Evert Andersson
	Saeed Hossein Nia

Sources of funding: Trafikverket, Bombardier Transportation, SLL, Tågoperatörerna, Interfleet Technology, LKAB.

The project is aimed to study and learn how freight wagons behave dynamically on track, both for standardised running gear and for novel designs. Another goal 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 2010 work on modelling the latest iron ore wagon from 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 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. The first study conducted was to find the reasons for the increase of the frequency of Rolling Contact Fatigue (RCF) during winter. In subsequent studies also analyses of the iron ore locomotives were carried out. The long term behaviour of wheel profiles with regard to wear and RCF was

Saeed Hossein Nia in front of an iron ore locomotive.



Examples of running gear investigated.

investigated both for the iron ore wagons and locomotives. Results were presented on the IHHA conferences in New Delhi in 2013 and in Perth in 2015.

Saeed Hossein Nia presented and defended his licentiate thesis in February 2015.

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, pp 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, pp 445-452, Kiruna, June11-13, 2007.

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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.

Hossein Nia S., Stichel, S., Jönsson P.-A., Nordmark, T., Bogojevic, N: Can simulation help to find the sources of wheel damages? Proc. of 10th International Heavy Haul Conference. New Delhi, February 2013.

Stichel S., Jönsson P.-A., Casanueva C., Hossein Nia S. Modeling and simulation of freight wagon with special attention to the prediction of track damage. International Journal of Railway Technology, Vol. 3, 2014.

Hossein Nia S., Jönsson P.-A., Stichel S. Wheel damage on the Swedish iron ore line investigated via multibody simulation. Proceedings of the Institution of Mechanical Engineers, Part F, Journal of Rail and Rapid Transit, ISSN 0954-4097, Vol. 228, no. 6, pp. 652-662, 2014.

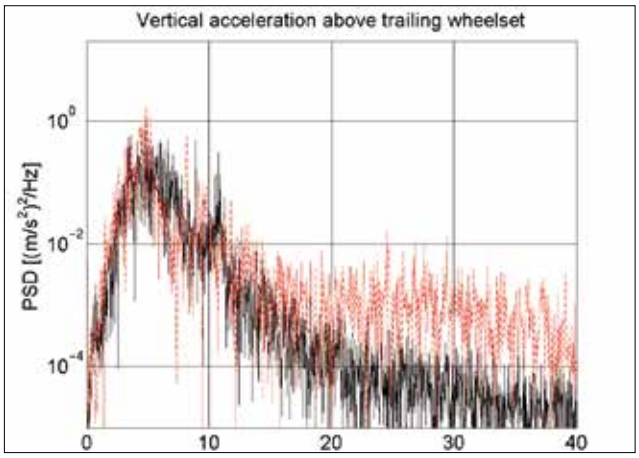
Hossein Nia S., Stichel, S., Casanueva, C., Nordmark, T. Study of the long term evolution of low-RCF wheel profiles for LKAB iron-ore wagons. Proc. of 10th International Heavy Haul Conference. Perth, June 2015.

Iwnicki, S.D., Stichel, S., Orlova, A., Hecht, M. Dynamics of railway freight vehicles. Vehicle System Dynamics, 53(7), pp 995-1033, 2015.

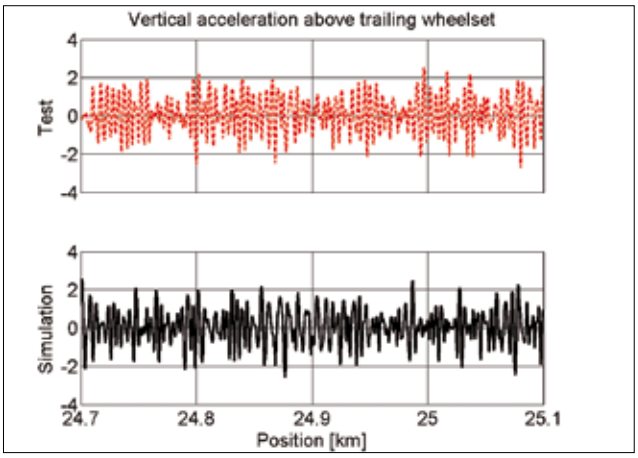
Hossein Nia, S., Casanueva, C., Stichel, S. Prediction of RCF and wear evolution of iron-ore locomotive wheels. Wear 338-339, pp 62-72, 2015.

Hossein Nia, S. An Investigation of the Iron-Ore Wheel Damages using Vehicle Dynamics Simulation, Licentiate thesis, TRITA-AVE 2014:80, KTH, Stockholm, 2014. ISBN 978-91-7595-405-9

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, SLL, Tågoperatörerna, Interfleet Technology, Sweco.

The project started in May 2008 with the employment of Babette Dirks as Ph.D. student and finished in the summer of 2015.

The research focus was 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 was 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, were used.

The prediction methodology was 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 provided input to the tribological models. The real operation conditions were 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 starting point was 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. But the success here was limited.

• For assessing the fatigue damage, a quantitative damage accumulation rate was proposed. The purpose was 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, also extended to a Wear journal paper, available models for prediction of rolling contact fatigue were evaluated and some trial simulations and parameter studies were reported. In the Cape Town paper further parametric studies and accumulated damage comparisons related to the Stockholm commuter service were carried out. The performance of two vehicle concepts, two wear models, and two RCF models was evaluated and vehicle related as well as model related differences were addressed.

Extensive recording of wear and RCF development on wheels and rails of the Stockholm commuter operation, selected as the reference application, was carried out during the last four years. The objective of the work was to arrive at a calibrated RCF model using crack and rail profile measurements, tentatively for the iron ore line in northern Sweden. But rather an extensive rail measurement programme in the Netherlands was used for the calibration and the RCF model is presented in a journal paper. This model was then used for the Stockholm commuter trains to predict wheel profile wear and crack growth and comparing with the wheel measurements above. This part of the project was presented at a conference in Colorado Springs.

Babette Dirks presented and defended her PhD thesis in June 2015.

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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.

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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.

Dirks B: Simulation of wheel on rail deterioration phenomena – A literature survey, KTH Rail Vehicles, April 2014.

Dirks B, Enblom R, Ekberg A and Berg M: The development of a crack propagation model for railway wheels and rails. Accepted in April 2015 for publication in Fatigue and Fracture of Engineering Materials and Structures.

Dirks B: Simulation and Measurement of Wheel on Rail Fatigue and Wear, PhD Thesis, Report TRITA-AVE 2015:16, KTH Rail Vehicles, 2015. ISBN 978-91-7595-544-5.

Dirks B, Enblom R and Berg M: Prediction of wheel profile wear and crack growth – Comparisons with measurements. Paper presented at the 10th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Colorado Springs, 30 August – 3 September, 2015.

RV3. Modelling of rail vehicle dynamics

Project leader	Mats Berg
Scientists	Nizar Chaar
	Mats Berg

Sources of funding: Trafikverket, Bombardier Transportation, SLL, 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 was 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.

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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, ”Paper D” in the PhD thesis above.

RV4. Track stiffness, irregularities and maintenance

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

Sources of funding: 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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Smekal A, Berggren E and Silvast M: Monitoring and Substructure Condition Assessment of Existing Railway Lines for Upgrading to Higher Axle Loads and Speeds, Proceedings of 7th World Congress on Railway Research, Montreal, 5-7 June, 2006.

Berggren E: Measurements of Track Stiffness and Track 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.

Berggren E, Li M and Spännar J: A New Approach to the Analysis and Presentation of Vertical Track Geometry Quality and Rail Roughness, Proceedings of 7th International Conference on Contact Mechanics and Wear of Rail/Wheel

Systems (CM2006), Brisbane, 24-27 September, 2006. Also in journal of WEAR, Vol 265, pp 1488-1496, 2008.

Berggren E: Railway Track Stiffness - Dynamic Measurements and Evaluation for Efficient Maintenance, Ph.D. Thesis, Report TRITA AVE 2009:17, KTH Rail Vehicles, 2009. ISBN 978-91-7415-293-7.

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Li M and Berggren E: A Study of the Effect of Global Track Stiffness and its Variations on Track Performance: Simulation and Measurement, Proceedings of 9th International Heavy Haul Conference, Shanghai, 2009. Also in Proc IMechE Part F: Journal of Rail and Rapid Transit, Vol. 224, pp. 375-382, September 2010.

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: Trafikverket

In this project high-speed train aerodynamics inside tunnels was mainly studied. Through computational fluid dynamics and multibody vehicle simulations it was 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.

Diedrichs B: Studies of Two Aerodynamic Effects on High-Speed Trains: Crosswind Stability and Discomforting Car Body Vibrations Inside Tunnels, Ph.D. Thesis, Report TRITA AVE 2006:81, KTH Rail Vehicles, 2006.

Diedrichs B, Sima M, Orellano A and Tengstrand H: Crosswind stability of a high-speed train on a high embankment. Proc. Instn Mech. Engrs, Part F: J. Rail and Rapid Transit, 221 (F2), 205–225, 2007.

Diedrichs B, Berg M, Stichel S and Krajnovic S: Vehicle dynamics of a high-speed passenger car due to aerodynamics inside tunnels. Proc. Instn Mech. Engrs, Part F: J. Rail and Rapid Transit, 221 (F4), 527–545, 2007.

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RV6. Robust safety systems for trains

Project leader	Evert Andersson
Scientists	Dan Brabie
	Evert Andersson

Sources of funding: Trafikverket, Bombardier Transportation, SLL, 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.

Brabie D and Andersson E: Means of minimizing post-derailment consequences by alternative guidance mechanisms, BOGIE'07, Budapest, 3-6 September, 2007. Proceedings of the 7th International Conference on Railway Bogies and Running Gears.

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.

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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.

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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: 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 was put on driver style and how it can effect the energy consumption and running time; a number of different driver models were formulated for that purpose promoting so-called eco driving. The project was integrated with the EU project Railenergy in the context of energy efficient timetabling.

Lukaszewicz P: SimERT Project - Simulation of Energy Usage and Running Time for Trains. 2nd UIC Energy Efficiency Conference, Paris, 4-5 February 2004.

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.

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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.

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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, 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 was 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.

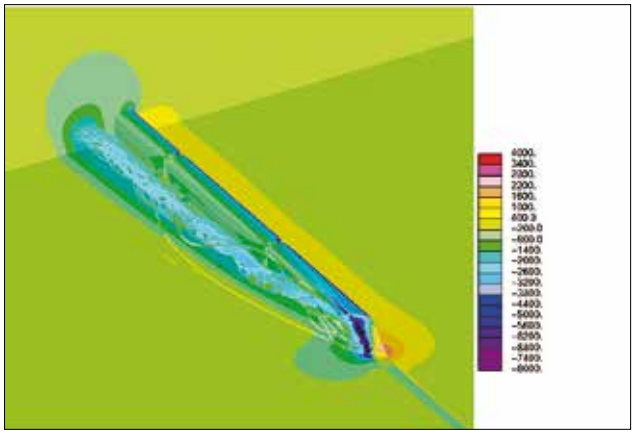
Forsberg T, Berg M, Stichel S and Andersson E: Condition monitoring of train ride stability. BOGIE'07, Budapest, 3-6 September, 2007. Proceedings of the 7th International Conference on Railway Bogies and Running Gears, pp 271-280.

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 was a project within the Vinnova Centre for ECO2 Vehicle Design.

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



CFD calculation of train in strong crosswind.

Dirk Thomas presented and defended his PhD thesis in December 2013.

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.

Thomas D, Berg M and Stichel S: Measurements and Simulations of Rail Vehicle Dynamics with respect to Overturning Risk, XXII International Congress of Theoretical and Applied Mechanics (ICTAM), Adelaide, 24-29 August, 2008. Also in Vehicle System Dynamics, Vol 48, No 1, pp 97-112, January 2010.

Favre T, Efraimsson G and Diedrichs B: Numerical Investigation of Unsteady Crosswind Vehicle Aerodynamics using Time-Dependent Inflow Conditions, 7th MIRA International Vehicle Aerodynamics Conference, Coventry, 22-23 October, 2008.

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 Hyrbrid 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.

Thomas D, Diedrichs B, Berg M and Stichel S: Dynamics of a high-speed rail vehicle negotiating curves at unsteady crosswind, Proc. IMechE Journal of Rail and Rapid Transit, Vol 224, pp 567-579, November 2010.

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. Extended version published in Proc. IMechE Journal of Rail and Rapid Transit, Vol 229, pp 34-47, 2015.

Thomas D: On Rail Vehicle Dynamics in Unsteady Crosswind Conditions, PhD Thesis, Report TRITA-AVE 2013:61, KTH Rail Vehicles, 2013. ISBN 978-91-7501-914-7.

Thomas D, Berg M, Persson R and Stichel S: Improving crosswind stability of fast rail vehicles using active secondary suspension, Vehicle System Dynamics, Vol 52, No 7, pp 909-921, 2014.

RV10. Gröna Tåget (Green Train) : Programme management

Research leader Evert Andersson

Sources of funding: Trafikverket

Gröna Tåget was a multi-disciplinary research and development programme involving several members of the KTH Railway Group. KTH was performing research on selected topics and was also appointed as total programme manager. The programme also involved several other members of the Swedish railway sector, such as Trafikverket, 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 constituted some 50 MSEK (5 MEUR) besides still higher contributions from industry. The duration was from 2005 to 2012.

The overall aim was 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 was aimed for 250-300 km/h, running both on the existing Swedish rail network and on future high-speed lines.

In 2014 a special issue on the Gröna Tåget programme was published in the International Journal of Rail Transportation.

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

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

Fröidh O: Green train - Basis for a Scandinavian high-speed train concept, Final Report, Part A, Publication 12-01, KTH Railway Group, 2012.

Andersson E: Green train - Concept proposal for a Scandinavian high-speed train, Final Report, Part B, Publication 12-02, KTH Railway Group, 2012.

Andersson E., Fröidh O., Stichel S., Bustad T. and Tengstrand H. Green Train: Concept and technology overview. International Journal of Rail Transportation, Volume 2, Issue 1, pp 2-16, 2014. DOI:10.1080/23248378.2013.878291

RV11. Gröna Tåget: Track-friendly bogies

Project leader Evert Andersson
Scientists Anneli Orvnäs
Rickard Persson
Evert Andersson

Sources of funding: Trafikverket

The project dealt with investigation and specification of appropriate suspension parameters for radial self-steering high-speed bogies. The aim was 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 was 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 September 2008, on a conventional Swedish track for 200 km/h.

Orvnäs A, Andersson E and Persson R: Developent 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.

Persson R. Andersson, E., Stichel S., Orvnäs A. Bogies towards higher speed on existing tracks. International Journal of Rail Transportation, Volume 2, Issue 1, pp 40-49, 2014. DOI:10.1080/23248378.2013.878294

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: Trafikverket, Bombardier Transportation, SLL, Tågoperatörerna, Interfleet Technology, Vinnova, VTI.

This project aimed 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 were investigated as well as suggestions for suitable track geometry parameters. In particular a more advanced choice of tilting angle was studied. Field tests, including test subjects, were carried out in 2010 and a PhD thesis was presented in 2011.

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

Persson R: Spårvänliga boggier 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.

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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.

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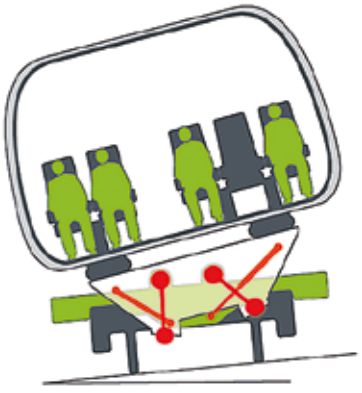
Persson R: Tilting trains - benefits and motion sickness, Proc. IMechE Journal of Rail and Rapid Transit, Vol 224, pp 513-522, November 2010.

Persson R, Kufver B: Strategies for less motion sickness on tilting trains, Proceedings of Comprail 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 tilt control strategies for less motion sickness on tilting trains, Vehicle System Dynamics, Vol 50, No 7, pp 1103-1120, London 2012.

Persson R, Kufver B and Berg M: Improving the competitiveness of tilting trains, Proceedings of the STECH Conference 2012.



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: Trafikverket 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: 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 possbile 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 CO_2-utsläpp reduceras? Invited speaker, NJS konferens "Jernbaner og CO_2", Köpenhamn, 31 oktober 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.

Sjöholm M: Benefits of regenerative braking and eco driving for high-speed trains -- Energy consumption and brake wear, MSc thesis, TRITA AVE 2011:23, KTH Rail Vehicles, 2011. ISBN 978-91-7415-920-2

Andersson E, Carlsson U, Lukaszewicz P and Leth S: On the environmental performance of a high-speed train, International Journal of Rail Transportation, Volume 2, Issue 1, pp 59-66, 2014. DOI:10.1080/23248378.2013.878296

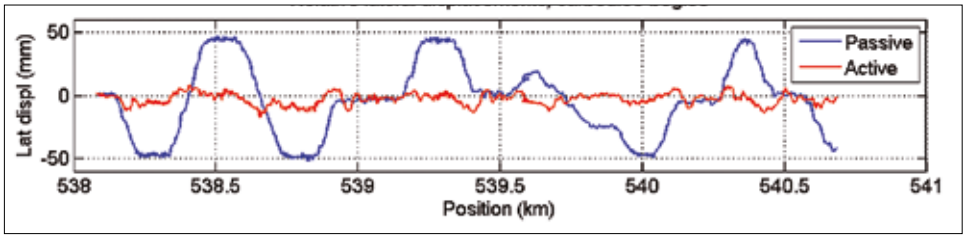
RV15. Gröna Tåget: Active lateral suspension

Project leader	Sebastian Stichel
Scientists	Anneli Orvnäs
	Rickard Persson
	Alireza Qazizadeh
	Sebastian Stichel

Sources of funding: Trafikverket, Bombardier Transportation, SLL, Tågoperatörerna, Interfleet Technology, Sweco

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 been operating from March 2009 until the beginning of 2013. In 2011 Anneli Orvnäs defended her PhD thesis with the title "On Active Secondary Suspension in Rail Vehicles to Improve Ride Comfort".



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

In 2012 a new PhD student, Alireza Qazizadeh, started

within the project. The first task was to perform simulations for the design of the controller for tests on active vertical secondary suspension. Tests were carried out in May 2013 with very promising results. The vertical ride comfort could be improved with 20%-30%. Further studies carried out are an improved implementation of the sky-hook control method. In 2015 also studies on a vehicle with single axle running gear and active suspension started.

Alireza Qazizadeh presented and defended his licentiate thesis in February 2015.

Anneli Orvnäs on the Green Train during measurements with active suspension.

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, ZEVrail 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.

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.

Orvnäs A: Methods for Reducing Vertical Carbody Vibrations of a Rail Vehicle – A Literature Survey, Publ. 1002, ISBN 978-91-7415-631-7, KTH Railway Group, Stockholm, Sweden, 2010.

