

Publication 20–02

KTH Railway Group

Status Report 2020





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

RV RAIL VEHICLES		RV RAIL VEHICLES		RV RAIL VEHICLES		RV RAIL VEHICLES	
RV1	Running gear for freight wagons	RV10	Gröna Tåget – Programme Management	RV19	Technology opportunities and strategies toward climate-friendly transport (TOSCA)	RV28	New dependable rolling stock for a more sustainable, intelligent and comfortable rail transport in Europe (Roll2Rail)
RV2	Simulation of wheel-on-rail deterioration phenomena	RV11	Gröna Tåget – Track-friendly bogies	RV20	Lightweight carbody for high-speed trains	RV29	Onboard condition monitoring of vehicle-track dynamic interaction
RV3	Modelling of rail vehicles dynamics	RV12	Gröna Tåget – High-speed vehicles with carbody tilt	RV21	Wheel profile for freight wagons in Sweden	RV30	Innovative technical solutions for improved train DYNAMics and operation of longer FREIGHT Trains (DYNAREIGHT)
RV4	Track stiffness, irregularities and maintenance	RV13	Gröna Tåget – Sound quality of external railway noise	RV22	Modelling contact in the wheel-rail interface	RV31	Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles (RUN2RAIL)
RV5	Dynamic instability and discomfort of high-speed trains due to aerodynamics in tunnels	RV14	Gröna Tåget – Energy consumption	RV23	Make Rail The Hope for protecting Nature (MARATHON)	RV32	Performance Improvement for Vehicles On Track (PIVOT-1 and PIVOT-2)
RV6	Robust safety systems of trains	RV15	Gröna Tåget – Active lateral suspension	RV24	The sustainable freight railway (SUSTRAIL)	RV33	IMPACT-1 and IMPACT-2
RV7	Simulation of energy consumption and running time of trains	RV16	Gröna Tåget – Overhead power systems for operation of high-speed trains in Sweden	RV25	Planning tool for energy-saving loading strategy for intermodal freight trains	RV34	Future Improvement for Noise and Energy (FINE-1 and FINE-2)
RV8	Train formation management and monitoring (TIMM)	RV17	Collaboration in research and development of new curriculum in sound and vibration (CIRCIS)	RV26	Track irregularities and vehicle response	RV35	Real time information applications and energy efficient solutions for rail freight (FR8HUB)
RV9	Crosswind stability and unstaedy aerodynamics in vehicle design	RV18	Railway vehicle dynamics and track interactions: Total regulatory acceptance for the interoperable network (DynoTRAIN)	RV27	Towards an affordable, rsilient, innovative and high-capacity European Railway System för 2030/2050 (Capacity4Rail)		GREY BOXES INDICATE TERMINATED PROJECTS

RV RAIL VEHICLES		SB STRUCTURAL ENGINEERING AND BRIDGES		SB STRUCTURAL ENGINEERING AND BRIDGES		EP ELECTRIC POWER ENGINEERING	
RV36	Research into enhanced track and switch and crossing system 2 (IN2TRACK-2)	SB1	Loads and Load Influence on Structures	SB11	Development and Implementation of Monitoring Systems for Increased Safety and Improved Operation and Maintenance of Railway Bridges	EP1	New converter topologies for electric railway traction
RV37	NEXT generation methods, concepts and solutions for the design of robust and sustainable running GEAR (NEXTGEAR)	SB2	Long-term Monitoring and Assessment of Bridges	SB12	Development of Methodology for LCC and LCA of Railway Bridges	EP2	Dual system locomotives for rail freight transportation/ Drive cycles for freight locomotives
RV38	Development of Functional Requirements for Sustainable and Attractive European Rail Freight (FR8RAIL)	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	SB13	Efficient Assessment Methods of the Dynamic Response of Existing Railway Bridges to High-speed Trains	EP3	System aspects of permanent magnet traction motors
RV39	Digitalization and Automation of Freight Rail (FR8RAIL-2)	SB5	Sustainable bridges	SB14	Train-track-bridge interaction	EP4	Train information Management and Monitoring (TIMM)
RV40	Economic priorities that enable reliable and attractive railway transportations	SB6	Soil-Structure Interaction for Integral Bridges and Culverts	SB15	Controlled dynamic field tests for accurate assessment of railway bridges to higher train speeds	EP5	Dynamic maintenance, Planning and Scheduling for Train Operation, DUST
		SB7	Dynamic response of railway bridges subjected to high-speed trains	SB17	Risk- and reliability-based assessment of existing steel bridges	EP6	Railway Power Supplies with new converter and system topologies
		SB8	Bridge Weigh-in-motion for railway bridges	SB18	IN2TRACK2 WP5	EP7	AC/AC Modular Multilevel Converters for Railway Applications
		SB9	BRIDCAP – Increased load capacity of existing bridges on corridors			EP8	Silicon carbide based power electronics for electric trains
		SB10	Enhanced Fatigue Evaluation of Old Steel Railway Bridges				
GREY BOXES INDICATE TERMINATED PROJECTS							

ME
MACHINE ELEMENTS
(DEPT OF MACHINE DESIGN)

TPL
TRANSPORT PLANNING

TPL
TRANSPORT PLANNING

TPL
TRANSPORT PLANNING

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

TPL F2
 Regional intermodal transport systems – Analysis and case study

TPL F21
 FR8RAIL III WP2: Real-time network management

TPL P11
 Operating costs for high-speed trains (THHT)

ME 2
 Adhesion between railway wheel and rail

TPL F13
 Capacity4Rail (C4R)

TPL F22
 FR8RAIL III WP3: Intelligent video gate / Demogate

TPL P12
 Delays' impact on demand on train journeys – a time series analysis (DeDe)

ME 3
 Airborne particles generated from train-track interaction

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

TPL P2
 High-Speed Rail in Sweden – Supply and demand

TPL C3
 Development of timetable strategies

ME 4
 Block brakes during winter conditions

TPL F15
 City logistics with pilot study of Tomtebodavägen yard

TPL P4
 Database of supply and prices for railway lines in Sweden

TPL C12
 Major traffic interruptions and major delays

ME 5
 Quiet track

TPL F16
 ARCC WP2: Real-time yard management

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

TPL C13
 The railway market and the track access charges

ME 6
 Models for rail traffic emission factors

TPL F17
 FR8HUB WP3: Real-time network management and simulation of increasing speed for freight trains

TPL P7
 Travelling flows on the Swedish rail network

TPL C14
 Flexåter

TPL F18
 FR8HUB WP4: Intelligent video gate

TPL P8
 Uppkomm 1 – Tendered and commercial rail services on the same track

TPL C15
 KAIN – Capacity in networks

TPL F19
 FR8RAIL II WP3: Real-time network management and improved methods for timetable planning

TPL P9
 Uppkomm 2 – Mixed rail market dynamics

TPL C16
 PLASA

TPL F20
 FR8RAIL II WP5: Freight Automation

TPL P10
 Economics of the future passenger train fleet

TPL C17
 PLASA 2 Smart planning and virtual certification

GREY BOXES INDICATE TERMINATED PROJECTS

TPL TRANSPORT PLANNING		JOB SOIL AND ROCK MECHANICS	
TPL C18	ERTMS Long-term development	JOB 1	Compaction of embankments for high-speed railway
TPL C19	Mathematical methods for greater signalling system safety	JOB 2	Simulation of ballast and embankment fill
TPL ISE C18	Fail-Safe Train Positioning	JOB 3	Transition zones
TPL ISE C19	Wireless Communications for Railways	JOB 4	Evaluation of railway track stiffness by static plate load tests
TPL NSE C20	Formal Modelling of Security in Safety Critical Systems		

MW
MARCUS WALLENBERG
LABORATORY FOR
SOUND AND VIBRATION
RESEARCH

MW 1	Gröna Tåget – noise and vibration part
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MW 2	Electromagnetic noise generation
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GREY BOXES INDICATE
TERMINATED PROJECTS



KTH Railway Group in 2020

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 railway 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 regulated by an agreement between KTH, the Swedish Transport Administration (Trafikverket), Bombardier Transportation, Region Stockholm (formerly SLL), SJ AB and the consultant companies Atkins (formerly SNC-Lavalin) and SWECO.

KTH Railway Group is a multidisciplinary research centre with a holistic approach. It consists of ten 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 programmes 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 at increasing the efficiency and the competitiveness of the railway transport 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.

The Railway Group is very international. We are involved in about ten Shift2Rail projects where we work together with basically all European stakeholders as vehicle suppliers, infrastructure managers, train operators, universities and consulting companies. The amount of scientific exchange with partner universities in Europe, USA, China, Australia, India, Thailand and Indonesia is continuously increasing.

The KTH Railway Group is also very active in railway education and training. We teach railway students in mechanical, civil and electrical engineering. We offer a two-year master programme in Vehicle Engineering (Road and Rail). In the autumn of 2018 a new master programme in Railway Engineering in cooperation with the University of

Illinois at Urbana-Champaign (UIUC) was inaugurated. Students enrolled at KTH spend one semester at UIUC and vice versa. The Railway Group is regularly arranging training courses for engineers in industry and train operators/infrastructure managers.

Research on and investments in railways are more important than ever. The effects of climate change become more and more visible. Rail transport is and will remain the most environmentally friendly means of transport. The European Commission has proposed designating 2021 as the European Year of Rail. We are helping Trafikverket with investigations into offering better night train services from Sweden to e.g. Berlin, Brussels or Paris. Our university urges us all to reduce CO₂ emissions from our business travels. The terrible Corona pandemic hopefully can lead to a more powerful rethinking of transport, which, however, will put high demands on future railway systems. Let us all together take on the challenge. This report hopefully can inspire you with the variety of activities that are described. If you have any questions, do not hesitate to contact me or any other member of the KTH Railway Group.

September 2020

Professor Sebastian Stichel
Director



Professor Sebastian Stichel,
Director of the KTH
Railway Group

The Board 2020

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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Henrik Tengstrand, Mats Berg, Roger Lundén, Mats Jonsson, Sebastian Stichel, Anders Lindahl, Raid Karoumi, Emma Selén, Kristina Frölander, Christer Löfving,
Not present on photo: Susanne Rymell, Magnus Forsén, Pia Lagerlöf, Håkan Andersson, Tohmmmy Bustad, Stefan Östlund, Björn Westerberg, Uday Kumar

Research groups 2020

SCHOOL OF ENGINEERING SCIENCES

Rail Vehicles – Professor Mats Berg

The Marcus Wallenberg Laboratory for Sound and Vibration Research – PhD Ulf Carlsson

Lightweight Structures – Associate Professor Per Wennhage

SCHOOL OF ARCHITECTURE AND THE BUILT ENVIRONMENT

Transport Planning – Associate Professor Oskar Fröidh

Structural Engineering and Bridges – Professor Raid Karoumi

Soil and Rock Mechanics – PhD Carl Wersäll

SCHOOL OF INDUSTRIAL ENGINEERING AND MANAGEMENT

Systems and Component Design – Professor Ulf Olofsson

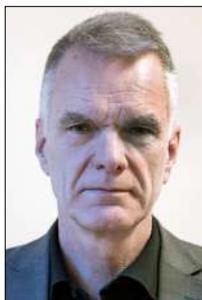
SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Electric Power and Energy Systems – Professor Stefan Östlund

Information Science and Engineering – Professor Mats Bengtsson

Network and Systems Engineering – Professor György Dán

The Board members 2020



Christer Löfving



Emma Selén



Susanne Rymell



Mats Berg



Anders Lindahl



Raid Karoumi



Mats Jonsson



Tohmy Bustad



Stefan Östlund



Henrik Tengstrand



Roger Lundén



Sebastian Stichel

Not present on photo: Magnus Forsén, Pia Lagerlöf, Håkan Andersson, Björn Westerberg, Uday Kumar

Railway Education at KTH Railway Group

Four of the KTH Railway Group's research groups are involved in railway related educational programmes and courses, i.e. Rail Vehicles, Transport Planning, Structural Engineering and Bridges, and Electric Power Engineering. These contribute to many different educational programmes, with a strong specialization at Master level in the form of four subsystem-specialised programmes (Vehicle Engineering, Civil and Architectural Engineering, Transport and Geoinformation Technology, Electric Power Engineering) and one transversal system-perspective programme (Railway Engineering).

Key importance of Education in Railway Systems

Railway Education is of strategic importance for the society as it creates a dynamic workforce in a sector that is intrinsically working towards the UN Sustainable Development Goals. The effort of KTH Railway Group towards this societal challenge has led to the start of the new master programme in Railway Engineering in 2018, in collaboration with RailTEC at the University of Illinois in Urbana Champaign (UIUC). Together, the two universities provide leading expertise in Railway Systems research and education.

The programme offers a unique railway systems education where graduates are prepared for working in a global industry, administrations and research institutions active in Railways with a broad systems perspective.

A complete and organic education

The courses in the Railway Group are carried out in a variety of formats and levels, offering a unique overall perspective of the different specialization areas and their mutual interaction and influence. Bachelor, Master, and PhD programmes in different subjects can take advantage of the multidisciplinary integral to the KTH Railway Group for creating highly dynamic courses with up to date content and easy access to adjacent disciplinary areas.

Seamless coupling to the professional life

The Railway Group actively works towards maintaining a strong coupling with the different companies, public authorities and research centres that work in the Railway Sector. In the undergraduate and graduate courses there are many opportunities to interact with partners in the form of study visits or invited industry lectures, but the strongest coupling happens when carrying out a Bachelor or Master Thesis.

The continuous work towards a highly skilled workforce also happens in the form of training for company development. These personalised courses are given on request from companies by each of the research groups, tailored for the actual needs of the specific company.

Rail Vehicles Carlos Casanueva https://www.kth.se/profile/carlosc	Structural Engineering and Bridges Raid Karoumi https://www.kth.se/profile/raidk
Railway Traffic Planning Anders Lindahl https://www.kth.se/profile/lindahl	Electrical Machines & Power Electronics Stefan Östlund https://www.kth.se/profile/stefano

Railway Programmes in 2020-2021

There are a number of 5-year programmes (Civilingenjörsutbildning) leading to education in railways. From those, a student can take the following Specializations/Master Programmes:

Rail Vehicles

2-year MSc Vehicle Engineering
2-year MSc Railway Engineering

Built Environment

2-year MSc Civil and Architectural Engineering
2-year MSc Transport and Geoinformation Technology
2-year MSc Railway Engineering

Electrical Engineering

2-year MSc Electric Power Engineering

Railway Courses in 2020-2021

Division of Rail Vehicles

SD2221 Vehicle System Technology (8 hp)
SD2307 Rail Vehicle Technology (7,5 hp)
SD2313 Rail Vehicle Dynamics (8 hp)

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

AH1025 Kollektivtrafiksystem, bussar och spårtrafik, gk (7,5 hp)
AH2026 Railway Traffic - Market and Planning, Basic Course (7,5 hp)
AH2028 Railway Traffic - Market and Planning, Advanced Course (7,5 hp)
AH2029 Railway Signalling System, Basic Course (7,5 hp)

AH2031 Railway Signalling System - Project Planning (7,5 hp)

Division for Road and Rail Engineering

AF2901 Road- and Railway Track Engineering (7,5 hp)
AH1908 Anläggning 2. Byggnad drift och underhåll av vägar och järnvägar (7,5 hp).

Division for Structural Engineering and Bridges

AF2011 Structural Dynamics for Civil Engineers (7,5 hp)
AF2201 Bridge Design (7,5 hp)
AF2203 Bridge Design, Advanced Course (7,5 hp)

Division for Electric Power Engineering

EJ2400 Electric Traction (6 hp)

Training courses

In the springs of 2016, 2018 and 2019 the KTH Railway Group gave an overview rail system course for persons working in the rail business. On average there were about 60 participants at these seven-day courses. A course was also planned for the spring of 2020, but was postponed by one year.

KTH Railway Group has also contributed to the annual training courses of Nordisk Banteknisk Ingenjörutbildning (NBIU) och Nordisk Elektroteknisk Ingenjörutbildning (NEIU).

Special educational events

- 2019, Visit to SJ depot in the context of SD2307 Rail Vehicle Technology course
- 2019, Visit to the Nordic Rail in Jönköping for the students in the different Railway related programmes.
- 2019, organization of railway related career promotion activities for 1st cycle students in construction engineering at KTH, coordinated by JBS.
- 2018 and 2019, collaboration in the Järnvägsbranschens Mastermessa at KTH, coordinated by JBS.

Special events and achievements

Railway Group Spring seminars

How can digitalisation and automation make railways more efficient? Oct 2020

The European railway system of 2050: What is needed and how can Shift2Rail contribute? 2019

Effektiva tågssystem för godstransporter 2.0. Strategier, forsknings- och innovationsbehov när digitalisering och automatisering av transporterna skapar nya möjligheter. 2018

Framtidens infrastruktur och transporter – utmaningar och möjligheter i den nya nationella transportplanen för 2018–2029. 2017

Höghastighetsbanor i Sverige – Utmaningar och möjligheter. 2016

Järnvägens organisation – ett lyft för järnvägen. 2015

Keynote presentations on conferences

International Seminar of Railroad Bridge & Track Interaction, Seoul 2019. Recent research in railway bridge dynamics. R. Karoumi

11th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems (CM 2018), Delft 2018. Wear and RCF prediction based on improved contact mechanics modelling. S. Stichel, C. Casanueva, M. Berg

1st International Conference on Rail Transportation, Chengdu 2017. Integrated wheel and rail damage prediction using vehicle-track dynamic simulations. M. Berg, C. Casanueva, R. Enblom, S. Stichel

General and best paper awards

Research on intelligent compaction by Carl Wersäll – IVA's 100 list 2020 (Royal Swedish Academy of Engineering Sciences)

Best paper (rail) at 26th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks (IAVSD2019). Gothenburg 2019. V. Krishna, S. Hossein-Nia, S. Stichel. New methodology to estimate costs due to rail wear & RCF w.r.t. running gear.

Norman Weik, Jennifer Warg, Ingrid Johansson, Nils

Nießen and Markus Bohlin: Extending UIC 406-based capacity analysis – New approaches for railway nodes and network effects. Selected as a top 10 best paper at RailNorrköping 2019.

In 2016 Ulf Olofsson received the IMechE John F Alcock Memorial Prize for work regarding block brakes during winter conditions.

SAGE Best Paper Prize 2015 of Journal of Rail and Rapid Transit. Validation of simulation models in the context of railway vehicle acceptance. O. Polach, A. Böttcher, D. Vannucci, J. Sima, H. Schelle, H. Chollet, G. Götz, M. G. Prada, D. Nicklisch, L. Mazzola, M. Berg, M. Osman

Guest researchers

Outgoing

Mats Berg, Sebastian Stichel and Carlos Casanueva, key members of the academic exchange project Railway Engineering System Dynamics with Southwest Jiaotong University, 2016-2020

Sebastian Stichel, Adjunct professor at Beijing Jiaotong University, 2017-2020

Carl Wersäll, guest researcher at University of Tokyo for 2 months in 2019

Incoming

Xu Ning, Assistant professor from Beijing Jiaotong University at KTH for one year in 2020.

María D. Martínez-Rodrigo, Associate Professor from Universitat Jaume I, Spain, at KTH for half year 2019.

Pedro Museros Romero, Professor from Universitat Politècnica de València, Spain, at KTH for half year 2019.

Zhang Lele, professor from Beijing Jiaotong University at KTH for one month in 2017.

Ren Zunsong, professor from Beijing Jiaotong University at KTH for one month in 2017.

Reports related to the new high-speed lines in Sweden

KTH Railway Group has carried out several studies on the technical and economical viability of dedicated high-speed railways in Sweden. Some of them are mentioned below.

Report *Nya stambanor till lägre kostnader* (in Swedish), 2016.

