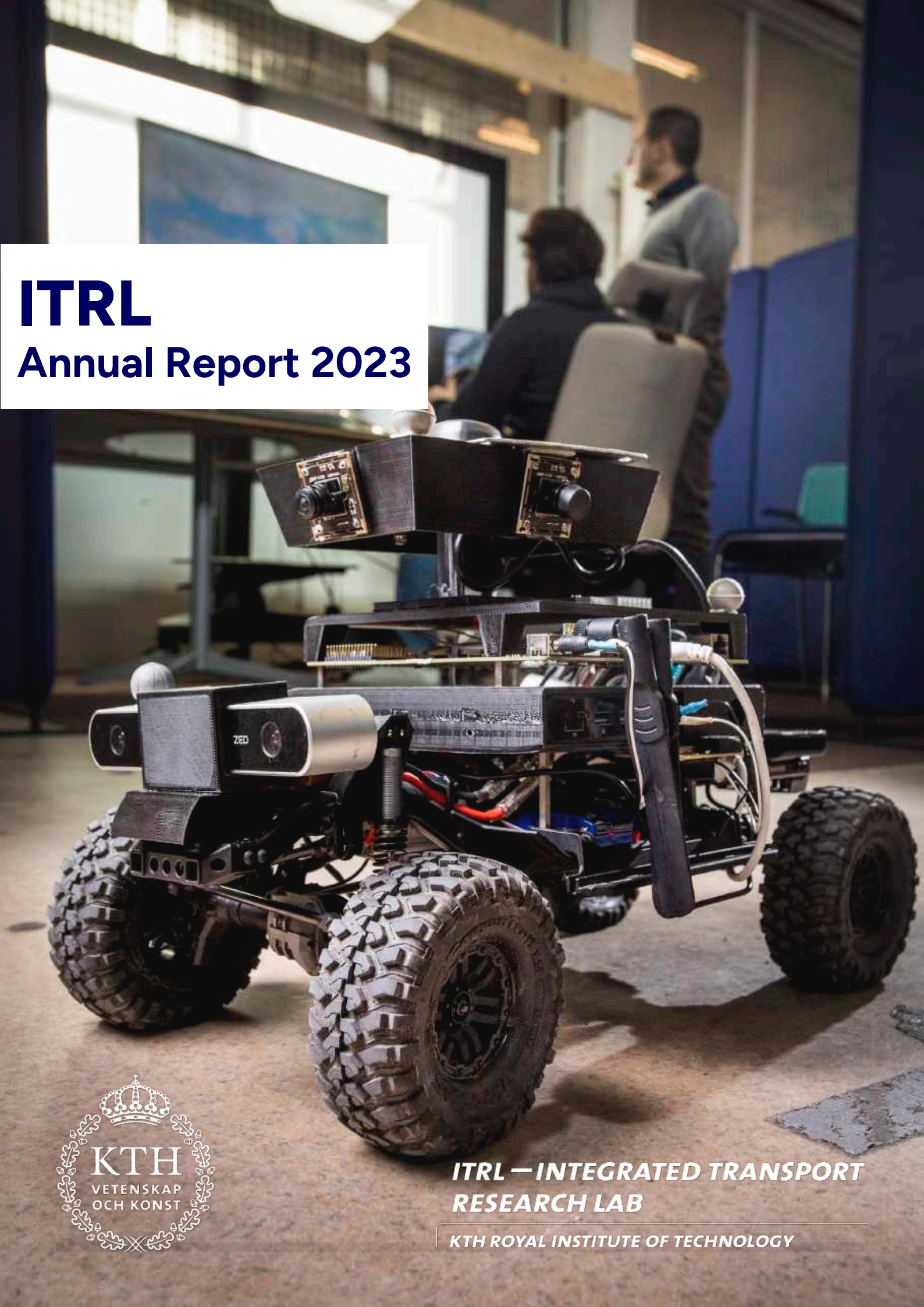

ITRL
Annual Report 2023

KTH VETENSKAP OCH KONST

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

KTH ROYAL INSTITUTE OF TECHNOLOGY

Transformation to sustainable transport ecosystems

The transport sector is facing complex challenges that are connected to the need of rapidly decreasing fossil footprint and the integration of new technologies to stay competitive.

Global events over the past year have shown two aspects: on one side, traffic, congestions and rush hours found their way back into our weekly life. On the other side, the geopolitical landscape has shifted in a way that is forcing regions around the world to reconsider their global supply chains and fuel dependencies.

This is seen as a key factor accelerating the development and deployment of electric freight transport on commercial roads. Large-scale deployment of electric heavy-duty vehicles is challenging both from logistics and energy perspectives.

Solutions based on AI and automation are massively entering the automotive domain and we can expect them to have huge impacts on the design and operation of vehicles and transport systems.

Digitalization and access to various data sources lead to new business opportunities and the transport, energy and IT business sectors are being more integrated. The solutions often need changes in socio-technical systems which implies interactions between research, innovative new technological solutions together with new business models, policy efforts as well as social acceptance.

Report designed by Malin Danielsson & Bhavana Vaddadi; Front cover image: ITRL Project Archives

The complexity of the challenges demands interdisciplinary research and collaborations between stakeholders that together have the capacity to drive the transition.

The purpose of ITRL is to meet the need for integrated and multidisciplinary research to find solutions for the emerging complex transport systems challenges, and to understand how the transformation to a sustainable transport ecosystem can be achieved.

We bring together researchers from several disciplines, students from various programs, partners from different business and public sectors, to deal with the complexity.

Introduction by Jonas Mårtensson
Director at ITRL

Our Vision...
is that society's needs of accessible and affordable transportation are met by safe, clean, efficient, and sustainable transport systems.

Our Mission...
is to build, maintain, and convey knowledge of how new technologies should be used for the transition towards sustainable road transport. We do this by multidisciplinary research and innovation together with our partners.

Our Ambition...
is to be an internationally recognized research center and to be among the leading Swedish research networks within sustainable integrated transport systems.

CONTENTS

ITRL's Growth

ITRL's staff consists of a diverse group of people with various disciplines and backgrounds. The ITRL staff is comprised of PhD students, Post-Doctoral Researchers, Professors, Researchers and partners

4 affiliated members

22 juniors members

7 members in the executive committee

19 faculty members

Meet some of our new colleagues!

Claire Fragkedaki
Research Engineer working on Experimental Research on 5G technology and developing a transformer-based framework at ITRL

Simon Frölander
Research Engineer Working on handling deep uncertainty in transport planning at ITRL

Vivek Venkatesh Shenoy
Industrial Ph.D. student hosted by ITRL working on creating a roadmap for the transition towards electrification of the heavy-duty vehicle fleet

Annika Wong
Research Assistant working on outdoor localization for SVEA platform at the Smart Mobility Lab

Nils Kiefer
Research Assistant working on updating the hardware systems and developing manufacturing processes for the SVEA cars at the Smart Mobility Lab

Sulthan Suresh Fazeela
Research Engineer working on sidewalk mobility and autonomous navigation for svea robots at the Smart Mobility Lab

PhD Student achievements this year...