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 2011. DOI:10.1080/00423114.2010.527011

Orvnäs A, Stichel S, Persson R. Aspects of Using Active Vertical Secondary Suspension to Improve Ride Comfort. In: 22nd International Symposium on Dynamics of Vehicles on Roads and Tracks, IAVSD'11. Manchester, August 14-19, 2011.

Orvnäs, A. On Active Secondary Suspension in Rail Vehicles to Improve Ride Comfort. PhD thesis KTH. TRITA-AVE, ISSN 1651-7660, 2011:79. Stockholm, 2011. ISBN 978-91-7501-155-4

Qazizadeh, A. Development and On-Track Tests of Active Vertical Secondary Suspension for Passenger Trains, Licentiate thesis, TRITA-AVE 2014:76, KTH, Stockholm, 2014. ISBN 978-91-7595-383-0

Qazizadeh, A., Persson, R., Stichel, S. Preparation and Execution of On-track Tests with Active Vertical Secondary Suspension. International Journal of Railway Technology, 2015.

Qazizadeh, A., Persson, R., Stichel, S. On-track tests of active vertical suspension on a passenger train. Vehicle System Dynamics, 53 (6), pp. 798-811, 2015.

Qazizadeh, A., Persson, R., Stichel, S. Studying Variations of Skyhook Method for Comfort Improvement. Paper presented at the Stephenson conference. London, UK. April 2015.

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
	Zhendong Liu

Sources of funding: Trafikverket, Chinese Scholarship Council

The overhead power system has been identified as one of the critical areas when increasing train speed especially on upgraded Swedish lines.

Within the project the dynamic interaction pantograph/catenary has been studied mainly by use of computer simulation. An existing 2-D model has been extended to a 3-D model.

The potential to reduce contact force variation with help of actively controlled pantographs has been investigated within two master theses.

KTH also participated in an international benchmark study with the aim to compare simulation results of a large number of codes worldwide. The first stage of the

benchmark is finished. The results are presented on the IAVSD conference in Qingdao in 2013. A special issue with the results of the benchmark was published in 2014.

Recently the research was mainly focused on multi-pantograph operation. The physical phenomena arising when several pantographs are in contact at the same time were investigated in detail. Also possibilities to use multi-pantograph operation in a positive way, i.e. to improve the dynamic performance of the trailing pantograph with help of the leading one, were proposed.

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 on existing lines. Proc.of 22nd Symposium of the International Association for Vehicle System Dynamics, IAVSD. Manchester, 14-19 August, 2011.

Tieri R., Collina A., Carnevale M., Stichel S, Jönsson P.-A. Pneumatic active control system for pantograph catenary interaction. Accepted for presentation at WCRR, Sydney, Australia, 2013.

Bruni, S. et al. The Pantograph-Catenary Interaction Benchmark. Proc. of 23rd Symposium of the International Association for Vehicle System Dynamics, IAVSD. Qingdao, 19-23 August 2013.

Liu, Z., Jönsson, P.-A., Stichel, S. and Rønnquist, A., Implication of multiple pantograph operation on soft catenary systems in Sweden, IMechE Part F: Journal of Rail and Rapid Transit, available online, DOI: 10.1177/0954409714559317.

Jönsson P-A., Stichel S. and Nilsson C., CaPaSIM statement of methods, Journal of Vehicle System Dynamics, 53(3), pp 341-346, 2015.

Bruni, S, Ambrosio, J, Carnicero, A, Cho, Y.H., Finner, L., Ikeda, M., Kwon, S.J., Massat, J.-P., Stichel, S., Tur, M. Zhang W. The results of the pantograph–catenary interaction benchmark. Vehicle System Dynamics, 53(3), pp 412-435, 2015.

Liu, Z., Jönsson, P.-A., Stichel, S. and Rønnquist, A., Possible speed increase on soft catenary system with help of auxiliary pantograph, Proceedings of the 24th International Symposium on Dynamics of Vehicles on Roads and Tracks, IAVSD 2015, Austria, accepted for oral presentation.

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 were 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 and Berg M: Influence of Mono-axis Random Vibration on Reading Activity, Industrial Health, Vol 48, pp 675-681, 2010.

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.

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, Sebastian Stichel, Gustav Lönnbark, Vladislav Petrov)

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, was to propose an innovative methodology via 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 was participating in three work packages: Track geometry quality (WP2), Contact geometry (WP3) and Model building and validation (WP5). There were two parallel projects to DynoTrain: Aerodynamics (AeroTrain) and Pantograph-Catenary Interaction (PantoTrain). These three projects formed the TrioTrain cluster. See www.triotrain.eu for further information. DynoTrain ended in September 2013.

DynoTrain D5.1: State-of-the-art of railway vehicle modelling and validation, WP5 - Model building and validation, Deliverable D5.1, 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, Vol 49, No 7, pp 1021-1072, July 2011.

DynoTrain RP7: Air spring modelling, WP5 - Model building and validation, Report RP7, February 2012.

Lönnbark G: Characterization of track irregularities with respect to vehicle response, MSc thesis, Report TRITA AVE 2012:30, KTH, March 2012.

DynoTrain D2.1: Report on methods for description of track geometry quality, WP2 - Track geometry quality, Deliverable D2.1, June 2012.

DynoTrain D5.2: Assessment of suspension modelling and identification of input parameters, WP5 - Model building and validation, Deliverable D5.2, July 2012.

Petrov V: Algorithm for estimation of wheel-rail friction coefficient from vehicle-track forces, MSc thesis, Report TRITA AVE 2012:80, KTH, September 2012.

Mazzola L and Berg M: Secondary suspension of railway vehicles - air spring modelling: performance and critical issues, IMechE Journal of Rail and Rapid Transit, Vol 228, pp 225-241, 2014.

DynoTrain D5.5: Final report on model validation process, WP5 - Model building and validation, Deliverable D5.5, June 2013.

Petrov V, Berg M and Persson I: Estimation of wheel-rail friction for vehicle certification. Proc. of 23rd Symposium of the International Association for Vehicle System Dynamics, IAVSD. Qingdao, 19-23 August 2013. Extended version is published in Vehicle System Dynamics, Vol 52, No 8, pp 1099-1114, 2014.

Polach O et al.: Validation of multi-body models for simulations in authorisation of rail vehicles, 9th International Conference on Railway Bogies and Running Gears (Bogie´13), Budapest, 9-12 September 2013.

DynoTrain D3.3: Estimation of wheel-rail friction for vehicle certification, WP3 - Contact geometry, Deliverable D3.3, September 2013.

Polach O et al.: Validation of simulation models in the context of railway vehicle acceptance, IMechE Journal of Rail and Rapid Transit. Available online since 28 October 2014.

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

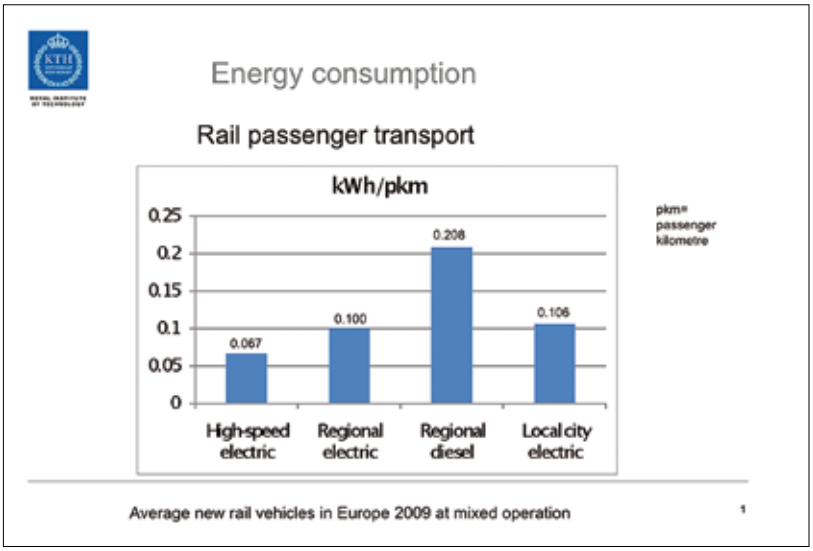
Bo-Lennart Nelldal

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



Average new rail vehicles 2009 at mixed operation.

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

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

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

TOSCA D4: Rail passenger transport - Techno-economic analysis of energy and greenhouse gas reductions, WP3 report No 1, Deliverable D4, March 2011.

TOSCA D4: Rail freight transport - Techno-economic analysis of energy and greenhouse gas reductions, WP3 report No 2, Deliverable D4, March 2011.

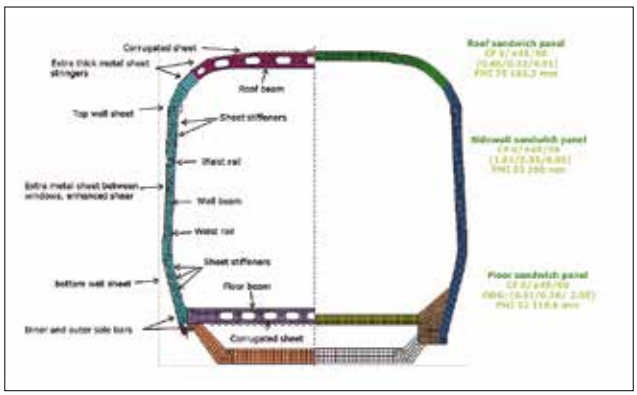
Nelldal B-L and Andersson E: Mode shift as a measure to reduce greenhouse gas emissions, presented at Transport Research Arena conference (TRA 2012). Published by Elsevier Ltd.

RV20. Lightweight Carbody for High Speed Trains

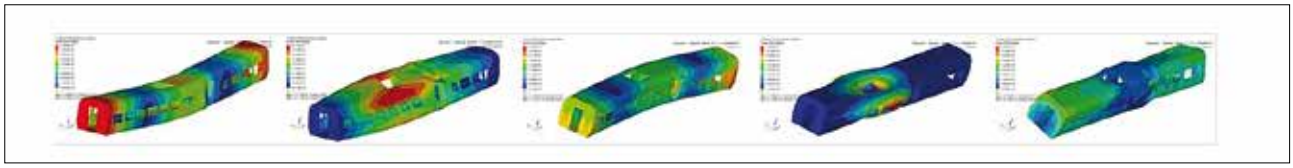
Project leader Peter Göransson / Sebastian Stichel
Scientists David Wennberg
Per Wennhage
Sebastian Stichel

Sources of funding: KTH, Vinnova, Scania, Volvo, Saab, Bombardier, A2Zound, VTI, Trafikverket. This was 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 500000 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.



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.

In June 2013 David Wennberg defended his PhD thesis with the topic "Multi-Functional Composite Design Concepts for Rail Vehicle Car Bodies". The main outcomes of the thesis are: A weight reduction of at least 30% regarding the carbody structure can be achieved. At the same time the wall thickness can be reduced increasing passenger comfort, and the complexity of the carbody is reduced decreasing manufacturing costs. However, it is necessary to use carbon fiber laminates to achieve sufficient stiffness.

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.

Wennberg D, Stichel S, Wennhage P. Optimisation of sandwich panels for the load carrying structure of high-speed rail vehicles. Research Publishing Services; International Journal of Aerospace and Lightweight Structures. 2012;2(1):19-40.

Wennberg D, Stichel S, Wennhage P. Benefits of weight reduction in high speed train operations. ZEV rail Glaser Annalen. 2013;137(3):77-87.

Wennberg, D. Multi-Functional Composite Design Concepts for Rail Vehicle Car Bodies. PhD thesis. TRITA-AVE 2013:20, KTH, Stockholm, 2013. ISBN 978-91-7501-751-8

Wennberg D., Stichel S. Multi-Functional Design of a Composite High-Speed Train Body Structure. Journal of Structural and Multidisciplinary Optimization, ISSN 1615-147X, Vol. 50, no. 3, pp. 475-488, 2014.

Wennberg, D. Stichel, S. Wennhage, P. Finite difference adaptation of the decomposition of layered composite structures on irregular grid. Journal of Composite Materials, ISSN 0021-9983, Vol. 48, no. 20, pp. 2427-2439, 2014.

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 30 MSEK per year. Some wagon types are more critical than others, with reprofiling intervals of sometimes less than 100000 km.

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

Timber wagon from below.

Part of Unitruck running gear.

design which are not applicable to all types of running gear. Thus, the purpose of this research project was 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 was validated for freight transport. The wear predicted by computer models was validated with experimental results. To start with, wheel-profile measurements on Laaps wagons with Unitruck running gear that transport timber by Trätåg timber logistic company around Gävle, Borlänge and Hällefors were used for validation. It turned out that it was not possible to get good agreement between measured and simulated wheel wear with only taking straight track and curves into consideration. Only by also simulating negotiation of switches wear on certain parts of the wheel profiles observed in measurements can be achieved.

Casanueva C, Jönsson P, Stichel S. Uniform Wheel Wear of a Two Axle Freight Vehicle with Friction Dampers. In: Proceedings of the First International Conference on Railway Technology: Research, Development and Maintenance. 18-20 April 2012, Las Palmas de Gran Canaria - Spain. Stirlingshire, UK: Civil-Comp Press; 2012.

Casanueva C., Hjulprofil för godsvagnar i Sverige - Wheel profiles for freight wagons in Sweden, KTH Report, TRITA AVE 2012:74, ISSN 1651-7660.

Casanueva C., Jönsson P.-A., and Stichel S., Use of Archard's wear law for the calculation of uniform wheel wear of high tonnage freight vehicles, in Proceedings of the 2013 Joint Rail Conference, Knoxville, Tennessee, USA.

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Casanueva C., Doulgerakis E., Jönsson P.-A., and Stichel S., Influence of switches and crossings on wheel profile evolution in freight vehicles, Vehicle System Dynamics, vol. 52, no. sup1, pp. 317–337, 2014.

Stichel S., Jönsson P.-A., Casanueva C., and Hossein Nia S., Modeling and simulation of freight wagon with special attention to the prediction of track damage, International Journal of Railway Technology, vol. 3, no. 1, pp. 1–36, 2014.

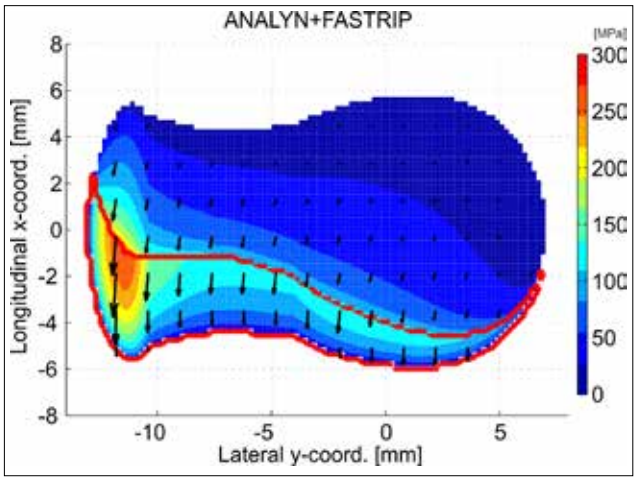
RV22. Modelling contact in the wheel-rail interface

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

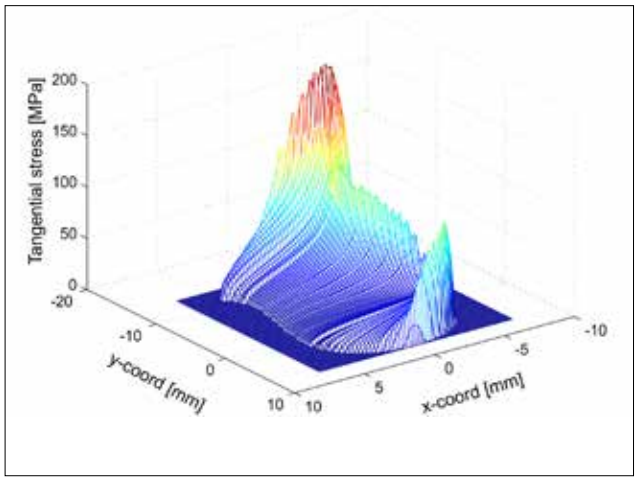
Sources of funding: Trafikverket, Bombardier Transportation, SLL, Tågoperatörerna, Interfleet Technology, Sweco.

The project started in January 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.

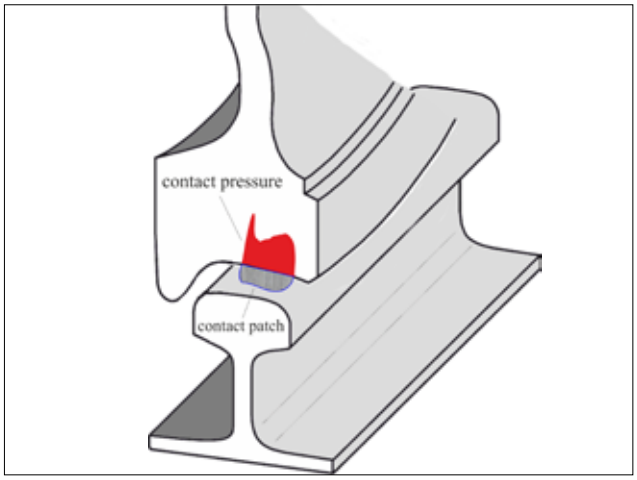
The small and highly stressed contact patch is the interface to the infrastructure to be evaluated at each time step in a transient analysis. Thus the model has to be numerically efficient. Traditional methods often used in this context are Hertz' method for the normal contact and Kalker's



Example of contact patch and tangential stress distribution (magnitude, direction). The red line encircles the slip part of the patch.



Example of tangential stress distribution (magnitude).



Example of half contact patch (grey) and pressure distribution across the patch at longitudinal mid-position (red).

simplified model for the tangential solution. The starting point of this project was 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 and Winkler-type elastic foundations was carried out. The feasibility of modern numerical methods like boundary element discretisation should be investigated as well.

Some important steps in general are:

• 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 (traction) 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.

Matin Sh Sichani presented and defended his licentiate thesis in October 2013 and plans his PhD disputation for January 2016. A number of conference contributions and journal papers have been published.

Sichani M Sh, Enblom R and Berg M: Comparison of non-elliptic contact models - Towards fast and accurate modelling of wheel-rail contact. Proc. of the 9th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems (CM2012), Chengdu, August 27-30, 2012. Extended version published in Wear 314, pp. 111-117, 2014.

Sichani M Sh: Wheel-rail contact modelling in vehicle dynamics simulation, Licentiate thesis, Report TRITA-AVE 2013:47, Dep. of Aeronautical and Vehicle Engineering, KTH, Stockholm, 2013. ISBN 978-91-7501-852-2

Sichani M Sh, Enblom R and Berg M: A novel method to model wheel-rail normal contact in vehicle dynamics simulation, Vehicle System Dynamics, Vol 52, No 12, pp 1752-1764, 2014.