Report *Höghastighetsbanor – en investering för hållbart resande och godstrafik* (in Swedish), 2019.

https://kth.diva-portal.org/smash/record.jsf?dswid=8543&pid=diva2%3A1357442&c=3&searchType=SIMPLE&language=en&query=Nelldal&af=%5B%5D&aq=%5B%5B%5D%5D&aq2=%5B%5B%5D%5D&aqe=%5B%5D&noOfRows=50&sortOrder=datelssued_sort_desc&sortOrder2=title_sort_asc&onlyFullText=false&sf=all

Report *Analys av prognoser för nya stambanor och jämförelse med internationella erfarenheter av höghastighetståg* (in Swedish), 2019.

https://kth.diva-portal.org/smash/record.jsf?dswid=8543&pid=diva2%3A1287535&c=2&searchType=SIMPLE&language=en&query=Nelldal&af=%5B%5D&aq=%5B%5B%5D%5D&aq2=%5B%5B%5D%5D&aqe=%5B%5D&noOfRows=50&sortOrder=datelssued_sort_desc&sortOrder2=title_sort_asc&onlyFullText=false&sf=all

Report *Varför behövs Nya Stambanor i Sverige?* (in Swedish), 2020.

https://kth.diva-portal.org/smash/record.jsf?dswid=8543&pid=diva2%3A1391407&c=3&searchType=SIMPLE&language=en&query=Nelldal&af=%5B%5D&aq=%5B%5B%5D%5D&aq2=%5B%5B%5D%5D&aqe=%5B%5D&noOfRows=50&sortOrder=author_sort_asc&sortOrder2=title_sort_asc&onlyFullText=false&sf=all

Promotions

In 2019 Oskar Fröidh was promoted to Associate Professor in Railway Systems

In 2019, Markus Bohlin was appointed Full Professor in Computer Science with focus on Artificial Intelligence at Mälardalen University. Markus was subsequently accepted as Visiting Professor at KTH Transport Planning.

In 2018 Carlos Casanueva was promoted to Associate Professor in Rail Vehicle Technology.

Faculty opponent or evaluation committee for PhD

2020 Markus Bohlin, Second supervisor (Zweitgutachter) Norman Weik, RWTH Aachen.

2019 Mats Berg, evaluation committee of Annemieke Meghoe, University of Twente, Enschede

2019 Carlos Casanueva, evaluation committee of Mandeep Singh Walia, Chalmers, Gothenburg.

2019 Sebastian Stichel, evaluation committee of Xin Li, Chalmers, Gothenburg.

2018 Sebastian Stichel, Second supervisor of Frédéric Schöler, RWTH Aachen.

2018 Sebastian Stichel, Second supervisor of Christof Bernsteiner, TU Graz.

2017 Sebastian Stichel, Second supervisor of Ulrich Spangenberg, University of Pretoria.

2017 Sebastian Stichel, evaluation committee of Ivan Zenzerovic, Chalmers, Gothenburg.

2016 Mats Berg, evaluation committee of Petter Røe Nåvik, NTNU, Trondheim.

2016 Mats Berg, evaluation committee of Seyed Milad Mousavi Bideleh, Chalmers, Gothenburg.

2016 Sebastian Stichel, Second supervisor of Gero Zechel, TU Dresden.

2016 Sebastian Stichel, evaluation committee of Matthias Asplund, LTU, Luleå.

2016 Mats Berg, evaluation committee of Peter Persson, LTH, Lund.

2016 Mats Berg, evaluation committee of Behrouz Afzali-Far, LTH, Lund.

2015 Sebastian Stichel, evaluation committee of Kalle Karttunen, Chalmers, Gothenburg.

2015 Sebastian Stichel, Second supervisor of Holger Gemeiner, TU Berlin.

International Conference host

Markus Bohlin acted as Program Chair and Johan Högdahl as Program Co-Chair for RailNorrköping 2019.

Editorial board member of international journals

Journal of Rail and Rapid Transit: Carlos Casanueva (associate editor) and Mats Berg

Vehicle System Dynamics: Mats Berg

International Journal of Rail Transportation: Mats Berg (associate editor)

International Journal of Railway Technology: Sebastian Stichel and Ulf Olofsson

Journal of Railway Engineering Science: Sebastian Stichel (associate editor) and Raid Karoumi

Handbook co-authorship

Handbook of Railway Vehicle Dynamics, 2nd edition, CRC Press, 2020. S. Stichel, M. Berg and U. Olofsson co-authored three chapters.

Special issue co-authorship

WEAR special issue of CM2015 conference: Mats Berg and Sebastian Stichel

KTH Railway Group in media 2019 and 2020

Bo-Lennart Nelldal - Transport Planning

<https://www.nyteknik.se/opinion/visioner-duger-inte-som-underlag-for-framtidens-transporter-6971553>

<https://www.svt.se/nyheter/utebliven-effekt-for-tagavgift>

<http://www.affarsresenaren.se/2019/07/03/dags-att-krossa-myterna--42820496>

<https://www.transportochlogistik.se/20190803/6506/transportforum-sa-kan-transporter-flyttas-fran-lastbil-till-tag>

<https://www.dn.se/ekonomi/hogastighetstag-trafikverket-stoppade-kalkyl-som-gynnade-utbyggnad/>

<https://www.trafikverket.se/resa-och-trafik/trafikinformation/punktlighet-i-tagtrafiken/Tillsammans-for-tag-i-tid/nyhetsarkiv-tillsammans-for-tag-i-tid/2019/sjalvkritik-och-omtag-pa-jarnvagsbranschens-resultatkonferens/>

<http://www.europakorridoren.se/sv/blogg/med-nya-stambanor-prioriterar-vi-ett-langsiktigt-hallbart-samhalle-2/>

<https://www.vagabond.se/artiklar/nyheter/20200203/taget-punktligare-an-flyget/>

<https://sverigesradio.se/sida/gruppsida.aspx?programid=83&grupp=3692&artikel=7343376>

<https://www.gp.se/nyheter/sverige/experterna-oense-om-h%C3%B6ghastighetsbanornas-l%C3%B6nsamhet-l.22362777>

<https://bothniamkorridor.com/sv/2019/06/25/ner-pa-jorden-igen-kan-flyget-klara-konkurrensen-fran-snabbare-tag/>

<https://omni.se/straffavgift-for-tagbolag-har-inte-haft-nagon-effekt/a/JoRoy7>

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Oskar Fröidh - Transport Planning

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Karl Kottenhoff - Transport Planning

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Gerhard Troche - Transport Planning

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Raid Karoumi – Structural Engineering and Bridges

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Stichel/Berg/Andersson - Rail Vehicles

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Photo: Stefan Nilsson



PhD theses at the KTH Railway Group 1995–2020

1. Anders Nordborg: Vertical rail vibrations - Noise and structure-born sound generation, 1995.
2. Raid Karoumi: Response of Cable-Stayed and Suspension Bridges to Moving Vehicles, Analysis methods and practical modeling techniques, 1998,
3. Karl Kottenhoff: Evaluation of passenger train concepts – methods and results of measuring travellers' preferences in relation to costs, 1999.
4. Eckart Nipp: Permanent magnet motor drives with switched stator windings, 1999.
5. Johan Förstberg: Ride comfort and motion sickness in tilting trains – Human responses to motion environments in train and simulator experiments, 2000.
6. Pelle Carlbon: Carbody and passengers in rail vehicle dynamics, 2000.
7. Romain Haettel: Vibration Transmission in Plate Structures - Special Application to Train Car Bodies, 2000
8. Björn Kufver: Optimisation of horizontal alignments in railways – Procedures involving evaluation of dynamic vehicle response, 2000.
9. Lars Hall: Simulations and analyses of train-induced ground vibrations. A comparative study of two- and three-dimensional calculations with actual measurements, 2000.
10. Robert Hildebrand: Countermeasures Against Railway Ground and Track Vibrations, 2001
11. Piotr Lukaszewicz: Energy consumption and running time for trains – Modelling of running resistance and driver behaviour based on full scale testing, 2001.
12. Per Wennhage: Structural-Acoustic Optimization of Sandwich Panels. 2001
13. Peter Kjellqvist: Modelling and design of electromechanical actuators for active suspension in rail vehicles, 2002.
14. Gerard James: Analysis of Traffic Load Effects on Railway Bridges., 2003,
15. Tanel Telliskivi: Wheel-Rail Interaction Analysis, 2003
16. Oskar Fröidh: Introduction of regional high-speed trains – A study of the effects of the Svealand line on the travel market, travel behaviour and accessibility, 2003.
17. Mehdi Bahrekazemi: Train-Induced Ground Vibration and Its Prediction, 2004.
18. Staffan Norrga: On soft-switching isolated AC/DC Converters without Auxiliary Circuit, 2005.
19. Rickard Nilsson: On wear in rolling/sliding contacts, 2005
20. Jerker Sundström: Difficulties to read and write under lateral vibration exposure – Contextual studies of train passengers ride comfort, 2006.
21. Ben Diedrichs: Studies of two aerodynamic effects on high-speed trains: Crosswind stability and discomforting car body vibrations in tunnels, 2006.
22. Roger Enblom: On simulation of uniform wear and profile evolution in the wheel-rail contact, 2006.
23. Nizar Chaar: Wheelset structural flexibility and track flexibility in vehicle-track dynamic interaction, 2007.
24. Per-Anders Jönsson: Dynamic vehicle-track interaction of European standard freight wagons with link suspension, 2007.
25. Dan Brabie: On derailment-worthiness in rail vehicle design – Analysis of vehicle features influencing derailment processes and consequences, 2007.
26. Christoffer With: Train-Induced Vibrations on Embankments and in Buildings - Prediction and Validation of Some Models, 2008.
27. Eric Berggren: Railway track stiffness – Dynamic measurements and evaluation for efficient maintenance, 2009.
28. Gerhard Troche: Activity-based rail freight costing – A model for calculating transport costs in different production systems, 2009.
29. Tommy Kjellqvist: On design of a compact primary switched conversion system for electric railway propulsion, 2009.
30. Esra Bayoglu Flener: Static and dynamic behaviour of soil-steel composite bridges obtained by field testing, 2009.
31. Johan Wiberg: Railway bridge response to passing trains. Measurements and FE model updating, 2009.
32. Jon Sundh: On wear transitions in the wheel-rail contact, 2009.
33. Olov Lindfeldt: Railway operational analysis. Evaluation of quality, infrastructure and timetable on single track and doubletrack lines with analytical models and simulation. 2010.

34. Andreas Andersson: Capacity assessment of arch bridges with backfill: Case of the old Årsta railway bridge, 2011.
35. Rickard Persson: Tilting trains – Enhanced benefits and strategies for less motion sickness, 2011.
36. Anneli Orvnäs: On Active Secondary Suspension in Rail Vehicles to Improve Ride Comfort, 2011.
37. Lars Abrahamsson: Optimal Railroad Power Supply System Operation and Design, 2012.
38. David Wennberg: Multi-Functional Composite Design Concepts for Rail Vehicle Car Bodies, 2013.
39. Dirk Thomas: On rail vehicle dynamics in unsteady crosswind conditions - Studies related to modelling, model validation and active suspension, 2013.
40. Saeed Abbasi: Towards Elimination of Airborne particles from rail traffic, 2013.
41. Yi Zhu: Adhesion in the Wheel-Rail Contact”, 2013.
42. Mahir Ülker-Kaustell: Essential modelling details in dynamic FE-analyses of railway bridges, 2013.
43. John Leander: Refining the fatigue assessment procedure of existing steel bridges, 2013.
44. Mohammed Safi: Life-Cycle Costing - Applications and Implementations in Bridge Investment and Management, 2013.
45. Ignacio Gonzalez: Application of monitoring to dynamic characterization and damage detection in bridges, 2014.
46. Shahrin Nasir: Intermodal container transport logistics to and from Malaysian ports – Evaluation of customer requirements and environmental effects, 2015.
47. Hans Sipilä: Simulation of rail traffic. Methods for timetable construction, delay modeling and infrastructure evaluation, 2015.
48. Guangli Du: Life cycle assessment of bridges, model development and case studies, 2015.
49. Babette Dirks: Simulation and measurement of wheel on rail fatigue and wear, 2015.
50. Anders Lindfeldt: Railway capacity analysis – Methods for simulation and evaluation of timetables, delays and infrastructure, 2015.
51. Behzad Kordnejad: Evaluation and modelling of short haul intermodal transport systems. TRITA-TSC-PHD-16-003. 2016.
52. Matin Shahzamanian Sichani: On Efficient Modelling of Wheel-Rail Contact in Vehicle Dynamics Simulation, 2016.
53. Carl Wersäll: Frequency Optimization of Vibratory Rollers and Plates for Compaction of Granular Soil, 2016.
54. Christoffer Svedholm: Efficient Modelling Techniques for Vibration Analyses of Railway Bridges, 2017.
55. Alireza Qazizadeh: On Active Suspension in Railway Vehicles, 2017.
56. Zhendong Liu: Measures to Enhance the Dynamic Performance of Railway Catenaries, 2017.
57. Saeed Hossein-Nia: On Heavy-Haul Wheel Damage using Vehicle Dynamics Simulations, 2017.
58. Therese Arvidsson: Train–Track–Bridge Interaction for the Analysis of Railway Bridges and Train Running Safety, 2018.
59. Yehze Lyu: Open Rail System Tribology, 2018.
60. Yingying Cha: Airborne particles in railway tunnels, 2018.
61. Luca Bessegato: Modeling and Control of Modular Multilevel Converters for Stability Analysis, 2019.
62. Ricardo De Frias Lopez: DEM Modelling of Unbound Granular Materials for Transport Infrastructures – On soil fabric and rockfill embankments, 2020.



Photo: Tilda Nilsson Gige



Rail Vehicles – RV

The research focus at the Rail Vehicles unit is vehicle-track dynamic interaction, but studies are also carried out on pantograph-catenary interaction and on vehicle energy usage. The staff members are listed below.



Professor Mats Berg

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Researcher	Rickard Persson	patper@kth.se
Researcher	Alireza Qazizadeh	alirezaq@kth.se

RESEARCH PROJECTS

RV29. Onboard condition monitoring of vehicle-track dynamic interaction

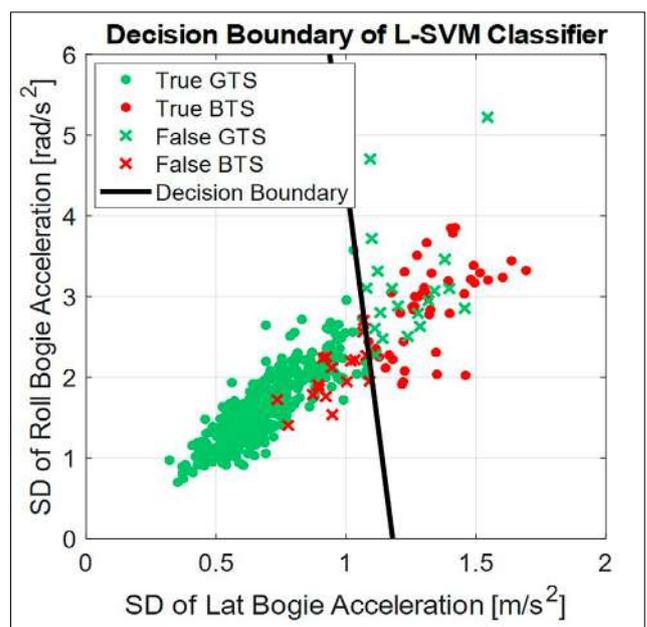
Project coordinator	KTH
Project leader at KTH	Mats Berg
Scientists at KTH	Rohan Kulkarni, Alireza Qazizadeh, Ulf Carlsson, Sebastian Stichel
Source of funding:	KTH Railway Group (mainly).

Condition monitoring is introduced more and more in rail systems to support decisions on vehicle and infrastructure maintenance. Vehicle-track interaction is traditionally monitored from the track, but the present project aims at using sensors onboard in-service vehicles to detect malfunctions and suggest proper vehicle and/or track actions. Key malfunctions are ride discomfort and running instability with focus on resolving such issues by relevant maintenance. The work is a collaboration with the Railway Group members.

Literature studies in the field have been carried out including different algorithms and signal processing methods. Running instability detection and proper mitigation is planned to be in focus. If possible, axle box accelerations measured on X2000 vehicles should be used for case study.

First a joint PhD work was carried out with Politecnico di Milano dealing with monitoring of track irregularities from accelerations of Italian in-service vehicles using machine

learning classification. Both simulation and measurement results were used in this process and limit values for the irregularities were introduced. Promising results were achieved and an associated paper has been published.



Decision boundary for bogie response in relation to good/bad track standard (GTS/BTS).

As a first step in condition monitoring of running instability, simulations were performed for a vehicle similar to an X2000 coach including measured wheel profiles and degraded yaw dampers. Vehicle speed was varied slightly in the different simulations, but the rail profile and the track gauge were kept constant. Lateral accelerations of the bogie frames and axle boxes were recorded and subject to different machine learning classification algorithms. Also here promising results were obtained and the work was presented at an international conference in September 2019. The work on running instability has continued changing other parameters etc and is linked to the Shift2Rail projects IN2TRACK2 (WP3) and PIVOT-2 (WP5 & WP7).

A. De Rosa, R. Kulkarni, A. Qazizadeh, M. Berg, E. Di Gialleonardo, A. Facchinetti and S. Bruni. Monitoring of lateral and cross level track geometry irregularities from onboard vehicle dynamics measurements using machine learning classification, *Journal of Rail and Rapid Transit*, online February 2020.

R. Kulkarni, A. Qazizadeh, M. Berg and S. Stichel. Fault detection and isolation method for vehicle running instability from vehicle dynamic response using machine learning, *Proceedings of the 11th International Conference on Railway Bogies and Running Gears*, Budapest, Hungary, September 2019.

RV30. Innovative technical solutions for improved train DYNAMics and operation of longer FREIGHT Trains (DYNAFREIGHT)

Project coordinator UNIFE
 Project leader at KTH Mats Berg
 Scientists from 10 European partners (at KTH: Visakh Krishna, Sebastian Stichel)
 Source of funding: European Commission (Horizon 2020).

The DYNAFREIGHT project provides inputs for the development of the next railway freight propulsion concepts within Shift2Rail. Two main areas are addressed:

Freight running gear for locomotives: DYNAFREIGHT designs and develops the necessary concepts that allows a locomotive freight bogie to reduce wheel and track wear, to have lower noise and lower LCC, by focusing on:

- Materials with freight vehicle applicability that allow a lighter bogie frame.
- Noise optimized wheelsets and absorbing structures to reduce bogie noise.

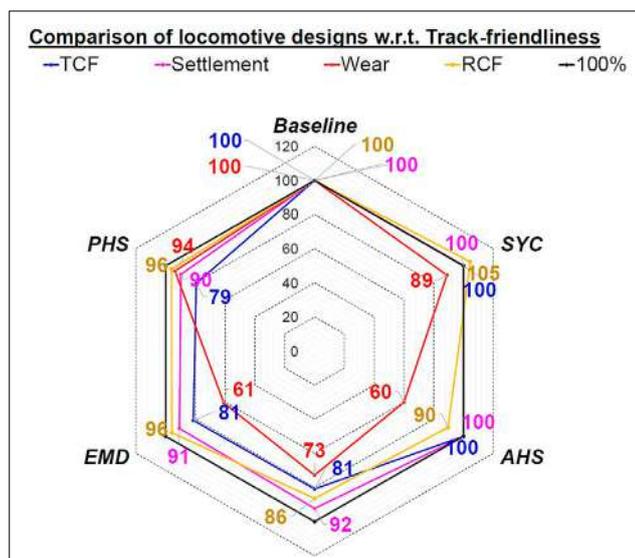
- Passive and mechatronic systems for radial steering, improving running performances compared to conventional bogies. Reduction of wheel wear and RCF, improved traction in curves and reduced curving resistance.
 - Monitoring of the most maintenance cost-intensive bogie elements, reducing LCC and improving the reliability and availability of the locomotive.
 - Operation of long freight trains: following the outcomes of MARATHON, DYNAFREIGHT prepares the path for regular operations of long freight trains:
 - Defining functional, technical and homologation requirements for a radio remote controlled system.
 - Proposing safety precautions in train configuration and brake application by simulating the longitudinal forces and the derailment risk of long freight trains.
 - Identifying infrastructure adaptations for the operation of long freight trains.
- KTH mainly participates in the project by evaluating radial steering bogie concepts and tolerable longitudinal (compressive) forces in long freight trains.

M. Pàlinkò, S. Bruni, E. Di Gialleonardo, B. Liu and V. Krishna. Evaluation of passive and mechatronic steering systems for three-axle locomotive bogies by means of multibody simulations, *Proceedings of the 11th International Conference on Railway Bogies and Running Gears*, Budapest, Hungary, September 2019.

C. Vaghi, M. Berg, J. Acevedo, V. Boeckenholt and A. Demadonna. Scenarios and requirements for the operation of longer freight trains in Europe. *Proceedings of the 7th Transport Research Arena conference*, Vienna, Austria, April 2018.

V. Krishna, M. Berg and S. Stichel. Tolerable longitudinal forces for freight trains in tight S-curves using three-dimensional multibody simulations, *Journal of Rail and Rapid Transit*, vol. 234, p. 454-467, 2020.