ITRL had a licentiate defences of Lina Rylander, PhD student at Scania working closely with ITRL and Lin Zhao, PhD student working at ITRL. Claudia Andruetto and Zeinab Raoofi also successfuly presented their research at thier half-time seminars.

Lina Rylander
Project: STIFF;
Licentiate Thesis: Design reconsiderations for Uptime in a transportation system with driverless trucks

Lin Zhao
Project: REDO2;
Licentiate Thesis: Teleoperation and the influence of driving feedback on drivers' behaviour and experience

Zeinab Raoofi
Project: Impact-AED;
Half-Time Seminar: System-level Impact of Electrification on the Road Freight Transport System: A System Dynamics Modelling

Claudia Andruetto
Project: HITS2;
Half-Time Seminar: Towards the understanding of system level impacts of changes on the sustainability of the urban freight transport system

ITRL projects

26 active projects

14 medium duration projects (1-3 years)

6 small duration projects (0-1 year)

6 long duration projects (more than 3 years)

Project with largest KTH budget:

HITS2 Project 10223ksek

Partners: KTH, Scania, Haninge Kommun, Stockholm Stad, Havi AB, IVL, Closer AB, RISE, Svedin

ITRL's social media presence

LinkedIn followers

2023: 1649

2022: 1312

Facebook followers

2023: 650

2022: 643

Newsletter subscribers

579

Core Partners

SCANIA, Region Stockholm, TRAFIKVERKET, ERICSSON

Key Project Partners

Nobina, Inno, RI.SE, vti, GORDIAN, SmartResenär, HAVI, kista SCIENCE CITY, carmenta, einride, Karlstads Universitet, Lunds Universitet, ivl Swedish Environmental Research Institute, keolis, Svenska Taxiförbundet, Stockholms stad, postnord, ABCONNECT, LINKÖPING UNIVERSITY, Telia, Furhat Robotics, CLOSER, Haninge kommun, BOTKYRKA KOMMUN

LIST OF PROJECTS

PROJECTS STARTED IN 2023

EFFECT ChEss Machines For ElectriFiEd Construction SiTes
Description: The EFFECT project aims to develop a digital twin of electrified construction site resources, processes, and their dependencies to evaluate the potential cost and benefit of best-practice electrification of a construction site.

IOD-PT Inclusive On-Demand Public Transport
Description: In this project, we wish to study the case of an established on-demand public transportation service, in preparation for subsequently designing concepts for inclusive on-demand public transport.

ISMIR Investigating Sidewalks' Mobility and Improving it with Robots
Description: The ISMIR project aims to develop innovative routing solutions for sidewalk delivery by leveraging empirical findings from actual trips and accounting for the various uncertainties that can impact trip efficiency.

PREDICT PREDICTing and evaluating driveability and performance of zero emission heavy duty vehicles
Description: The PREDICT project aims to develop tools and methods for assessment of energy consumption and performance.

Pre study electrification and logistics
Description: A prestudy to understand the most important challenges and trade-offs in the broad area of electrified logistics, ranging from vehicle systems, energy supply and charging to and transportation, logistics and business ecosystems.

REDO2 Remote automated vehicle operation 2
Description: The project is working towards developing an understanding of how remote operation can be implemented to create a safer and more efficient operation of connected and automated vehicles.

SCOES Sustainable Commuting Obstacle Exploration Study
Description: By utilising the app CommuteSaver, this project will explore the obstacles to choosing sustainable transport options for work commuting, in collaboration with employers and employees at Borlänge municipality.

TRACER TRanport DemAnd Centric Decision Support for Electric ChaRging Infrastructure Planning and Operations
Description: Accelerate the electrification of the Heavy Freight Transport (HFT) industry and the realization of the positive effects thereof by deriving transport electrification scenarios that maximize the benefit and minimize the cost of electrification for all stakeholders.

TREE Transition to efficient electrified forestry transport
Description: TREE focuses on the electrification of the forestry transport industry, which accounts for nearly 20% of Swedish heavy road transport.

WASP Bridge Intelligent Intersections: Enhanced Awareness and Safe Coordination for 5G-Connected Traffic Digital Services
Description: The primary objective of this project is to design and implement a regional intelligence that can enhance the safety of traffic by leveraging novel control algorithms, 5G networking technology, and tight integration with mature automated driving systems.

ONGOING PROJECTS

DATASETS exploring DynAmic environmental TAxation for a Sustainable, Efficient urban Transport System
Description: Creating a model and an associated GIS decision support tool for assessing the cumulative societal impact of noise emissions, air pollution, and congestion associated with road traffic.

Future 5G Ride
Description: Develop and test technology to create functions in the control tower for safe implementation of driverless vehicles on public roads.

GEOMETRIC GEO-based Multi-layer Environmental Modelling of Urban TRaffIC
Description: The project aims to implement a dynamic traffic control framework in Stockholm, utilizing a sensor network to gather and analyze traffic, noise, and emission data, ultimately aiming to mitigate congestion, pollutants, and noise in dense urban areas.

HITS2 Hållbara Integrerade Transportsystem 2
Description: HITS vision is to increase system efficiency in terms of increased use of vehicles and infrastructure. The project aims to accelerate the development of an efficient and sustainable urban freight transport system.

IMPACT AED System Effects of Automation, Electrification and Digitalization on Freight Transport
Description: A system level study to improve understanding of how Automation, Electrification and Digitalization could impact the freight transport system.

MERGEN Multi-purpose biometric Evaluation Research tool Grounded in Emerging Network technologies
Description: Understand level of cognitive workload and how to measure it for traffic control operators in different situations.

MUST methods for Managing deep Uncertainty in planning for Sustainable Transport
Description: Developing and exploring methods for long-term transport system foresight under deep uncertainty with a focus on automated vehicles.

SAMS2 Mistra SAMS - Phase 2
Description: Study digital supported services for accessibility and mobility, to understand their potential to transform society and contribute to sustainability.

SEAMLESS Systematic Evaluations and Assessments of MaaS – Leading towards Sustainable Solutions
Description: Using the KOMPIS framework, SEAMLESS will conduct assessments on various MaaS pilots to understand the implications of such a service at Micro, Meso and Macro level.

STIFF System Transformation for Uptime for Driverless vehicles
Description: A project studying fault-handling systems in driverless transport systems. The focus is on how to address the several critical aspects of removing the driver that will affect the measurement of the vehicle's functional state.

SocRob Social robots accelerating the transition to sustainable transport
Description: Increase knowledge of how AI and social robots can contribute to increasing the attractiveness and above all the perceived level of safety of passengers, onboard of shared, driverless vehicles.