Burgelman N, Sichani, M Sh, Enblom R, Berg M, Li Z, Dollevoet, R: Influence of wheel-rail contact modelling on vehicle dynamic simulation, Vehicle System Dynamics, Vol 53, No 8, pp 1190-1203, 2015.

Sichani M Sh, Enblom R and Berg M: A fast non-elliptic contact model for application to rail vehicle dynamics, Proc. of 2nd International Conference on Railway Technology, Corsica, France, 8-11 April 2014.

Sichani M Sh, Enblom R and Berg M: Non-elliptic wheel-rail contact modelling in vehicle dynamics simulation, accepted for publication in International Journal of Railway Technology.

Sichani M Sh, Enblom R and Berg M: An alternative to FASTSIM for tangential solution of the wheel-rail contact, Proc. of the 24th International Symposium on Dynamics of Vehicles on Roads and Tracks, Graz, Austria, 17-21 August, 2015.

Sichani M Sh, Enblom R and Berg M: Wheel-rail contact modelling for damage predictions in dynamics simulation software, Proc. of the 10th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, 30 August – 3 September, 2015.

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

Project Co-ordinator D'Appolonia

Scientists from 16 partners

(KTH: Mats Berg, Ingemar Persson)

Sources of funding: European Commission (FP7).

MARATHON was a 3.5-year project, completed in September 2014, that was investigating the possibilities of making European rail freight transport more efficient through running longer trains. The focus was 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 was developed for a reliable and safe train operation. KTH was, together with University of Rome Tor Vergata, studying the risk of train derailment at poorly synchronized braking conditions between the two halves of the long train. Tor Vergata focussed on simulation of the pneumatic brake pressure distribution in space and time, whereas KTH used resulting brake shoe force histories to carry out 1D and 3D

multibody dynamics simulations for various train braking conditions, on tangent&curved as well as gradient track. In particular derailments through buffer climbing and wheel flange climbing were studied. In January and April 2014 successful tests of long freight trains were carried out, mainly in France. See www.marathon-project.eu

Marathon D3.3: Longitudinal dynamics report, WP3 - The application of technologies , report for Deliverable D3.3, November 2012. Annex added in November 2013.

RV24. The sustainable freight railway (SUSTRAIL)

Project Co-ordinator	Train Consortium
Scientists	from 29 partners

(KTH: Sebastian Stichel, Stefan Östlund, Carlos Casanueva, Per-Anders Jönsson)

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 took into account Methodology, Implementation Timeframe, and Means of Application. SUSTRAIL employed an integrated approach. Contributions from the different topic areas (vehicles, track, and operations) were 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.

The main contribution of KTH within the project was together with other universities to develop a new version of the Y25 bogie with among others double Lenoir links. The bogie was tested successfully with speeds up to 140 km/h on a test ring in Romania. SUSTRAIL was finished in May 2015.

Casanueva C, Jönsson P.-A., and Stichel S: SUSTRAIL - Designing the freight running gear of the future, presented at the 18th Nordic Seminar on Railway Technology, Bergen, Norway, 2014.

Iwnicki S D, Stichel S, Orlova A and Hecht M: Dynamics of railway freight vehicles, State-of-the-art paper, Vehicle System Dynamics, vol 53, no 7, 995-1033, 2015.

RV25. Planning tool for energy-saving loading strategy for intermodal freight trains

Project leader	Mats Berg
Scientists	Sebastian Bäckström (WSP/IVL)
	Johan Öberg
	Mats Berg

Sources of funding: Trafikverket, Energimyndigheten

Actions to make freight trains more efficient in terms of energy use have yet to be implemented to a large extent. This project aimed at reducing the energy use for operation of intermodal trains by changing strategy for the loading of the trains. In this way the air resistance of the often heterogeneous geometry of intermodal trains can be reduced. Optimizing the loading procedure according to the lowest possible air resistance yields at least a 10% decrease in energy use. In cooperation with partners the software tool Artemis Rail was extended to facilitate air drag optimization and in turn propose low-energy loading practices of intermodal trains. The running cycles of such trains were also determined based on GPS measurements on some Swedish railway lines and then implemented in Artemis Rail. In addition, two intermodal freight terminals were studied with respect to loading processes.

Padilla F: Train air resistance with special application to intermodal freight, MSc thesis, Report TRITA AVE 2012:15, KTH, 2012.

Bäckström S and Berg M: Planeringsverktyg för energibesparande lastningsstrategi av kombigodståg. Transportforum 2013, Linköping, January 2013.

Bäckström S and Berg M: Planeringsverktyg för energibesparande lastningsstrategi av kombigodståg. Slutrapport, 2014.

RV26. Track irregularities and vehicle response

Project leader	Mats Berg
Scientists	Tomas Karis
	Sebastian Stichel
	Mats Berg

Sources of funding: Trafikverket, Bombardier Transportation, SLL, Tågoperatörerna, Interfleet Technology, Sweco

The project started in November 2014 with the (part-time) employment of Tomas Karis as PhD student.

Rail vehicle motions and wheel-rail dynamic forces are strongly dependent on the track irregularities. For approval of new rail vehicles with respect to their dynamic running behaviour the track irregularities therefore need to be properly characterized. Today these irregularities are classified by maxima and standard deviations for broad wavelength spans. However, these quantities do not correlate well with the vehicle dynamic response. Thus two track sections with similar maxima and standard deviations can result in very different response of the vehicle.

The main aim of this PhD project is to find methods for characterization of track irregularities that better correlate with the vehicle dynamic response. Successful research results would, to the benefit of vehicle suppliers and train operators, significantly increase the probability that vehicles that have been designed by means of dynamic simulations will meet the demands in the certification tests and in turn be approved faster. For the infrastructure manager the possibilities increase to judge the maintenance needs in relation to the vehicle behaviour.

A literature study on the present topic is ongoing to find out possibilities and limitations with existing methods as well as establishing a firm platform for the present project. Also measurement results from the Gröna Tåget programme and the DynoTrain project are evaluated to find similarities and differences for the indicated correlation.

RV27. Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050 (Capacity4Rail)

Project Co-ordinator	International Union of Railways (UIC)
Scientists	from 46 partners

(KTH: Sebastian Stichel, Mats Berg, Bo-Lennart Nelldal, Carlos Casanueva, Behzad Kordnejad, Raid Karoumi et al.)

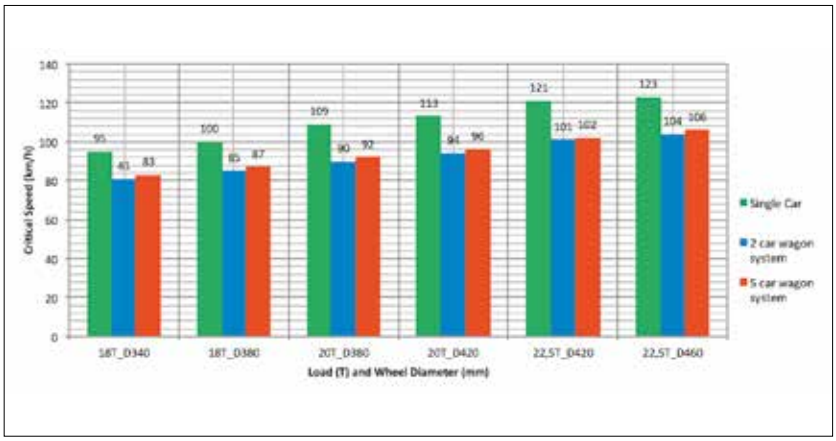
Sources of funding: European Commission (FP7).

To face the future challenge of increasing traffic and make the railway system more attractive and competitive, a step change is needed to guarantee an adaptable system, offering a high operational capacity with high reliability and resilience to hazards. This step change will only be achieved through a global and combined optimisation of infrastructure, operation and vehicle performances.

Capacity4Rail contributes to this development identifying further actions to be taken and the future technologies and systems to be developed, paving the way for the specification of future railway technologies and systems. It will demonstrate that step change in railway infrastructure and operations can be achieved while maintaining railway services.

Capacity4Rail will carry out the following activities:

- Study infrastructure solutions for conventional mixed traffic and very high speeds, reduced maintenance, and highly reliable switches (WP1).
- Design modern, automated, intelligent and fully-integrated system for efficient, reliable freight operations (WP2).
- Traffic capacity modelling and simulation, including the resilience to disturbances and improving the communication by offering real time information to customers and operators (WP3).
- Integration of Advanced Monitoring Technologies in the design and built-in process for an easier-to-monitor (self-monitoring) infrastructure with low cost and low impact inspection (WP4).
- Obtain a vision and roadmap for 2050, including



Comparison of critical speeds for different vehicle configurations.

scenarios for a smooth migration, assessment of the sustainability of the developed solutions. Build demonstrators and write recommendations and guidelines for all the involved stakeholders. (WP5)

- Dissemination and publication of project results; training on project outputs; and exploitation and implementation of innovations. (WP6)

The KTH Railway Group is engaged in WP1-WP3, where the Division of Rail Vehicles is working within WP2.

RV28. New dependable rolling stock for a more sustainable, intelligent and comfortable rail transport in Europe (Roll2Rail)

Project Co-ordinator UNIFE

Scientists from 31 partners

(KTH: Sebastian Stichel, Mats Berg, Peter Göransson, Ines Lopez Arteaga)

Sources of funding: European Commission (Horizon 2020).

The Roll2Rail project aims to develop key technologies and to remove already identified blocking points for radical innovation in the field of railway vehicles, as part of a longer term strategy to revolutionise the rolling stock for the future. The high level objectives of the work are to pave the way to:

- Increase the capacity of the railway system and bring flexibility to adapt capacity to demand;
- Increase operational reliability and therefore punctuality of the vehicles;
- Increase availability of vehicles;
- Reduce the life cycle costs of the vehicle and the track;
- Increase the energy efficiency of the system; and
- Improve passenger comfort, thereby increasing the attractiveness of rail transport to passengers.

KTH is within the project mainly working on lightweight carbodies, traction acoustics and a universal cost model for running gear. The last topic will also include models for differentiated track access charges.

MW2. Electromagnetic noise generation

Project leaders Ines Lopez Arteaga (KTH)
Siv Leth (Bombardier Transportation)

Researchers Hanna Amlinger
Fredrik Botling

Sources of funding: KTH Railway Group and Bombardier Transportation.

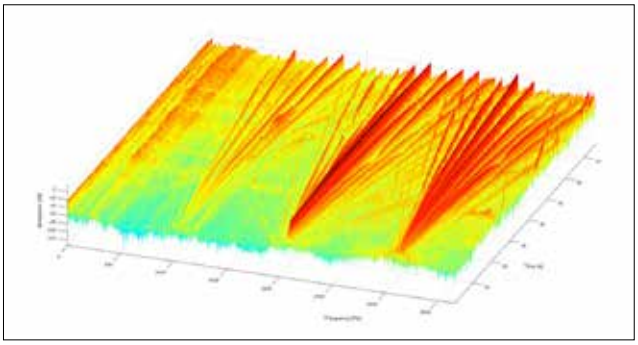
The project started in September 2014. The overall aim of this project is to develop control strategies for, and understanding of the vibro-acoustic behaviour of electrically fed traction components on trains to be able to improve the design and control of the system with respect to electromagnetic generated noise.

There are many steps behind the electromagnetic generated noise for traction components. The vibration of the mechanical component is influenced by electromagnetic forces and results in radiated sound. This radiated sound depends both on the design of the mechanical system, but also of the design of the electrical system including the software control.

To understand the behaviour of the generated sound, a real traction motor has been tested in the Power Lab at Bombardier Transportation Västerås. Both experimental modal analysis and operational deflection shape measurements have been performed.

Modal data from the experimental modal analysis has been used to create a reduced order modal model. This model can be used to simulate the time domain vibro-acoustic behaviour during operational conditions. The simulation results can be used to understand and find strategies to reduce the emitted sound by modifications of the different components.

During operational deflection shape measurements, the motor was fed by a pulse-width-modulated (PWM) frequency converter. Vibration levels were measured on the stator shield and the deflection shapes with the largest vibration levels were studied and evaluated. Measurements were performed for both different PWM switching frequencies and different motor speeds. The measurements were also compared with the simulation results from the reduced order modal model.



Noise spectrogram of the tested traction motor during acceleration

Structural Engineering and Bridges – SB

Professor Raid Karoumi

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

SB 1. Loads and Load Influence on Structures

Researchers: Raid Karoumi, Gerard James

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

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 weigh-in-motion systems including interpretation of statistical results are developed. The project ended in 2006. The project has resulted in the following publications:

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.

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

SB 2. Long-term Monitoring and Assessment of Bridges

Researchers: Håkan Sundquist, Merit Enckell, Richard Malm

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. The project ended in 2009. The project has resulted in the following publications:

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

Karoumi R., Seminarium om Modern mät- och övervakningsmetodik för bedömning av befintliga broar. TRITA-BKN. Rapport 125, 2007.

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.

Enckell M and Wiberg J, Monitoring of the New Årsta Railway Bridge – Instrumentation and preliminary results from the construction phase, Teknisk rapport, Brobyggnad, 2005.

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

Andersson A och Sundquist H, Gamla Årstabron, Utvärdering av verkningssätt hos betongvalv genom mätning och FEM-modellering – Etapp 1, Teknisk rapport 2005:13, Brobyggnad, 2005.

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 at least 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 Transport Administration and KTH Railway Group. The project ended in 2009. The project has resulted in the following publications:

González I., The validity of simplified dynamic analysis of the New Årsta Bridge's response to moving trains, Tenth International Conference on Computational Structures Technologies, Valencia, 2010.

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, Brobyggnad, 2006.

SB 5. 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. The project ended in 2007. The project has resulted in the following publications:

D4.2 Guideline for Load and Resistance Assessment of Existing European Railway Bridges - Advices on the use of advanced methods. Sixth framework programme Sustainable Bridges, 2007.

Karoumi R., Jensen J.S., Casas J.R., Plos M., Cremona C., Melbourne C., Guideline for load and resistance assessment of existing European railway bridges. International Conference "Sustainable Bridges – Assessment for Future Traffic Demands and Longer Lives", Wrocław, Poland, October 10-11, 2007.

Karoumi R., Some modeling aspects in the analysis of dynamic effects of passing trains on bridges. Sustainable Bridges WP4 Workshop, Denmark, 21–22 May 2007.

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.

SB 6. Soil-Structure Interaction for Integral Bridges and Culverts

Researchers Håkan Sundquist
Lars Pettersson
Costin Pacoste
Jean-Marc Battini
Abbas Zangeneh
Esra Bayoglu
Mahir Ülker-Kaustell
Raid Karoumi

The aim of the research is to study the effect of soil-structure interaction on the dynamic response of bridges. The effect of foundation stiffness and radiation damping will be investigated as the surrounding soil often shows to have a significant influence on the dynamic response. The behaviour of integral concrete bridges and steel culvert bridges are studied considering soil-structure interaction and dynamic effects from passing trains. The project has been financed by KTH Railway Group, Trafikverket

(the Swedish Transport Administration), Formas, ELU and Viacon. The project has resulted in the following publications:

Ülker-Kaustell M., Essential modelling details in dynamic FE-analyses of railway bridges, doctoral thesis, 2013.

Ülker-Kaustell M., Karoumi M., Pacoste C., Simplified analysis of the dynamic soil-structure interaction of a portal frame railway bridge, Engineering structures, Vol. 32, No. 11, pp. 3692-3698, 2010.

Bayoglu E. 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.

Bayoglu E., Static and dynamic behaviour of soil-steel composite bridges obtained by field testing, doctoral thesis, 2009.

Ülker-Kaustell M., Karoumi R., Uppskattning av upplagsstyvheter 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, Brobyggnad 2005.

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

Researchers Raid Karoumi
Andreas Andersson
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. The project ended in 2013. The project has resulted in the following publications:

Ülker-Kaustell M., Essential modelling details in dynamic FE-analyses of railway bridges, doctoral thesis, 2013.

Ülker-Kaustell M., Karoumi R., Influence of non-linear stiffness and damping on the train-bridge resonance of a simply supported railway bridge, Engineering structures, Vol. 41, pp. 350-355, 2012

Wiberg J., Karoumi R., Pacoste C., Statistical screening of individual and joint effect of several modelling factors on the dynamic finite element response of a railway bridge, Computers & structures, Vol. 106, pp. 91-104, 2012.

Wallin J., Leander J., Karoumi R., Strengthening of a steel railway bridge and its impact on the dynamic response to passing trains, Engineering structures, Vol. 33, No. 2, pp. 635-646, 2011.

Ulker-Kaustell M., Karoumi R., Application of the continuous wavelet transform on the free vibrations of a steel-concrete composite railway bridge, Engineering structures, Vol. 33, No. 3, pp. 911-919, 2011.

Battini J-M, Ulker-Kaustell M., A simple finite element to consider the non-linear influence of the ballast on vibrations of railway bridges, J. Engineering Structures, Vol 33, pp 2597–2602, 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.

Railway bridge across road 890 at Rössjö, Botnia line. Measurement during tests with Gröna Tåget.

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. The project ended in 2007. The project has resulted in the following publications:

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. The project has resulted in the following publications:

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 the KTH Railway Group. The project started in 2008 and ended in 2013. 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. The project has resulted in the following publications:

Leander, J., Refining the fatigue assessment procedure of existing steel bridges, doctoral thesis, 2013.

Andersson, A., Leander, J., Karoumi, R., Extending the fatigue service life of a railway bridge by local approaches. International IABSE Conference, Assessment, Upgrading and Refurbishment of Infrastructures, Rotterdam May 6 - 8, 2013.

Leander, J., Karoumi, R., Rate of convergence of measured stress range spectra. Proceedings of the Sixth International Conference on Bridge Maintenance, Safety and Management (IABMAS), 2012.

Leander, J., Karoumi, R., Quality Assurance of Measured Response Intended for Fatigue Life Prediction. Journal of Bridge Engineering 17(4), 2012.

Leander, J., Andersson, A., Järnvägsbro under bevakning. Samhällsbyggaren (3), 2011.

Leander, J., Improving a bridge fatigue life prediction by monitoring. Licentiate thesis, KTH Royal Institute of Technology, TRITA-BKN. Bulletin 106, 2010..

Leander, J., Andersson, A., Karoumi, R., Monitoring and enhanced fatigue evaluation of a steel railway bridge. Engineering structures 32(3), 2010.

Leander, J., Andersson, A., Karoumi, R., Enhanced Assessment of the Remaining Service Life of a Steel Railway Bridge. Key Engineering Materials, Damage Assessment of Structures VIII, 2009.

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

Leander J., Bro över Söderström, mätning och utvärdering m.a.p. utmattning. Report, KTH 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 ended in 2014. 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 resulted in the following publications:

Gonzalez, I., Application of monitoring to dynamic characterization and damage detection in bridges, doctoral thesis, 2014.