V. Krishna, D. Jobstfinke, S. Melzi and M. Berg. An integrated numerical framework to investigate the running safety of overlong freight trains, *Journal of Rail and Rapid Transit*, online February 2020.



Track friendliness of locomotives with different active steering schemes

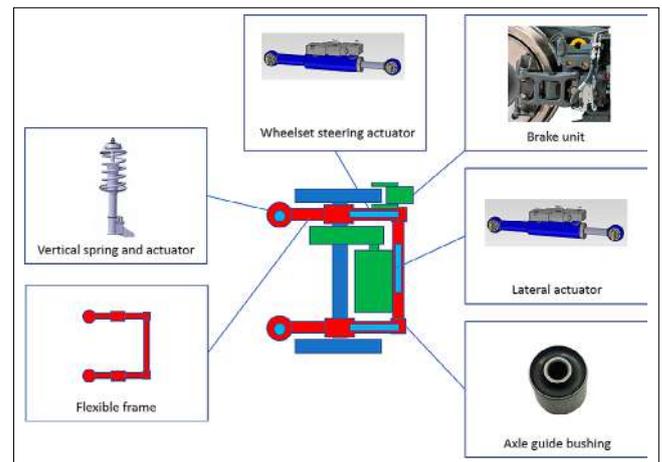
RV31. Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles (RUN2RAIL)

Project coordinator UNIFE
 Project leader at KTH Sebastian Stichel
 Scientists from 15 European partners (at KTH: Rickard Persson, Per Wennhage, Rocco Giossi, Ines Lopez Arteaga)
 Source of funding: European Commission (Horizon 2020).

R. Libero Giossi, R. Persson and S. Stichel. Gain scaling for active wheelset steering on innovative two-axle vehicle. Proceedings of the 26th International Conference on Dynamics of Vehicles on Roads and Tracks, IAVSD, Gothenburg, Sweden, August 2019.

B. Fu, R. Libero Giossi, R. Persson, S. Stichel, S. Bruni and R. Goodall. Active suspension in railway vehicles: a literature survey. Railway Engineering Science, vol. 28, p. 3-35, 2020.

The RUN2RAIL project explores an ensemble of technical developments for future running gear, looking into ways to design trains that are more reliable, lighter, less damaging to the track, more comfortable and less noisy. The project develops across four thematic Work Streams: (1) Innovative sensors & condition monitoring, (2) Optimised materials & manufacturing technologies, (3) Active suspensions & mechatronics, (4) Noise & Vibration. KTH worked in work streams (2) to (4). In (2) the general feasibility of using composite materials was investigated. KTH was leading (3) and mainly developing a concept for an innovative two-axle vehicle with only one suspension step and active vertical and lateral suspension as well as active wheelset steering. We also contributed to a possible future homologation strategy for rail vehicles with active suspension. In (4) KTH mainly worked on theoretical and experimental characterisation of suspension elements with respect to vibration transmission.



Innovative two-axle running gear

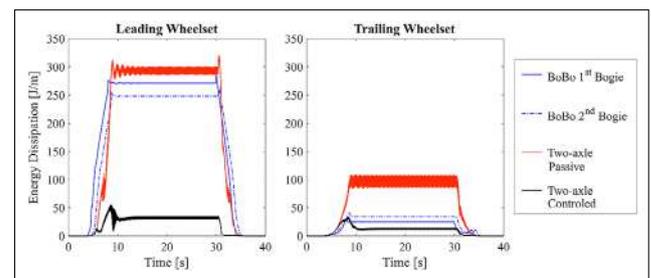
RV32. Performance Improvement for Vehicles On Track (PIVOT-1 and PIVOT-2)

Project coordinator Siemens Mobility GmbH
 Project leader at KTH Sebastian Stichel
 Scientists from 16 European partners (at KTH: Mats Berg, Peter Göransson, Rickard Persson, Per Wennhage, Carlos Casanueva, Saeed Hossein-Nia, Anton Shipsha, Rocco Giossi, Johan Larsson, Visakh Krishna, Rohan Kulkarni)

the track, thereby reducing the life cycle cost not only of the vehicle itself, but of the entire railway system. Technologies that increase the operational reliability of trains, causing less travel disruptions, ensuring that passengers get to destination on time and delivering a better service are also objectives. It is expected that technologies developed should automatically promote the increase of the transport capacity of railway lines.

Sources of funding: Trafikverket and European Commission (Horizon 2020).

PIVOT-1 and PIVOT-2 build on the ROLL2RAIL lighthouse project and address mechanical systems within rail vehicles: Carbodies, Running Gear, Brakes, Entry Systems and Interiors including the Cab. The projects use a system engineering approach. The overall ambition is to develop technologies that are lighter, more energy efficient, more comfortable for passengers and with a lower impact on



Curving performance of two-axle concept vehicle with passive respectively active steering

KTH is in these projects mainly working on the development of concepts for light weight carbody and bogie frames with novel materials like sandwich materials. Another concept that is pursued is a two-axle single stage suspension vehicle with active wheelset guidance and active suspension to improve ride comfort, cf. RUN2RAIL and NEXTGEAR.

RV33. IMPACT-1 and IMPACT-2

Project coordinator DLR / Trafikverket
 Project leader at KTH Mats Berg
 Scientists from 7 / 13 European partners (at KTH: Mats Berg)
 Sources of funding: Trafikverket and European Commission (Horizon 2020)

The Shift2Rail research programme is monitoring the impact of its research and demonstration activities. For this purpose, Key Performance Indicators (KPIs) are used. In particular, three high-level KPIs are defined and quantified:

- Capacity of the European rail system should be doubled.
- Life Cycle Cost of the system should be halved.
- Reliability of the system should be improved so that the lack of punctuality is halved (e.g. increasing punctuality from 80 to 90%).

To coordinate these efforts a so-called Cross Cutting Activity through IMPACT-1 and IMPACT-2 (WP4 in both projects) is launched. A challenge in the KPI definitions is that the Shift2Rail research is very broad in scope covering all components (infrastructure, vehicles, operation etc) in the

R. Persson, S. Stichel and R. Giossi. How can active suspension reduce cost in rail vehicles? TRA2020, Helsinki, Finland, April 2020, postponed to April 2021.

R. Libero Giossi, R. Persson and S. Stichel. Gain scaling for active wheelset steering on innovative two-axle vehicle. Proceedings of the 26th International Conference on Dynamics of Vehicles on Roads and Tracks, IAVSD, Gothenburg, Sweden, August 2019.

rail systems which in turn comprise of high-speed, regional and urban passenger systems as well as rail freight. The research is organized in more than 40 so-called Technology Demonstrators (TDs) and in principle each TD should contribute to the goals listed above.

Each TD leader is to indicate which (low-level) KPIs the TD has defined and how these can be linked to the high-level KPIs through interface KPIs, including their units, proposed by the IMPACT projects. Further, reference parameters and values are being defined as a baseline for Shift2Rail and estimates on percentage improvements on these are obtained from the TD leaders. KTH is mainly involved in the railway infrastructure part (IP3), excluding signalling, in this process and is collaborating with VTI.

A model for the IP3 contributions to the Shift2Rail high-level KPIs is formulated and quantitative estimates are calculated. Further model improvements are ongoing.

M. Meyer zu Hörste, F. Brinkmann and M. Berg: Impact of Shift2Rail – A KPI model for the entire railway system, Proceedings of the 7th Transport Research Arena conference, Vienna, Austria, April 2018.

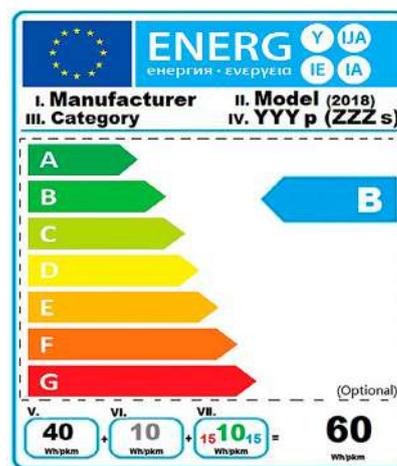
RV34. Future Improvement for Noise and Energy (FINE-1 and FINE-2)

Project coordinator Bombardier Transportation GmbH / Thales
 Project leader at KTH Mats Berg
 Scientists from 9 / 14 European partners (at KTH: Zhendong Liu, Peter Göransson, Romain Rimpler, Siddharth Venkataraman)
 Sources of funding: Trafikverket and European Commission (Horizon 2020)

The Shift2Rail research programme is monitoring the impact of its research and demonstration activities, in particular by means of three high-level Key Performance Indicators: Capacity, Life Cycle Cost and Reliability. One indicator at a lower level, but still important, is the energy usage at train operation. To coordinate the energy efforts a so-called Cross Cutting Activity is launched through the projects FINE-1 and FINE-2. These projects also include studies on noise from trains.

A first step was to define an energy baseline for the four

main service categories of Shift2Rail: High-speed, regional and urban passenger trains as well as freight trains. State-of-the-art technology with respect to energy performance



Proposal of energy labelling for rail vehicles.

was surveyed and representative train configurations and operational conditions were defined. A software for train energy simulation was developed through the Shift2Rail open-call project OPEUS. The improvements in energy performance in Shift2Rail are being evaluated with this software. Reductions in energy usage at train operation are foreseen by improved traction and braking technologies, reduced running resistance, eco-driving, more efficient energy supply etc.

An important aspect is also energy labelling, that is how train energy performance can be quantified in a simple way so that different trains can be compared with each other and also how trains can be compared with other modes of transport from an energy perspective. In the European Union there are many products that have standardized ways of labelling their energy performance. So far the labelling mainly applies to household products, but efforts are now ongoing to also include other sectors like transport. For transport the units might be Wh per person-km or net-tonne-km. The labelling may also include corresponding CO₂ emissions.

KTH has completed a literature study on energy labelling into a FINE-1 technical report. KTH has also, after

extensive interaction with the project partners, proposed an energy label for trains referring to different train categories and operational conditions found in EN 50591. This kind of label should be useful to train manufacturers, operators and passengers etc as well as infrastructure managers and other authorities. The KTH contributions have been consolidated into a journal paper.

In FINE-2 the KTH work on energy labelling is continuing including further stakeholder analysis by means of a questionnaire as well as refinements on the labelling proposal. KTH will also continue working on modelling and simulation of sound radiation from trains for defined cases.

Z. Liu, M. Berg and T. Bustad. Review of energy labelling systems, Technical Report, FINE-T2.1-T-KTH-028-03, Dec 2018.

Z. Liu, M. Berg and T. Bustad. Energy labelling proposal, Chapter 2, Deliverable D2.1, FINE-T2.1-D-BTD-021-09, Sept 2019.

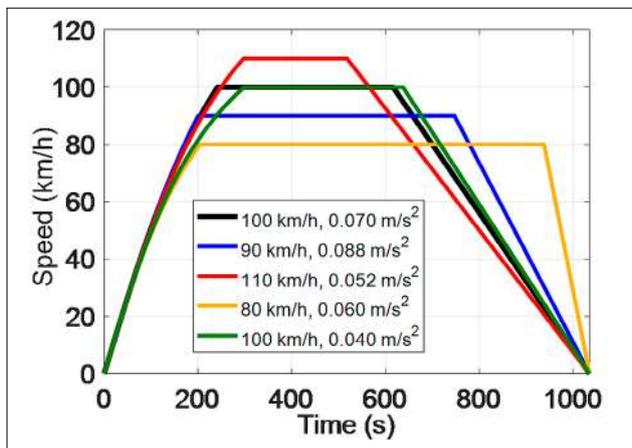
Z. Liu, M. Berg and T. Bustad: Review of existing energy labelling systems and a proposal for rail vehicles, Journal of Rail and Rapid Transit, online June 2020.

RV35. Real time information applications and energy efficient solutions for rail freight (FR8HUB)

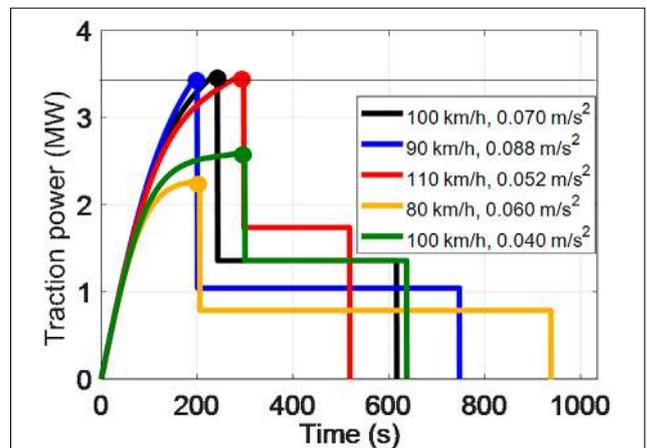
Project coordinator Trafikverket
 Project leader at KTH Mats Berg (WP1, WP4, WP6)
 Scientists from 14 European partners (at KTH/WP6: Zhendong Liu)
 Sources of funding: Trafikverket and European Commission (Horizon 2020)

FR8HUB is to bring advanced technologies and digitalization processes to the rail freight market and consists of six work packages. The KTH Railway Group is participating in WP1 Migration plan, WP4 Intelligent video gate, and WP6 Freight loco of the future. The KTH involvement in WP6 is described below.

In WP6 KTH works on Task 6.4 Study implementation of power peak shaving. For smart electric power grids, power peak shaving is being used to avoid installation of capacity to supply peaks of variable loads. KTH works on smart train operation for which the power demand is reduced without changing the timetable (and other partners work on onboard energy storages). In contrast to ECO driving, aiming at reducing the energy usage, this approach will focus on studying the influence of train speed profile (driving style) reducing the amplitude of the highest power peaks without violating the timetable. For a given railway line, freight train and timetable, simulations are suggesting an optimized speed profile with respect to power demand



Five speed profiles giving the same travel time and distance.



Traction power vs time for the five cases above.

and energy usage. It would be a simple and economical way for both infrastructure managers and train operators, especially in countries where the train operators have also to pay for high power demand, not only for the energy usage.

A simplified study was carried out to highlight the applied methodology. It assumes a synthetic track profile and freight train defined in EN 50591.

For a given Swedish railway line, power and energy

simulations are carried out for a specified freight train running at different speed profiles but still with the same total running time. The KTH in-house software STEC is being used for this purpose. We are also using energy and GPS data recorded by the train's energy meter, provided by Trafikverket, as a reference. An important issue is the ability to extract power demand as two-second samples from the energy meter.

RV36. Research into enhanced track and switch and crossing system 2 (IN2TRACK-2)

Project coordinator	Network Rail
Project leader at KTH	Mats Berg (WP3)
Scientists	from 28 European partners (at KTH/WP3: Rohan Kulkarni, Alireza Qazizadeh, Saeed Hossein-Nia)
Sources of funding:	Trafikverket and European Commission (Horizon 2020)

In WP3 Optimised track system, KTH is working on Task 3.5 Wheel-rail interaction, more precisely on two topics: Investigate and control the hunting motions on track, and Understanding and mitigating curve squeal.

Investigate and control the hunting motions on track

Vehicle hunting motion is a classical issue in vehicle-track dynamic interaction. This periodic (sinusoidal) lateral motion is a safety concern and can also cause passenger discomfort. Typically, this running instability appears at fairly high vehicle speed and on straight track or in large-radius curves.

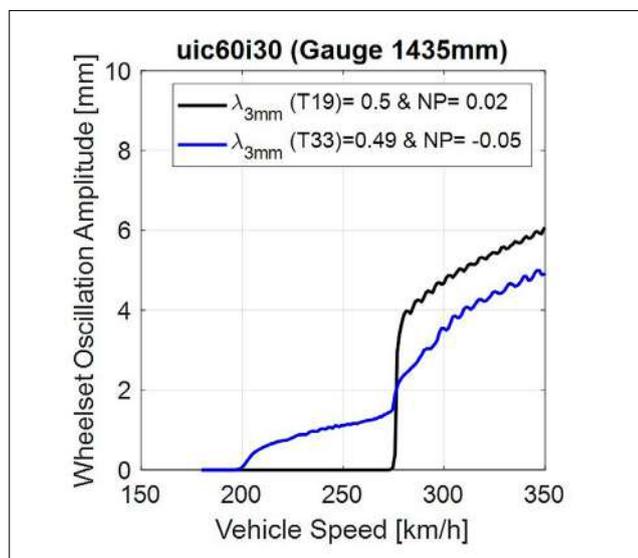
The main cause could be poor vehicle yaw dampers or too soft primary suspension. But the actual wheel-rail geometry match and track gauge are also key quantities. A key geometric quantity for the wheel-rail (wheelset-track) interface is the equivalent conicity, cf. EN 15302. The wheel-rail pair is categorised based on the equivalent

conicity corresponding to 3 mm lateral wheelset displacement. Usually this conicity should be kept low to reduce the risk of hunting motion. However, having fairly low equivalent conicity is not sufficient to avoid running instability, as this instability of the vehicle also depends on the equivalent conicity function with lateral wheelset displacement. Therefore, a question has arisen if there are other parameters at the wheel-rail interface that play a decisive role for the running stability. Polach proposed a Nonlinearity Parameter (NP) to quantify the nonlinearity of equivalent conicity function. The objective of the present work is to investigate, through simulations, the effect of NP on running instability and to suggest further vehicle and track actions (limit values etc) to reduce the risk of vehicle hunting motion. The conclusions should state to what extent equivalent conicity should/could be accompanied by other geometric parameters, like NP, to better explain and mitigate running instability.

Understanding and mitigating curve squeal

In the wheel-rail rolling contact there is always some degree of sliding motion in the contact patch, both laterally and longitudinally. At traction (acceleration) and braking (retardation) the sliding motion is mainly longitudinal whereas in curve negotiation also the lateral sliding motion can be substantial. Curve negotiation, especially in tight curves, can cause excessive wheel and rail damage but also noise. In particular, squeal noise causes human annoyance. Squeal noise often occurs at the leading inner wheel of a bogie or two-axle vehicle. It can also occur at the flange of the outer wheel but less common. Squeal noise is associated with the falling part of the creep curve in which the friction value drops at higher creepages and the creep forces drop consequently. This causes instability in the system which eventually leads to stick-slip motion and squeal noise. A key system design and maintenance action is therefore to reduce the sliding motion in the contact patches during curve negotiation.

The objective of this work is to investigate, through simulations, system parameters that are closely related to the sliding motion and the associated curve squeal as well as mitigations of the squeal noise. In addition to the curve radius, wheel and rail profiles, wheel-rail friction and bogie steering ability are key parameters. The study will present numerical results along with design and maintenance actions to reduce the occurrence and level of curve squeal noise.

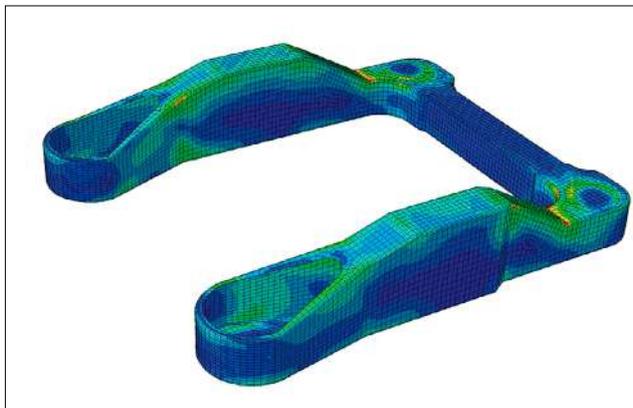


Running instability for a vehicle with two different wheel profiles.

RV37. NEXT generation methods, concepts and solutions for the design of robust and sustainable running GEAR (NEXTGEAR)

Project coordinator	UNIFE
Project leader at KTH	Sebastian Stichel
Scientists	from 16 European partners (at KTH: Carlos Casanueva, Rickard Persson, Per Wennhage, Saeed Hossein-Nia, Anton Shipsha, Rocco Giossi)
Source of funding:	European Commission (Horizon 2020)

The rail sector has recently seen only limited changes in the running gear. A reason is that innovations have the tendency to increase the first cost of the running gear while they reduce the LCC by reduced maintenance costs. The long-term cost reduction, however, is not easy to quantify.