FINISHED PROJECTS

Campus 2030 Enabling systemic solutions for smart roads
Description: KTH Campus Testbed and digital twin for connected infrastructure and vehicles

CORD Cognitive assessment of Remote Drive
Description: This pre-study will test a new approach based on Neuroscience-AI to see how it could be used in the context of semi-autonomous and remote driving.

DS BM2 Drive Sweden Business Model Lab 2
Description: Collaboration on business models with industrial partners

E98ton Förutsättningar för eldriven 98-tons fordonskombination
Description: Investigating the conditions for electrification of a 98 ton truck-based last-mile transport of chips between a transshipment hub and a heat plant.

ELKOLL E-scooters and public transport
Description: The ELKOLL project aims to increase our understanding of how e-scooters are used and what the alternatives for travelers would have been, had they not chosen to use an e-scooter.

EmobBM Business models in E-mobility future transport ecosystems
Descriptive: This project investigates the business model dynamics in future transport ecosystems with focus on electrification.

FOKA Operating unmanned autonomous buses
Description: Building knowledge on potentials and barriers for integrating autonomous vehicles without drivers in future public transport systems, and to understand how shared transport solutions can become preferred by more people.

PSSST Policies for sustainable, shared self-driving transportation
Description: Investigate policies related to self-driven shared vehicles, especially public transport.

REDO REmote Driving Operations
Description: Understand how remote driving could be better with new feedback models and supporting control functions.

SDP Stockholm Digital Parking
Description: This project explores the viability of crowd-sensing street parking availability by employing smartphone-equipped taxi fleets.

Urban Logistik Barkarby
Description: Investigation of business model for physical and digital platform for combined consolidation of last-mile deliveries and waste management in the district of Barkarby.

PROJECT HIGHLIGHTS INDEX

Research

Mobility of People

The projects in the Mobility of People research program 2023 built further knowledge about the three challenge areas of uncertainties of mobility systems, the effects of new technologies, and how to change people's behaviours and practices in sustainable directions. The work is ongoing, and research activities and project results presented here are in progress.

UNCERTAINTIES OF MOBILITY SYSTEMS

During 2023, within our research projects, we explored the impacts of new mobility systems at micro, meso, and macro levels, separately and integrated at a system level. Understanding the uncertainties of developing, implementing, operating, and governing mobility systems remains challenging. Besides individually assessing the micro, meso and macro levels of innovations in mobility systems, we also worked towards developing an assessment framework to analyse the system-level impacts of these mobility systems.

Framework-based assessments

SEAMLESS

In the SEAMLESS project, the aim is to explore the current state of Mobility as a Service concepts and the likley future directions it might take and how and to what extent MaaS would impact factors such as travel behaviour, accessibility, emissions, and business opportunities, to name a few. During 2022-2023, SEAMLESS project identified several complexities for MaaS development and implementations in the post-COVID climate. Therefore, ITRL, involved in Macro/system level assessments of MaaS (WP4) reformed the goal so as to address MaaS evolution and and impacts through co-creation and valorisation of future scenarios builds on what Jittrapitom et al. (2017) found regarding stakeholders' approaches and "communication processes" for the development of MaaS in future deployments. For our research, this represents a strategic step to support the assessment of the effects of MaaS on mobility ecosystems without depending highly on data availability.

Therefore, we explore the question: what directions MaaS will take in the future under the various uncertainties and to what extent will that lead to sustainable mobility system? We will explore this research question by co-constructing scenarios towards the year 2035 to understand the role of MaaS towards sustainable mobility systems.

Between 2022-2023, we launched a survey to identify current uncertainties associate to MaaS development and implementation. Based on the survey, we conducted in depth interviews with MaaS experts in various fields to explore posisble MaaS futures. The project is currently in the process of analysing the interviews and writing two publications based on the survey and interview results.

UNCERTAINTIES ABOUT THE EFFECTS OF NEW TECHNOLOGIES

During 2023, we have researched the effects of autonomous vehicles and remote driving on drivers from different perspectives and levels in several projects. Furthermore, we have studied the impact of autonomous buses and artificial intelligence on an individual passenger level. Moreover, we have researched the impact of autonomous, electrified and shared transport systems on a policy level. We have also examined methods for measuring the psychological effects of micro-mobility, focusing on the hardware and software solutions needed for large-scale testing.

Autonomous vehicles and remote driving

When moving to automated road transport systems, there will be an increased need to manage fleets and their operations and solve problems that the autonomous vehicle might have, e.g. decision problems due to changing environments needing

remote assistance. These could be solved by giving the vehicle permission to proceed, giving it a new safe path, or even taking control and remotely driving it.

MERGEN

In the MERGEN research project, we study the methods of measuring the cognitive load of travellers. One focus group is remote operators and how remote driving affects them differently than actual driving. It also assesses challenging scenarios for remote operators in traffic control towers to acquire knowledge of the requirements of the remote operation of autonomous vehicles.

So far, we have conducted several tests and learned that our test methods work well to measure cognitive load. Furthermore, a study on electric scooter drivers has been conducted together with BOKU in Vienna, resulting in two research publications. The REDO2 research project focuses on the feedback to the remote driver and supporting control strategies to support the remote driver for better precision and safety.

Here, we have found that the steering feedback needed during remote driving differs from what is required during actual driving, so feedback cues for remote driving must be explicitly designed for that case. Both projects have initiated collaborations with the start-up company InnoBrain to include their measurement equipment of brain activity (EEG) in future experiments. Results from both MERGEN and REDO2 can be used for scale-up studies in AVTCT2 and future projects to understand the feasibility and impacts of transport systems' transitions towards autonomous vehicles and remote driving. MERGEN has also collaborated with BOKU (University of Natural Resources and Life Sciences, Vienna) on more in-depth methods for understanding how action cues are perceived differently in simulator studies, which should be applicable in remote vehicle operations in the future.

Autonomous buses and artificial intelligence

Artificial intelligence is booming and offers opportunities in self-driving public transport. Since self-driving vehicle technologies are increasingly ready for broad implementation, tailoring them to users' needs becomes more important.

SOCIAL ROBOTS

In the research project Social Robots, we investigate whether social robots can be strong contenders to human operators and if they can fulfil the users' needs in future driverless buses and push the idea of shared mobility in this unique format. Structuring the unstructured, i.e., to provide real-time travel data, has been identified as the main potential of social robots, according to the public transport industry and academic professionals.

We are exploring this increased level of convenience and assessing how the introduction of social robots in driverless buses can impact passengers' comfort levels and safety. By applying both qualitative and quantitative data collection methods; we are also exploring how this unique combination of innovations can drive people towards adopting shared mobility solutions in their daily lives. During 2022-2023, we performed on site experiements with a voice assistant and a Furhat Robot called Elin. Post the experiment, the participants were interviewed regarding their experience. During this period we also sent in two papers for conference presentation at the HRI conference in Coloarado and TRA 24 conference in Dublin. Currently a mixed methods paper using data collected via the robot and the interviews is underway for a journal publication.