Gonzalez, I., Karoumi, R., BMIM Aided Damage Detection in Bridges Using Machine Learning, submmited for publication, 2015.

Gonzalez, I., Ülker-Kaustell, M., Karoumi, R., Seasonal effects on the stiffness properties of a ballasted railway bridge, Engineering Structures, 2013.

Gonzalez, I., Karoumi, R., Analysis of the annual variations in the dynamic behavior of a ballasted railway bridge using Hilbert transform, Engineering Structures, 2014.

Gonzalez, I., Study and Application of Modern Bridge Monitoring Techniques. Licentiate Thesis. KTH, Royal Institute of Technology. Stockholm, 2011.

González, I., Traffic monitoring using a deployed Structural Health Monitoring System. Accepted for publication in ICE Bridge Engineering.

Shu, J., Karoumi, R., Gonzalez, I., The application of a damage detection method using Artificial Neural Network and train-induced vibrations on a simplified railway bridges model. Engineering Structures, 52, pp 408–421, 2013.

Railway bridge at "Döda fallet" at road 87, Österede.

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 ended in 2014. 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. The project has resulted in the following publications:

Du, G., Life cycle assessment of bridges, model development and case studies, doctoral thesis, 2015.

Safi, M., Life-Cycle Costing - Applications and Implementations in Bridge Investment and Management, doctoral thesis, 2013.

Safi M., Sundquist H., Racutanu G., Life-Cycle Costing

Integration with Bridge Management Systems, J. ICE-Bridge Engineering.

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.

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.

Racutanu G., Safi M., Sundquist H., LCC applications for bridges & Integration with BaTMan. Technical Report for Trafickverket, Royal Institute of Technology.

Du, G., Towards sustainable construction: life cycle assessment of railway bridges, Licentiate thesis in Division of Structural Engineering and Bridges, KTH Royal Institute of Technology, Stockholm, 2012.

Du, G., and Karoumi, R., Life cycle assessment of a railway bridge: comparison of two superstructure designs, Structure and Infrastructure Engineering, accepted for publication in 2012.

Du, G, and Karoumi R., Life cycle assessment framework for railway bridges: literature survey and critical issues, Structure and Infrastructure Engineering, accepted for publication in 2012.

Thirbault V., Du G., Karoumi R., Design of railway bridges considering LCA, Journal of ICE Bridge Engineering, accepted for publication in 2012.

Rossi, B., Lukic I., Iqbal N., Du G, 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., and Karoumi R., Environmental life cycle assessment comparison between two bridge types: reinforced concrete bridge and steel composite bridge, The Third International Conference on Sustainable Construction Materials and Technologies (SCMT3), Kyoto, Japan, 2013.

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

Researchers Raid Karoumi
Costin Pacoste
Andreas Andersson
Christoffer Svedhom (f.d. Johansson)

This project is financed by Trafikverket (the Swedish Transport Administration) and KTH. The project started in 2010 and will continue until 2015. 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 analyse 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:

Svedholm, C., Simplified dynamic analysis of railway bridges under high-speed trains, licentiate thesis, 2013.

Johansson, C., Pacoste, C., and Karoumi, R., Closed-form solution for the mode superposition analysis of the vibration in multi-span beam bridges caused by concentrated moving loads. Computers and Structures, 119, pp 85–94, 2013.

Johansson, C., Pacoste, C., and Karoumi, R., Development of design curves for preliminary dynamic assessment of railway bridges to higher speeds, accepted by International Journal of Railway Technology, 2013.

Ní Nualláin, N.Á., Johansson, C., Andersson, A., Karoumi, R., and Pacoste, C., Applicability of probabilistic methods of assessing a network of bridges, submitted to Engineering Structures in Aug 2012.

Johansson, C., Ní Nualláin, N.Á., Andersson, A., and Pacoste, C., Probabilistic dynamic analysis of existing railway bridges for high-speed traffic, submitted to Engineering Structures in Oct 2012.

KTH-Brobyggnad rapport, 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, 2010.

SB14. Train-track-bridge interaction

Researchers Raid Karoumi
Therese Arvidsson

The project is financed by KTH Railway Group. The aim is to develop models that consider the influence of train-track-bridge dynamic interaction. Guidelines and recommendations are to be developed for how to model the train and the track for different types of bridges and different span lengths. The project investigates also how future heavy freight trains influence the bridges. One of the goals is to determine which bridge types and span lengths that are particularly sensitive to future heavy freight trains. The project started in 2011 and a licentiate ¬ thesis was presented in 2014. The project has resulted in the following publications:

Cantero, D., Arvidsson, T., Obrien, E., Karoumi, R., Train–track–bridge dynamic model, validation and review of parameters, submitted to Structure and Infrastructure Engineering, 2015.

Arvidsson, T., Train–Bridge Interaction: Literature Review and Parameter Screening, licentiate thesis, 2014.

Arvidsson, T., Karoumi, R., Pacoste, C., Statistical screening

of modelling alternatives in train-bridge interaction systems, Engineering Structures, 2014.

Arvidsson, T., Karoumi, R., Train-bridge interaction - a review and discussion of key model parameters, International Journal of Rail Transportation2014.

Arvidsson, T., Karoumi, R., Modelling Alternatives in the Dynamic Interaction of Freight Trains and Bridges, proceedings of the Second International Conference on Railway Technology, 2014.

SB15. Controlled dynamic field tests for accurate assessment of railway bridges to higher train speeds

Researchers Jean-Marc Battini
Mahir Ülker-Kaustell
Raid Karoumi
Hesham Elgazzar

Dynamic analyses of railway bridges present several uncertainties and often predict vibrations which are higher than in reality, especially when high speed trains are considered. These uncertainties are due to the soil-structure interaction, the friction at the supports, the effect of the ballast and the value of the damping at large vibrations. The purpose of this project is to study these parameters by combining FEM analyses and field measurements and to propose guidelines for implementing accurate FE models of railway bridges. The first part of the project will focus on the bridges with integrated backwalls along the Bothnia Line.

The project started in 2014 and is financed by KTH Railway Group.

A three span concrete railway bridge in Södertälje, Pershagen.

Pilot testing of a hydraulic bridge exciter developed by KTH.

Electric Power Engineering – EP

Professor
Stefan Östlund

The Department for Electrical Energy Conversion 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. Research on railway power supply systems is conducted together with the Department for Electric Power Systems.

RESEARCH PROJECTS

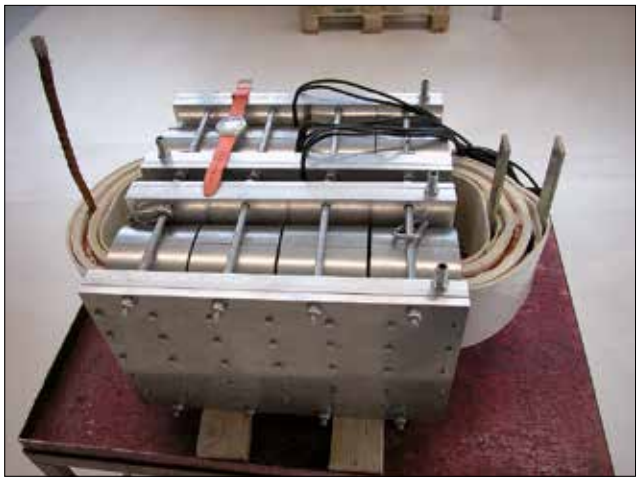
EP 1. New converter topologies for electric railway traction

Researchers Stefan Östlund
stefan.ostlund@ee.kth.se
Tommy Kjellqvist
Lars Abrahamsson
lars.abrahamsson@ee.kth.se
Staffan Norrga, norrga@kth.se

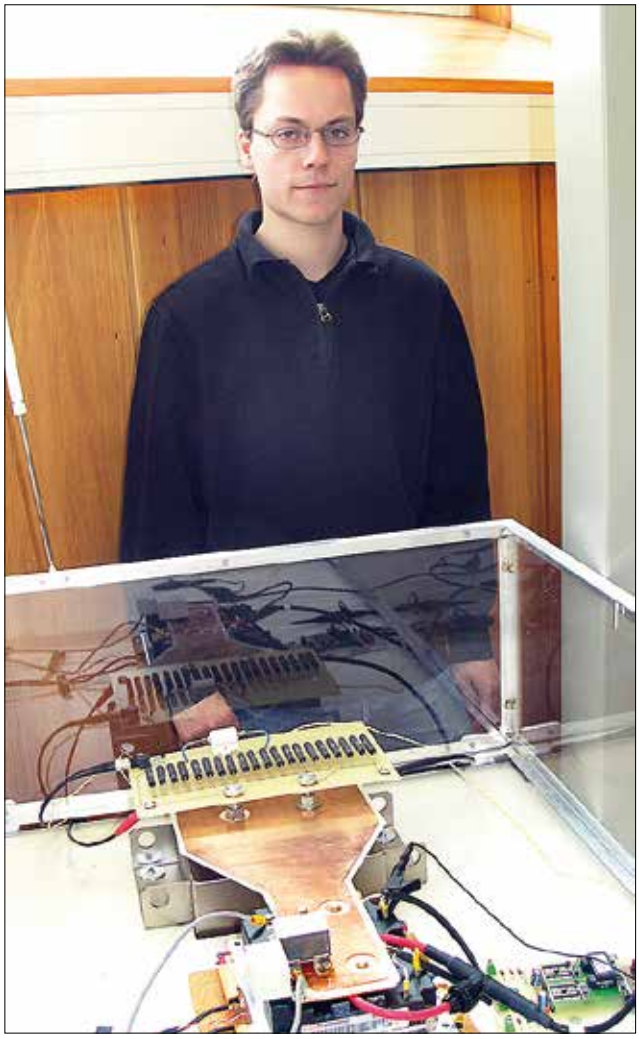
Period: Stage 1 00-05, Stage 2 05-11

Source of funding/partners: Banverket/Trafikverket

PhD degrees awarded:
Staffan Norrga ”On Soft-Switching” Isolated AC/DC Converters without Auxiliary Circuit”, May 2005



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



PhD Tommy Kjellqvist, Researcher in EP1.

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

The project was concerned with a new soft-switched medium frequency converter topology for railways. The proposed 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 zero-current conditions and the switching losses will be kept at a low level. This allows for high switching frequency which means that the transformer will be smaller and more efficient. The project consisted of four parts, design of the transformer; characterization of soft-switched IGBTs for use in a snubbered VSC; Design of a high-voltage cyclo-converter including gate-drives for series-connection of devices and finally system issues and applications.

Kjellqvist T, Norrga S, Östlund S: Switching Frequency Limit for Soft-Switching MF Transformer System for AC-fed Traction. Proceedings the 36th IEEE Power Electronic Specialists Conference, Recife Brazil, 2005.

Norrga S: Modulation Strategies for Mutually Commutated Isolated Three-Phase Converter Systems. Proceedings the 36th IEEE Power Electronic Specialists Conference, Recife Brazil, 2005.

Kjellqvist T, Norrga S: Harmonic Mitigation in Single Phase Mutually Commutated Converter Systems. Proceedings the 37th IEEE Power Electronic Specialists Conference, Korea, 2006.

Kjellqvist T and Norrga S: Active Snubber Circuit for Source Commutated Converters, Proceedings of the EPE 2007 conference, Aalborg 2007

Norrga S: Experimental Study of a Soft-Switched Isolated Bidirectional AC–DC Converter Without Auxiliary Circuit, IEEE Transactions on Power Electronics, volume 21, 1580-1587, 2007

Kjellqvist T, Östlund S and Norrga S: Active Snubber Circuit for Source Commutated Converters Utilizing the IGBT in the Linear Region, IEEE Transactions on Power Electronics, volume 22, 2595-2601, 2008,

Kjellqvist T: On Design of a Compact Primary Switched Conversion System for Electric Railway Propulsion, PhD thesis Royal Institute of Technology, TRITA EE 2009:029, KTH, 2009

Kjellqvist T, Norrga S, Östlund S and Ilves K: 'Evaluation of a Medium Frequency Transformer in a Line Side Conversion System, Proceedings of the 13th European Conference on Power Electronics and Applications September 2009, Aalborg, Denmark

EP 2. Dual system locomotives for rail freight transportation/ Drive cycles for freight locomotives

Researchers Stefan Östlund PhD
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Mattias Skoglund MSc
Mattias.skoglund@tfk.se
Peter Bark, Ph.D
peter.bark@tfk.se

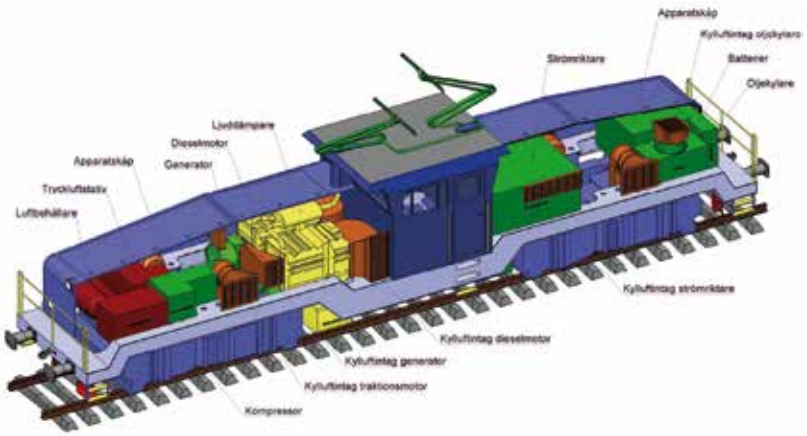
Source of funding/partners: Banverket/ Bombardier Transportation

Period: Stage 1 06-09, Stage 2 06 – 11..

The project was carried out in cooperation with TFK. It consisted of two parts. The objective of the first part was to develop a specification for a dual-system freight locomotive. That is, a train with both a diesel engine and electrical supply. In the project has been studied both the design of the locomotive and its impact on the operation regarding for instance energy consumption, logistics and emissions. The objective of the second part was to study drive cycles for freight locomotives. Better drive cycles are required for a more accurate evaluation of different locomotive concepts.

Skoglund M, Bark P and Östlund S: Experiences from the Swedish T43H Hybrid Locomotive, Nordiskt seminarium i Järnvägsteknik, Hook 22-23 maj 2008

Skoglund M, Bark P and Östlund S: Dual mode locomotives – System studies of new freight locomotives for Sweden, IEEE/ ASME Joint Railroad Conference, April 2008



Dual system locomotive

EP 3. System aspects of Permanent magnet traction motors

Researcher: Juliette Soulard Ph.D
juliette.soulard@ee.kth.se

Source of funding/partners: Bombardier Transportation

The project studies design aspects of permanent magnet traction motor drive including converter and gear as well as fundamental system issues for permanent magnet motor drives.

PhD Juliette Soulard, Researcher in EP 3

EP 4. Train Information Management and Monitoring (TIMM)

Researchers Stefan Östlund KTH
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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

Period 2006-2007

The project was carried out in cooperation with the 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 dealt 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. Our part has been focused on monitoring of the the current collection.

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 was a follow-up of the TIMM project focusing on issues regarding Condition based maintenance in train operations, and its consequences for production planning and control. The focus has been 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 was 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' Proceesinds of International Conference on Condition Monitoring and Diagnosis, Sept. 6–11, 2010, Toyosu, Tokyo

EP 6. Railway Power Supplies with new converter and system topologies

Researchers: Staffan Norrga
norrga@kth.se
Stefan Östlund
stefan.ostlund@ee.kth.se
Lars Abrahamsson
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Period: 2013-2015

Source of funding: Railway Group

For AC railway power supply systems with a different frequency than the public grid, high-voltage AC (HVAC) transmission lines are common, connected to the catenary by transformers. This project proposes an alternative design based on an HVDC (High Voltage DC) feeder, which is connected to the catenary by converters. Such an HVDC line would also be appropriate for DC-fed railways and AC-fed railways working at public-grid frequency.

The converter stations between the public grid and the HVDC feeder can be sparsely distributed, not denser than on 100 km distances, whereas the converters connecting the HVDC feeder to the catenary are distributed denser. Their ratings can be lower than present-day substation transformers or converters, since the power flows can be fully controlled.

The proposed feeding system results in lower material usage, lower losses and higher controllability compared to present solutions.

Simulations of the proposed solution show clear advantages regarding transmission losses and voltages compared to conventional systems, especially for cases with weak feeding, and when there are substantial amounts of regeneration from the trains.

Abrahamsson, L, Kjellqvist, T and Östlund, S: High-voltage DC-feeder solution for electric railways. IET Power Electronics, 5(9), 1776-1784, 2012

Laury, J, Abrahamsson, L and Östlund, S: OPF for an HVDC Feeder Solution for Railway Power Supply Systems. Paper presented at The 13th International Conference on Design and Operation in Railway Engineering (COMPRAIL 2012), The New Forest, UK, 2012

Abrahamsson, L, Östlund, S, Schütte, T and Söder, L: An electromechanical moving load fixed node position and fixed node number railway power supply systems optimization model. Transportation Research Part C, 30, 23-40, 2013

Abrahamsson, L, Östlund, S: Optimizing the power flows in a railway power supply system fed by rotary converters, presented at the IEEE/ASME Joint Railroad Conference, 2015

EP7 AC/AC Modular Multilevel Converters for Railway Applications (EP7)

Researchers: PhD student: Luca Bessegato

Supervisors: Staffan Norrga Stefan Östlund

Reference group members: Hans-Peter Nee KTH, Lennart Ängqvist KTH, Håkan Kols Trafikverket, Andes Bulund Trafikverket, Niklas Biedermann Trafikverket.

Period 2014-2019

Source of funding/partners: Railway Group/Trafikverket

Trafikverket has introduced new modular multi-level railway power supply converters. These converters have characteristics that are different from previous generations. The project focuses on the dynamic behavior of the converters as seen from the railway power grid and the three-phase grid. The PhD student has performed a thorough literature study on line side control of converters and initial work on modelling of the converter has been started. So far the work has resulted in two conference publications.

K. Ilves, L. Bessegato, S. Norrga, "Comparison of cascaded multilevel converter topologies for AC/AC conversion", 2014. ECCE Asia,

L. Bessegato, T. Modeer, S. Norrga, "Modeling and Control of a Tapped-Inductor Buck Converter with Pulse Frequency Modulation", 2014 ECCE US.

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 ail 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 inrelation 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 adhesion models for the railway wheel rail contact including contaminants. Yi Zhu defended his PhD thesis in November 2013.

Publications 2008-2014

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

U. Olofsson, Adhesion and Friction Modification at the Wheel–Rail Contact, in Handbook of the wheel rail interface, Ed. R. Lewis and U. Olofsson.

U. Olofsson, A study of top of rail contaminants, Nordtrib 10 Storforsen Sweden, June 10 – 14 2010.

S. Lewis, R. Lewis, Y. Zhu , S. Abbasi,U. Olofsson, The Modification of a Slip Resistance Meter for Measurement of Railhead Adhesion, IHHA-2011, Calgary Canada June 19-22 2011. Best paper award IHHA.