Carbon fibre bogie frame for innovative single-axle running gear

This dilemma will be addressed in WP1 where an updated so-called Universal Cost Model based on the one from the ROLL2RAIL project will be developed that makes it possible to judge the economic impact of the innovation suggested for an operator using the vehicle. How can the costs for buying, operating and maintaining the vehicle be influenced? Lower bogie weight would reduce wheel-rail forces and allow for higher payload. In WP2, the project is going to suggest ideas that are based both on the use of new materials and new manufacturing methods. Simulation techniques will be explored to allow optimisation of designs. It will be investigated whether required properties of the running gear such as stiffness and damping could be distributed through the structure rather than requiring specific components. In parallel, active control strategies will be investigated to improve the level of ride comfort or reduce wheel and rail damage.

The wheelset is another extremely important and safety-critical component in a rail vehicle. Since it represents a so-called “unsuspended mass” there is a desire to minimize the wheelset weight. The main objective of WP3 is a feasibility study on the use of composite materials for the construction of railway wheelsets. Technology concepts for a lightweight wheelset will be defined. Main focus areas are material selection, durability, manufacturing process and joining methods.

The output of this project will be an important input for the parallel member project in IP1 (PIVOT-2) both regarding the Cost Model and the technical innovations. There will also be a contribution to the overall Shift2Rail KPI's and partly IP3.

RV38. Development of Functional Requirements for Sustainable and Attractive European Rail Freight (FR8RAIL)

Project coordinator	Trafikverket
Project leader at KTH	Sebastian Stichel
Scientists	from 18 European partners (at KTH: Mats Berg, Carlos Casanueva, Saeed Hossein-Nia, Visakh Krishna)
Sources of funding:	Trafikverket and European Commission (Horizon 2020)

The main aim of the FR8RAIL project is the development of functional requirements for a sustainable and attractive European rail freight. The objectives of FR8RAIL are: A 10% reduction on the cost of freight transport measured by tonnes per km. A 20% reduction in the time variations during dwelling and increase attractiveness of logistic chains by making available 100% of the rail freight transport information to logistic chain information.

KTH was one of the main contributors to a WP4 state-of-the-art report reviewing wagon, running gear, wheelset and

brake design of freight wagons and also indicating existing models to predict wheel and track deterioration.

A multibody dynamics (Gensys) model of a newly developed Y25 bogie with double Lenoir links and cross bracing from Tatravagonka was built, simulations were performed, and the running (hunting) stability and curving performance was compared to a standard Y25 bogie and the running gear developed in the SUSTRAIL project. Also, comparisons of wheel and track wear and Rolling Contact Fatigue were performed together with Virtual Vehicle in Graz. The vehicle dynamics simulations and the wheel wear and RCF calculations were performed by KTH. Rail wear and RCF calculations were performed by Virtual Vehicle with input from KTH.

With first measurement data from Tatravagonka the simulation model has been validated. With the validated model more systematic studies on stability, curving behaviour, track friendliness, wear and RCF have been performed. It turns out that the FR8RAIL bogie is much

more track friendly than the standard UIC bogie and also more track friendly than the SUSTRAIL bogie.

In parallel together with CAF new models for wear prediction are developed that shall include material parameters. The aim is to be able in the future to make more educated choices of wheel materials with regard to wear behaviour. Today basically only the initial wheel hardness is part of the prediction model.

We also developed a methodology to use dynamic simulation as a virtual twin to predict wheel life of railway vehicles to optimize maintenance actions. In parallel another method is developed to judge track friendliness taking also rail grinding due to rail damages into account. This methodology gives the opportunity to optimize rail grinding as function of the vehicle performance and in this way makes maximum use of track friendly running gear.

V. Krishna, S. Stichel and S. Hossein-Nia. Running behaviour of modified Y25 running gear with double Lenoir link and cross-bracing: Wheel damage and stability. Proceedings of the Fourth International Conference on Railway Technology, Barcelona, Spain, September 2018.

V. Krishna, S. Hossein-Nia, C. Casanueva and S. Stichel. FR8RAIL Y25 running gear for high tonnage and speed, Proceedings of the IHHA conference, Narvik, Norway, June 2019.

S. Hossein-Nia and S. Stichel. Multibody simulation as virtual twin to predict the wheel life for Iron-ore locomotive wheels. Proceedings of the IHHA conference, Narvik, Norway, June 2019.

A. Alonso, C. Casanueva, J. Perez and S. Stichel. Modelling of rough wheel-rail contact for physical damage calculations, *Wear*, vol. 436, 2019.

K. Six, T. Mihalj, G. Trummer, C. Marte, V. Krishna, S. Hossein-Nia and S. Stichel. Assessment of running gear performance in relation to rolling contact fatigue of wheels and rails based on stochastic simulations. *Journal of Rail and Rapid Transit*, vol. 234, p. 405-416, 2019. <https://doi.org/10.1177/0954409719879600>

Y. Li, Z. Ren, R. Enblom and S. Stichel. Wheel wear prediction on a high-speed train in China, *Vehicle System Dynamics*, online August 2019.

RV39. Digitalization and Automation of Freight Rail (FR8RAIL-2)

Project coordinator	Bombardier Transportation GmbH
Project leader at KTH	Sebastian Stichel
Scientists	from 18 European partners (at KTH: Mats Berg, Carlos Casanueva, Saeed Hossein-Nia, Visakh Krishna)
Sources of funding:	Trafikverket and European Commission (Horizon 2020).

FR8RAIL-2 focuses on improving the freight eco system by addressing various challenges: Automatic couplers, provided with electrical and data transmission functionalities will massively improve the efficiency of the train composition process, new telematics and electrification will enable Condition Based Maintenance (CBM), improved methods for annual and short-term timetable planning will help traffic operators increasing the overall capacity and raise punctuality, future freight wagon design is a stream that will contribute in improving reliability of the freight transport while increasing the payload per metre of train. The latter one will be propelled by future mainline electric freight locomotives featuring highly flexible freight propulsion

systems with reduced operational costs. Furthermore, these new freight trains will be propelled by more than one locomotive running with distributed power, thus allowing long freight trains up to 1500 m. Last but not least, focus is given to driver advisory systems that are connected (C-DAS) to the traffic management systems, further enhancing capacity, improving punctuality and optimize energy consumption of the railway system.

In FR8RAIL-2 for KTH the activities that started in the first phase of the project continue (see above). In 2019 also work on a new methodology to predict wheel wear and RCF with help of machine learning techniques has been started. Since the simulation times for wear and RCF prediction are drastically reduced, this new methodology can be used to optimize wheel profiles also with respect to the long-term behaviour. This is up to now not possible because of the long simulation times.

V. Krishna, S. Hossein-Nia and S. Stichel. New methodology to estimate costs caused by rail wear and RCF depending on the type of running gear. Proceedings of the 26th International Conference on Dynamics of Vehicles on Roads and Tracks, IAVSD, Gothenburg, Sweden, August 2019.

RV40. Economic priorities that enable reliable and attractive railway transportations

Project coordinator VTI
Project leader at KTH Sebastian Stichel
Scientists at KTH Saeed Hossein-Nia, Visakh Krishna, Carlos Casanueva, the third project partner is Trafikverket
Source of funding: Vinnova.

The annual increase in traffic creates a high capacity utilization on many parts of the railway network. Hence, the consequences of disturbances in the traffic due to infrastructure failures are increasing over time. Another issue is the increasing costs for maintenance.

Whilst there is a well-developed methodology for infrastructure investments, there is a lack of corresponding knowledge to prioritize between maintenance activities and to take informed decisions on when to renew the asset instead of continuing the maintenance activities. A multi-

disciplinary approach and knowledge from the industry is required in order to tackle the railway sector’s problems and challenges and provide better conditions for prioritizing between activities, as well as creating more reliable and attractive railway transportations. The purpose of the project is thus to generate knowledge on the relationships that are necessary to strengthen the attractiveness of the railway system and its ability to provide transport services. Specifically, by engaging different disciplines and the industry, the project will provide better conditions for carrying out the right maintenance and renewal activities at the right time and to prevent disturbances in traffic. In addition, the project will generate knowledge on how a socio-economic priority of activities can be put into practice in a cost-efficient way, while also providing scope for innovations and productivity improvements.



Photo: Stefan Nilsson



Structural Engineering and Bridges – SB

The division is conducting research and education in planning and design of structures including railway bridges. One important part of this research focuses on the modelling and simulation of the static/dynamic behaviour and fatigue lifespan of railway bridges and on the

application of modern measurement technique for the assessment of bridges and for calibration of numerical models. More information on the research performed at the division and the publications are available on www.byv.kth.se.



**Professor
Raid Karoumi**

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RESEARCH PROJECTS

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

Researchers Jean-Marc Battini (main supervisor)
Andreas Andersson (co-supervisor)
Mahir Ülker Kaustell (co-supervisor)
Hesham Elgazzar (PhD student until 2016-07-31)
Johan Lind Östlund (PhD student from 2016-08-01)

Dynamic analyses of railway bridges present several uncertainties and often predict vibrations that 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 focused on the bridges with integrated backwalls along the Bothnia Line. The second part of the project focuses more specifically on the influence of the soil-structure interaction on simply supported bridges. The project started in 2014.

The project has resulted in the following publications:

Östlund J.L., Andersson A., Ülker-Kaustell M., Battini J.M., 2020. The effects of model assumptions on the dynamic

impedance functions of a shallow foundation. In: XI International Conference on Structural Dynamic, EUROLYN 2020, Athens, Sept. 23-25.

Östlund J.L., Ülker-Kaustell M., Andersson A., Battini J.M., 2017. Considering dynamic soil-structure interaction in design of high-speed railway bridges. In: X International Conference on Structural Dynamic, EUROLYN 2017, Rome, Sept. 10-13.

Andersson A., Östlund J., Ülker-Kaustell M., Battini J.M., Karoumi R., 2017. Full-scale dynamic testing of a railway bridge using a hydraulic exciter. In: International Conference on Experimental Vibration Analysis for Civil Engineering Structures, EVACES 2017, San Diego, USA, July 12-14.

Elgazzar H., 2017. End-Shield Bridges for High-Speed Railway- Full scale dynamic testing and numerical simulations. Licentiate thesis, KTH.



Bridge over Brynge river on the Bothnia Line.

SB17. Risk- and reliability-based assessment of existing steel bridges

Researchers John Leander (main supervisor)
 Raid Karoumi (co-supervisor)
 Ruoqi Wang (PhD student)

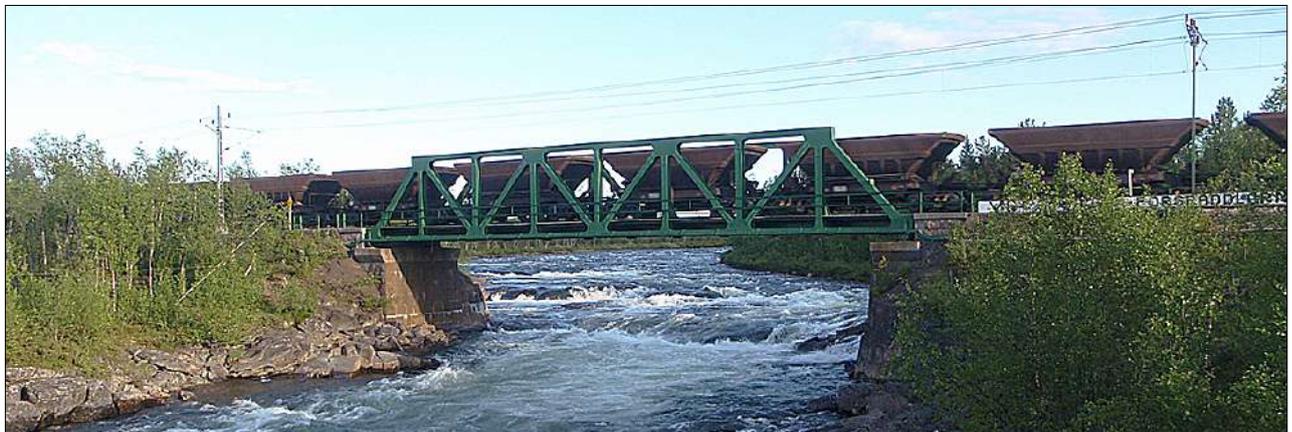
The aim is to develop a risk-based framework with the purpose of supporting decision makers in the choice of actions to extend the service life of steel bridges. The framework should be able to consider and combine information from previous investigations, inspections, measurements and sophisticated theoretical analyses. The project will be limited to steel bridges and degradation phenomena as fatigue and corrosion. The expected outcome of the project is a detailed risk-based methodology supporting rational decisions considering a combination of theoretical assessments, monitoring, and inspections.

The project has resulted in the following publications:

Wang R, Leander J, Karoumi R, 2020. Fatigue reliability assessment of steel bridges considering spatial correlation in system evaluation. Submitted for review.

Wang R, Leander J, Karoumi R, 2020. Risk analysis for decision support – a case study on fatigue assessment of a steel bridge. In: 30th European Safety and Reliability Conference, ESREL 2020, Venice, Italy, June 21-26.

Wang R, Leander J, Karoumi R, 2019. Comparison of simulation methods applied to steel bridge reliability evaluations. In: 13th International Conference on Applications of Statistics and Probability in Civil Engineering, ICASP13, Seoul, South Korea, May 26-30.



The Rautasjokk bridge.

SB18. IN2TRACK2 WP5

Researchers Raid Karoumi (main supervisor)
 Andreas Andersson (co-supervisor)
 John Leander (co-supervisor)
 Sarah Tell (PhD student)
 Reza Allahvirdizadeh (PhD student)

For railway bridges on high-speed lines, the dynamic performance needs to be assessed to assure traffic safety and riding comfort during train passages. The current design codes are results from research done in the 1980ies and 1990ies, e.g. reported in ERRI D214. Recent research indicate that several of these regulations are in need of revision.

The project deals with assessing the actual dynamic behaviour of railway bridges as well as development of a damper device for improving the dynamic behaviour of critical bridges. Issues such as soil-structure interaction, support conditions, and load amplitude dependent behaviour will be studied, using a mobile dynamic exciter.

The work includes extensive field tests on bridges in Sweden and in Portugal.

Methods for dynamic analysis will be improved and new approach will be proposed that can be further developed and implemented in future bridge design codes. The project will also develop guidelines for how to model new and existing bridges for bridge-train dynamic analysis.

The work is divided in the following research activities

- Damping and resonance under rapid cyclic loading.
- Passive dampers to improve bridge damping.
- Proposal for improved design philosophy.

The project has resulted in the following publications:

Allahvirdizadeh R., Andersson A., Karoumi R., 2020. Reliability assessment of the dynamic behavior of high-speed railway bridges using First Order Reliability Method. In XI International Conference on Structural Dynamics, EURO DYN 2020, Athens, June 22-24.

Deliverable D5.1, 2019. IN2TRACK2 WP5 Tunnel and Bridge I2T2 report.



Electric Power Engineering – EP

The Department for Electric Power and Energy Systems at the School of Electrical Engineering and Computer Science 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.



**Professor
Stefan Östlund**

RESEARCH PROJECTS

EP7 AC/AC Modular Multilevel Converters for Railway Applications

Researchers: PhD student: Luca Bessegato. Luca Bessegato defended his Ph.D, thesis on April 26, 2019

Supervisors: Staffan Norrga, norrga@kth.se
Stefan Östlund, stefano@kth.se

Reference group members:

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

Period 2014–2019

Source of funding/partners: Railway Group/Trafikverket

Trafikverket has introduced new modular multi-level railway power supply converters. These converters have characteristics that are different from previous generations.

The project focuses on the dynamic behavior of the converters as seen from the railway power grid and the three-phase grid. Studies on the input admittance of the modular multilevel converter (MMC), have provided an insight on the interactions between the three-phase grid and the converter. The results have been verified on a developed prototype converter.

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

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

K. Ilves, L. Bessegato, L. Harnefors, S. Norrga and H. P. Nee, “Semi-full-bridge submodule for modular multilevel converters,” 2015 9th International Conference on Power Electronics and ECCE Asia (ICPE-ECCE Asia), Seoul, 2015, pp. 1067-1074.

L. Bessegato, S. Norrga, K. Ilves and L. Harnefors, “Control of

modular multilevel matrix converters based on capacitor voltage estimation,” 2016 IEEE 8th International Power Electronics and Motion Control Conference (IPEMC-ECCE Asia), Hefei, 2016, pp. 3447-3452.

L. Bessegato, L. Harnefors, K. Ilves, S. Norrga, S. Östlund, “Control of Direct AC/AC Modular Multilevel Converters Using Capacitor Voltage Estimation,” 2016 IEEE 18th European Conference on Power Electronics and Applications (EPE 2016), Karlsruhe, 2016.

L. Bessegato, S. Norrga, K. Ilves and L. Harnefors, “ac-Side Admittance Calculation for Modular Multilevel Converters,” International Future Energy Electronics Conference 2017 – ECCE Asia, Kaohsiung, 2017.

L. Bessegato, A. Narula, P. Bakas, and S. Norrga, “Design of a modular multilevel converter prototype for research purposes,” in 2018 20th Eur. Conf. Power Electronics and Applications, EPE'18 ECCE Eur., 2018.

L. Bessegato, L. Harnefors, K. Ilves, and S. Norrga, “A method for the calculation of the ac-side admittance of a modular multilevel converter,” IEEE Trans. Power Electronics, <https://ieeexplore.ieee.org/document/8424056>

L. Bessegato, K. Ilves, L. Harnefors, and S. Norrga, “Effects of control on the ac-side admittance of a modular multilevel converter,” IEEE Trans. Power Electronics, <https://ieeexplore.ieee.org/document/8514034>

S. Heinig, K. Jacobs, K. Ilves, L. Bessegato, P. Bakas, S. Norrga, and H.-P. Nee, “Implications of Capacitor Voltage Imbalance on the Operation of the Semi-Full-Bridge Submodule,” IEEE Trans. Power Electronics, 2018.

L. Bessegato, K. Ilves, L. Harnefors, S. Norrga, and S. Östlund “Control and admittance modeling of an ac/ac modular multilevel converter for railway supplies,” IEEE Trans. Power Electronics, 2019.

EP8 Silicon carbide based power electronics for electric trains

Researchers: PhD student Martin Lindahl

martlin@kth.se

Supervisors: Hans-Peter Nee, hansi@kth.se

Stefan Östlund, stefano@kth.se

Reference group members:

Hans-Peter Née KTH, Anders Blomberg Bombardier Transportation, Stefan Östlund KTH

Period 2018—2022

Sources of funding: KTH Railway Group, Bombardier Transportation

The power semiconductor material silicon carbide (SiC) gives the benefits of large reductions of power losses. SiC power semiconductors have the potential to enter the commercial market in electric traction for trains. The purpose of this work is to investigate how the benefits of SiC can be utilized in the best way for rail applications. Areas of investigation are e.g. reduced total energy losses, improvements in system topology and overvoltages on the motor winding. The work includes building of prototype converters.

M. Lindahl, T. Trostén, D. Jansson, M. Johansson, E. Velander, A. Blomberg, H.-P. Nee, "Field Test of a Silicon Carbide Metro

Propulsion System with Reduced Losses and Acoustic Noise", IET Electrical Systems in Transportation, in press.

M. Lindahl, E. Velander, A. Blomberg and H.-P. Nee, "Threshold for Induction Motor Terminal Transient Peak Voltage with Fast Switching Inverters," 2019 21st European Conference on Power Electronics and Applications (EPE '19 ECCE Europe), Genova, Italy, 2019, pp. P.1-P.6, doi: [10.23919/EPE.2019.8914765](https://doi.org/10.23919/EPE.2019.8914765).

M. Lindahl, E. Velander, M. H. Johansson, A. Blomberg, and H.-P. Nee, "Silicon carbide MOSFET traction inverter operated in the Stockholm metro system demonstrating customer values," in 2018 IEEE Vehicle Power and Propulsion Conference (VPPC), Aug 2018, pp. 1–6.

T. Trostén, H. Mosskull, M. Lindahl, E. Dahlquist, and M. Azaza, "Energy optimal switching frequency for a 750V metro traction drive using silicon carbide MOSFET inverter," in Applied Energy Conference ICAE2018 Hong Kong, Aug 2018, in press.

E. Velander, G. Bohlin, Å. Sandberg, T. Wiik, F. Botling, M. Lindahl, G. Zanuso, and H.-P. Nee, "An ultralow loss inductorless dv/dt filter concept for medium-power voltage source motor drive converters with SiC devices," IEEE Transactions on Power Electronics, vol. 33, no. 7, pp. 6072–6081, Jul 2018.