Autonomous, electric and shared transport systems

FOKA

FOKA was a project conducted during 2022 and 2023 together with Nobina Technology, Region Stockholm, Järfälla municipality, ObserveIT, and Telia, funded by Vinnova. The project consisted of several parts, mainly concerned with realising the operation of an autonomous bus service. ITRL researchers focused on understanding how the service was organised and how citizens in the area perceived it. We found that citizens were essentially benevolent to the autonomous service but did not find it particularly useful in its current state. Moreover, the results indicated that considerable hurdles remain for large-scale service deployment, where non-technical issues are often overlooked. These issues involved communication with other road users or legal aspects regarding risks.

ELKOLL

The ELKOLL project was funded by Voi Technology AB and Västtrafik and was conducted in 2022 and 2023. The project investigated the use of e-scooters in Gothenburg and their relationship to public transport. We found that many e-scooter trips are short, less than 1 km, suggesting that e-scooters mainly replace walking. Further, many trips seem connected to public transport, likely serving as a more extended journey's first or last leg.

UNCERTAINTIES ABOUT HOW TO CHANGE PEOPLE

In 2023, we continued to conduct research projects to understand how to shift people's behaviours and practices in sustainable directions. During 2023, we concluded the living lab in Riksten, south of Stockholm, where sustainable accessibility and mobility services have been tested.

Changes when mobility services were introduced

SAMS2

As a part of Mistra SAMS Living Lab, we tested shared mobility services and how these enable more sustainable everyday life. Fourteen households in Riksten were engaged as co-researchers, and for a year, they tried shared electric bikes, box bikes and scooters. The bikes were in one of the parks where a cycle parking, including a charging station, was built. Furthermore, an app was designed and developed to book the vehicles and share experiences from using the services. Moreover, throughout the year, mobility challenges were introduced to the co-researchers to encourage them to embrace alternative mobility practices. For example, they were requested to use a bike instead of their car for a trip they usually would have used. Also, as part of the research project, the participants set individual goals of reducing their car usage.

The co-researchers' experiences from trying the mobility services in the Living Lab Riksten to reduce their car trips have been discussed in policy lab workshops with planners and policymakers at the local and regional levels. In these discussions, for example, the need for infrastructure to be in place and new tools to support the prioritisation of mobility services have been discussed.

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Research

Urban Goods Distribution

The Urban Goods Distribution (UGD) research program has the scope of distribution of goods (and collection of waste and recycling) within the urban environment and aim at Sustainable urban goods distribution through collaboration.

HITS 2024 (SUSTAINABLE AND INTEGRATED URBAN TRANSPORT SYSTEM)

This project is the light-house project of the UGD program where with the lead of Scania and the coordination of CLOSER, KTH researchers alongside 16 other academic and industrial partners conduct research with the aim to accelerate the development of an efficient and sustainable urban freight transport system towards the vision of increased system efficiency in terms of increased use of vehicles and infrastructure.

Researchers in HITS 2024 have carried out research in six topics that aim to address some aspects of all the five challenges of the UGD program. The following is a summary of the research from the first part of the project (until 2021/22) and the ongoing and planed future research activities for the second parts of the project (from 2022/23).

Collaborative Innovation and Design

KTH researchers (Diana Saleh, Mia Hesselgren and Mats Magnusson) study tests and pilots that are carried out within the HITS 2024 project, to gain more knowledge about collaborative innovation processes.

Thereby, they are building knowledge on conditions for sustainability transitions of transport systems and understand how these are affected by and affect different innovation ecosystems, different lock-ins (technological, organizational and social) and at different levels (micro, meso and macro).

As collaborative innovation cannot be understood from a single perspective. Thus, they use a multi-disciplinary theoretical lens and design methods which include field observations and interviews.

Specifically, they investigate possibilities of re-configuring and re-organising socio-technical systems through studying trials of off-peak deliveries and urban consolidation centers in Stockholm.

Findings so far indicate that the efficient use of resources was considered the main business and societal value of implementing off- peak deliveries and urban consolidation centers and that the barriers to overcome included uncertainties regarding costs, lack of regulations and trust which requires collaboration, re-organisation and re-configuration.

Environmental assessment of city distribution

KTH-researcher (Helry Dias and Erik Jenelius) together with colleagues from IVL and RISE (Sebastian Bäckström and Sönke Behrends), conduct quantitative research using traffic/logistic data together with modelling tools.

They use simulations models together with collected real data, official statistical data, and on-site observations, to investigate
1) what the environmental impact of delivery traffic that enters today are and;
2) how large the reduction potential by freight consolidation systems and 'off peak'-solutions is.

They are together studying three main geographical areas: Södermalm, Stockholm city-center area North of Hamngatan and Arenastaden. They have found that the current external costs are approximately 20 000 € per day of which 80% is due to congestion and that the consolidation scenarios studied can reduce the costs by 75% and

that a combination of suburban- and urban consolidation centers can lead to the largest reductions. Our colleagues have also evaluated the potential of urban consolidated delivery solutions that use fixed and mobile parcel lockers as destinations for the "last-mile" delivery and have found that mobile lockers have higher external costs, but still result in significant reductions compared to today's operations.

HITS 2024 - Driverless Multipurpose Vehicles for Sustainable Urban Mobility

In this research topic, our industrial PhD student (Raphael Andreolli) from Scania supervised by KTH researchers (Mikael Nybacka, Erik Jenelius, Ciarán O'Reilly) investigate how emerging heavy-duty vehicle solutions, such as Driverless Multipurpose Vehicles (DMVs) impact system efficiency and sustainability in urban mobility.

These emerging vehicles have potential to improve urban road transport by enabling higher energy-efficiency and resource-efficiency than conventional vehicles with a fixed transport application. This may be possible because DMVs can change their transport application in a short manner of time or combine different applications during operations. In 2023, we developed a novel electric vehicle routing problem to study the total energy consumption of emerging and current vehicle fleets in urban logistics.

In particular, we compared the total fleet energy consumption of DMVs and battery electric vehicle (BEV) fleets against conventional combustion vehicle (CV) fleets for a couple of delivery and pickup transport operations in urban areas. We found that:
1) the combustion vehicle fleets consumed significant more energy for the same operation than the other fleets,
2) the DMV and BEV fleets consumed similar amount of energy for most case-studies simulated, however,

3) the DMV fleet consumed less energy and required a smaller fleet size for operations with higher vehicle utilization, and more than six customers.

These results highlight the potential benefits of DMVs in city transport with respect to minimizing fleet size and total fleet energy consumption. In 2024, we will continue to develop the electric vehicle routing problem to integrate real road network data and to perform a more comprehensive comparative study of emerging and conventional heavy-duty vehicle fleets in urban logistics.