R. Lewis, S. Lewis, U. Olofsson, D. T. Eadie, J. Cotter, X. Lu, Effect of Humidity, Temperature and Railhead Contamination on the Performance of Friction Modifiers: Pin-on-Disk Study, IHHA-2011, Calgary Canada June 19-22 2011.

Y. Zhu, A Söderberg, U. Olofsson Adhesion in wheel-rail contact: NSJ 2010, September 14-15 2010, Stockholm, Sweden

Y. Zhu, A Söderberg, U. Olofsson Adhesion Modeling in the Wheel-rail Contact under Wet Condition using Measured 3D Surfaces: 22nd international symposium on dynamics of vehicles on roads and tracks 2011, Manchester, U.K

Y. Zhu, U. Olofsson, "An adhesion model for wheel–rail contact at the micro level using measured 3d surfaces", Submitted to 9th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems 2012, Aug 27-30, Chengdu, China

U Olofsson, Y Zhu, S Löfving, J Casselgren, L Mayer, R Nilsson, "An optical sensor for the identification of low adhesion in the wheel rail contact", Submitted to 9th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems 2012, Aug 27-30, Chengdu, China

Y. Zhu, U. Olofsson, R. Nilsson: "A field test study of leaf contamination on the rail head surfaces", the first International conference on Railway Technology: Research, Development and Maintenance, Apr 18-20, 2012, Las Palmas, Spain

Y. Zhu, U. Olofsson, A.Söderberg: "Adhesion modeling in the wheel-rail contact under dry and lubricated conditions using measured 3D surfaces", Tribology International 61 (2013) 1-10

Y. Zhu, U. Olofsson, K. Persson: "Investigation of factors influencing wheel-rail adhesion using a mini traction machine", Wear 292-293 (2012) 218-231

Y. Zhu, U. Olofsson, R. Nilsson: "A field test study of leaf contamination on the rail head surfaces", Article in press, IMechE Part F: J. of Rail and Rapid Transit

Y. Zhu, U. Olofsson, "An adhesion model for wheel–rail contact at the micro level using measured 3d surfaces", Wear 2013.

U. Olofsson, Y. Zhu, S. Löfving, J. Casselgren, L. Mayer, R. Nilsson, "An optical sensor for the identification of low adhesion in the wheel rail contact", International Journal of Railway Technology 2014

S.R. Lewis, R. Lewis, & U. Olofsson, "An alternative method for the assessment of railhead traction", Wear, vol. 271, no. 1-2, pp. 62-70 (2011).

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R. Lewis, S. Lewis, Y. Zhu, S. Abbasi, U. Olofsson, "The Modification of a Slip Resistance Meter for Measurement of Railhead Adhesion", IMechE Part F: J. Rail and Rapid Transit 2013

Y. Zhu, U. Olofsson "An adhesion model for wheel rail contact at the micro level using measured 3d surfaces, Wear 2014

Y. Zhu, U. Olofsson, H. Chen "Friction between wheel and rail: a pin-on-disc study of environmental conditions and iron oxides", Tribology Letters 2013

Y. Zhu, "Adhesion in the Wheel-Rail Contact", Doctoral thesis in Machine Design Stockholm Sweden 2013.

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. Saeed Abbasi defended his PhD thesis in November 2013.

Publications since 2008-

U. Olofsson, L. Olander, A. Jansson, Towards a model for the number of airborne particles generated from a sliding contact. Nordtrib-08, Tampere Finland 2008, also Wear (2009) 267, 2252–2256.

U. Olofsson,, A study of airborne wear particles generated from the train traffic – a pin on disc simulation of block brake materials, 8th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Firenze, Italy, September 15-18, 2009, also Wear (2011) 271(1–2), 86–91.

S. Abbasi, J. Wahlstrom, L. Olander, C. Larsson, U. Olofsson, U. Sellgren, A study of airborne wear particles generated from railway organic brake pads and brake discs, June 8-11 Nordtrib 2010. Accepted for publication in WEAR.

S. Abbasi, J. Wahlstrom, L. Olander, C. Larsson, U. Olofsson, U. Sellgren A field investigation of morphology and chemical composition of airborne particles in rail transport" ;NSJ2010, 14-15th September 2010

S. Abbasi, J. Wahlstrom, L. Olander, C. Larsson, U. Olofsson, U. Sellgren A proposed methodology for predicting railway brake pad wear with thermomechanical finite-element simulations ; Nordic 2010 NAFEMS, 26-27th October 2010

S. Abbasi, J. Wahlstrom, L. Olander, C. Larsson, U. Olofsson, U. Sellgren A field investigation of the size, morphology and chemical composition of airborne particles in rail transport; RAILWAYS & ENVIRONMENT International conference 16th December 2010

U. Olofsson A study of airborne wear particles generated from the train traffic-Block braking simulation in a pin-on-disc machine", Wear, vol. 271, no. 1-2, pp. 86-91 (2011).

S. Abbasi, L. Olander, C. Larsson, A. Jansson, U. Olofsson, U. Sellgren, A field test study of airborne wear particles from a running regional train, IMechE, Part F: Journal of Rail and Rapid Transit, vol. 226 (2012) 18-29.

S. Abbasi, A. Jansson, L. Olander, U. Olofsson, U. Sellgren, A pin-on-disc study of the rate of airborne wear particles emission from railway braking materials', Wear vol. 284-285 (2012) 18-29.

S. Abbasi, U. Sellgren, A. Jansson, U. Olofsson, Particle emissions from rail traffic: A literature review, proceeding Critical Reviews un Environmental Science and Technology, In press (2012)

S. Abbasi, Characterization of airborne particles from rail traffic, licentiate thesis, Department of Machine Design KTH August 2011, TRITA-MMK 2011:11.

S. Abbasi, J. Wahlstrom, L. Olander, C. Larsson, U. Olofsson, U. Sellgren, A study of airborne wear particles generated from railway organic brake pads and brake discs, WEAR vol. 273(2011) 93-99

S. Abbasi, U. Olofsson, U. Sellgren, A Review of Particle Emissions from Rail Vehicles, Railway Technology: Research, Development and Maintenance, 18-20 April, Spain (2012)

T. Vernersson, R. Lundén, S. Abbasi, U. Olofsson, Wear of Railway brake block materials at elevated temperatures; pin-on-disc experiments, Euro brake, April 16-18, Germany 2012

S. Abbasi, U. Olofsson, U. Sellgren, A study of friction modifiers on airborne wear particles from wheel-rail contact, Nordtrib 2012, June 12-15, Norway 2012

S. Abbasi, U. Sellgren, U, Olofsson Experiences of measuring airborne particles from braking materials and wheel-rail contact, Contact mechanics 2012, August 27-30, China

S. Abbasi, S. Teimourimanesh, T. Vernersson, U. Sellgren, U, Olofsson, R. Lundén Temperature and thermo-elastic instability of Tread braking friction materials, Contact mechanics 2012, August 27-30, China

S. Abbasi, Towards Elimination of Airborne particles from rail traffic, Doctoral thesis in Machine Design Stockholm Sweden 2013.

ME4. Block brakes during winter conditions

Project leader:	Ulf Olofsson
Research engineer	Peter Carlsson

Source of founding commission from SL

In trains with tread brakes, the coefficient of friction between the brake block and the railway wheel determines the stopping distance. The blocks have traditionally been manufactured from cast iron materials. Although these blocks have good braking capacity, their use can be restricted due to the squealing noise they emit. Tests of alternative composite block materials have been successful under summer conditions; in regions with snowy winters, however, the use of such materials has been limited due to problems with braking capacity under snowy conditions.

This research aims to develop a laboratory-scale test methodology for evaluating the braking capacity of tread brake materials under winter and snowy conditions. A pin-on-disc machine placed in a climate chamber was used for testing, and standard cast iron block material was compared with standard composite block materials. The results indicate that the standard composite block materials generate a much smoother counter wheel surface and a significantly lower friction coefficient under snowy conditions. A second test series evaluated alternative composite block materials, and a candidate material with low noise and a sufficiently high sliding friction coefficient was selected for further study. A third test series examining geometrical changes in the contact surface in terms of milled parallel traces revealed that the braking capacity under

winter conditions can be increased by such milling if the parallel traces are properly oriented – in this case, at an angle of 45° to the sliding direction.

U. Olofsson, J. Sundh, U. Bik, R. Nilsson, Influence of snow on train tread braking performance: a pin-on-disc simulation in a climate chamber, Nordtrib 2013 and an updated version in IMechE Part F: J. Rail and Rapid Transit 2015

ME5. Quiet track

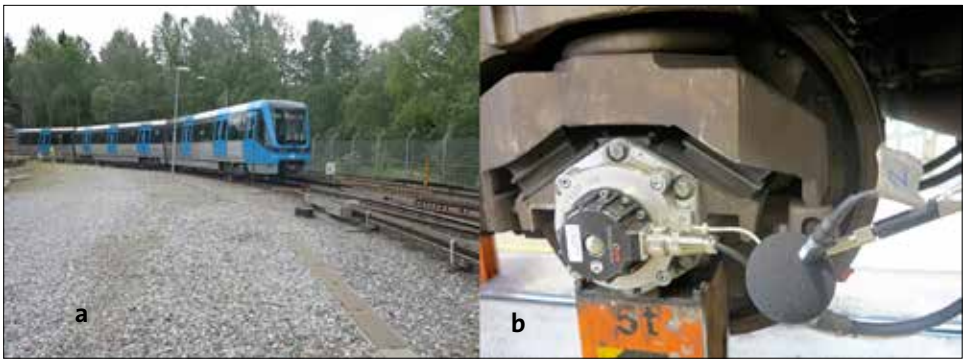
Project leader:	Ulf Olofsson
Senior lecturer	Stefan Björklund
Researcher	Ellen Bergseth
Research engineer	Peter Carlsson

Source of founding EU project FP7

The purpose of this work-package within the Quiet-track, FP7, is to develop a noise related track maintenance tool, in the form of an on-board measurement system. As a first step, lab scale tests using a pin-on-disc tribometer were used in order to distinguish how noise changes when the wear mechanism in a sliding contact shifts from normal wear to severe and catastrophic wear. Once the potential for using sound as an indication of severe wear transitions was established, full scale tests were carried out with a rapid transit (metro) train, type C20. The train was equipped with microphones that continuously measured the sound pressure near the wheel rail contact. In order to provoke severe/catastrophic wear, the test train was run in a curve with small radius, and the rails and wheels were carefully cleaned before the tests. The same kind of transfer from mild to severe/catastrophic wear was identified on the full scale test as in the laboratory scale test, confirmed by studying the surface topography and the morphology of the wear particles. Moreover, the full scale test results showed that the sound pressure changed significantly when transferring from mild to severe wear in agreement with the pin-on-disc test results. By comparing noise from the inner wheel/rail contact to noise form the outer wheel/rail contact a wear indication value for the outer wheel/rail contact is suggested in this study. This value can be seen as an advanced parameter from which the probability of severe wear, in the wheel flange/rail gauge face contact of the outer contact, can be estimated. At present, a real time condition monitoring system is set up in Stockholm (Metro line 1) in order to validate the results.

Y. Lyu, E. Bergseth, S. Björklund, U. Olofsson, A. Lindgren, M. Höjer, On the Relationships between Wheel and Rail Surface Topography, Interface Noise and Tribological Transitions, accepted for publication in Wear vol. 338-339 (2015) 36-46.

Y. Lyu, S. Björklund, E. Bergseth, U. Olofsson, R. Nilsson, A. Lindgren and M. Höjer, Development of a noise related track maintenance tool, ICSV 22, Firenze Italy 12-16 July 2015.



Above:
The instrumented C20 rapid transit train running on the test curve (a) and the mounted microphone instrumentation near the wheel (b).

Left:
Pendulum slip resistance measurement (a), wear particle collection (b), Miniprof rail profile measurement (c) and surface replica molding (d).

ME6 Models for rail traffic emission factors (ME4)

Project leader:	Ulf Olofsson
Graduate student	Katja Tasala Gradin
Graduate student	Yingying Cha (CSC)
Researcher	Anna Hedlund

The project focus is on particle emission factors from rail traffic.

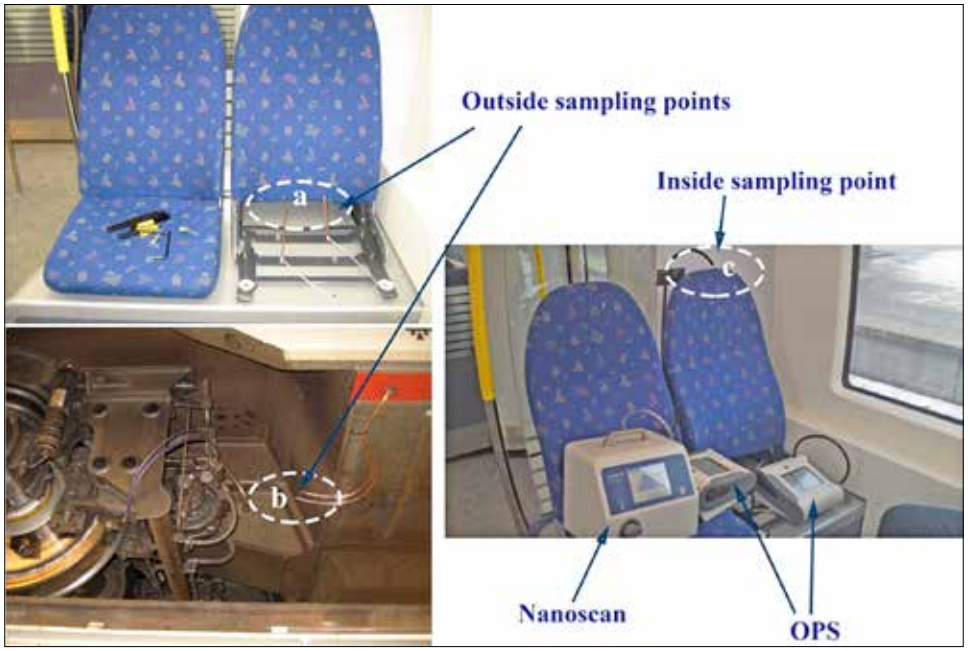
The aim of the project is to develop emission factors for their different sources in rail traffic. These emission factors should be integrated in to simulation models that can be used to predict the amount of particle emissions from different driving conditions.

Publications 2015-

Source analysis of airborne particles in train and road tunnel, submitted to International conference on Railway Technology: Research, Development and Maintenance 2016

Indoor and outdoor measurement of airborne particulates on a commuter train running partly in tunnels, submitted to IMechE Part F: J. Rail and Rapid Transit 2015.

On particulate emissions from individual trains in the tunnel environment, submitted to International conference on Railway Technology: Research, Development and Maintenance 2016.



Two sampling points, outside sampling point under the train between two bogies (left a and b), inside sampling point close to passenger's breathing area (right c), attached to particle counters inside the train cabin.

Transport planning, Economy and Engineering – TET

PhD Oskar Fröidh

The group that works with railway traffic and infrastructure planning belongs to the Division of Transport planning, Economy and Engineering (TET) at the Department of Transport Science (TSc), School of Architecture and the Built Environment (ABE) at KTH. Research is conducted in the areas of freight transportation and passenger transportation, capacity analysis including simulation and signalling systems, and traffic and maintenance. Unofficially called the Rail Group, the group has specialist competence in traffic planning, railway operation and economics, forecasting models and customer valuations, market analysis for passenger and freight traffic, simulation models for railway capacity, and infrastructure planning.

The Rail Group currently has 11 members composed of researchers, PhD students and research engineers. The group was formed in 1991 and was led by adjunct professor Bo-Lennart Nelldal, but since 2013 Dr. Oskar Fröidh has taken over the leadership. In 2014, Docent Markus Bohlin (SICS Swedish ICT) was appointed an adjunct professorship at the TET division. Dr. Gerhard Troche is appointed as a national expert at EU DG MOVE in 2010-2015.

RESEARCH PROJECTS OVERVIEW

New Code	(Previus Code)	Grey shading indicates completed project
		Freight and logistics
TET F1	(ToL 1, ToL 7)	Model for supply and costs for freight transport by rail
TET F2	(ToL 2)	Regional Intermodal Transport Systems – Analysis and Case Study
TET F3	(ToL 3, ToL 11)	Efficient rail freight transportation and production systems
TET F4	(ToL 4, ToL 5, ToL 6)	Rail Freight Corridors
TET F8	(ToL 8)	TRANSFORUM – Possibilities to realise the goals in the EU's White Paper
TET F9	(ToL 9)	Major traffic interruptions on Sweden's railways 2000-2014 and their impact for customers
TET F10	(ToL 10)	Freight transportation by rail – stage 2 measures
TET F11	(new)	Transportation by rail for the forest industry
TET F12	(ToL 12)	Green Freight Train - Roadmap for rail and intermodal freight transportation
TET F13	(new)	Capacity 4 Rail (C4R)
TET F14	(new)	Sustainable and energy efficient regional logistics in the Mälardalen area
		Passenger transport and customer preferences
TET P1	(ToL 13)	Green Train market prerequisites, passenger valuations and service concepts
TET P2	(ToL 14, ToL 15)	High-Speed Rail in Sweden – Supply and demand
TET P3	(ToL 16, new)	Development of passenger forecast models
TET P4	(ToL 17)	Database of supply and prices for railway lines in Sweden
TET P5	(ToL 18)	Evaluation of the deregulation and competition in interregional rail services
TET P6	(new)	Peripherally located railway stations – effects for train travel and society
		Capacity analysis and signalling
TET C1	(ToL 20)	Congested infrastructure
TET C2	(ToL 21)	Timetable planning with simulation
TET C3	(ToL 22)	Development of time-table strategies
TET C4	(ToL 24)	Analysis of capacity and punctuality 2008-2012
TET C5	(ToL 25)	Development of methods for capacity analysis
TET C6	(ToL 26)	Analysis of track access charges and the rail market
TET C7	(ToL 19)	Future rail vehicle maintenance and depots – research road map
TET C8	(new, ToL 23)	Capacity analysis in a network perspective
TET C9	(new)	Prestudy – Cause and effects for the maintenance of railways
TET C10	(ToL 27)	Programme for research and innovation in signalling systems
TET C11	(new)	Procurement and implementation of complex signalling systems – work processes and tools

FREIGHT AND LOGISTICS

TET F1. Model for supply and costs for freight transport by rail

Researchers: Bo-Lennart Nelldal
Behzad Kordnejad

Source of funding: Swedish National Transport Administration (Trafikverket) and EU

Duration: 1998-2014

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 get input data for forecast-models and calculations of new transport-systems. A cost model for the railway was presented in a doctoral thesis in 2009 which consists of three levels: Infrastructure, rail operation and freight flows.

