Running gear for freight wagons

Simulation of wheel-on-rail deterioration phenomena

Modelling of rail vehicles dynamics

Track stiffness, irregularities and maintenance

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

Robust safety systems of trains

Simulation of energy consumption and running time of trains

Train formation management and monitoring (TIMM)

Crosswind stability and unsteady aerodynamics in vehicle design

Gröna Tåget – Programme Management

Gröna Tåget – Track-friendly bogies

Gröna Tåget – High-speed vehicles with carbody tilt

Gröna Tåget – Sound quality of external railway noise

Gröna Tåget – Energy consumption

Gröna Tåget – Active lateral suspension

Gröna Tåget – Overhead power systems for operation of high-speed trains in Sweden

Collaboration in research and development of new curriculum in sound and vibration (CIRCIS)

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

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

Lightweight carbody for high-speed trains

Wheel profile for freight wagons in Sweden

Modelling contact in the wheel-rail interface

Make Rail The Hope for protecting Nature (MARATHON)

The sustainable freight railway (SUSTRAIL)

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

Track irregularities and vehicle response

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

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

Grey boxes indicate terminated projects.
<p>| SB  | Loads and Load Influence on Structures | SB  | Development and Implementation of Monitoring Systems for Increased Safety and Improved Operation and Maintenance of Railway Bridges | EP  | New converter topologies for electric railway traction | ME  | Track-vehicle interaction (SAMBA 6) – Wheel rail wear mechanisms and transitions |
|-----|--------------------------------------|-----|----------------------------------------------------------------------------------------------------------------======|-----|------------------------------------------------------|-----|------------------------------------------------------------------------------------------------|
| SB  | Long-term Monitoring and Assessment of Bridges | SB  | Development of Methodology for LCC and LCA of Railway Bridges | EP  | Dual system locomotives for rail freight transportation/ Drive cycles for freight locomotives | ME  | Adhesion between railway wheel and rail |
| SB  | A study of the dynamic interaction between train and bridge and the long-term changes in the dynamic properties of the new Årsta bridge | ME  | Efficient Assessment Methods of the Dynamic Response of Existing Railway Bridges to High-speed Trains | EP  | System aspects of Permanent magnet traction motors | ME  | Airborne particles generated from train-track interaction |
| SB  | Sustainable bridges | SB  | Train-track-bridge interaction | EP  | Train information Management and Monitoring (TIMM) | ME  | Block brakes during winter conditions |
| SB  | Soil-Structure Interaction for Integral Bridges and Culverts | SB  | Controlled dynamic field tests for accurate assessment of railway bridges to higher train speeds | EP  | Dynamic maintenance, Planning and Scheduling for Train Operation, DUST | ME  | Quiet track |
| SB  | Dynamic response of railway bridges subjected to high-speed trains | SB  |  | EP  | Railway Power Supplies with new converter and system topologies | ME  | Models for rail traffic emission factors (ME4) |
| SB  | BRIDCAP – Increased load capacity of existing bridges on corridors | SB  |  |  |  |  |  |
| SB  | Enhanced Fatigue Evaluation of Old Steel Railway Bridges | ME  | GREY BOXES INDICATE TERMINATED PROJECTS |  |  |  |  |</p>
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**MW**

MARCUS WALLENBERG LABORATORY FOR SOUND AND VIBRATION RESEARCH

- MW1: Gröna Tåget – noise and vibration part
- MW2: Electromagnetic noise generation

Grey boxes indicate terminated projects.
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 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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Research groups 2015

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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 Ödeen, 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.

<table>
<thead>
<tr>
<th>Division of Rail Vehicles</th>
<th>Division of Structural Engineering and Bridges</th>
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<tbody>
<tr>
<td>Mats Berg  070-652 24 41  <a href="mailto:mabe@kth.se">mabe@kth.se</a></td>
<td>Raid Karoumi  08-790 90 84  <a href="mailto:raid.karoumi@byv.kth.se">raid.karoumi@byv.kth.se</a></td>
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<tr>
<td>Anders Lindahl  08-790 80 95  <a href="mailto:anders.lindahl@abe.kth.se">anders.lindahl@abe.kth.se</a></td>
<td>Stefan Östlund  08-790 77 45  <a href="mailto:stefan.oestlund@ee.kth.se">stefan.oestlund@ee.kth.se</a></td>
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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 Kollektivtrafiks system, bussar och spårtrafik, gk (7,5 hp)
Public Transport Systems, Buses and Rail, BC

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

AH2029 Järnväg signalteknik –信号システム (7,5 hp)
Railway Signalling System, Basic Course

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

Division of Structural Engineering and Bridges

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 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

AF2203 Brokonstruktion fk (7,5 hp)
Bridge Design, Advanced Course

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

17. Jerker Sundström: Difficulties to read and write under lateral vibration exposure – Contextual studies of train passengers’ ride comfort, 2006.