Other highlights from 2023:
- Published first conference paper "A review on real vehicle usage modelling of driverless multipurpose vehicles in vehicle routing problems" in Proceedings of the Design Society published by Cambridge University Press.

- Presented the first conference paper at the International Conference on Engineering Design in Bordeaux, France between 24-28th of July 2023.

- Second conference paper accepted for the conference called Transport Research Area 2024 (TRA2024) in Dublin, 15-18th of April 2024, and conference proceedings Lecture Notes in Mobility, Springer book series.

System level effects of urban logistics concepts

In this research topic, our PhD student (Claudia Andruetto) supervised by KTH researcher (Anna Pernestål) investigate how to model and design an urban freight transport system using system

dynamics modelling such that the transport related externalities that negatively affect the liveability of the urban environment and the health of citizens can be minimized. We identified a set of indicators from the Sustainable Development Goals, defined from the perspective of society and of the Logistics Service Providers (LSPs). Using the set of indicators, we evaluated the sustainability of electrification, consolidation, cargo bikes and automation. The results (see Figure 1) show that the indicators regarding the environment (i.e.,air pollution, congestion) are emphasised; however, sustainability is more than just the environment, therefore indicators such as land use, noise and working conditions should be explored further.

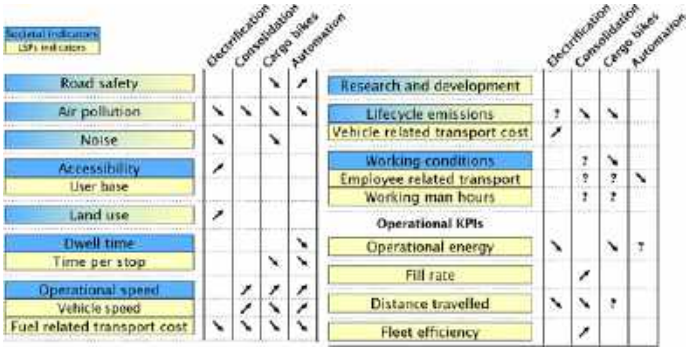

Figure 1: Indicators of sustainability of electrification, consolidation, cargo bikes and automation from societal and LSP perspectives.

We have used system dynamics to implement a model of a city hub system to improve consolidation in the last mile. Such system dynamic models can be used to understand the dynamics of system, the feedback mechanisms and the time delays. Specifically, we will use our model for scenario analysis to understand the impacts of the modelled urban logistics practices. Currently, the model is a graphical qualitative model. Next, we will make the model quantitative and perform sensitivity testing and scenario analysis.

Data sharing

In this research topic, our visiting researcher (Annette Hultåker) from Scania investigates what is needed to succeed with data sharing and explores value adding services, especially with sustainability effects. We have found that successfully data sharing requires 8 factors: data, business value, regulatory foundation, trust, infrastructure, security, meta data, and skills. We have also found that data sharing between transport actors can enable analytical services with societal benefits, sustainability benefits, and internal and external business benefits. One key takeaway from the study is that hubs often seem to be excluded from the data sharing, which makes mainly their planning difficult.

Policy, legislation, and regulation

In this research topic, our colleagues from Uppsala University (Kristina Andresson) primarily investigate the current and expected legal obstacles or enablers of data sharing and off-peak deliveries. We have found that lots of legislation regarding data sharing will change during 2022-23 and a several new EU Acts will come in place. First comes the “Sales of Goods Act” and then comes “Law on Domestic Road Transport.” A key takeaway is that one needs to pay close attention because legislation will affect business models.

DATASETS + GEOMETRIC – MODELLING FRAMEWORK FOR OFF-PEAK / SILENT / ZERO EMISSION DELIVERIES

In continuation of the 2023 activities in the two projects “DATASETS: exploring DynAmic environmental TAxation for a Sustainable, Efficient urban Transport System” and “GEOMETRIC: GEO-based Multi- layer Environmental Modelling of Urban TRaffIC”, reaching their mid-term, KTH researchers (Romain Rumpler, Gyözö Gidofalvi, and Jonas Mårtensson), visiting Postdoc (Kaveh Khoshkhah, Tartu University) and PhD students

(Siddharth Venkataraman and Sacha Baclet) continued to develop a mixed experimental-numerical method enabling real-time micro-traffic representation and noise exposure assessment.

ITRL has a new collaboration with Stockholms Stad and Kista Science City, in a project GEOMETRIC, funded by Digital Futures and ITRL, utilizing a testbed at Hornsgatan. The goal is to study the effect on noise and emissions from urban traffic in a multi-sensor testbed. In 2023, the sensor network on Hornsgatan was extended, now counting 12 acoustic sensors, 4 cameras and 8 radars. The collected data: timestamped (directional) traffic events, vehicle class, vehicle speed, spectrograms and noise levels, have been merged for selected periods of times, and curated in order to generate a reference dataset.

This dataset has been used to train several neural network architectures with the objective to detect and classify traffic events from spectrograms. The preliminary results highlight the potential to rely on acoustic sensors for traffic count and classification purposes. Mostly sparse traffic has been considered as a first step, and ongoing extensions are seeking to make similar estimates for dense traffic conditions.

The objective of the activities in 2024 is to increase the robustness of inference across acoustic sensors, and to include the resulting real-time inference into a modelling chain consisting of micro-level traffic simulations, noise and pollutant emission models, and noise propagation calculations.

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Research

Connected Transport

Mobile connectivity and the access to transport and vehicle data will be a critical factor in the road transport system infrastructure. It is estimated that there will be half a billion connected vehicles in 2025. Vehicles will be connected to the internet and cloud services to gain access to online services such as traffic and route information. Vehicles will also be connected to each other and to the road infrastructure in order to handle to handle complex situations and coordinate decisions. These systems will bring new demands on reliability, latency, and efficiency.

Two projects funded by Trafikverket are investigating the system-level technical, societal, and environmental impacts of digitalization and connectivity in transport.

SLICE-T

The SLICE-T project is focused on 5G connectivity with current focus on budgeted cell planning and the Digital Services project is focused on how physical road infrastructure can be replaced or enhanced with digital services. One question of particular interest is to analyze the connectivity requirements of the most relevant connected-vehicle functions and digital services.

The required network performance along different types of roads, and how those networks can be deployed, is being assessed. Costs of deploying and operating the network and the added value provided for the transport operator and end users – including individuals, public transport and cargo service providers -- will also be investigated.

Based on the technical and economic analysis, the project will identify hurdles and possibilities for deployment, adoption, and usage. The projects will identify technical and business solutions for mobile network operators, transport service providers and road infrastructure operators that contribute to a sustainable transport evolution.

5G RIDE & WASP BRIDGE

In the projects Future 5G Ride and the WASP Bridge project ("Intelligent Intersections: Enhanced Awareness and Safe Coordination for 5G-Connected Traffic"), we have developed use cases wherein connected vehicles can receive assistance from intelligent infrastructure and remote operators.