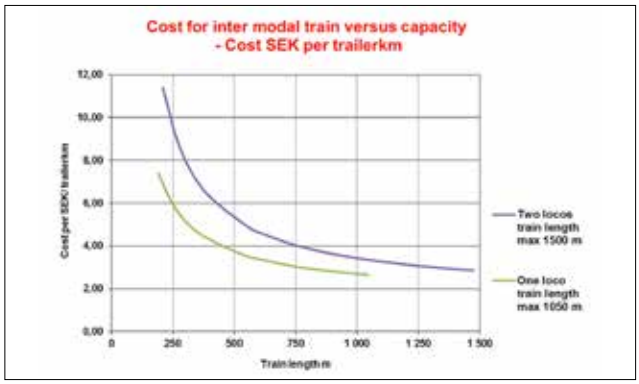
The models have subsequently been developed further in other projects, i.e. models for calculation of intermodal transportation, terminal costs and truck costs. A model for evaluation of different wagon types and train configurations has also been developed and used in the Green Freight Train project.

The latest contributions are models for shunting and marshalling including socio-economic models for delays and interruptions in the freight rail system. In this is also a new method for the value of time for freight transports calculated. It is the missing value of the transported goods which complete the actual value of the capital cost for freight. This method can be used at large delays and interruptions when the consequenses for the customers are that they will loose the whole or a part of the income for their goods.

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

Study on railway business for VEL-wagon and target costs. Armando Carrillo Zanuy, Bo-Lennart Nelldal, Hans Boysen. D3.1 VEL-wagon report 30.4.2012.

Utvecklingen av rangerbangårdarna i Sverige – Hittillsvarande utveckling, samhällsekonomiska kalkyler för rangerbangårdar och prognoser för järnvägens produkter. Bo-Lennart Nelldal and Jakob Wajsman (Trafikverket), 2014. KTH report TRITA-TSC RR 14-010.



Models to evaluate operating costs can be used to evaluate the effects of longer trains.

TET F2. Regional intermodal transport systems – Analysis and case study

Researcher: PhD student Behzad Kordnejad

Supervisors: Sebastian Stichel, Bo-Lennart Nelldal and Sebastiaan Meijer

Sources of funding: Swedish National Traffic Administration (Trafikverket) and KTH Railway Group

Duration 2010-2015

The railway's market share for transportation in major metropolitan areas has steadily declined 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.

Conventional rail freight is commonly competitive on long distances and in endpoint relations between two nodes. An intermodal liner train, however, makes stops along the route for loading and unloading. In regional or interregional relations, the concept has the potential to reduce drayage by truck to and from intermodal terminals and to make rail freight competitive also over medium and short distances.

The main aim of this thesis project has been to analyse under what conditions a combined transport system based on the railway can be implemented in the Stockholm-Mälaren region. Based on a case study for a shipper distributing daily consumables in the region, the feasibility of creating a regional rail freight transport system has been evaluated. A licentiate thesis was published in 2013 and

the project is planned to continue to a doctoral thesis in 2016.

In connection to this project pre-studies has been done for an efficient horizontal transfer systems of containers called CarConTrain (CCT). An evaluation has been made of the logistics, the costs, energy consumption and greenhouse gases for loading and unloading with this system compared with traditional reach-stacker handling.

Regional Intermodal Transport Systems – Analysis and Case Study in the Stockholm-Mälaren region. Behzad Kordnejad, 2013. KTH Licentiate Thesis TRITA-TSC-RR 13-006.

CCT – An intermodal terminal handling system for horizontal transfer - Effects on costs, logistics, energy consumption and greenhouse gases. Bo-Lennart Nelldal, 2014. KTH report TRITA-TSC RR 14-012.

TET F3. Efficient rail freight transportation and production systems

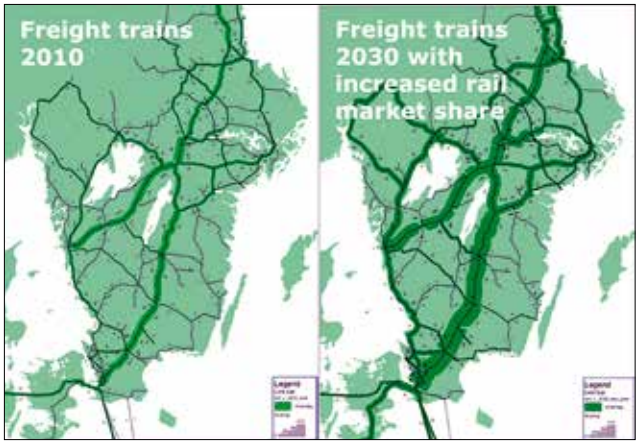
Researcher: Bo-Lennart Nelldal
Fredrik Hagelin
Armando Carillo Zanuy

Source of funding: Swedish National Traffic Administration (Trafikverket)

Duration 2013-2015

This project includes analysis of the freight rail production system especially connected to the single wagon load (SWL) system. In two projects feeder transports has been analysed and cost models for this has been developed. Also marshalling in Germany and Austria has been studied and different models for marshalling and feeder transports on a market with competition between different operators.

The latest project is a forecast for rail products in Sweden 2014-2030-2050. The products are wagon load, train load (block train), intermodal and iron ore traffic. The historical development of the production systems from wagon load with marshalling yards has been studied and future scenarios for the production systems have been constructed.



Effektiva matartransporter till järnväg - Utvecklingen av vagnslasttrafiken och möjligheter att vidareutveckla matartransporterna. Bo-Lennart Nelldal, 2014. KTH Report TRITA-TSC-RR 14-004.

Cost Efficient Feeder Transport by Rail. Fredrik Hagelin, 2014. Report for Bothnian Green Logistic Corridor (BGLC) 2014. KTH Report TRITA-TSC-RR 14-013.

Marshalling yards and feeder transports for new operators; Germany and Austria. Armando Carrillo Zanuy, 2014. KTH Report TRITA-TSC-RR 14-011

Godstransporter 2014-2030-2050 – Analys av godsflöden, järnvägens produkter och produktionssystem. Bo-Lennart Nelldal and Jakob Wajsman (Trafikverket), 2015. KTH report TRITA-TSC RR 15-003.

TET F4. Rail freight corridors

Researchers: Bo-Lennart Nelldal
Hans Boysen

Source of funding: European Union FP7

Duration: 2010–2014

KTH Railway Group has been involved in multiple Rail Freight Corridor projects, the most important are summarized here.

SCANDRIA. Scandinavian-Adriatic Corridor for Growth and Innovation – aims to improve transport possibilities and increase the exchange between Scandinavia and northern Germany in a manner that is sustainable in the long term. KTH Railway Group has analysed operational and infrastructure standards 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. Most important is a high capacity transport corridor via the fixed links on the Fehmarn Belt that are due for completion in 2024.

Bothnian Green Logistic Corridor (BGLC). The overall objective of BGLC is to increase 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. KTH Railway group has been contributed with analysis and proposals for future rail corridor standards and also a capacity analysis of the iron ore line between Kiruna and Narvik. This project was finalized 2014.

COINCO II Cross-border freight Transports by rail, Oslo-Gothenburg-Copenhagen-Hamburg – Challenges and opportunities. Train traffic in Sweden has seen very positive development but cross-border traffic has not developed as positively. This means that on the Oslo-Gothenburg-Copenhagen route, the railway has a very small share of the market despite high volumes and long distances suitable for rail. The aim of the project was to describe the technical and administrative problems that exist that can be related to freight transportation over national borders, primarily between Sweden and Norway and Denmark and to propose how they can be solved.

In addition to technical problems at border crossongs, for example different loading gauges and axle loads, administrative problems can also constitute an obstacle. These may for example be in the form of different brake regulations and vehicles needing to be approved to operate in another country. Proposals for how the problems can be reduced or eliminated have been drawn up. This project was finalized 2014.

Scandria Railway Corridor Performance. Baltic Sea Region Project 26, Scandinavian Adriatic Corridor for Growth and Innovation. Bo-Lennart Nelldal and Hans Boysen, 2012.

Scandria report 2012-09-07.

Cross-border freight transports by rail, Oslo-Gothenburg-Copenhagen-Hamburg – Challenges and opportunities. Bo-Lennart Nelldal, Hans Boysen, 2014. KTH Report TRITA-TSC RR 14-006.

Gränsöverskridande godstransporter på järnväg Oslo-Göteborg-Köpenhamn-Hamburg - Utmaningar och möjligheter (for COINCO II). Bo-Lennart Nelldal, Hans Boysen, 2014. KTH Report TRITA-TSC RR 14-001.

General model of railway transportation capacity. Hans Boysen. 13th International Conference on Design and Operation in Railway Engineering (Comprail), New Forest 2012.

Quicker meets, heavier loads and faster empties – effects on transportation capacity and cycle time. Hans Boysen, 2013. 10th International Heavy Haul Conference (IHHA), New Delhi 2013.

Øresund and Fehmarnbelt high-capacity rail corridor standards. Hans Boysen. 12th International Railway Engineering Conference, London 2013.

TET F8. TRANSFORUM – Possibilities to realise the goals in the EU's White Paper

Researchers: Jonas Åkerman (MISTRA KTH)
Bo-Lennart Nelldal

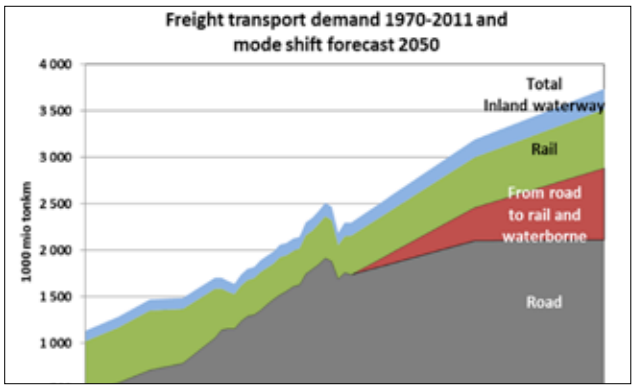
Source of funding: EU

Duration: 2013-2015

TRANSFORUM is an EU project that focuses on how to realise four of the ten goals in the EU White Paper. The aim was to outline roadmaps for achieving these goals and formulate policy recommendations to be submitted to the European Commission and other key actors. A series of workshops will be organised to pinpoint significant recommendations. The aim is to look at challenges, barriers and key trends in relation to Goal 3 of the White Paper:

"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, facilitated by efficient and green freight corridors. To meet this goal will also require appropriate infrastructure to be developed."

It is the prerequisites to reach these goals which will has been examined by the freight group, and which ended up with a final seminar with stake-holders in Brussels 2014-12-08 and for final reports of which one for freight.



TRANSFORuM has been dealing with how to implement EUs target to shift to rail and waterborne transports up to 2030-2050.

Long Distance Freight Roadmap TRANSFORuM Deliverable D2.6 2014-12-08

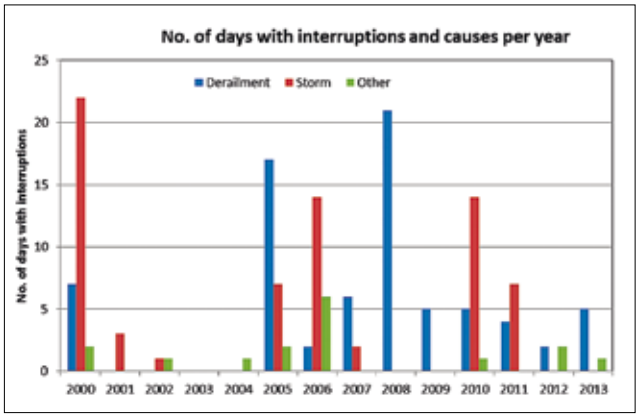
TET F9. Major traffic interruptions on Sweden's railways 2000-2014 and their impact for customers

Researcher: Bo-Lennart Nelldal

Source of funding: Swedish National Transport Administration (Trafikverket) via WSP

Duration: 2013-2015

In recent years, major disruptions and interruptions in the railway system lasting one or more days have been increasingly common due among other things to extreme weather conditions resulting from the climate crisis.
No overall statistics have been found on major traffic interruptions. KTH has therefore made a survey of these interruptions between 2000 and 2013. This has been updated with data from 2014.



In the period 2000-2014 an average of 4.2 interruptions a year thus lasted 5 days and affected approximately 60 freight trains. These appear to have increased in particular after 2005, mainly for two reasons: derailments and extreme weather conditions. Derailments have increased as a consequence of increased traffic and thereby increased wear and backlogged maintenance. The extreme weather conditions have increased due to the climate crisis.

Information provided by the company also confirms the picture given by the survey of major traffic interruptions in Sweden. A special investigation has been made of the cost for a big customer of the interruption in the rail system. This show very high cost because of customer income losses as a consequence of to late or missed delivery of goods.

In 2015 this study will be completed with analyses of major traffic interruptions for passenger traffic.

Major traffic interruptions on Sweden's railways 2000-2013 and their impact for transportation customers. Bo-Lennart Nelldal, KTH report 2013-07-01.

Större trafikavbrott vid Sveriges järnvägar 2000-2013 och dess effekter på transportkunderna. Bo-Lennart Nelldal, KTH Report 2013-07-01.

Större trafikavbrott vid Sveriges järnvägar – Preliminär redovisning för 2014. Bo-Lennart Nelldal KTH PM 2015-03-17.

TET F10. Freight transportation by rail – stage 2 measure

Researcher: Hans Boysen

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2013-2015

Stage 2 measures for freight transportation involves using existing infrastructure more efficiently without any major investments. A high, rectangular loading gauge is of crucial importance for intermodal transportation on the railway. 2.6 m width is sufficient for intermodal loads and certain other loads, such as packaged lumber, and this generally faces very few obstacles. When a trailer is loaded onto a railway wagon, height is the main constraint. Trailers of 4.5 m height, as are permitted on the highways in Sweden, Norway, France, the UK and Ireland, when loaded onto a European-standard pocket wagon of 0.33 m pocket height project to 4.83 m above top of rail, corresponding to the international gauge P/C 450 (2.60 m x 4.83 m).

Only a limited part of Sweden's railway network has so far been approved for regular traffic with the P/C 450 intermodal gauge, and only as a sub-set where loading gauge C is allowed. A review by the KTH Railway Group on the other hand showed that a large portion of the railway

network can permit loading gauge P/C 450 and an even greater proportion if a few obstacles are removed. These obstacles are in most cases minor and can therefore be considered Stage 2 measures.

Developing larger loading gauges for Europe. Hans Boysen, 10th World Congress on Railway Research, Sydney 2013.

Entwicklung größerer Lademaße für Europa. Hans Boysen, Eisenbahntechnische Rundschau (ETR), July+August 2014.

TET F11. Transportation by rail for the forest industry

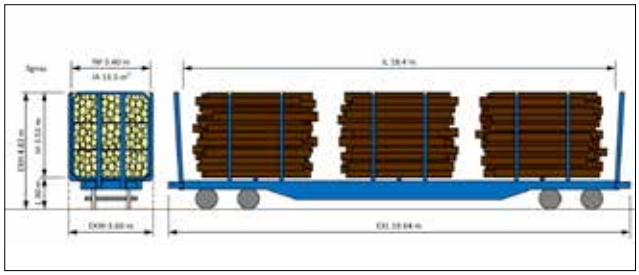
Researcher: Hans Boysen

Source of funding: The Swedish Forest Industries Federation (Skogsindustrierna) and Swedish National Transport Administration (Trafikverket)

Duration: 2015

Logs and pulpwood are one of the five dominating commodity groups carried by rail in Sweden. An investigation is made of the prerequisites for the transportation of logs by rail: existing track standards in the dominating corridors and existing wagons.

Many of those corridors where large flows of logs are carried are already upgraded for 25 tons axle load and loading gauge C. This creates the prerequisites for more efficient transportation of logs, with higher payload per wagon than what is now carried.



Of the wagons now used to transport logs, the majority are designed for 22.5 tons axle load. All of the wagons with large log bunks (SR12 or TVP) exceed loading gauge A, but none of them fully uses loading gauge C.

By using both 25 tons axle load and loading gauge C the payload per wagon and per train can be raised compared to with the wagons used presently. A new log wagon is proposed: Sgnss for 25 tons axle load of an existing design, equipped with log bunks SR14 of a new design. This way the payload per wagon can be raised from 67 tons to 78 tons, i.e. +16%. The payload per metre length and per train can be raised correspondingly, where the train is constraining.

The same wagon, Sgnss for 25 tons axle load, is judged suitable also for the transportation of wood chip, biofuel and paper in containers. For paper in containers the payload per wagon would increase from 58.6 tons to 70 tons, i.e. +19%. The payload per metre length and per train can also be raised correspondingly, where the train length is constraining.

More efficient transportation of logs by rail with 100-ton wagons. Hans Boysen. Report, 2015.

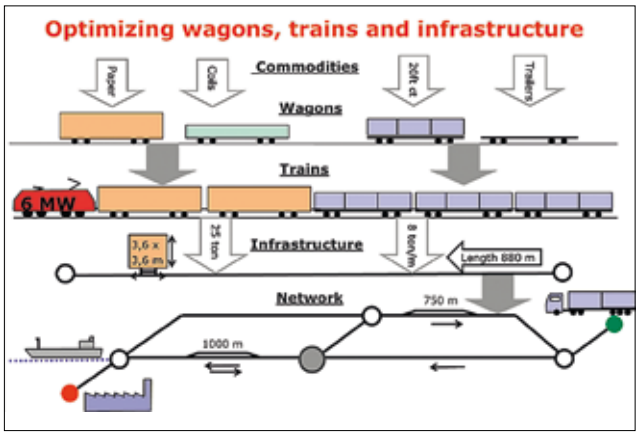
TET 12. - Green Freight Train – Roadmap for rail and intermodal freight transportation

Researchers: Bo-Lennart Nelldal
Oskar Fröidh

Source of funding: VINNOVA

Duration: 2012-2014

The purpose of HCT for the railways/Gröna Godståget (Green Freight Train) is to draw up a programme to develop more efficient transport systems where the railway constitutes a high-capacity transport mode of high quality. It contributes to improving trade and industry's transportation possibilities and to customers choosing the railway and intermodal transport to a greater extent. Since the railway has low energy consumption and emissions per transported unit and these can also be reduced further, this contributes to a reduction in energy consumption and emissions both from the railway itself and from the transport system as a whole. Greater capacity also often leads to lower cost per transported unit.



In 2014 KTH finalised a programme for research and demonstration projects for future freight transportation by rail together with the stakeholders, the rail industry, customers and other universities. KTH will continue with this and apply for funds to implement research, development and demonstration projects.

Roadmap for development of rail and intermodal freight transportations – High Capacity Transport for rail - Green Freight Train. Bo-Lennart Nelldal, 2013. KTH report TRITA-TSC-RR 13-006.

Färdplan för utveckling av godstransporter på järnväg och kombitransporter – High Capacity Transports för järnväg – Gröna godståget. Bo-Lennart Nelldal, 2013. KTH report TRITA-TSC-RR 13-005.