Photo: Thomas Johansson

System and Component Design (Dept of Machine Design) – ME

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

contact. A focus area is also the air quality around underground railway platforms and their source focusing on mitigation of the problems. 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. In 2016 Ulf Olofsson received the IMechE John F Alcock Memorial Prize for work regarding block brakes during winter conditions.



**Professor
Ulf Olofsson**

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 rail contact conditions and contact points (tread/flange). Such wear assessments are becoming more significant as train speeds are increasing and new specifications are being imposed relating to safety and reliability. It can also help in determining more efficient maintenance schedules on particular routes; where different track profiles may be needed to reduce the severity of the

wheel rail contact and where application of lubrication or change of material may be necessary to reduce wear problems. The transitions between the different wear mechanisms were studied with special emphasis on the transition between mild and severe wear. Jon Sundh Defended his PhD thesis on the 11th of December 2009.

Some selected publications

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

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

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

ME 2. Adhesion between railway wheel and rail

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

Sources of funding: Banverket, SL and KTH Railway Group

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

project is firstly to develop a test method where friction modifiers can be evaluated in contact conditions and an environment that correspond to the wheel rail contact. Secondly, the research aims to develop adhesion models for the railway wheel rail contact including contaminants. Yi Zhu defended his PhD thesis in November 2013.

Some selected publications

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

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

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

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

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

ME 3. Airborne particles generated from train-track interaction

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

Source of funding: KTH Railway Group

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

where generated airborne particles can be evaluated in contact conditions and an environment that correspond to the wheel rail contact. Saeed Abbasi defended his PhD thesis in November 2013.

Some selected publications

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

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

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

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

ME4. Block brakes during winter conditions

Project leader: Ulf Olofsson
Researcher: Yezhe Lyu
Research engineer: Peter Carlsson

Source of founding commission from SL

In trains with tread brakes, the coefficient of friction between the brake block and the railway wheel determines the stopping distance. The blocks have traditionally been manufactured from cast iron materials. Although these blocks have good braking capacity, their use can be restricted due to the squealing noise they emit. Tests of alternative composite block materials have been successful under summer conditions; in regions with snowy winters, however, the use of such materials has been limited due to problems with braking capacity under snowy conditions. This research aims to develop a laboratory-scale test methodology for evaluating the braking capacity of tread brake materials under winter and snowy conditions. A pin-on-disc machine placed in a climate chamber was used for testing, and standard cast iron block material was compared with standard composite block materials. The results indicate that the standard composite block materials generate a much smoother counter wheel surface and a significantly lower friction coefficient under snowy conditions. A second test series evaluated alternative composite block materials, and a candidate material with low noise and a sufficiently high sliding friction coefficient was selected for further study. A third test series examining geometrical changes in the contact surface in terms of milled parallel traces revealed that the braking capacity under winter conditions can be increased by such milling if the parallel traces are properly oriented – in this case, at an

angle of 45° to the sliding direction. Both friction coefficient and wear have been evaluated at five different temperatures from + 10 to – 30 °C. The cast iron block demonstrated the greatest wear at – 10 and – 20 °C, due to the ductile-to-brittle transition at low temperatures. For the composite brake block, a gradual decrease in friction with decreasing temperature was found. The sinter brake block was not sensitive to changes in ambient temperature.

Some selected publications

U. Olofsson, J. Sundh, U. Bik, R. Nilsson, Influence of snow on train tread braking performance: a pin-on-disc simulation in a climate chamber, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit 230(6), pp. 1521-1530

Lyu, Y., Bergseth, E., Tu, M., Olofsson, U. Effect of humidity on the tribological behaviour and airborne particle emissions of railway brake block materials, Tribology International, Volume 118, February 2018, Pages 360-367

Lyu, Y., Bergseth, E., Wahlström, J., Olofsson, U. A pin-on-disc study on the tribology of cast iron, sinter and composite railway brake blocks at low temperatures, Wear Volume 424-425, 15 April 2019, Pages 48-52



Laboratory test equipment for low temperatures.

ME5. Quiet track

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

Source of founding EU project FP7 and CSC

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, the real time condition monitoring system is set up in Stockholm metro system C20 trains and in the ore line Malmbanan.

Yezhe Lyu defended his PhD thesis in April 2018.

Some publications

Y. Lyu, E. Bergseth, S. Björklund, U. Olofsson, A. Lindgren, M. Höjer, On the Relationships between Wheel and Rail Surface Topography, Interface Noise and Tribological Transitions, *Wear* Volume 338-339, September 05, 2015, Pages 36-46

E. Bergseth, Y. Lyu, S. Björklund, U. Olofsson, R. Nilsson, A. Lindgren and M. Höjer, A Wear Detection Parameter for the Wheel–Rail Contact Based on Emitted Noise, *Tribology Transactions*, Volume 62, Issue 3, 4 May 2019, Pages 496-503.

Y. Lyu, *Railway Open System Tribology*, Doctoral thesis in Machine Design Stockholm Sweden 2018

Field test for the research project Quiet Track in the Högdalen metro depot in Stockholm.



ME6 Models for rail traffic emission factors

Project leader:	Ulf Olofsson
Graduate student	Minghui Tu
Graduate student	Yingying Cha (CSC)
Researcher	Anna Hedlund
Research Engineer	Peter Carlsson

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

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

The air quality in the new opened Citybanan has been studied before and after its opening. One study on the air quality levels on the platforms is published in *Aerosol and Air Quality Research*. A further study on the air quality inside the train, driver and passenger cabins is published in *Environmental Research*. A third study model study on how the train frequency and the number of braking events affect the airborne particle emission levels in tunnels is published in *Transportation research part D*.

A data mining approach has been performed, in which the technical reports, unpublished Swedish reports, on the air quality of the Stockholm Metro system. Together with SLL has measurement stations for air quality been established on the red line in the Stockholm Underground system.

Yingying Cha defended her thesis on September 28, 2018.

Some selected publications

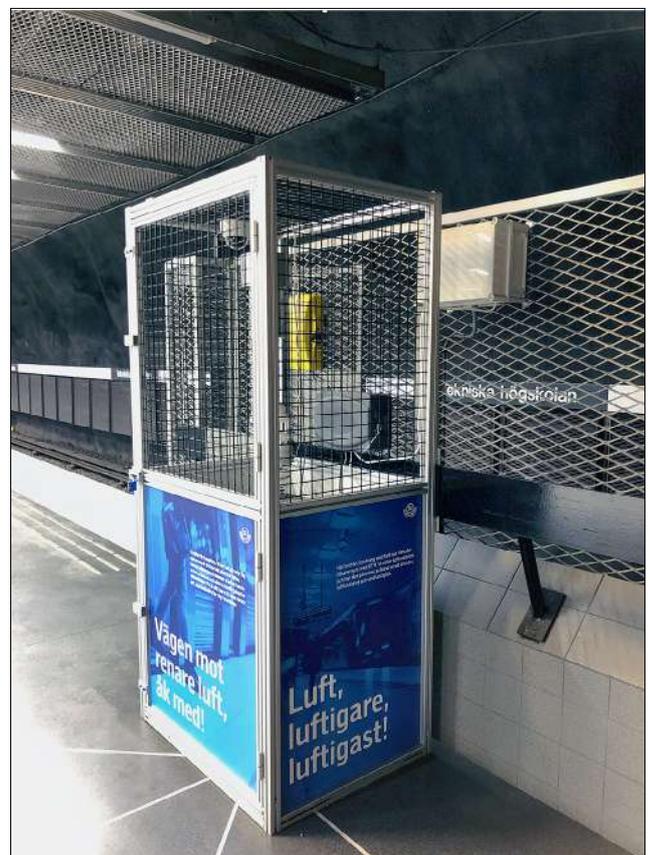
Tu, M., Cha, Y., Wahlström, J., and Olofsson, U. Towards a two-part train traffic emission factors model of airborne wear particles. *Transp. Res. Part D Transp. Environ* 2018 67: 67-76.

Cha, Y., Abbasi, S., and Olofsson, U. (2018). Indoor and outdoor measurement of airborne particulates on a commuter train

running partly in tunnels. *Proc. Inst. Mech. Eng. Part F: J. Rail Rapid Transit*, 232(1):3–13.

Cha, Y., Tu, M., Elmgren, M., Silvergren, S., and Olofsson, U. (2018). Factors affecting the exposure of passengers, service staff and train drivers inside trains to airborne particles. *Environ. Res.*, 166:16-24.

Cha Y., *Airborne Particles in Railway Tunnels*, Doctoral thesis, KTH Royal Institute of Technology 2018.



Test equipment in the Tekniska högskolan metro station in Stockholm.



Transport planning – TPL

Planning is essential to make the railway system function and fulfil customer demand, along with societal goals. Important aspects are the efficiency of operations including cooperation and competition with other transport modes, which on an overarching level include accessibility and sustainability – including environmental considerations. The group that works with planning of railway transportation, railway traffic and infrastructure belongs to the Division of Transport Planning (TPL) at the Department of Civil and Architectural Engineering, School of Architecture and the Built Environment (ABE) at KTH. Research and teaching is conducted regarding aspects of railway planning in the

areas of freight transportation (including logistics), rail passenger services (including supply and demand), capacity analysis, and signalling system effects on capacity. The group has specialist competencies in traffic planning, railway operation and economics, forecasting models and customer valuations, market analysis for passenger and freight traffic, optimization and simulation models for railway capacity, signalling system traffic implications, and infrastructure planning.

The rail transport planning group currently has 15 members under division head Associate Professor Erik Jenelius with visiting and associate professors, researchers, research engineers, and PhD students.



PhD Oskar Fröidh

Personnel

Markus Bohlin, Visiting Professor	Oskar Fröidh, Associate Professor	Behzad Kordnejad, Researcher
Gerhard Troche, Researcher	Hans Sipilä, Researcher	Anders Lindahl, Research engineer
Josef Andersson, Research engineer	Mohammad Al-Mousa, Research engineer.	

In spring 2020, seven PhD students (of which three women) were employed and active within the group’s research projects, and one additional PhD student at VTI (Tomas Rosberg) is supervised:

Jennifer Warg	Ingrid Johansson	Johan Högdahl	Niloofar Minbashi
Félix Vautard	Vahid Ranjbar	Dimitrios Rizopoulos	

We also cooperate in projects with Professor Nils Olsson (NTNU, Trondheim) and Bo-Lennart Nelldal (Bolle Rail Research) among others.



Transport Planning represented of (from left to right) Anders Lindahl, Behzad Kordnejad, Bo-Lennart Nelldal, Tomas Rosberg (VTI), Josef Andersson, Ingrid Johansson, Jennifer Warg, Vahid Ranjbar, Oskar Fröidh and Albania Nissan, in deep studies in LKAB Kiirunavaara mine, 2019. Picture: Oskar Fröidh

RESEARCH PROJECTS OVERVIEW

New Code (Previous Code) Grey shading indicates completed project

Freight and logistics

TPL F2	(TET F2; ToL 2)	Regional Intermodal Transport Systems – Analysis and Case Study
TPL F13	(TET F13)	Capacity 4 Rail (C4R)
TPL F14	(TET F14)	Sustainable and energy efficient regional logistics in the Mälardalen area
TPL F15		City logistics with pilot study of Tomtebodavägen yard
TPL F16		ARCC WP2: Real-time yard management
TPL F17		FR8HUB WP3: Real-time network management and simulation of increasing speed for freight trains
TPL F18		FR8HUB WP4: Intelligent video gate
TPL F19		FR8RAIL II WP3: Real-time network management and improved methods for timetable planning
TPL F20		FR8RAIL II WP5: Freight Automation
TPL F21		FR8RAIL III WP2: Real-time network management
TPL F22		FR8RAIL III WP3: Intelligent video gate / Demogate

Passenger transport and customer preferences

TPL P2	(TET P2; ToL 14, ToL 15)	High-Speed Rail in Sweden – Supply and demand
TPL P4	(TET P4; ToL 17)	Database of supply and prices for railway lines in Sweden
TPL P6	(TET P6)	Peripherally located railway stations – effects for train travel and society
TPL P7		Travelling flows on the Swedish rail network
TPL P8		Uppkomm 1 – Tendered and commercial rail services on the same track
TPL P9		Uppkomm 2 – Mixed rail market dynamics
TPL P10		Economics of future passenger train fleet
TPL P11		Operating costs for high-speed trains (THHT)
TPL P12		Delays' impact on demand on train journeys – a time series analysis (DeDe)

Capacity analysis and signalling

TPL C3	(TET C3; ToL 22)	Development of timetable strategies
TPL C12		Major traffic interruptions and major delays
TPL C13		The Railway market and the track access charges
TPL C14		Flexåter
TPL C15		KAIN. Capacity in networks
TPL C16		PLASA Smart planning
TPL C17		PLASA 2. Smart planning and virtual certification
TPL C18		ERTMS Long-term development
TPL C19		Mathematical methods for greater signalling system safety

RESEARCH PROJECTS

TPL F13. Capacity4Rail (C4R)

Researchers: Bo-Lennart Nelldal,
Behzad Kordnejad, Hans Boysen

Source of funding: European Union FP7

Duration: 2013–2017

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

Project coordinator was the International Union of Railways

(UIC) and 49 partners from major stakeholders in Industry, Infrastructure managers, railway undertakings, engineering and academic sciences also participated. At KTH divisions of TPL (former TET), REV and SB participated in this project. KTH Railway Group at TPL conducted 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 transshipment and interchange/logistics.

WP 2.4: Catalogue of specifications.

WP 3.2: Simulation and models to evaluate enhanced capacity.

Publications

Casanueva, C., Krishna, V. V., Jönsson, R., Nelldal, B.-L., 2015. Payload optimization of articulated wagons regarding train length and vehicle dynamic behavior. Paper presented at RAIL2015.

Islam, D., Ricci, S and Nelldal, B.-L., 2016. How to make modal shift from road to rail possible in the European transport market, as aspired to in the EU Transport White Paper 2011. European Transport Research Review, DOI 10.1007/s12544-016-0204-x.

Nelldal, B.-L., (ed.) 2017. Capacity4Rail: Requirements toward the freight system of 2030/2050. Deliverable 21.2. KTH Report TRITA-TSC-RR 17-002.

Nelldal, B.-L., 2017. Capacity4Rail: Scenarios of Development of new rail freight vehicles. MS 15 in WP2.2. KTH Report TRITA-TSC-RR 17-005.

Kordnejad, B., Carrillo Zanuy, A. (eds.), 2017. Capacity4Rail: Conceptual terminals' design methodology for different markets. Working report in WP 2.3.1. KTH Report TRITA-TSC-RR 17-006.

Kordnejad, B. (ed.), 2017. Capacity4Rail: Measurements for Intermodal Transport Chains. Working report in WP 2.3.2. KTH Report TRITA-TSC-RR 17-007.

Kordnejad, B., and Nelldal, B.-L., 2017. Capacity4Rail Economic evaluation of intermodal terminals and marshalling yards. Working report in WP 2. KTH Report TRITA-TSC-RR 17-008.

Ricci, S. (ed.), 2017. Capacity4Rail: Co-modal transshipments and terminals. Deliverable D23.2. KTH Report TRITA-TSC-RR 17-009.

NEWOPERA (ed.), 2017. Capacity4Rail: Standards Deliverable D24.3. KTH Report TRITA-TSC-RR 17-010.

Nelldal, B.-L., 2017. Capacity4Rail: Line capacity and train capacity for future rail freight corridors. Appendix to Deliverable D32.2. KTH Report TRITA-TSC-RR 17-011.

Nelldal, B.-L., 2017. Capacity4Rail: Parameters for capacity and costs of freight trains in Sweden including MS23 Business cases and validation of new freight wagons. Appendix to Deliverable D5.4.2/3. KTH Report TRITA-TSC-RR 17-012.

IST, (ed.), 2017. Capacity4Rail: Assessment of technologies, scenarios and impacts. Deliverable D5.4.2/3 by Instituto Superior Técnico (IST). KTH Report TRITA-TSC-RR 17-013.

TPL 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: Energimyndigheten (Swedish Energy Agency)

Duration: 2015-2016

The study explores possibilities for shifting regional flow of goods in the greater Stockholm and Mälardalen area from road to sea and rail transport, and in that way increase energy efficiency in transport. It maps the extent to which import and export flows to and from ports in the region can shifted to sea or rail transport. 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 flows of goods on the railway. Such trimodal regional logistics systems can contribute to a transition to 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 jointly with Transport Research Institute (TfK) and industry players include Coop Logistics, ICA, Jernhusen, M4, Mälardalen, Port of Oxelösund, Ports of Stockholm and Södertälje and Thor Shipping.

Publications

Kordnejad, B., Karlens, K. and Bark, P., 2016. Hållbar och energieffektiv regionallogistik i Mälardalen, TFK rapport 2016:4. Stockholm

TPL F15. City logistics with pilot study of Tomtebodavägen yard

Researchers: Behzad Kordnejad (Project manager), Bo-Lennart Nelldal

Source of funding: Trafikverket (Swedish Transport Administration)

Duration: 2016-2017

The study explores the possibilities to use a central terminal in Stockholm City for distribution of intermodal containers. This looks into transporting goods in unit loads near the City-Center with electric trains and then distributed by vehicle to the peak direction over a shorter distance. This will enable using electric battery-powered vehicles and to establish a non-polluting transport system in the Stockholm

area. This system will be compared to direct vehicle transport to customers. Two different regional intermodal lines are investigated: A 30 km line from Rosersberg to Tomtebodå and a 100 km line from Våsterås to Tomtebodå. The shorter line means lower energy consumption and pollution but higher costs than direct vehicle transport. The longer line will reduce energy consumption 73% and CO₂ emissions 87% and also the transportation cost 12%.

Publications

Kordnejad, B., Nelldal, B.-L., 2017. Idéstudie Citylogistik med Tomtebodå som pilot – Ett långsiktigt hållbart transportsystem för Stockholmsregionen. KTH report TRITA-TEC-RR 17-004.

TPL F16. ARCC WP2: Real-time yard management

Researchers: Behzad Kordnejad
 Source of funding: Trafikverket (Swedish Transport Administration) KAJT / EU S2R - IP5
 Duration: 2016-2019

KTH contributed to deliverable D2.1 in the ARCC Work package (WP) 2 'Real-time Yard Management' (RTYM), which is a main topic of the Automated Rail Cargo Consortium (ARCC) project. The overall aim of the ARCC project was to conduct an initial phase of rail freight automation research activities designed to boost levels of quality, efficiency, and cost effectiveness in rail freight operations of the European rail sector.

WP2 Swe was the Swedish part of the WP2 work package and intended to study and develop methods of planning and control at marshalling yards and inland intermodal terminals. Of particular interest was the interface between rail yard / terminal and other parts of the network. In this context, the objectives of the ARCC WP2 Swe included answering questions related to both operational and strategic/tactical processes.

Publications

ARCC. (2017). D2.1 - Description of automation/optimisation requirements and capabilities of decision making process in marshalling yards and terminals. DB Cargo AG.

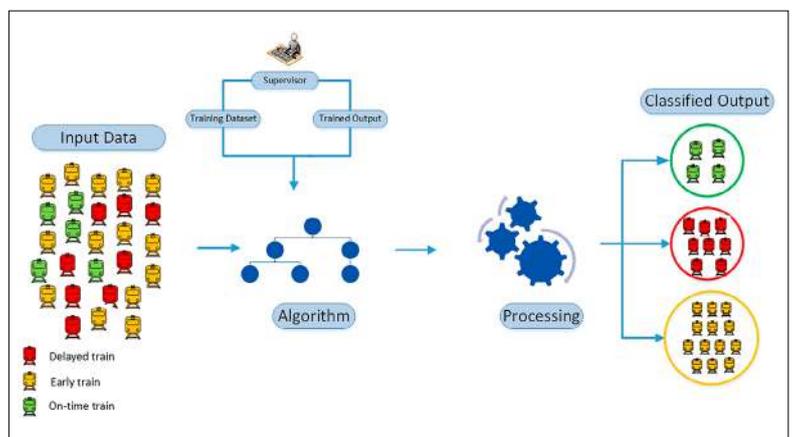
TPL F17. FR8HUB WP3: Real-time network management and simulation of increasing speed for freight trains

Researchers: Markus Bohlin (principal investigator), Behzad Kordnejad (senior researcher), Johan Högdahl (PhD Student), Niloofar Minbashi (PhD Student), Josef Andersson (Research Engineer)
 Source of funding: Trafikverket (Swedish Transport Administration) / EU S2R - IP5
 Duration: 2017-2020

For yard analysis, the study aims to implement a departure delay prediction model from the yards with the application of supervised learning methods. The case study will include Malmö and Hallsberg yards and the line connecting them. The method will also be adapted for using data as produced in FR8HUB WP4 (IVG). In addition, applying input from the ARCC project will be considered.