Currently, the projects aim to implement some of these use cases to showcase the effectiveness of the technology and its potential impact on intelligent transportation systems (ITS). To support this development, we have implemented a testbed for evaluating the real-life performance of vehicle-to-everything (V2X) applications on 5G cellular networks.

The testbed integrates small-scale vehicles in the Smart Mobility Lab with Ericsson's 5G testbed "Kista Innovation Park", and Scania's connected vehicle and cloud platform. We have conducted preliminary experiments and comparisons to assess how 5G network features can protect safety-critical cellular-based V2X communication.

As connectivity becomes increasingly more important due to the rapid development of advanced ITS, we look forward to continuing to evaluate how 5G cellular networks will impact the future transportation systems.

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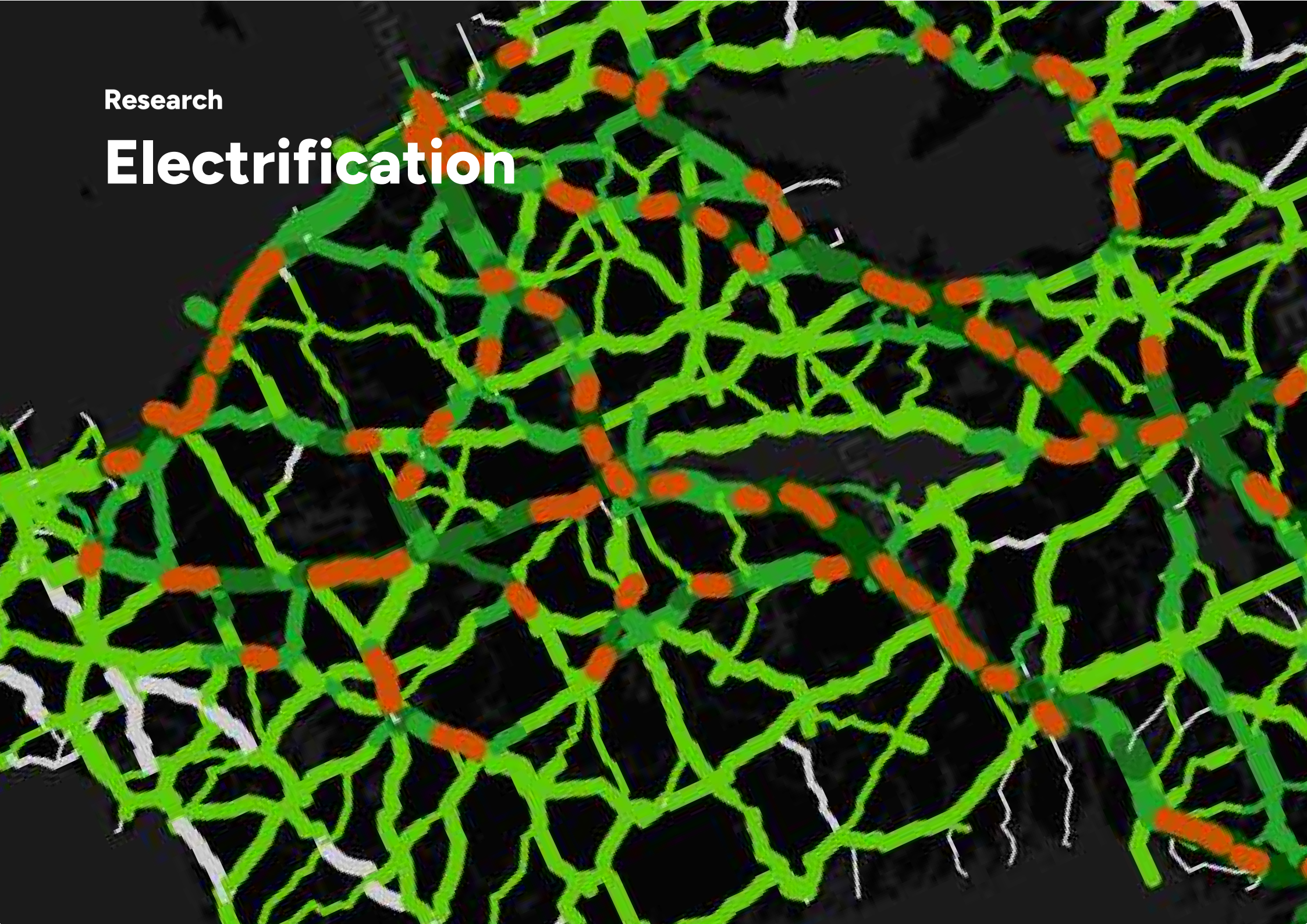
Research

Electrification



Electrification is one of the megatrends that has the potential to decarbonize transportation and is currently disrupting the transport industry. It has been one of the cross-cutting focus areas of ITRL since its inception. Earlier electrification projects focused on the use and demonstration of electrified transport solutions (e.g., EVs / electric trucks, stationary and dynamic charging). More recent projects focused on planning and optimizing large-scale transport electrification via simulations. The aims and results of current electrification project below give a good indication of the problem complexities and the approaches needed.

E98TON: PREREQUISITES FOR ELECTRIC 98-TON VEHICLE COMBINATION

In this Vinnova funded study, as a follow-up to the Electrified Transport in South Stockholm project, KTH researcher Adam Uhrdin and partners (Skogsfors - Henrik von Hofsten and Daniel Noreland and Söderenergi), through a practical case study of electrification of a 98-tonne vehicle combination that is planned to drive in a 21 km long shuttle traffic with fuel chips from a terminal in Nykvarn to Igelstaverket heating plant in Södertälje, analyzed what is required to create a sustainable ecosystem of actors to enable the electrification of heavy road transports.

The study found that Sustainable business models are required to make the transition to electric transports possible. Long-term planning, optimized routes and life cycle management of batteries are important aspects. For more see a more detailed summary and a link to the report on the ITRL project page.

TRACER: TRANSPORT DEMAND CENTRIC DECISION SUPPORT FOR ELECTRIC CHARGING INFRASTRUCTURE PLANNING AND OPERATIONS

In this Trafikverket / TripleF funded PhD project, KTH researchers (Ehsan Saqib, Gyözö Gidofalvi, and György Dán) in collaboration with new project partners Ellevio, PostNord and Trafikverket, investigate how to accelerate the electrification of the heavy freight transport industry and the realization of the positive effects thereof by providing comprehensive data-driven decision support for charging infrastructure developments / investments and operations of- and on them. To this extent, in 2023 they have proposed a transport energy demand centric dynamic adaptive planning approach and a data-driven Spatial Decision Support System (SDSS).

In it, with the help of a realistic digital twin of an electrified road transport system, infrastructure developers can quickly and accurately estimate key performance measures (e.g., charging demand, BEV enablement) of a candidate charging location or a network of locations under user-specified transport electrification scenarios and interactively and continuously adjust and reoptimize network plans as facts about the deep uncertainties about the supply side of transport electrification (i.e., access the grid capacity and real-estate and presence of competition) are gradually discovered / observed.