Effektiva gröna godståg – Åtgärder för ökad kvalitet, kapacitet och minskad kostnad. Bo-Lennart Nelldal, 2013. KTH report TRITA-TSC-RR 13-004.

TET F13. Capacity4Rail (C4R)

Researchers: Bo-Lennart Nelldal
Behzad Kordnejad
Hans Boysen

Source of funding: European Union FP7

Duration: 2013–2017

KTH Railway Group is participating in the Capacity 4 Rail project which is paving the way towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050. The aim is to specify the future railway technologies and systems and will contribute to the development of guidance documents identifying further actions to be taken and the future technologies and systems to be developed.

Project coordination is International Union of Railways (UIC) and 49 partners from major stakeholders of Industry, Infrastructure managers, Railway Undertakings, Engineering and Academic sciences are participating. At KTH divisions of TET, REV and SB participate in this project. KTH Railway Group at TET are dealing with the following work packages (WP):

WP 2.1: Progress beyond State of the Art on Rail Freight Systems (KTH is project leader)

WP 2.2: Novel rail freight vehicles

WP 2.3: Co-modal transhipment and interchange/logistics

WP 2.4: Catalogue of specifications

WP 3.2: Simulation and models to evaluate enhanced capacity

Capacity4Rail is dealing with technical and operational improvements of the freight rail system to reach EU:s white paper targets of shift to rail. One critical question is if there will be an incremental or system change of the freight wagons

TET F14. Sustainable and energy efficient regional logistics in the Greater Stockholm area

Researcher: Behzad Kordnejad, KTH, in cooperation with the Transport Research Institute (TfK)

Source of funding: Swedish Energy Agency (Energimyndigheten)

Duration: 2015-2016

The study explores the possibilities of shifting regional flow of goods in the Greater Stockholm and Mälardalen area from road to sea and rail transport and in that way increasing the energy efficiency of transport. It maps the extent of import and export flows to and from the ports of the region can be transported in the region on the sea or on the railway. Maritime systems as may be appropriate can be based on e.g. motor barges that are currently used in inland shipping in the continental Europe. It can be supplemented with rail shuttles between ports and inland terminals, which are then tied together with regional flow of goods on the railway. Such trimodalt regional logistics systems can contribute to a transition to a more environmentally friendly transport through improved energy efficiency and reduced emissions.

The project is a continuation of the completed project 'Regional combi transport - a system study in Mälardalen'. The project is designed as a pilot study funded by the Swedish Energy Agency and run together with Transport Research Institute (TfK) and among industry players include the Coop Logistics, ICA, Jernhusen, M4, Mälarhamnar, Port of Oxelösund, Ports of Stockholm and Södertälje and Thor Shipping.

PASSENGER TRANSPORT AND CUSTOMER PREFERENCES

TET P1. Green Train market prerequisites, passenger valuations and service concepts

Researchers: Oskar Fröidh
Jennifer Warg
Karl Kottenhoff

Source of funding: Swedish National Transport Administration (Trafikverket).

Duration: 2005–2013

The aim of the Green Train (Gröna tåget) research and development programme is to strengthen Swedish competence in developing a technical platform for tomorrow's generation of high-speed trains interoperable in Scandinavia. The TET part in Gröna Tåget was focused on market prerequisites, passenger valuations and service concepts.

In this part of the 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).

Within this project, an evaluation was made in 2013 of customers' valuation of active lateral suspension (ALS) and active vertical suspension (AVS). AVS and ALS increases comfort and enables faster running on non-perfect tracks. Trials have been carried out operating a non-tilting Regina train equipped with ALS/AVS between Stockholm and Hallsberg.

As an application of the wide-body Green Train concept, the "Scandinavian Express Loop" of a combined day and night-train is analysed. The Green Train gives better possibilities to design a comfortable and efficient day and night-train.

An onboard passenger valuation study during a Green Train test run. Photo: Oskar Fröidh

Körtidsberäkningar för Gröna tåget. Analys av tågkonfigurationer. Hans Sipilä, 2010. KTH Railway Group publication 0802.

Resande och trafik med Gröna tåget. Oskar Fröidh, 2010. KTH Railway Group publication 1001.

Green train. Basis for a Scandinavian high-speed train concept. Final report, part A. Oskar Fröidh, 2012. KTH Railway Group publication 12-01.

Kapacitetsanalys av Södra stambanan. Hans Sipilä and Jennifer Warg, 2012. KTH Railway Group publication 1203.

Comfort evaluation of active secondary suspension. Oskar Fröidh, Karl Kottenhoff and Jennifer Warg, 2013. KTH Railway Group publication 13-03.

Tågtrafiken Stockholm-Östersund-Trondheim med en elektrifierad Meråkersbana - Scandinavian Express Loop i ett långsiktigt perspektiv. Bo-Lennart Nelldal, 2013. KTH Report TRITA-TEC-RR 13-008.

Green Train: concept and technology overview. E. Andersson, O. Fröidh, S. Stichel, T. Bustad & H. Tengstrand, 2014. International Journal of Rail Transportation, 2 (1), pp 2-16.

Capacity for express trains on mixed traffic lines. Oskar Fröidh, Hans Sipilä and Jennifer Warg, 2014. International Journal of Rail Transportation, 2 (1), pp 17-27.

Green Train concept and interior design. Oskar Fröidh, Karl Kottenhoff & Evert Andersson, 2014. International Journal of Rail Transportation, 2 (1), pp 28-39.

TET P2. High-Speed Rail in Sweden – Supply and demand

Researchers: Bo-Lennart Nelldal
Oskar Fröidh
Jennifer Warg

Source of funding: Various

Duration: Continuous

High-speed trains have successfully been in service in Japan since 1964 and in France since 1981. The vision of the Götaland Line and the Europe Line has gradually become more distinct and in 2012 the Swedish Government gave go-ahead for construction of the first sections of new high-speed lines, the East Link from (Stockholm) Södertälje to Linköping and a section between Borås and Gothenburg as the first stretches of the Götaland line. Since 2014, planning has accelerated for a complete high-speed system Stockholm–Jönköping–Gothenburg, and from Jönköping a southward branch to Malmö with connection to Copenhagen and via the planned fixed link at the Fehmarn Belt to Hamburg.

The fundamental characteristic of high-speed trains on new main lines is that they reach a high average speed, often exceeding 200 km/h with top speeds between 300 and 360 km/h, and thus achieving competitively short journey times. When express and fast trains on the conventional lines are replaced by high-speed trains on the new main line, capacity is relieved for expanding freight train and regional train services. The punctuality is also improved by separation of slower and faster trains.

KTH Railway Group has participated in several studies and research projects concerning high-speed trains. During 2009 KTH Railway Group participated in the commission on high-speed trains appointed by the Government. In 2010-2012 we participated in a similar assessment for the Norwegian rail administration (Jernbaneverket). In 2012-2015 minor commissions for future high-speed projects including an upgraded connection Oslo–Stockholm have been performed, as well as continuous support in the planning of the Swedish high-speed system.

HSLdim (High-Speed Line dimensional speed) is a research project of which the purpose is to develop a model for calculating the optimal dimensional speed for new high-speed lines at the planning stage. The model is based on empirical construction and maintenance costs for new lines and modelled train traffic costs. The benefits of a new line are dependent on the demand for travel by high-speed

train. Demand calculations are consequently an important component of the model.

COINCO 8 Million City has presented an idea is to construct an entirely new railway for high-speed trains parallel to the existing Oslo–Gothenburg–Malmö/Copenhagen line. KTH was commissioned to make analyses, on the basis of earlier studies, of the supply of and demand for passenger and freight transportation in this corridor also included conducting a review of the forecasts made in the project.

The conclusion was that to operate high speed trains from Stockholm via Gothenburg to Malmö/Copenhagen and Oslo is not a realistic alternative compared with the planned direct high-speed line Stockholm–Jönköping–Malmö/Copenhagen and upgraded lines to 200-250 km/h Oslo–Gothenburg–Malmö/Copenhagen and Stockholm–Oslo. The forecast model which has been used in the project could not be used to evaluate the combination of different lines. To resolve these problems, a new forecast model with both domestic and international travel, must be further developed, see project TET P3.

Höghastighetsbanor i Sverige, Trafikprognoser och samhällsekonomiska kalkyler med Samvips-metoden för utbyggda stambanor och separata höghastighetsbanor. Includes summary in English: High-speed lines in Sweden Traffic forecasts and socioeconomic calculations using the Samvips

method for expanded main lines and separate high-speed lines. Bo-Lennart Nelldal, Kjell Jansson and Chris Halldin, 2010. KTH Report TRITA-TEC-RR 10-005.

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

Europakorridoren: Kapacitet och restider (in Swedish). Oskar Fröidh and Jennifer Warg, 2013. KTH Report TRITA-TSC-RR 13-009.

The European Corridor: Capacity and journey times (in English). Oskar Fröidh and Jennifer Warg, 2014. KTH Report TRITA-TSC-RR 14-007.

Optimising design speed for new high-speed lines. Oskar Fröidh. Paper for presentation at 10th World Congress on Railway Research (WCRR), Sydney 25th – 27th November 2013.

Design speed for new high-speed lines. Oskar Fröidh, 2014. Journal of Rail Transport Planning and Management, 4, pp. 59-69.

Höghastighetståg i korridoren Oslo-Göteborg-Köpenhamn – Marknad och prognoser, with summary in English: Oslo-Gothenburg-Copenhagen corridor – Market and forecasts (for COINCO 8MC). Bo-Lennart Nelldal, 2014. KTH Report TRITA-TSC-RR 14-002.

TET P3. Development of passenger forecast models

Researchers: Bo-Lennart Nelldal
Josef Andersson
Oskar Fröidh

Source of funding: Swedish National Transport Administration (Trafikverket) and regional authorities

Duration: Continuous

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/Visum forecasting tool.

A theorethical framework has been done together with researchers from other universities and the result is presented in two reports "Towards a model for long distance passenger travel in the context of infrastructure and public transport planning".

One problem when to make projections is to produce detailed data on both the population and its regional distribution transport network and the range of public transport. In the project "Scenario-based forecasting model", a method is developed where one can make use of the data at the aggregate level, eg from sampling. Regional division that previously produced and shown to have great explanatory value are urban regions, or T-regions. By using the T-region, forecasts made at the aggregate level, which is then broken down to the disaggregated level. KTH Railway Group and WSP have previously developed a car ownership model with T-regions as a base which worked fine.

A special study has also been made of the relation between rail-air and rail-car depending on travel time.

A new project "Skandpers" has been formed together with consultancies Sweco, ÅF and Norconsult. The aim is to develop a new forecast model for travel based on the Samvips model. The background is that today´s models are not able to make reliable forecasts including international journeys between Sweden, Norway, Denmark and northern Germany, journeys with radically improved travel time, i.e. high-speed rail, intermodal journeys with rail-air, rail-car and intramodal with different trains, and scenarios with competition between operators and products for air, rail and coach (bus). This will be managed by new model. There is a need for this model to plan the Swedish high speed network as well as investigate new connections between Sweden and Norway.

Figure: On the track competition is challenging to develop better forecast models taken different products, price levels and service factors into account.

Towards a model for long distance passenger travel in the context of infrastructure and public transport planning. Staffan Algers, John Bates, Kjell Jansson, Harald Lang, Odd Larsen, Henrik Swahn, 2013. KTH Report TRITA-TSC-RR 13-013.

Descriptive and theory report for "Towards a model for long distance passenger travel in the context of infrastructure and public transport planning". Kjell Jansson, Staffan Algers, Harald Lang, Odd Larsen, Reza Mortazavi, John Bates, Andrew Daly, 2013. KTH Report TRITA-TSC-RR 13-014.

Scenariobaserad prognosmodell – förstudie. Includes summary in English: Forecast model based on scenarios. Bo-Lennart Nelldal, KTH Stehn Svalgård (WSP), 2013. KTH report TRITA-TSC-RR 13-012.

Effektsamband tåg-flyg och flyg-bil beroende på restid. Bo-Lennart Nelldal, 2015. KTH Report TRITA-TSC-RR 15-001.

TET P4. Database of supply and prices for railway lines in Sweden

Researchers: Bo-Lennart Nelldal
Josef Andersson
Oskar Fröidh
Gerhard Troche

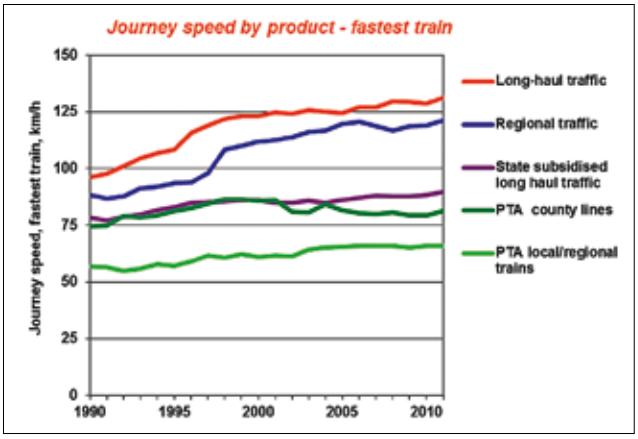
Sources of funding: The Swedish Rail Administration (Banverket) up to 2010, thereafter the agency Transport Analysis and currently the Swedish Transport Agency (Transportstyrelsen)

Duration: 1990–2015

The department of Transport Science has continuously built up a database of supply and prices for 85 railway lines in Sweden. The database now consists of the years 1990-2015 and is planned to be updated every year. The content is facts about travelling times, frequency and prices for relations for different products (i.e. high-speed, Intercity, commuter trains) for a selection of interregional and regional passenger services on rail. This database could be used in any analyses of development over time of the supply of rail services in Sweden. Some data for competing coach as well as air supply is also included.

Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2013 och Utvärdering av avreglering och konkurrens samt Utvecklingen av länshuvudmännens trafik. Bo-Lennart Nelldal, Oskar Fröidh and Gerhard Troche, 2013. KTH Report TRITA-TEC-RR 13-017.

Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2014 och Utvärdering av avreglering och konkurrens samt analys av kommersiell och planeringsstyrd trafik. Bo-Lennart Nelldal, Josef Andersson and Oskar Fröidh, 2014. KTH Report, TRITA-TSC-RR 14-008.



TET P5. Evaluation of the deregulation and competition in interregional rail services

Researchers: Bo-Lennart Nelldal
Oskar Fröidh

Sources of funding: Swedish National Transport Administration (Trafikverket), the agency Transport Analysis and currently the Swedish Transport Agency (Transportstyrelsen).

Duration: 2009–2015

The work of collecting data 1990-2015 and describing the development of supply and prices on Sweden's railway lines also includes analyses of the effects of deregulation and intramodal as well as intermodal competition in interregional rail services. It includes development of incumbent's and entrant operators' services and in relation to state and regional subsidized services.

Interregional tågtrafik i konkurrens på Västkustbanan. Oskar Fröidh och Camilla Byström, 2012. KTH Report TRITA-TSC-RR 12-004.

Competition on the tracks – Passengers' response to deregulation of interregional rail services. Oskar Fröidh and Camilla Byström, 2013. Transportation Research Part A, 56, pp. 1-10.

The impact of market opening on the supply of interregional train services. Oskar Fröidh and Bo-Lennart Nelldal, 2015. Journal of Transport Geography (accepted June)

TET P6. Peripherally located railway stations – effects for train travel and society

Researchers: Oskar Fröidh (project leader), Josef Andersson, Daniel Jonsson and Marcus Adolphson

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2014-2016

For new construction or substantial rebuilding of railways it may be necessary to consider a new station in the urban fringe (periphery) rather than in a central location. First and foremost the high construction costs and possibly intrusions in the urban landscape for centrally situated tracks and stations that are a hindrance. It is unclear what effects the peripherally located stations have had on rail travel, service to travellers and urban development compared with centrally located stations. Clarification of these effects is important for many aspects of the future rail corridors and their planning.

In the research project, 13 since 1990 new and rebuilt stations in Sweden primarily for interregional services which have received an improved supply are evaluated. Effects for the train traffic, for the society by means of localisation, workplaces and population, and for the structure of the conurbation are analysed. The results and conclusions could be used in planning of new high-speed lines and stations.

Differences in stations' attractiveness, train supply and development of the area depending of location (peripher or central) is considered. Photo: Oskar Fröidh

CAPACITY ANALYSIS AND SIGNALLING

TET C1. Congested infrastructure

Researcher: PhD student Anders Lindfeldt

Supervisors: Bo-Lennart Nelldal, Lars-Göran Mattsson and Markus Bohlin

Source of funding: Swedish National Transport Administration (Trafikverket)

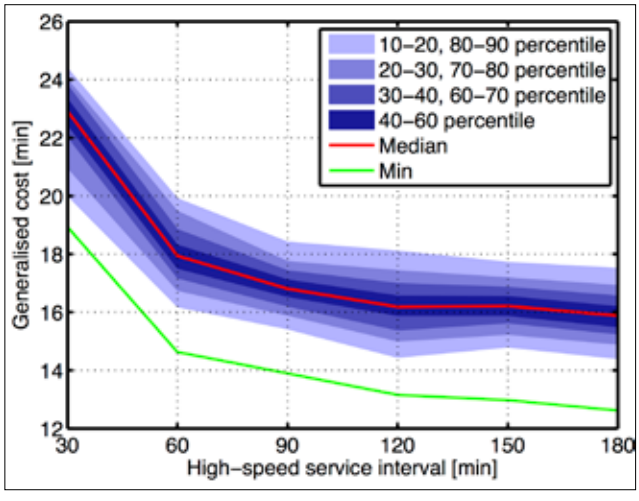
Duration: 2009-2015

The load on the Swedish rail network is increasing and parts of the rail network have been declared to be overloaded. The purpose of the project is to analyse what the capacity limit for rail traffic is under different prerequisites.

In this project the symptoms and underlying behaviour of congestion on railways are analysed and discussed. The sensitivity of the railway system rises as the capacity utilisation increases. At some point the marginal gain of operating one extra train is lower than the costs in term of increased sensitivity to delay, i.e. maximum capacity has been reached.

Several different methodologies are employed to analyse capacity. The first uses real data from the Swedish rail network, train operation and delays to analyse how different factors influence available capacity and delay creation. Several useful key performance indicators are defined to describe capacity influencing properties of the infrastructure and the rail traffic.

The second approach employs the railway simulation tool RailSys in extensive simulation experiments. This methodology is used to analyse the characteristics of double track operation. Simulation of several hundred scenarios are conducted to analyse the influence of traffic density, timetable speed heterogeneity, primary delays and inter-station distance on secondary delays and used timetable



Generalised cost as a function of service interval for the high-speed services on a line with mixed traffic.

allowance. The analysis gives an in-depth understanding of the mechanisms behind the performance of a double track.