This work package will deliver a demonstrator showcasing

This project will develop methods for improved interaction between network management and yard management. The methods will consider interactions between timetable planning on lines and terminals/ yards on a higher level, based on available statistics on arrivals and departures of trains, wagons and intermodal loading units. The project is focused on capacity analysis and planning and considers both railway timetabling and yard analysis. For short-term railway timetabling, a combined simulation-optimization approach has been demonstrated to reschedule freight trains to a later departure time.



Example of classification of train data. Illustration: Niloofar Minbashi

the effects of improved traffic management through better interaction between line and yard. The results will be validated using traffic simulations in Railsys.

Publications

Minbashi, N., Bohlin, M., Kordnejad, B., 2019. A Delay Prediction Model for Freight Trains in Swedish Yards. Swedish transportation research conference, October, Linköping, Sweden.

Minbashi, N., Bohlin, M., Kordnejad, B., 2020. A Departure Delay Estimation Model for Freight Trains. Transport Research Arena 2020, April 27-30, Helsinki, Finland (Conference cancelled)

Högdahl, J., 2019. Delay Prediction with Flexible Train Order in a MILP Simulation-Optimization Approach for Railway Timetabling. In: Proceedings of 8th International Conference on Railway Operations Modelling and Analysis (RailNorrköping 2019), June 17-20, Norrköping, Sweden

Högdahl, J., Bohlin, M., Fröidh, O., 2019. A combined simulation-optimization approach for minimizing travel time and delays in railway timetables. Transportation Research Part B: Methodological, Volume 126, pp. 192-212

TPL F18. FR8HUB WP4: Intelligent video gate

Researcher: Behzad Kordnejad (Project manager)
 Source of funding: Trafikverket (Swedish Transport Administration) / EU S2R - IP5
 Duration: 2018-2019

The project's overall objective is to digitize and automate processes in intermodal terminals using the concept of 'Intelligent video gates' and thus achieve efficient data collection and processing. This will enable fast and reliable recognition of incoming and outgoing rolling stock and load carriers.

New technologies, such as optical code recognition (OCR), RFID, and sensors enable automatic recognition of rail car numbers and codes on intermodal loading units (containers, semi-trailers, and swap-bodies) and their sequence in the train. Visible damage can also be detected and other possibilities to improve current processes through digitalization and automation are evaluated. Terminals in

Sweden and Germany have been analyzed in case studies.

Within the framework of the project, functional and technical requirements were investigated, components were selected, technical proof-of-concept was conducted, and an implementation plan was presented, concentrating on prerequisites in Sweden and Germany. Also, a demonstration of the concept was performed at Innotrans 2018 using model trains.

The project is led by DB (DUSS), other European parties are Hitachi, Indra, and the Swedish Transport Administration (Trafikverket). KTH is a linked third party to the Swedish Transport Administration for the project. Other Swedish linked third parties are RISE, Ericsson, TransportForsK (TfK), and LearningWell.

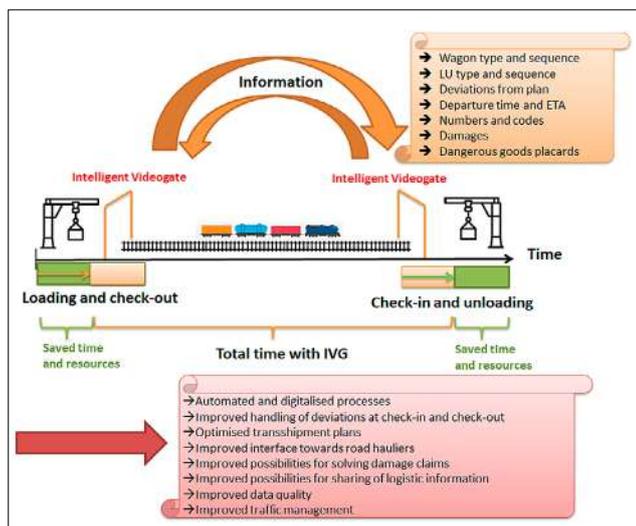
Publications

Kordnejad, B., Karl, J., Lengu, R., Gotelli, G., Barbi, C. E., Diotallevi, C., Merle Carrera, L., Garcés Mencía, H., Irala Briones, A., Mitrovic, B., Ivansson, G., Aronsson, M., Kjellin, M., Nordmark, I., Åkerfeldt, M. WP4: Intelligent Video Gate, FR8HUB: D4.2 Technical Proof of Concept and Roll-out and Implementation Plan, 2019, Shift2Rail

Kordnejad, B., Karl, J., Lengu, R., Gotelli, G., Barbi, C. E., Diotallevi, C., Merle Carrera, L., Garcés Mencía, H., Irala Briones, A., Ivansson, G., Posseger, E., Aronsson, M., Kjellin, M., Treiber, A., Åkerfeldt, M. WP4: Intelligent Video Gate, FR8HUB: D4.1 Description of functional and technical requirements and selection of components, 2018, Shift2Rail

Kordnejad, B., Aronsson, Diotallevia, C., van Bunningen, T., Bergstrand, J., Åkerfeldt, M., 2020. Internet of Logistics: A New Opportunity for the Digitalization of Logistics, Transport Research Arena 2020, April 27-30, Helsinki, Finland

Kordnejad, B., Mitrovic, B., Aronsson, M., Nordmark, I., Bergstrand, J., Åkerfeldt, M., 2020. Intelligent Video Gate – A Conceptual Application of Emerging Technologies in Rail Freight Transports, Transport Research Arena 2020, April 27-30, Helsinki, Finland



TPL F19. FR8RAIL II WP3: Real-time network management and improved methods for timetable planning

Researcher: Behzad Kordnejad (Project manager), Jennifer Warg (PhD student), Ingrid Johansson (PhD student), Hans Sipilä, Mohammad Al-Mousa

Source of funding: Trafikverket (Swedish Transport Administration) / EU S2R - IP5

Duration: 2018-2021

Integrating real-time network management and improved methods for timetable planning is essential for efficient rail network management, especially during both minor and major disturbances. This will make passenger and freight rail services more competitive.

Currently, network planning and real-time management are disconnected. This disconnect needs to be eliminated. This concept is based on maintaining a continuously conflict-free

traffic plan that is updated in both planning and real-time, and is likely to be consistent with operational constraints for railway undertakings, and for yard and terminal managers. This enables automation, ensures feasibility of operational contingencies, and enables more efficient co-operation between infrastructure managers, railway undertakings, and yard or terminal managers.

The work package will deliver a demonstrator for improved short-term planning and daily planning. Requirements will be specified for a demonstrator for testing real time network management concepts.

Publications

Deliverable D 3.1, 2019, Analysis of the gap between daily timetable and operational traffic. Report

TPL F20. FR8RAIL II WP5: Freight Automation

Researcher: Behzad Kordnejad (Project manager)

Source of funding: Swedish Transport Administration / EU S2R - IP5

Duration: 2019-2020

This work package is designed to define and develop concepts and requirements for automating train preparation to further improve efficiency and safety. For example, an automatic brake test, linked to the operator's database,

will significantly shorten train preparation times while increasing safety. Or, an autonomous locomotive start-up, with subsequent heating or cooling of auxiliaries, or automated train data entry will reduce the lead time in the start-up assignment.

Publications

Deliverable D 5.1, 2020, Automation Concepts. Report

TPL F21. FR8RAIL III WP2: Real-time network management

Researcher: Behzad Kordnejad (Project manager)

Source of funding: Trafikverket (Swedish Transport Administration) / EU S2R - IP5

Duration: 2019-2022

Research in Real-time network management will improve operational processes using improved methods and information support, and human interaction. The research will reduce the gaps between timetable planning and operational traffic, and between yard management and network management.

The project will make a TRL 6 demonstration utilizing the integrated information platform developed in the project. The demonstration will include several important actors of

the processes in scope, such as line planner, yard manager and arrival/departure yard planner.

The objectives can be summarized as follows:

- To automate sequential planning and efficient human interaction, overcoming the current lack of synergies when handling and sharing data among infrastructure managers, yard/terminal managers, railway undertakings and maintenance contractors.
- To improve interaction and balancing capacity utilization between infrastructure managers, yard/terminal managers, railway undertakings and maintenance contractors.
- To reduce the gap between timetable planning and operational traffic.

TPL F22. FR8RAIL III WP3: Intelligent video gate / Demogate

Researcher: Behzad Kordnejad (Project manager)
Source of funding: Trafikverket (Swedish Transport Administration) / EU S2R - IP5
Duration: 2019-2022

The overall objective of the project is to digitize and automate the processes at full-scale in freight terminal in Sweden and in a marshalling yard in Germany using 'Intelligent video gates,' to achieve efficient data collection and processing. This will enable fast and reliable recognition of incoming and outgoing rolling stock and load carriers. The project is a continuation of the work in FR8HUB WP4 'Intelligent Video gate.'

New technologies such as optical code recognition (OCR), RFID, and sensors enable automatic recognition of wagon numbers and codes on intermodal load carriers (containers, semi-trailers, and swap-bodies) and their sequence in the train. Visible damage can also be detected, and other possibilities introduced to improve current processes through digitalization and automation.

The project is led by KTH as a linked third party to the Swedish Transport Administration (Trafikverket), other Swedish linked third parties are RISE, Ericsson, TransportForsk (TfK) and LearningWell. Other European parties are DB, Hitachi, and Indra.



Fika on Valentine's day 2019: From left to right Abderrahman Ait Ali, Félix Vautard, Niloofar Minbashi, Ingrid Johansson, Oskar Fröidh, Jennifer Warg and Johan Högdahl. Picture: Niloofar Minbashi

PASSENGER TRANSPORT AND CUSTOMER PREFERENCES

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

Researchers: Bo-Lennart Nelldal and Oskar Fröidh
Source of funding: Various
Duration: Continuous

The fundamental characteristic of high-speed trains on new main lines is they reach a high average speed, often exceeding 200 km/h with top speeds between 250 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. Punctuality is also improved by separating 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. During later years, we have had a continuous dialogue with the New Generation Railway (NGJ) high-speed rail project of Trafikverket. The aspects discussed includes system requirements and technical standards, and not at least the performance of the national demand forecast model.

Publications

Nelldal, B.-L., 2019. Analys av prognoser för nya stambanor och jämförelse med internationella erfarenheter av höghastighetståg. KTH Railway Group publications 19-01. Stockholm

Fröidh, O., 2019. Förbindelsespår i Värnamo. Kopplingspunkt på NGJ för direkta resor mot sydöstra Sverige. Idéstudie 2019-09-17 (not published)

Nelldal, B.-L., 2019. Höghastighetsbanor: En investering för hållbart resande och godstrafik. KTH Railway Group publications 19-02. Stockholm

Andersson, E., Berg, M., Nelldal, B.-L. and Stichel, S., 2020. Varför behövs Nya Stambanor i Sverige? KTH Railway Group, publication 20-01. Stockholm

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

Researchers: Bo-Lennart Nelldal, Josef Andersson and Oskar Fröidh (Project manager)
Sources of funding: Transportstyrelsen (Swedish Transport Agency). Previously also Banverket (Swedish Rail Administration; 1990-2009) and the agency Transport Analysis (2010-2014)
Duration: 1990–2020

Publications

Nelldal, B.-L., Andersson, J. and Fröidh, O, 2015. Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2015: och Utvärdering av avreglering och konkurrens samt analys av regional utveckling. KTH Report, TRITA-TSC-RR 15-004

Nelldal, B.-L., Andersson, J. and Fröidh, O, 2016. Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2016: och avreglering och konkurrens mellan tåg, flyg och buss samt kopplingen mellan resandet och ekonomin. KTH Report, TRITA-TSC-RR 16-004

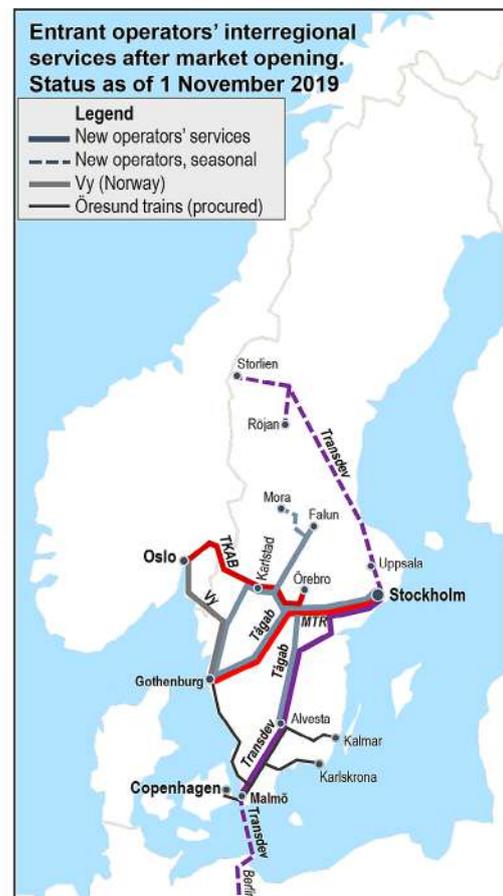
Nelldal, B.-L., Andersson, J. and Fröidh, O, 2017. Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2017: Avreglering och konkurrens mellan tåg, flyg och buss samt förseningarnas betydelse för tillgängligheten. KTH Report, TRITA-TSC-RR 17-003

Nelldal, B.-L., Andersson, J. and Fröidh, O, 2018. Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2018: Avreglering och konkurrens mellan tåg, flyg och buss samt utvecklingen av förseningarna. KTH Report, TRITA-ABE-RPT 1845

Nelldal, B.-L., Andersson, J. and Fröidh, O, 2019. Utveckling av utbud och priser på järnvägslinjer i Sverige 1990-2019: Avreglering och konkurrens mellan tåg, flyg och buss samt jämförelse mellan tåg- och resenärspunktighet. KTH Report, TRITA-ABE-RPT 1920

The KTH Railway Group in the Division for Transport Planning has continuously built a database of services available and prices for nearly one hundred rail lines in Sweden. This database currently covers the years 1990 to 2019 and is updated annually on assignment. This supply database contains data on travel times, frequency, and prices in relation to various products (such as high-speed service, Intercity (IC) service, regional service) for commercial rail services, tendered service contracts for regional public transport, and national principals.

A report is published annually with analyses of trends and changes to services available, the competitive situation between operators and between rail, bus, and auto, and often including special in-depth study, as with generalized travel cost with respect to various relationships.



SJ's interregional services (left) and entrant operators' services (right) as of 1 November 2019. Illustration: Oskar Fröidh

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

Researchers: Oskar Fröidh (Project manager), Josef Andersson, Daniel Jonsson and Marcus Adolphson

Source of funding: Trafikverket (Swedish Transport Administration)

Duration: 2014-2018

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. It is unclear what effects the peripherally located stations have had on rail travel, service in relation to travellers and urban development compared with centrally located stations. Clarification of these effects is important for many aspects of future rail corridors and their planning.

14 new or remodelled stations for primarily interregional and medium to longer regional train services with greatly improved train supply since 1990 were selected for the study: From south to north the stations are Malmö Hyllie, Triangeln and Malmö C, Laholm, Flemingsberg, Södertälje south, Läggesta, Strängnäs, Eskilstuna C, Bålsta, Uppsala C, Söderhamn, Umeå Ö and Umeå C. The analysis comprises three main parts: 1) Analysis of departing train travellers' travel habits and valuations; 2) Morphological study of the changes in the social structure 1993-2013 and the municipal plans; and 3) Model analysis of changes in traffic and accessibility at alternative locations.

In summary, the study suggests that localization of new stations will have an impact on society in terms of urban form, passenger satisfaction, travel habits and means of

transport and access to workplaces and services, which affects the attractiveness of the railway system and thus travel demand. Centrally or urban located stations thus appear more attractive and better from a system point of view than peripherally located stations.

However, the reason for localizing stations in peripheral settings involve intended reduction in construction costs and intrusion into built-up environments compared to an urban location. When this becomes relevant, it is important to have good public transport connections and other supportive strategies for exploitation and more. However, the present study adds arguments to value the positive effects of an urban located station higher than today.

We have identified opportunities to further develop the methods for evaluating the effects of station location in several areas. It is also possible to include the analyses in location investigations to improve the decision basis for future station location choices.

Publications

Adolphson, M. and Fröidh, O., 2017. Development of urban structure in proximity to new railway stations. RSA Annual Conference, 4-7 June, Dublin, Ireland

Fröidh, O., Adolphson, M., Jonsson, D. and Andersson, J., 2018. Lokalisering av järnvägsstationer – effekter för samhällsplanering, resande och tillgänglighet. KTH Report, TRITA-ABE-RPT 1815

Adolphson, M. and Fröidh, O., 2019. Impact on urban form by the localization of railway stations: Evidence from Sweden. Cities, Vol. 95, article id 102362



Läggesta station is located periferally with connecting bus services to nearest town. Picture: Oskar Fröidh

TPL P7. Travelling flows on the Swedish rail network

Researchers: Bo-Lennart Nelldal, Josef Andersson and Oskar Fröidh (Project manager)
 Sources of funding: Transportstyrelsen (Swedish Transport Agency)
 Duration: 2016-2018

The KTH supply database mentioned in project TPL P4 contains time series data of rail services supply. However, rail travel demand is not as well studied due to lack of obligation to report journeys for national statistics. The aim of this project was to describe the demand and implement flows to calibrate a forecast model. A method has been developed that includes the following steps:

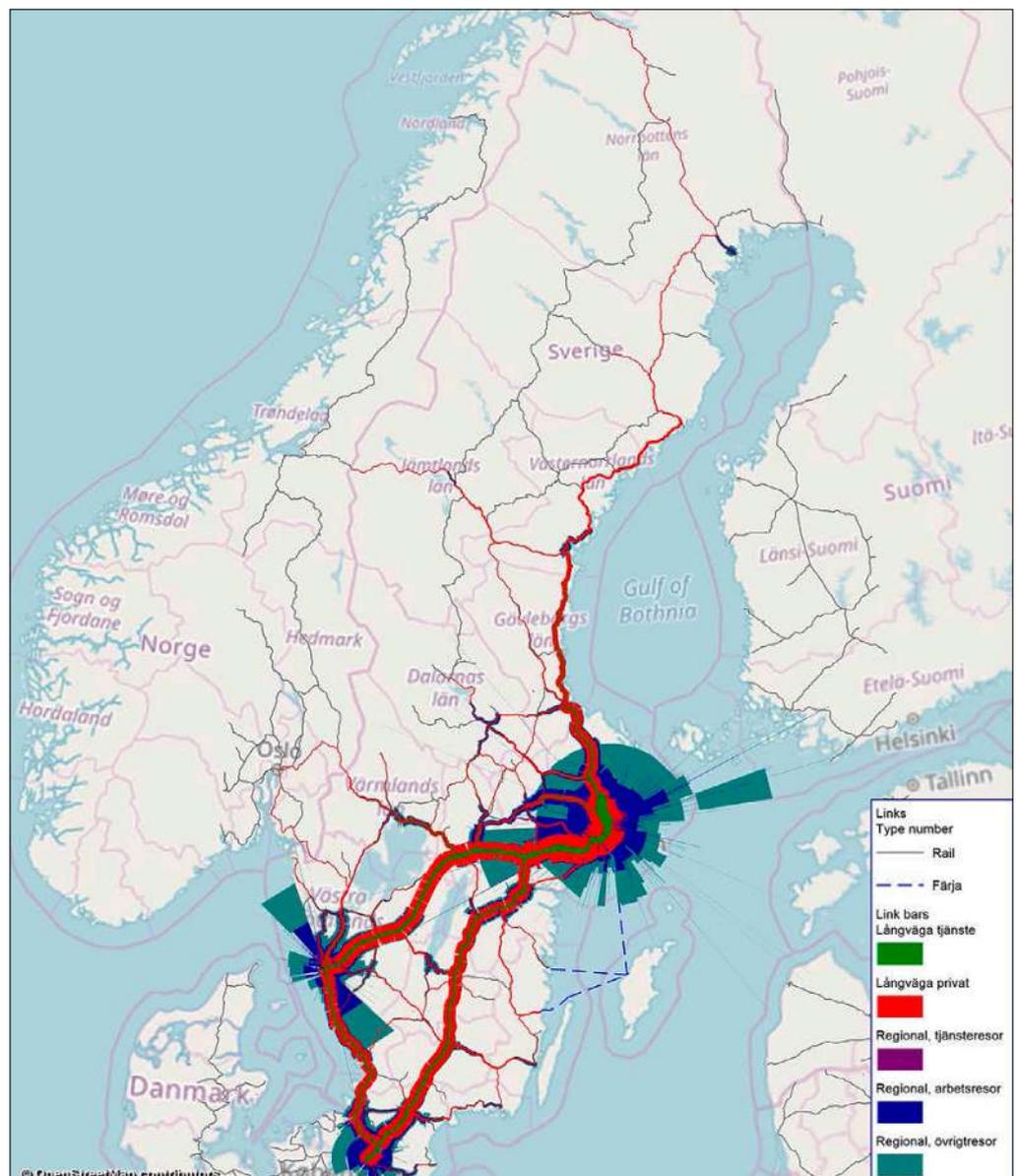
- Matrices with interregional and regional rail travel was taken from Trafikverket's forecast system Sampers 2014.
- Data of all departures in one day were taken from Samtrafiken's database.