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.


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

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
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.


Comparison between measured and simulated results...
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.


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


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.


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.


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,
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,
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,
Brabie D and Andersson E: High-speed Train Derailments -
Minimizing consequences through innovative design. World
Congress of Railway Research (WCRR’08), Seoul, Korea, May
Brabie D and Andersson E: Vehicle features minimizing
consequences of a train derailment. 15:e Nordiska seminariet för
Brabie D and Andersson E: Analysis of vehicle features
influencing train derailment processes and consequences.
38.Tagung Moderne Schienenfahrzeuge, Graz, September
2008. Also published as proceedings in ZEVrail, Vol 132 (2008),
Tagungsband SFT.
Brabie D and Andersson E: An overview of some high-speed
train derailments - means of minimizing consequences based on
empirical observations. Journal of Rail and Rapid Transit, Vol
222, p 441-463, 2008.
Brabie D and Andersson E: On minimizing derailment risks
and consequences of passenger trains at higher speeds. Journal of

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.

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.


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, AzZound, 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 Täget, 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.

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

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: Lateral stability of high-speed trains at unsteady


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.


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.


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.


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


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”.

In 2012 a new PhD student, Alireza Qazizadeh, started

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


**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.


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

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.
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


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.**
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.


RV21. Wheel profile for freight wagons in Sweden

<table>
<thead>
<tr>
<th>Project leader</th>
<th>Sebastian Stichel</th>
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<tr>
<td>Scientists</td>
<td>Carlos Casanueva</td>
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<td>Per-Anders Jönsson</td>
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<td>Sebastian Stichel</td>
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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.
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.

**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, SLT, Tägoperatörerna, 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...
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: 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.


**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
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.


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.


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 Nellldal, 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.](image-url)
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 carboilds, 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

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:


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:


SB3. A study of the dynamic interaction between train and bridge and the long-term changes in the dynamic properties of the new Årsta bridge

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:


**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:


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

Researchers  
Håkan Sundquist  
Lars Pettersson  
Costin Pacoste  
Jean-Marc Battini  
Abbas Zangeneh  
Eşra Bayoğlu  
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:


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

Researchers
Raid Karoumi
Andreas Andersson
Mahir Ulker-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:


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:


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:

- 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:

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

Researchers
Raid Karoumi
Igancio 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., Ulker-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.

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:

- 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.


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

Researchers
Raid Karoumi
Costin Pacoste
Andreas Andersson
Christoffer Svedholm (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:


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:


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


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.

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.
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

EP1. 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
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 snubbed VSC; Design of a high-voltage cyclo-converter including gate-drives for series-connection of devices and finally system issues and applications.


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

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.


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, 2599-2601, 2008,


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.


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, 2599-2601, 2008,


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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, 2599-2601, 2008,


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

Researchers Stefan Östlund PhD stefan.ostlund@ee.kth.se 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.
EP 3. System aspects of Permanent magnet traction motors

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

Source of funding/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.

EP 4. Train Information Management and Monitoring (TIMM)

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


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
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
lars.abrahamsson@ee.kth.se

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


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 Ångqvist KTH, Häkan 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,

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.

RESEARCH PROJECTS

ME1. 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 all 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 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, 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, and Olofsson U, Relating contact temperature and wear transitions 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.

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


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 g6/02/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-


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


ME4. Block brakes during winter conditions

Project leader: Ulf Olofsson
Research engineer Peter Carlsson

Source of funding 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.

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 from 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.


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 into simulation models that can be used to predict the amount of particle emissions from different driving conditions.

Publications 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

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 Neldal, 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

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RESEARCH PROJECTS

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 consequences for the customers are that they will lose the whole or a part of the income for their goods.


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.


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.


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

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 crossings, 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.

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 EU’s target to shift to rail and waterborne transports up to 2030-2050.

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 customers.

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.
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.


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.

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.


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


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
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 theoretical 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.


**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.

**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.


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.

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.


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**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 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 facilitate 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.


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.


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.
TET C5. Development of methods for capacity analysis

Researchers:  Anders Lindfeldt
Hans Sipilä
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.


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.


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).

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.


Modelled freight network in Austria. Source: IVE

### 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

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


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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