A simulation model for strategic capacity evaluation, TigerSim is developed that can be used to speed up and improve capacity planning and evaluation of future infrastructure designs and timetables on double track railway lines. For a given infrastructure and plan of operation, the model can be used to generate and simulate thousands of timetables. This gives two major advantages:

- Using many timetables makes results general
- It is possible consider both static and dynamic properties of the timetables in the capacity analysis.

The first aspect is especially useful in the evaluation of future scenarios when the timetable often is unknown. The second is an advantage since typically an improvement in capacity is measured in a combination of increased frequency of service, shorter travel time and reduced delays. The output of the model can either be used to directly determine capacity from a quality of service perspective, or used as input to cost-benefit analysis (CBA).

This project will be finalised 2015 with a doctoral thesis.

Congested railways–Influence of infrastructure and timetable properties on delay propagation. Anders Lindfeldt, 2015. KTH Licentiate Thesis TRITA-TSC-LIC 12-005.

Railway capacity analysis – Methods for simulation and evaluation of timetables, delays and infrastructure. Anders Lindfeldt, 2015. KTH Doctoral Thesis TRITA-TSC-PHD 15-002

TET C2. Timetable planning with simulation

Researcher: PhD student Hans Sipilä

Supervisors: Bo-Lennart Nelldal, Oskar Fröidh

Sources of funding: Swedish National Transport Administration (Trafikverket) and SJ

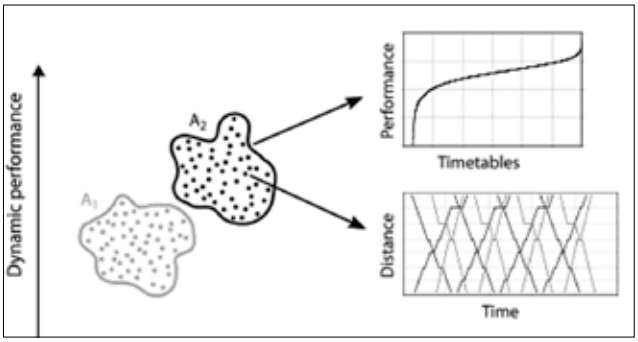
Duration: 2009-2015

As railway traffic increases, the infrastructure is being used more intensively and after deregulation more operators want to use the tracks, which increase 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.

Timetable changes with respect to allowances and buffer times are applied on a real case on the Stockholm-Gothenburg line in Sweden in order to see how the on-time performance is affected for high-speed passenger trains. The potential benefit is that increased allowances and buffer times will decrease the probability of train interactions and events where the scheduled train sequence is changed. The on-time performance improves when allowances are increased and when buffer times concerning high-speed trains are adjusted to at least five minutes in locations with potential conflicts. This has also been implemented in Sweden.

Setting up simulations, especially in large networks, can take significant amount of time and effort. Considering train registration data in Sweden, the separation in primary and secondary delays is not straightforward. A method has been developed that uses the basic train registration data to compile distributions of run time deviations for different train groups in a network. Applied on the Stockholm-Malmö line a reasonable good fit was obtained.

A method for capturing the variance in freight train operations is proposed, partly based on the findings from the aforementioned study. Instead of modeling early freight



Concept for analysing performance measures for multiple timetables on different infrastructure and/or train frequency scenarios.

trains on time, the true initiation distributions are applied on time-shifted freight trains.

A method for reducing the uncertainties by making assumptions of future conditions is proposed. It is based on creating combinatorial departure times for train groups and locations and formulating the input as nominal timetables to RailSys. The dispatching algorithm implemented in the software can then be utilized to provide feasible, conflict-managed, timetables which can be evaluated.

To facility the use of the infrastructure as a variable, an infrastructure generator has been developed which makes it relatively easy to design different station layouts and produce complete node-link structures. This method is useful when multiple scenarios are studied and the assumptions on timetables consist of departure intervals for train groups and their stop patterns.

This project was finalised 2015 with a doctoral thesis.

Simulation of rail traffic – Applications with timetable construction and delay modelling. Hans Sipilä, 2012. KTH Licentiate Thesis TRITA-TSC-LIC 12-003.

Simulation of rail traffic – Methods for timetable construction,delay modeling and infrastructure evaluation. Hans Sipilä, 2015. KTH Doctoral Thesis TRITA-TSC-PHD 15-001.

TET C3. Development of time-table strategies

Researcher: PhD student Jennifer Warg

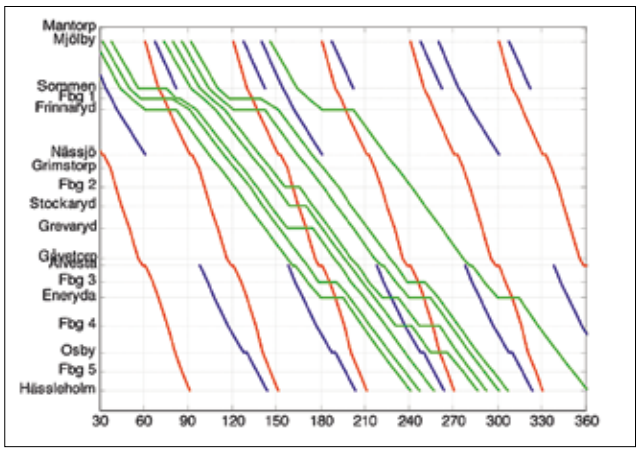
Supervisors: Markus Bohlin, Oskar Fröidh

Sources of funding: KTH Railway Group

Duration: 2012-2018

The intention of this project is to evaluate the results of simulations in the form of benefits and costs for travellers, transportation customers and railway companies of implementing various measures. This would make it possible to calculate the socioeconomic benefit and choose between different measures. The primary aim is to develop a method to evaluate timetable measures and then infrastructure measures where investment costs also come into the picture.

As regards benefits, there is a connection with research on evaluations made at KTH regarding for example the value of travelling time, frequency of service and delays. The linkages between business-economic costs through the cost models that have for example been developed in the Gröna tåget and freight transportation models are also part of this. A connection with the forecasting models developed with the Samvips method is also possible.



Effects of increased traffic and speed on capacity of a highly-utilized railway. Jennifer Warg, 2012. 13th International Conference on Design and Operation in Railway Engineering (Comprail), New Forest, UK.

Economic evaluation of time table strategies with simulation. Jennifer Warg, 2013. 10th World Congress on Railway Research (WCRR) Sydney, Australia.

The use of railway simulation as an input to economic assessment. Jennifer Warg and Markus Bohlin, 2015. 6th International Conference on Railway Operations Modelling and Analysis - RailTokyo2015. 23-26 March, Tokyo, Japan.

TET C4. Analysis of capacity and punctality 2008-2012

Researcher: Anders Lindfeldt

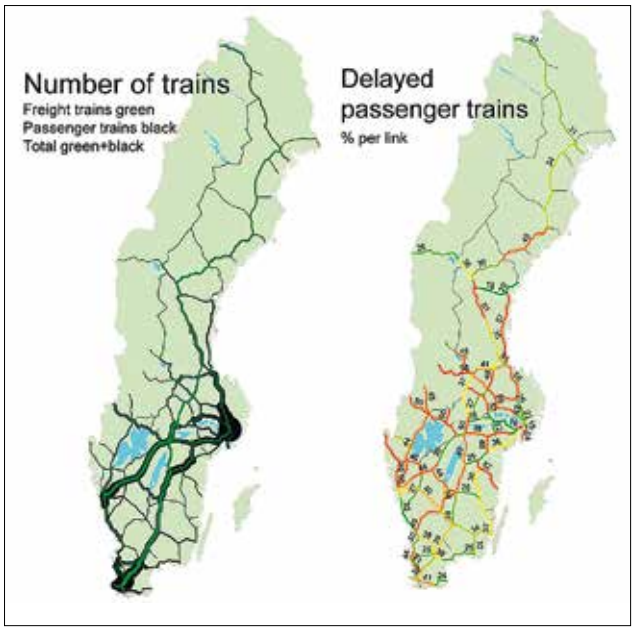
Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2013

In 2009 KTH was commissioned by the Swedish Transport Administration to conduct a major project called ”Capacity analysis of the rail network in Sweden”. A sub-project developed a database of timetable data, delay data, BIS and traffic statistics for 2008. A large number of measures of capacity utilisation were devised and calculated for all links in the Swedish railway network. Examples include speed mixing, delays per 100 km, mean train size and mean train length of freight trains. These were also shown on maps with colour codes to indicate the loadings on the different links.

A lot has happened on the railway since 2008. Traffic has increased but delays have also caused serious problems during certain periods. In 2013, KTH therefore received a grant from the Swedish Transport Administration to update this database and analyse the changes that had taken place between 2008 and 2012. The purpose is to refine the analyses. The analyses are also intended to constitute one of the bases for the National Audit Office’s study of the capacity planning process.

Bearbetning och analys av databas över infrastruktur, trafik, tidtabell och förseningar with summary in English: Processing and analysis of a database of infrastructure, traffic, timetables and delays. Anders Lindfeldt, 2010. KTH Report TRITA-TEC RR 10-03.



TET C5. Development of methods for capacity analysis

Researchers: Anders Lindfeldt
Hans Siplila
Jennifer Warg
Bo-Lennart Nelldal

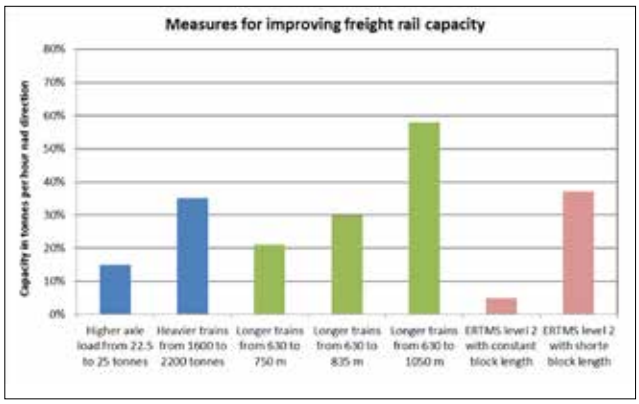
Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2013-2014

KAJT – Kapacitet i JärnvägsTrafiken – is an industry-specific programme for interaction between the academic world, authorities and the railway industry. Two collaborative projects within KAJT was a pilot study of measures, effects, market and strategic decisions on infrastructure and traffic operation together with VTI and SICS with the aim to create a common methodology for processing and analysing delay statistics and capacity utilisation. The other project was a pilot study on follow-ups, capacity planning, simulation and traffic control in collaboration with BTH, SICS and UU. The aim is to follow up a train plan with the help of models for optimisation, simulation and decision support.

KAJT Förstudie: Uppföljning, kapacitetsplanering, simulering och trafikstyrning (FUKS) – KTH del 2: Förseningsmått. Jennifer Warg och Bo-Lennart Nelldal, 2014. KTH PM 2014-04-28.

KAJT Förstudie: Förbättrad analys av förseningsdata med hjälp av RailSys. Anders Lindfeldt och Hans Sipilä, 2014. KTH PM 2014-04-28.



There are different measures to improve the capacity of a railway line.

TET C6. Analysis of track access charges and the rail market

Researchers: Bo-Lennart Nelldal
Jakob Wajsman (Trafikverket)

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2013-2015

Together with the Swedish Transport Administration, Railway Group KTH has evaluated different alternatives for changes in track access charges in Sweden. Databases and models have been built up for this purpose and have been used in several studies.

The project will describe the development of track access charges over the past 10 years alongside the development of the railway's market over the same period. The development of capacity utilisation and punctuality will also be described. Finally, a number of different scenarios for track access charges will be developed and possible consequences for capacity utilisation will be described

Järnvägens marknad och banavgifterna - Utvecklingen av järnvägssektorn och scenarier för framtida banavgifter. Bo-Lennart Nelldal, Jakob Wajsman (Trafikverket), 2014. KTH Report TRITA-TSC-RR 14-005.

TET C7. Future rail vehicle maintenance and depots – research roadmap

Researchers: Oskar Fröidh
Anders Lindahl
Mats Berg

From Chalmers University, Gothenburg: Ann-Brith Strömberg, Michael Patriksson and Anders Ekberg (Charmec)

From University of Gothenburg, School of Business, Economics and Law: Lars Brigelius

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2013–2015

As a consequence of the expansion and deregulation of train traffic, a number of new depots have been built and more are planned. Knowledge of how maintenance can be carried out and how depots can be designed and situated is limited. Localization of depots affects the railway network's capacity and operational costs.

TÅGAB's depot in Kristinehamn. Photo: Oskar Fröidh

The Swedish Transport Administration, however, wishes to increase knowledge of depots and maintenance and is seeking to build up research in this area. KTH Railway Group has therefore been commissioned to lead the work of developing a research programme in this area. The work has been done in collaboration with Chalmers and the School of Business, Economics and Law at the University of Gothenburg.

Färdplan för ökad forskning och innovation inom underhåll av järnvägsfordon. Editors: Oskar Fröidh and Anders Lindahl, 2015. KTH PM 2015-06-10

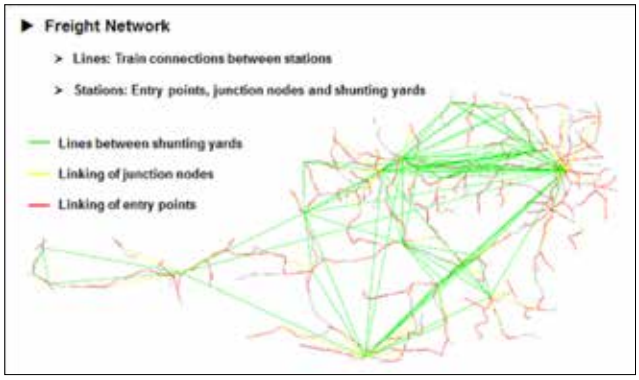
TET C8. Capacity analysis in a network perspective

Researchers: Oskar Fröidh
Ary Silvano

Source of funding: Swedish National Transport Administration (Trafikverket)

Duration: 2014-2015

Capacity analysis in network aims to develop a method to analyze the capacity of the rail network and not just the link-level which is usually done now. Network analysis can be used to improve the quality of transport as a tool for national traffic, differentiated track access charges, where trains can take different routes and to drive extra long freight trains and diversion of trains at major disruptions. In stage 1 the simulation tool, Nemo, was implemented using data of infrastructure, freight wagonload production system and freight transportation volumes (Samgods).



Modelled freight network in Austria. Source: IVE

Proposal for further analysis in the main study and use of Nemo as a possible planning tool for the Swedish Transport Administration was presented in the stage 1 report.

Related to this project, a background report to the Swedish Government Official Report "Fossilfri fordonsflotta" (approximately Vehicles independent of oil) was produced in 2012-2013. The results show that considerably more freight can be transported by rail than is carried today and what the Swedish Transport Administration has calculated in its base forecasts for 2030 and 2050. However, freight traffic will have less space on the tracks as passenger traffic expands especially on the main lines. Various measures can be considered to handle freight traffic. Standard factors like higher axle loads and greater bearing capacity (load/metre) a larger loading gauge and longer and heavier freight trains are essential to increase efficiency and reduce energy consumption and transport costs, but also traffic flows in the network. To cope with freight traffic over and above the base forecast (+50% and +100%, respectively), extra investment is needed in the most important freight corridors, mainly in extended crossing and passing tracks and marshalling yards for train lengths of 1,000 and 2,000 metres and some double-track sections.

Godstrafik på järnväg - åtgärder för ökad kapacitet på lång sikt. Oskar Fröidh, 2013. KTH report TRITA-TSC-RR 13-003.

Kapacitetsanalys i ett nätverksperspektiv. Etapp 1 – implementering av Nemo. Oskar Fröidh och Ary P. Silvano, 2015. KTH PM 2015

TET C9. Prestudy – Cause and effects for the maintenance of railways

Researcher: Oskar Fröidh, Josef Andersson and SICS

Source of funding: Swedish National Transport Administration (Trafikverket)

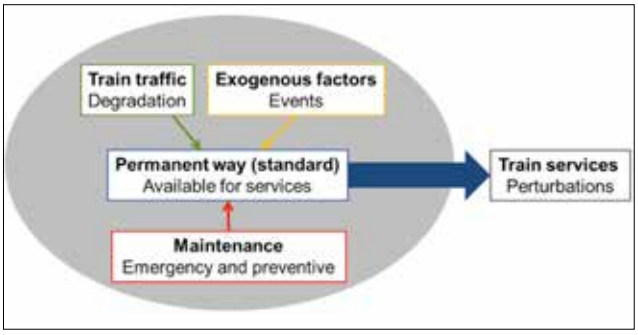
Duration: 2015

The need for better management of track maintenance of the network managed by Trafikverket has been debated for many years. Few infrastructure breakdowns are necessary to achieve good punctuality of rail services. By estimate effect relationship between maintenance operations and traffic disruptions, resources can be used more efficiently

and the balance between planned (preventive) maintenance and emergency (repair) maintenance can be done to create minimal impact on rail traffic.

The prestudy inventoried data access and data quality, based on the data and conditions that Trafikverket posses.

Förstudie: Effektsamband för underhåll av järnväg. Oskar Fröidh and Josef Andersson, 2015. KTH PM 2015 (final version pending)



TET C10. Programme for research and innovation in signalling systems

Researchers: Gustaf Lindström
Anders Lindahl

Source of funding: VINNOVA

Duration: 2012-2013

Sweden has been among the leaders as regards signalling systems for track-bound traffic. One example of this is the international ERTMS system for railway traffic where Sweden has played a prominent role. The aim of this project is to draw up an agenda for research and innovation for future cooperation within a future innovation platform. . A number of different organisations have participated in the project SICS, VTI, Bombardier and the Swedish Transport Administration. A proposed agenda has been drawn up as a basis for future research.

Strategisk F&I-agenda - Signalsystem för Spårtrafik. Jan Ekman, SICS, Peter Feltenmark, Bombardier, Magnus Kårström, Trafikverket, Anders Lindahl, KTH och Gustaf Lindström, KTH, 2013. KTH report 2013-03-31.

TET C11. Procurement and implementation of complex signalling systems – work processes and tools

Researcher: Gustaf Lindström
Anders Lindahl
Project leader: Ragnar Hedström, VTI

Source of funding: VINNOVA

Duration: 2015

The aim of this project is from a base of established knowledge and new development create a process and tools that handle procurement and implementation of complex signalling systems in a structured way. The intention is also to make clear which actors (disciplines) to be involved in the process chain, as well as their roles and responsibilities which are of importance to keep the expected time frame, budget and system functionality. Further on, to define work processes and tools that enable a client organization achieve the objectives of functionality, time and budget for innovation procurement.

The assessment is that there is great potential for developing innovative processes and tools for the implementation of complex systems, in this case rail signalling through cross-border constellations where respective discipline's expertise and experience considered from a systemic and holistic perspective. The developed methodology will use open solutions and allow for continuous updating of technology. This increases the chances for robust and reliable infrastructure within the rail-based public transport system which is very important for its attractiveness.

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