- A Register from Trafikverket with the specific composition of trains in one specific day was used to calculate the seating capacity. It has been completed with a vehicle register and product factors which describes the standard of the trains in a customer perspective.
- Supply and train types with comfort factors are input in forecast tool Visum which calculate and make route assignment on the rail network.
- Supply and demand during a day was calibrated to base year 2016 and key figures for traffic systems, products and lines was calculated.

Publications

Nelldal, B.-L., Andersson, J., and Fröidh, O., 2018. Resandeflöden på Sveriges järnvägsnät - Analys av utbud och efterfrågan på tågresor. KTH report TRITA-ABE-RPT-1818

Long distance and regional rail travel in Sweden.



TPL P8. Uppkomm 1 – Tendered and commercial rail services on the same track

Researchers: Félix Vautard (PhD student), Oskar Fröidh (Project manager), Josef Andersson, Camilla Byström, Chengxi Liu (VTI)

Source of funding: Trafikverket (Swedish Transport Administration)

Duration: 2017-2020



More operators on the tracks has increased the demand but sometimes the competition for capacity and passengers is noticeable. Picture: Oskar Fröidh

The Uppkomm research project is designed to study the effects of opening markets using tendered and commercial rail service provided on the same track. Competition between public transport services arise on certain track sections in Sweden involving commercially operated versus tendered rail services operated under a contracting governmental authority. The project included studying regional and inter-regional passengers' assessment of smaller shifts in departure times. The next stage involved using the forecasting tool Visum to analyze effects on demand due to adjustments in scheduling forced by limits to track capacity.

Publications

Vautard, F., 2020. Improvement of departure time suitability for interregional rail timetables. Licentiate Thesis. KTH TRITA-ABE-DLT-206. Stockholm

Vautard, F., Liu, C., Fröidh, O., (2020a). Assessing economic welfare for departure time shifts in interregional rail timetables. Submitted to Transportation Research Part A

Vautard, F., Liu, C., Fröidh, O., Byström, C., (2020b). Estimation of interregional rail passengers' valuations for their desired departure times. Submitted to Transport Policy

TPL P9. Uppkomm 2 – Mixed rail market dynamics

Researchers: Félix Vautard (PhD student), Oskar Fröidh (Project manager), Chengxi Liu (VTI), Jan-Eric Nilsson (VTI)

Source of funding: Trafikverket (Swedish Transport Administration)

Duration: 2020-2023

In Uppkomm stage 2, the aim is to analyse the market effects of competition on the tracks on mixed markets, i.e. passenger rail services with procured and commercial supplies on the same route which is wholly or partly interchangeable for travellers.

Therefore, our research questions for the doctoral project are:

1. What are the underlying drivers of rail operators' behaviours to design their supply in mixed rail markets?
 2. How can Public Transport Authorities (PTA) design the procured rail services to maximize the welfare given that competition on the tracks is a prerequisite?
 3. How can an infrastructure manager (e.g. Trafikverket) improve the capacity allocation (essentially its timetable planning) on a mixed market to maximize the welfare?
- The project will result a doctoral thesis. Uppkomm 2 is further based on the model that were produced in Uppkomm 1 and is expected to generate knowledge to increase the socio-economic benefits (welfare) of passenger traffic on the railways for several parties in the rail sector.



Passenger information in Malmö central station. Picture: Oskar Fröidh

TPL P10. Economics of the future passenger train fleet

Researchers: Oskar Fröidh (Project manager), Mats Berg
 Source of funding: Trafikverket (Swedish Transport Administration)
 Duration: 2017-2019

The research project 'Economics of the future passenger train fleet' aims to assess the future vehicle fleet in order to be able to calculate traffic costs and, in the long term, dimension the traffic range for future passenger train traffic in Sweden. The starting point is today's vehicle fleet and the forecast year is 2040 and 2065 with a particular focus

on identifying significant development steps and threshold effects in vehicle fleet development. Eight generalized train categories with different characteristics have been defined and operating costs estimated for use in Trafikverket's socio-economic calculations. Internationalization, technological development, investments in the railway network and restructuring in the industry affect the vehicle fleet in the long run.

Publications

Fröidh, O. and Berg, M., 2019. Framtida trafikeringskostnader och utveckling av persontågsparken. KTH, report TRITA-ABE-RPT-1912

TPL P11. Operating costs for high-speed trains (THHT)

Researchers: Oskar Fröidh (Project manager), Mats Berg
 Source of funding: Trafikverket (Swedish Transport Administration)
 Duration: 2019-2020

The project determines operating costs for rail service using high-speed trains in greater detail than previously possible in the project Economics of the future passenger train fleet (TPL P10).

The ongoing research and development program Shift2Rail (within IP1) generates finding in stages providing a good starting point for assessment of future trends. Information regarding economic trends and current technical

developments are collected and analysed. A cost estimation model for passenger services is updated to include new data in the high-speed train portion. This provides an updated proposal for a new type train.

Findings will be used as the basis for updating operating costs for passenger services and for Trafikverket's socio-economic costing calculations regarding future investment in rail infrastructure.

Publications

Fröidh, O., 2020. The importance of commercial speed and operating costs for planning high-speed train services. Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020, Helsinki, Finland (conference cancelled)

TPL P12. Delays' impact on demand on train journeys – a time series analysis (DeDe)

Researchers: Per Näsman (Project manager), Bo-Lennart Nelldal, Josef Andersson
 Source of funding: Trafikverket (Swedish Transport Administration)/KAJT
 Duration: 2020-2021

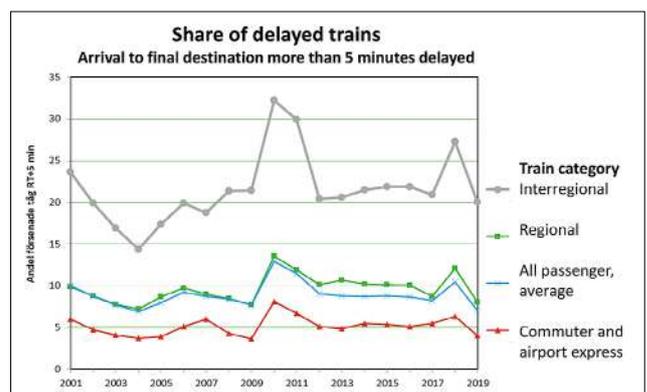
The project aims to calculate the relationship between delays and demand for train journeys over a longer term. Here, long term is defined as over the time remaining demand effects caused by delays and the minimum period of time in the data is one year.

The project will answer the question of how much travel is affected by delays and thus how it affects the revenues of

the operators and the socio-economic costs of travellers and society.

KTH has built up a unique database of train supply incl. prices for 1990-2019, and delays from 2001-2018 on various routes. This can be combined with information on the demand for train journeys.

Share of delayed passenger trains in Sweden 2001-2019. The 2010 and 2011 peaks were due to extremely cold and snowy winters, and 2018 the extremely warm summer.



TPL C3. Development of timetable strategies

Researchers: Jennifer Warg (PhD student), Markus Bohlin (Project manager), Oskar Fröidh, Bo-Lennart Nelldal, Lars-Göran Mattsson

Sources of funding: KTH Railway Group 2013-2016; (Various 2016-), Hesselmanska stiftelsen 2021

Duration: 2012-2021

This research project is designed to assess the results of timetable analyses and simulations to determine benefits to travellers and railway operators. Currently, such benefits are rarely considered in capacity analyses. Moreover, capacity characteristics are a minor consideration in socio-economic analyses. In the project, relevant capacity criteria are identified and assessed to establish relationships between the criteria to enable using these for assessment. Primary focus is on comparing various timetable slots and timetable alternatives. Further, a method for pricing commercial train slots in deregulated markets is developed in cooperation with the SAMEFF project. That method will be based on the social-economic costs of consequences resulting from changes to timetables in subsidised traffic. The Swedish western and southern main lines are used for case studies.

Publications

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

Fröidh, O., Warg, J., Sipilä, H., 2014. Capacity for express trains on mixed traffic lines. *International Journal of Rail Transportation*, vol. 2, iss. 1, pp. 17-27.

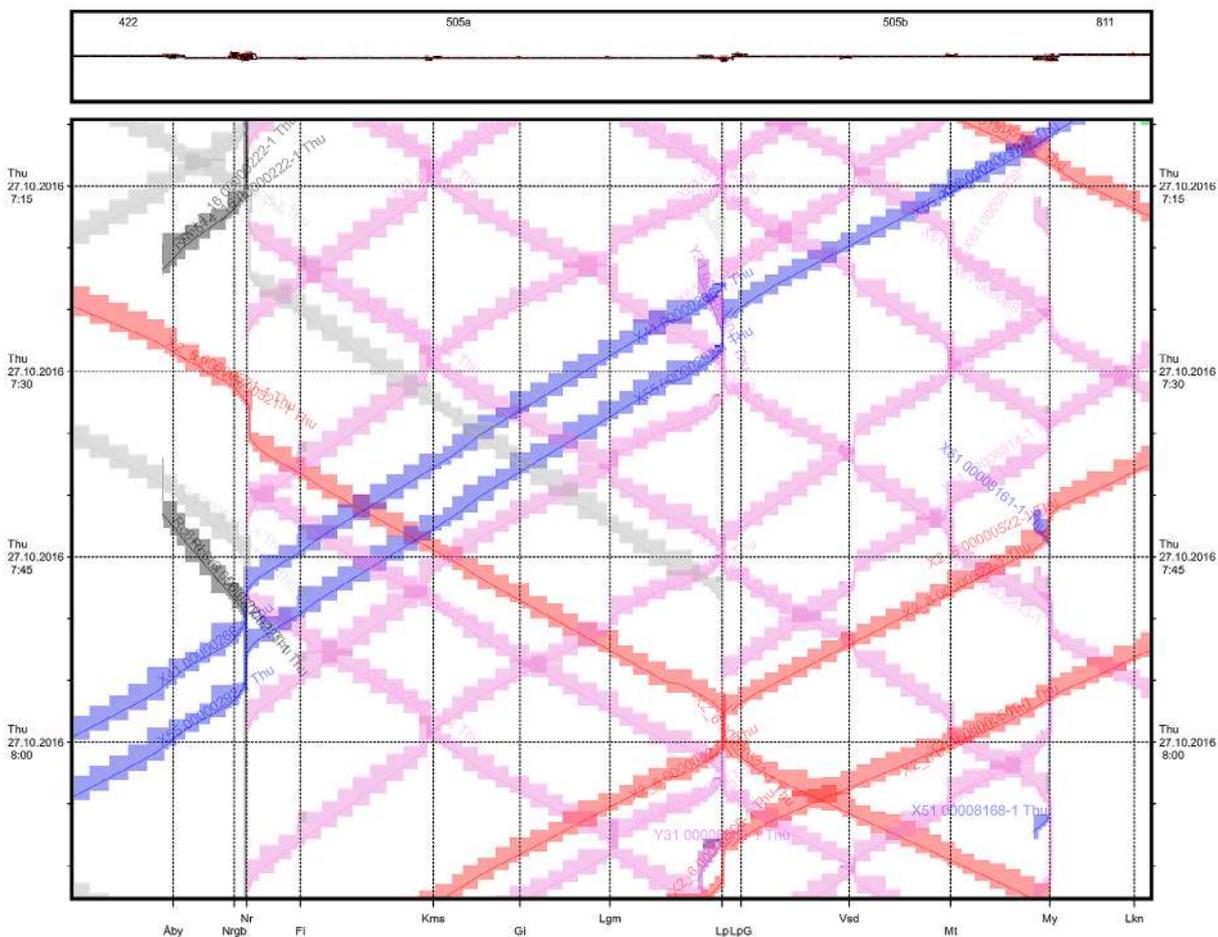
Warg, J., 2016. Timetable evaluation with focus on the travellers. Licentiate thesis. KTH TRITA-TSC-LIC 16-001. Stockholm

Warg, J. and Bohlin, M., 2016. The Use of Railway Simulation as an Input to Economic Assessment. *Journal of Rail Transport Planning & Management*, 6 (3), 2016, 255-270

Warg, J. and Bohlin, M., 2017. Simulation-based Timetable Evaluation with Focus on Passengers. IAROR RailLille2017, Lille.

Warg, J., Bohlin, M., 2019 Passenger-orientated Analysis of Railway Capacity Allocation with Help of Simulation. In: *Proceedings of 8th International Conference on Railway Operations Modelling and Analysis (RailNorrköping 2019)*, June 17-20, Norrköping, Sweden

Ait Ali, A., Warg, J., Eliasson, J., 2020. Pricing commercial train path requests based on societal costs. *Transportation Research Part A: Policy and Practice*, Volume 132, pp. 452-464.



Timetable in RailSys micro simulation for a double track line including block occupation fields.

TPL C12. Major traffic interruptions and major delays

Researcher: Bo-Lennart Nelldal
Sources of funding: Trafikverket (Swedish Transport Administration)
Duration: 2015-2016

Delays and traffic interruptions have become increasingly common in the railway system due to extreme weather as a result of climate change, increased traffic, and overdue maintenance. This report analyses both major traffic interruptions lasting more than 24 hours and major delays of more than one hour in passenger and freight traffic.

One conclusion drawn is that long delays in passenger traffic are due to external factors such as overhead line electrification faults, people on the tracks, storms, and disturbance from other trains to a greater extent than in freight traffic. Such causes are difficult for railway companies to influence directly and can only be influenced to a degree by the Swedish Transport Administration.

Regarding freight traffic, delays classified as Late from depot or to/from abroad and disturbed by other train are

highly significant and in some cases can be considered internal factors over which the railway companies themselves can exert a degree of control. On the other hand, the fact that Late from depot has such great impact is an indication of a need for more flexible timetable planning and operative management of freight traffic.

A recommendation is that statistics should differentiate between traffic interruptions of longer than 24 hours, major delays of longer than 1 hour, and minor delays, and show punctuality and cancelled trains as specific items. Studies should be made of travellers' valuations of the different types of delays that can be used in socio-economic calculations.

Publications

Nelldal, B.-L., 2016. Stora trafikavbrott och förseningar vid Sveriges järnvägar och dess effekter. Major traffic interruptions and major delays at Swedish Railways and their effects (summary in English). KTH Report TRITA-TSC-RR 16-003.

TPL C13. The railway market and the track access charges

Researchers: Bo-Lennart Nelldal, Jakob Wajzman (Trafikverket)
Sources of funding: Trafikverket (Swedish Transport Administration)
Duration: 2015-2016

This report includes an analysis of the Swedish Railway market since the transport policy reform in Sweden at 1988 and an evaluation of the development of the track access charges and suggestions of how the charges could be designed in the future.

Swedish track access charges have long been relatively low. However, since 2009 track access charges were increased significantly to internalize external effects and increase state revenues. Therefore, the charges are almost three times higher in 2017 than at 2009. Track access charges increased more for freight than for passenger trains. The problem is that the willingness to pay for rail freight is low because of stiff competition and low profitability for operators.

The best way to steer the capacity utilization is to differentiate charges in time and geography. This will lead to trains with higher capacity, changes in timetables to less overloaded hours and, in some cases. Using other lines.

An analysis of rolling stock has found that many new electric multiple units cause higher track wear than older vehicles. Differentiation of charges in relation to wear may reduce long term costs for track maintenance.

Alternative views of freight and passenger trains are also discussed: Increasing in passenger trains requires greater capacity investment and the increase in the speed of passenger trains requires better track maintenance. Then freight trains must pay for the destruction of track at a relatively higher cost than the need for freight. If there only was freight, infrastructure could be more adapted to freight, i.e. as in US, there will be more single tracks and longer trains, lower speeds, and with related (likely) lower freight fees. This may justify redistribution of charges from freight to passenger trains.

Publications

Nelldal, B.-L. and Wajzman, J., 2016. Järnvägens marknad och banavgifterna - Utvecklingen av järnvägssektorn och uppföljning av fordonsbestånd och kapacitetsutnyttjande. KTH Report TRITA-TSC-RR 16-002

TPL C14. Flexåter

Researchers: Johan Högdahl (PhD student),
Markus Bohlin (Project manager),
Oskar Fröidh

Sources of funding: Trafikverket (Swedish Transport
Administration)/ KAJT

Duration: 2016-2020

The project aims to develop new algorithms and methods to measure robustness, flexibility, and resilience in timetables, then describe and evaluate these, and develop a demonstrator to show the possibilities. In the longer term, the effect goal is to better measure capacity and the relationship between capacity-related parameters such as timetable robustness against interference and infrastructure flexibility to handle changes, utilized capacity, and resulting delays.

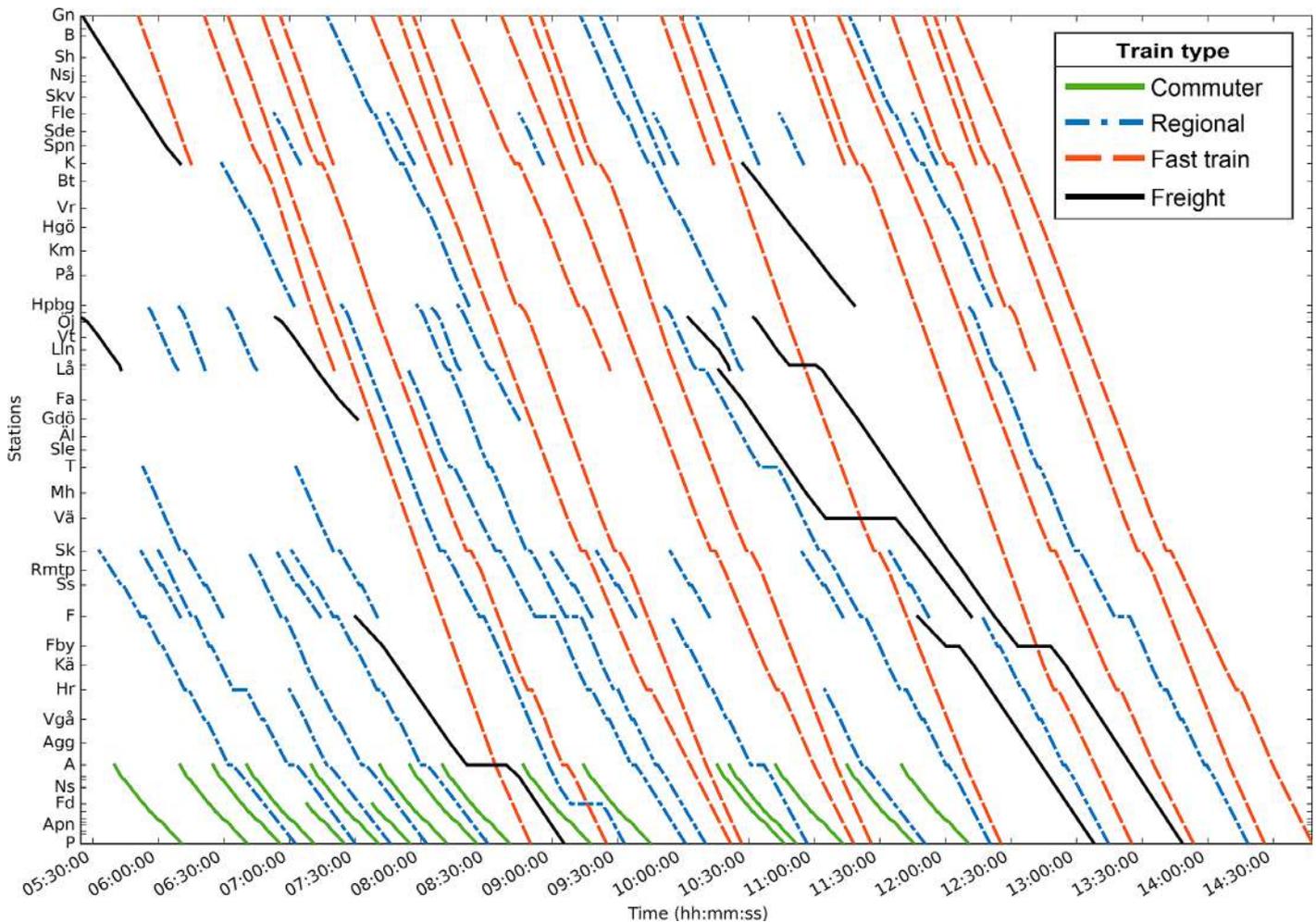
Publications

Högdahl, J., Bohlin, M., Fröidh, O., 2017. Combining optimization and simulation to improve railway timetable robustness. In Proc. 7th Int. Conf. On Railway Operations Modelling and Analysis RailLille, Lille, France

Högdahl, J., Bohlin, M., Fröidh, O., 2019. A Combined Simulation-Optimization Approach for Minimizing Travel Time and Delays in Railway Timetables. Transportation Research Part B: Methodological, 126, pp.192-212

Högdahl, J., 2019. Delay Prediction with Flexible Train Order in a MILP Simulation-Optimization Approach for Railway Timetabling. Paper presented to ICROMA RailNorrköping2019, 17-20 June, Norrköping, Sweden

Högdahl, J., 2019. A Simulation-Optimization Approach for Improved Robustness of Railway Timetables. Licentiate thesis, KTH. Stockholm



Optimization of a timetable with respect to delays and running times, here in one direction only on the Western main line.