In their TRA 2024 paper entitled “Methodology for continuous planning of charging infrastructure in the face of uncertainty and change”, they describe components and functional support of the system that is available as a web based platform to support the planning of public fast charging networks for freight and long-distance private car trips in 26 European countries and has been used in commercial pilots in both competitive and collaborative settings. Their research in 2024 will continue to focus on the importance of transport energy demand-centric optimized charging infrastructure network placement and dimensioning, pros and cons of static and dynamic charging, and network resilience.

LOLA - COST-BENEFIT OPTIMIZED CHARGING INFRASTRUCTURE

The RENO pre-study utilized the fact that transport routes record the energy use of transports and demonstrated how this information can be used to optimize the placement of charging network elements to maximize the benefits of electrification, i.e., maximize the total transport work that can be electrified on the network or the CO_2 that can be consequently displaced from the transport system.

But designing infrastructure without costs might yield network plans with excessive cost or might miss network plans that deliver slightly less benefit but have significantly lower cost. To avoid such suboptimal planning, during 2020-2023, as a follow-up to RENO, in the SEC funded LOLA pre-study KTH researchers (Gyözö Gidofalvi, Can Yan, and Ehsan Saqib) and partners LTH and Vattenfall, set out to model, integrate, and evaluate the importance of electric power production and distribution costs in transport route based electric charging infrastructure (charging stations and electric roads) placement optimizations.

Faced with the revelation that grid information, which is necessary to calculate grid surplus capacities or grid development / enforcement costs is not available for reasons of national security and business interests, the LOLA project
1) narrowed the costs to a terrain- and landcover based grid connection cost and a charging equipment costs,

2) extended the charging model to include stations with maximum rest stop and minimum SoC threshold based charging stops, and

3) introduced a cost-benefit framework for which charging infrastructure element to expand the network during optimization.

Empirical evaluations on annual un/loaded transport routes from the Swedish national freight model SAMGODS used the extended model to derive charging networks of stations, electric road segments, or a mix of the two and evaluated the utilization, benefit, cost, and BEV enablement of the so derived networks.

Results show that grid connection costs do not generally alter the optimized network placements and that under the limited costs model that does not include TCO and environmental footprint costs of larger batteries that are needed for charging infrastructures only containing stations, electric roads for trucks only in Sweden appear to be less cost-competitive than stations.

In addition to the above results of the empirical evaluations, the LOLA project also produced an interactive webmap that allows the exploration of 18 optimized charging infrastructures and comparable reference infrastructures. The webmap is accessible via https://thegordian.se/cip_s/ and a screenshot of the it is shown in Figure below.

LOLA interactive webmap for the exploration of 18 optimized charging infrastructures.

The webmap application allows the user to
1) view information about the model and the research,

2) view the estimated grid connection costs for each road segment,

3) select one of two transport electrification scenarios and one of the optimized or comparable reference charging infrastructures,

4) set some parameters to scale the costs and benefit estimates in the model[1],

5) show the simulation result for the selected scenario and infrastructure,

6) view statistics about the optimization task and the computations as well as summary statistics for the infrastructure plan and its transport electrification effects, and

7) examine the optimized charging infrastructure rollout sequence based on a ranking of the infrastructure elements.

Once the selected charging infrastructure plan is loaded the user can hover over individual charging infrastructure elements to examine their performance. Hovering over any road network segment allows the user to display the transport electrification effects that the network of charging infrastructure elements collectively deliver under the transport electrification scenario on the hovered road network segment.

A demo video of the LOLA webmap illustrating its interface and functionality can be found here: https://youtu.be/Bu5569P9NG0.

1 Note that setting these parameters does not reoptimize the placements but simple scales the cost and benefit estimate of the charging infrastructure elements and the network they form.

ROSE - LEARNING IN ROUTING GAMES FOR SUSTAINABLE ELECTROMOBILITY

In this C3.ai Digital Transformation Institute funded project within the framework of Digital Futures, KTH researchers (Henrik Sandberg, György Dán, and Gyözö Gidofalvi) with partners from MIT investigate how to make traffic routing for logistics operators more sustainable by accounting for electromobility, operations and infrastructure costs, and environmental externalities. To answer these questions, we have contributed with a simulation platform to guide the setup of electric trucks (EV) charging stations. The simulator considers how the placement and dimensioning of charging stations (i.e., the number and charging capacity of chargers at stations) will affect travel, including how long drivers might wait and how much energy they will use.

The simulator also estimates pollution from vehicles and overall electricity demands. Logistics operators can utilize the simulation platform to optimize fleet composition and traffic routes, enhancing efficiency and reducing costs. Traffic infrastructure managers can leverage the platform to strategically place and size charging stations, ensuring effective energy distribution and accessibility.

We have also introduced a game theoretical model to study how the decisions of logistics companies to use electric trucks and traditional internal combustion engine trucks (ICEVs) would affect decision-making at a societal scale. These companies must deal with two costs: the time lost while EVs are charged and the pollution fees for using diesel-powered trucks.

The “Green Routing Game” captures how these factors affect decisions, considering the limited battery life of electric trucks, shared charging stations, pollution fees, and company interactions. It can be used to predict companies’ choices (Nash equilibria) and shows how to calculate these choices in simplified real-world scenarios. This can, in turn, help infrastructure operators allocate resources and tune fees and information systems. Moreover, solving the Green Routing Game enables

logistics operators to forecast future expenses and determine the ideal fleet sizes.

Traffic infrastructure authorities can also use this feature to scale charging capacities and set pollution fees, thereby regulating traffic flow and environmental impact on various routes between two locations. For the simulation platform, the envisioned applications are manifold. The simulator is an essential building block of a digital twin for charging logistics. The digital twin can track and calculate KPIs for charging equipment utilization, demand, and individual and fleet-level route assignment costs and externalities.

These KPIs can evaluate and optimize charging infrastructure plans, route assignments, charging access assignments, dynamic pricing, etc. Connected to real-time vehicle sensors and the charging infrastructure, the digital twin can also provide real-time control of the aforementioned aspects of the stationary and moving assets in a model predictive control framework.

For the Green Routing Game, many exciting avenues of research have opened. We are now evaluating an incomplete information game and resulting Bayesian Nash Equilibria to model the uncertainty of information available to the operators. This will let us quantify the value of investing in more advanced traffic information infrastructure, which would decrease the uncertainty of the logistics operators.