TPL C15. KAIN – Capacity in networks

Researchers: Jennifer Warg (PhD student), Ingrid Johansson (PhD student), Markus Bohlin (Project manager)

Sources of funding: Trafikverket (Swedish Transport Administration)/KAJT

Duration: 2017-2019

The project investigated methods developed for capacity analysis in networks aiming for more efficient utilisation of existing infrastructure. The existing UIC406-based mathematical method for calculating capacity utilization was improved and expanded.

The project included a feasibility study on existing methods for calculating capacity utilization and identifying deficiencies in the Swedish Transport Administration's current method. Focus was development of a new, timetable-independent method for calculating capacity utilization on nodes and in networks. The project collaborated with the S2R project PLASA and PLASA 2, where the macroscopic simulation tool PRISM is being developed. A model description of that tool and an

investigation of its potential use in Sweden was part of the KAIN project. In both the capacity utilization model for nodes and the Swedish version of PRISM, timetable and infrastructure data are retrieved from the microscopic simulation tool RailSys.

Collaboration took place with Norman Weik at RWTH Aachen (Germany Research Foundation with research grant 283085490 "Integral capacity and reliability analysis of guided transport systems based on analytical models" and Research Training Group 2236 "UnRAVeL).

Publications

Weik, N., Warg, J., Johansson, I., Nießen, N., Bohlin, M., 2019. Extending UIC 406-based capacity analysis – New approaches for railway nodes and network effects. Conference paper presented at RailNorrköping, 17-20 June, Norrköping, Sweden

Weik, N., Warg, J., Johansson, I., Bohlin, M. and Nießen, N., (2020). Extending UIC 406-based capacity analysis - New approaches for railway nodes and network effects. In press for publication in a special issue of Journal of Rail Transport Planning & Management.

TPL C16. PLASA

Researchers: Markus Bohlin (Project manager), Jennifer Warg (PhD student), Behzad Kordnejad

Source of funding: Trafikverket (Swedish Transport Administration)/KAJT / EU S2R

Duration: 2017-2018

The Shift2Rail project, PLASA, was conducted by KTH in collaboration with the Swedish Transport Administration and international partners (DB Analytics, HaCon, SNCF and Thales). The project considered future methods for planning and controlling train traffic, so-called smart planning methods. Simulation, optimization and data analysis for timetable planning and prediction of punctuality were in the focus.

Today, microscopic simulation with RailSys is the usual method used in Sweden. The Swedish Transport Administration provides and maintains all of Sweden's

infrastructure and the annual timetable in the system to enable capacity analyses of various kinds. Travel times, delays and capacity utilization can be estimated efficiently.

The tool requires a high level of detail which uses complex networks, advanced investigation scenarios or future systems difficult. In addition, expert knowledge is required to use the program properly. To overcome these shortcomings, development of a macro simulation tool named PRISM was initiated in the project. It was tested in a case study on the Swedish southern mainline, as well as on the German railway network.

Publications

Zinser, M., Betz, T., Warg, J., Solinen, E. and Bohlin, M., 2018. Comparison of microscopic and macroscopic approaches to simulating the effects of infrastructure disruptions on railway networks. In Proc. 6th Transport Research Arena Conference, Vienna, April

TPL C17. PLASA 2 Smart planning and virtual certification

Researchers: Oskar Fröidh (Project manager), Ingrid Johansson (PhD student), Jennifer Warg (PhD student), Hans Sipilä

Source of funding: Trafikverket (Swedish Transport Administration)/ KAJT / EU S2R

Duration: 2018-2020

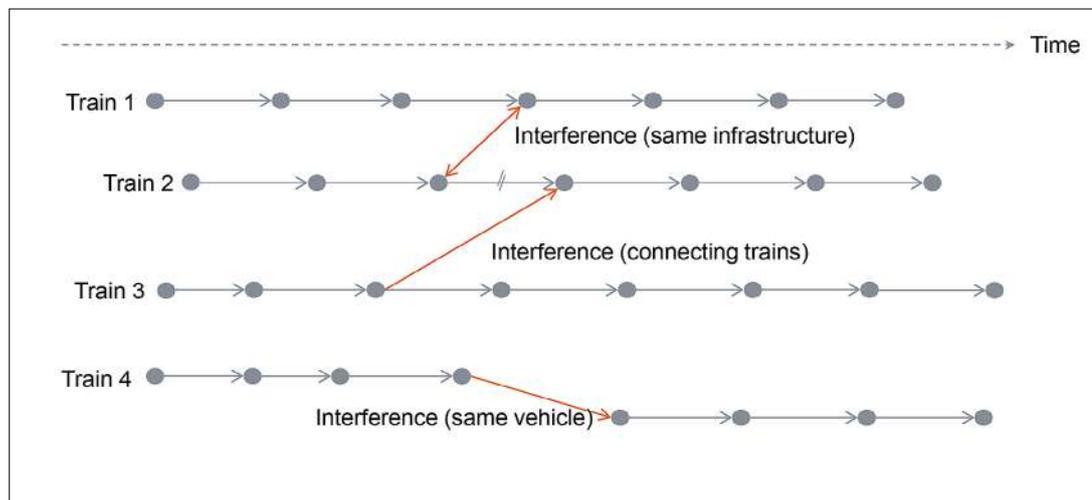
As PLASA 1, the project is about smart planning. Plasa 2 involves further development of the PRISM model and methodology developed in the first project. The macro-simulation tool PRISM enables faster analyses than the commonly used microscopic tool RailSys. In a case study on the line Hallsberg-Malmö, the tool is used and compared to simulation with RailSys, and to realistic data. While the case studies in PLASA 1 were theoretical with many assumptions, the further developed tool allows for a more

realistic analysis. Deutsche Bahn, as developer of the tool, are applying PRISM in a variety of case studies on the German railway network and developing it to include capability to use microscopic data when available, without reducing the advantage of fast simulation. An analysis of the program's advantages and disadvantages in comparison to RailSys as well as a description and method for use with incomplete data is also included in the project.

The project is under leadership from Deutsche Bahn (DB). Trafikverket is the Swedish partner using KTH and LU based researchers as linked third parties.

Publications

Zinser, M., Betz, T., Becker, M., Gielke, M., Terschlüsen, C., Kaluza, A., Johansson, I. and Warg, J., 2019. PRISM: A Macroscopic Monte Carlo Railway Simulation. Full paper, WCRR 2019, Tokyo



Example of interferences between trains in the PRISM macro simulation model.

The Railway Signalling Research Group is a subgroup of the Railway Group that today consists of research teams at the divisions of Transport Planning at ABE school and Information science and engineering

and Network and systems engineering at EECS school conducting research in technology and safety in the signalling and traffic control area to connect infrastructure, vehicles and traffic to a railway transport system.

TPL C18. ERTMS Long-term development

Researchers: Anders Lindahl (Project manager), Vahid Ranjbar (PhD Student), Oskar Fröidh, Nils Olsson and Olov Lindfeldt

Source of funding: Trafikverket (Swedish Transport Administration) / S2R

Duration: 2019-2021

The project is designed to analyze possible prerequisites for implementation of ERTMS Level 3 (L3) with moving blocks, which are the highest level of the current concept

of the future European railway signalling system. This analysis includes technological, organizational, legal, and other factors, but will concentrate on the technological. ERTMS L3 is largely based on current technology, but will be implemented in future.

This makes it desirable for the system to be based on standard solutions using new technology that can support both current and future signalling systems requirements. Backward compatibility with currently used ERTMS, simple and cost-effective migration, with flexibility for modifications to function with future technologies will also be important.

TPL C19. Mathematical methods for greater signalling system safety

Researchers: Anders Lindahl (Project manager), Dimitris Rizopoulos (PhD student), Erik Jenelius, Nils Olsson and Olov Lindfeldt

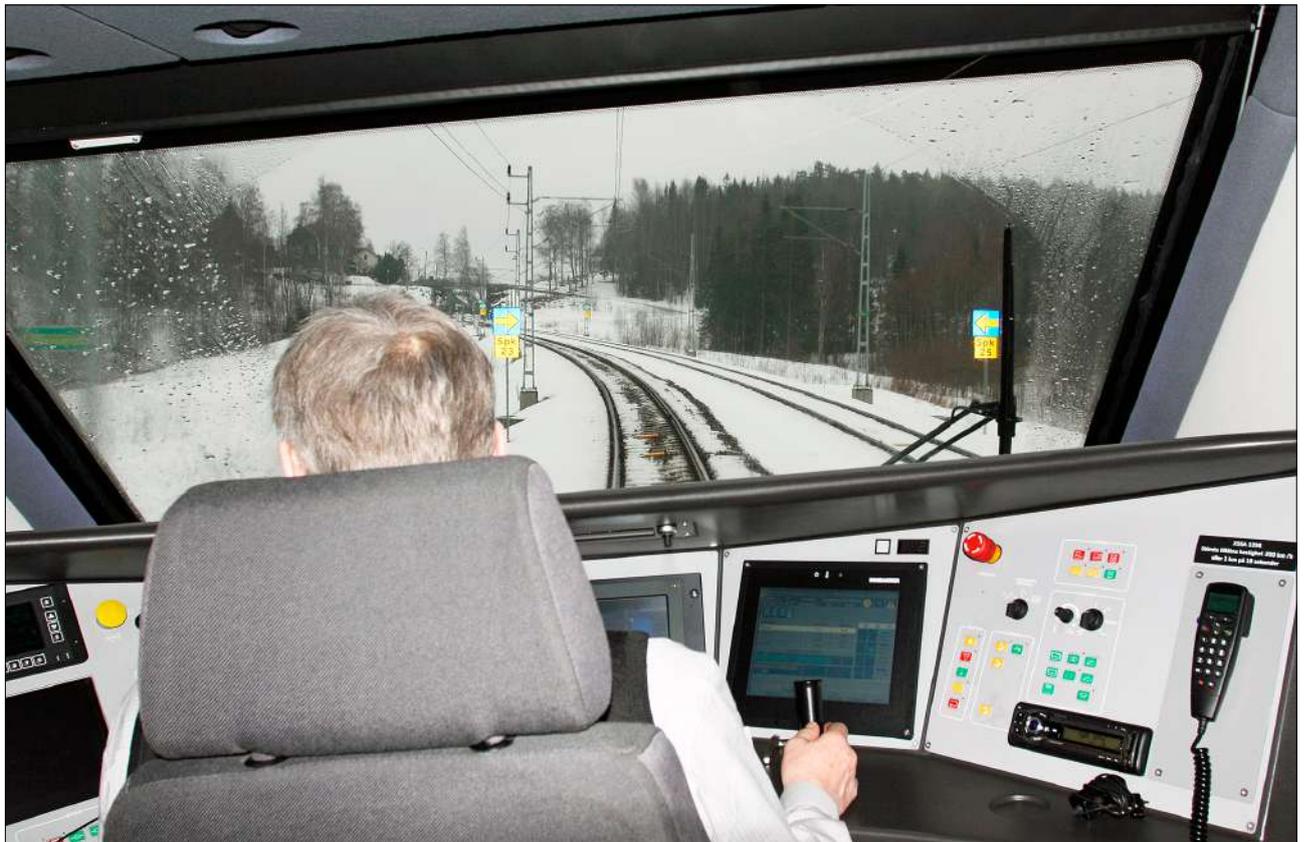
Source of funding: Trafikverket (Swedish Transport Administration)/ S2R

Duration: 2019-2022

The project is designed to study using mathematical methods for quality assurance of current and future rail traffic in various ways. New mathematical methods must be developed and implemented to maintain current railway operational safety levels even with future development of various traffic concepts.

For example, this can be applied to development of signal boxes for signal systems control to ensure no safety critical

conditions arise from using formal methods based on mathematical methods to specify, develop, and verify software. This would be for the purpose of increasing confidence in system reliability and correctness, and to reduce errors. Formal verification is through software tools performing automatic mathematical testing of the system. This includes for development of future traffic solutions using ‘virtual coupling of trains,’ where trains are not physically coupled but are run in tandem – known as platooning. Working with different distances between two trains, that is their headway (including coupling and uncoupling at speed), the virtually coupled train can be used to help increase flexibility and rail capacity.



ETCS on the Ådal line.

Photo: Oskar Fröidh

ISE C18. Fail-Safe Train Positioning

Researchers: Mats Bengtsson (Project manager),
Wendi Löffler (PhD student)

Source of funding: Trafikverket (Swedish Transport
Administration)/ S2R

Duration: 2019-2022

The project contributes to the work on train positioning within Shift2Rail, where Trafikverket is the Swedish partner in Shift2Rail using KTH based researchers as

linked third parties. The goal is to replace physical balises by a combination of odometry, satellite based navigation (GNSS) and other sources, such as inertial measurement units, as well as maps. The train position is obtained by fusing information from different sources and exploiting the known map. Obviously, safety to failures and measurement outliers is a crucial feature. In particular, we are analysing how sensitive the estimated position is to errors in the maps, since obtaining and maintaining accurate maps is costly.

ISE C19. Wireless Communications for Railways

Researchers: Mats Bengtsson (Project manager),
Leandro Lopez (PhD student)

Source of funding: Trafikverket (Swedish Transport
Administration)/ S2R

Duration: 2019-2022

The project contributes to the work on adaptable communications for railways within Shift2Rail, where Trafikverket is the Swedish partner in Shift2Rail using

KTH based researchers as linked third parties. In the project, we focus on understanding the particular aspects of radio propagation in railway environments. One such aspects is the high Doppler frequency and the possibly large spread of different Doppler frequencies between differently reflected multipath reflections of the radio wave, that will cause problems in most communication systems. However, the Doppler spread can also be exploited to improve the resilience to channel variations due to fading.

NSE C20. Formal Modelling of Security in Safety Critical Systems

Researchers: Ehsan Poorhadi (PhD student),
Elena Troubitsyna (Assoc. Prof.),
György Dán (Project manager)

Source of funding: Trafikverket (Swedish Transport
Administration)/ S2R

Duration: 2019-2022

The project contributes to the work on security analysis of railway signalling and control systems within Shift2Rail, and is performed as linked third party through

Trafikverket. In the project the focus is on extending formal verification of safety critical networked systems, with a focus on applications in railways, e.g., including interlocking and ETCS, so that the impact of potential vulnerabilities of IT components and subsystems can be included in the safety analysis. The main challenge lies in developing a scalable yet useful abstraction for security vulnerabilities, which allows modelling and analysis in well-established frameworks based on set theory, first order logic and temporal logic.



Division of soil and rock mechanics – JOB

The division conducts research within soil and rock engineering for railway structures, including foundations, embankments and tunnels and is responsible for several courses in geotechnical engineering and rock

mechanics. Research areas include behavior of embankment material, grouting and support of rock tunnels, deep soil mixing, ground vibrations and risk management.



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RESEARCH PROJECTS

JOB 1. Compaction of embankments for high-speed railway

Researchers: Carl Wersäll, Stefan Larsson, Nils Rydén

Source of funding: The Swedish Transport Administration (Trafikverket), Better Interaction in Geotechnics (BIG), The Development Fund of the Swedish Construction Industry (SBUF), PEAB AB, Dynapac Compaction Equipment AB.

The project aims to optimize roller compaction of high-speed railway embankments for slab-track with strict settlement requirements. Research methods consist mainly of full-scale tests and laboratory tests. Studied parameters include vibration frequency, lift thickness, material fraction and number of passes. A new compaction technique, called 'automatic frequency control', that continuously and automatically adjusts the vibration frequency based on soil conditions has been developed within the project. The technology has been implemented and is available on the market. Other results from the project are being implemented in requirement specifications for high-speed railway construction.

Publications:

Wersäll, C. & Larsson, S. (2013), Small-Scale Testing of Frequency-Dependent Compaction of Sand Using a Vertically Vibrating Plate, *Geotechnical Testing Journal*, Vol. 36, No. 3, pp. 1-10.

Wersäll, C., Larsson, S., Rydén, N. & Nordfelt, I., (2015). Frequency Variable Surface Compaction of Sand Using Rotating Mass Oscillators, *Geotechnical Testing Journal*, Vol. 38, No. 2, 2015, pp. 1-10.

Wersäll, C., Nordfelt, I. & Larsson, S., (2017). Soil compaction by vibratory roller with variable frequency, *Géotechnique*, Vol. 67, No. 3, pp. 272-278.

Wersäll, C., Nordfelt, I., & Larsson, S. (2018). Resonant roller compaction of gravel in full-scale tests. *Transportation Geotechnics*, 14, 93-97.

Wersäll, C., Nordfelt, I. & Larsson, S. (2019). Roller compaction of rock-fill with automatic frequency control. *Proceedings of the Institution of Civil Engineers – Geotechnical Engineering*, In press.

JOB 2. Simulation of ballast and embankment fill

Researchers: Denis Jelagin, Ricardo de Frias Lopez, Stefan Larsson, Feng Chen, Erik Olsson, Christoffer With

material parameters into ballast layer FE simulations at large length & time-scales. A model allowing for straightforward calibration with full-scale tests & field performance data is aimed at.

Source of funding: The Swedish Transport Administration (Trafikverket), Better Interaction in Geotechnics (BIG).

Publications:

Erik Olsson, Denis Jelagin, Pascal A. Forquin, 2019, Computational framework for analysis of contact-induced damage in brittle rocks, *International Journal of Solids and Structures*, 167

Correct predictions of ballast layer requirements are crucial, as under-dimensioning implies a risk for structural failure and large maintenance costs and over-dimensioning implies unnecessary large costs and environmental impact. The project aims to develop and implement a constitutive model for the ballast layers based on fundamental material properties. Constitutive model established through triaxial testing & DEM modelling will allow incorporating ballast

Ricardo de Frias Lopez, Stefan Larsson, Johan Silfwerbrand, 2019, A discrete element material model including particle degradation suitable for rockfill embankments, *Computers and Geotechnics*, 115.

Olsson, E., Jelagin D., Partl, M. N., 2020, Numerical evaluation of crushing resistance of unbound road material, *Proc. of MAIREPAV9*

JOB 3. Transition zones

Researchers: Carl Wersäll, Alireza Ahmadi

and stiffness gradients that cause a significant need for maintenance. This aim of this project is to understand the deformation processes and suggest and verify new transition zone solutions that minimize the need for maintenance. Methods include field instrumentation and numerical simulation.

Source of funding: The Swedish Transport Administration (Trafikverket)

Transition zones between embankments and stiff structures, such as bridges and culverts, are prone to settlements

JOB 4. Evaluation of railway track stiffness by static plate load tests

Researchers: Carl Wersäll, Sadek Baker, William Bjureland

This project studies how elastic moduli in simulations of track stiffness for railway embankments with slab track systems should be converted to requirement specifications for static plate load tests.

Source of funding: The Swedish Transport Administration (Trafikverket)



Photo: Stefan Nilsson

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