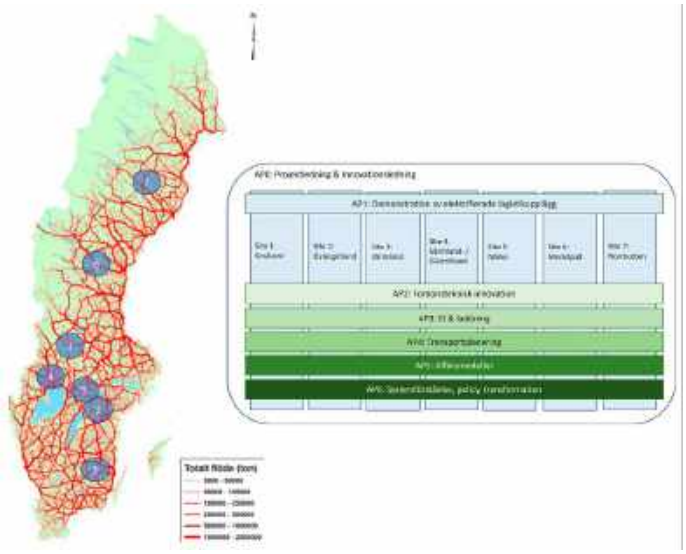
TREE: TRANSITION TO EFFICIENT ELECTRIFIED FORESTRY TRANSPORT

TREE focuses on the electrification of the forestry transport industry, which accounts for nearly 20% of Swedish heavy road transport. A systematic transition of this industry would lead to a significant reduction in greenhouse emissions.

The project's overall goal is to contribute to 50% of new forestry trucks being electrified by 2030. The Forestry Research Institute of Sweden (Skogforsk) and network organization CLOSER at Lindholmen Science Park coordinate the project. The project has 20+ partners, including forestry companies, logistics hauliers, logistics planning companies, charging solution providers, OEMs, and universities. The project runs from 2023-11-20 till 2026-11-19 with support from the R&D program FFI (Strategic Vehicle Research and Innovation) at Vinnova.

A system thinking approach is needed to cater to this demand of creating new ways of logistics operation, technological maturity of the products, and business models. A system demonstration is planned at seven sites across different parts of Sweden to accelerate the electrification drive. Here, new technological platforms will be tested, strategies for logistics movement will be developed, and new business models will be proposed for operation. Thus, the data from these sites will help in developing different work packages like innovative vehicular technologies (Like e-trailers, mobile charging hubs in the forest, e-HCT (High Capacity Transport) vehicles), thoughtful logistic planning with charging solutions, profitable business models, system understanding and policies for accelerating electrification.

Finally, a roadmap that captures the insights from the project for the electrification of the forestry industry will be created. Vivek Venkatesh Shenoy, Scania Industrial PhD student, works within work package six (System understanding, policy, transformation). Within the work package, Vivek will assist with the synthesis of results from interviews with partners, group causal loop diagram workshop, and contributions to system dynamics modeling with his research. He will analyse, simulate, and optimize the vehicular fleet, focusing on the total



Picture credit: Skogforsk

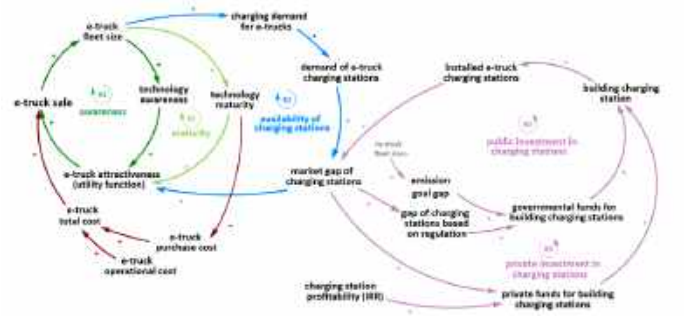
operating economy (TOE) to meet the project goal of 50% electrified vehicles by 2030.

These are subjected to the proposed logistic activity, technological development, and business model. Further in the project, he will contribute towards developing an industry-wide electrificationroadmap, helping stakeholders and decision-makers understand their role in this transformation towards electrification.

IMPACT-AED

The road freight transport system is transitioning towards electric trucks to achieve sustainability. Understanding the impact of electrification on the freight transport system is crucial, but this is a complex system with many stakeholders with different agendas and decision mechanisms. Moreover, there are many interrelationships between these decisions and different system variables. When electrification changes one variable, this change ripples through the whole system.

Thus, the main motivation of this study is to provide a system-level understanding of the impact of electrification on the system to facilitate systematic discussions and empower stakeholders, particularly policymakers, towards achieving sustainability. In the previous year, a system dynamics model was developed to explore the dynamic interplay between charging infrastructure expansion and electric heavy truck adoption and investigate how different policies could impact the system.



System Dynamics Model representing dynamics between infrastructure and truck adoption for electric vehicles

OUTLOOK

We foresee a potential future where the adoption of commercial EV fleets will be faster than the investment into charging infrastructure and fleet and grid operators will face a situation where the charging demand is larger than the charging supply at least during some time periods and/or in some regions in space. For logistics providers this could lead to charging queues and delay costs and uncertainties in logistics and supply chains. For grid operators this could lead to difficult to manage demand peaks. Therefore, we plan to investigate how to provide operational decision support / control systems for actors to manage these difficulties. The solutions could vary largely in approach and could include pricing, booking, and prediction and probably will always involve some form of optimization which may involve learning optimal control with AI/ML via fast and effective simulations in connected digital twins.

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Lab & Research Platforms

Experimentation and demonstration of research results are important parts of ITRL's activities. This is why we have developed various laboratory and research platforms that can be used to experiment on and demonstrate various aspects of the solutions we are working on. The platforms also serve as a meeting place for researchers, partners, engineers, and students.

This year we have worked on several upgrades in the ITRL Lab area. The aim is to support and meet the demands of upcoming projects which will take place at ITRL. We are housing a new lab in ITRL which will be dedicated for research on space robotics. This new lab space is built with a frictionless surface and a dedicated motion capture system, to support the work in the upcoming project, DISCOWER.

Furthermore, we have built new and updated stations with modern equipment for mechanical and electronics work and assemblies. These upgraded assembly stations is already in use for the work on the RCV Dynamic vehicle and in REDO2 project.

AUTOMATED VEHICLE CONTROL TOWER

The Control Tower at ITRL has long served as a flagship demonstration station for many aspects of the research at ITRL. It is an asset for researchers to visualise and work on complex large-scale system pipelines.

This year, we have made several improvements to the Control Tower to have a stronger integration between all platforms and labs at ITRL and to meet the demands of upcoming projects such as REDO2 and DISCOWER. The upgraded Control Tower will support development work on three different projects simultaneously.

Researchers will have access to the powerful computers at the Control Tower which will support multiple operating systems used within the different projects. Within the REDO2 project, the new Control Tower has a driving simulator which gives the user an immersive remote operation experience with sound, steering wheel force feedback, vibration actuators as well as motion in 6 degrees of freedom. Furthermore, we will be able to run at least two demonstrations at the same time, which means that all the new projects will be able to show off their great work all together with zero interruptions and total integration.

We have also put a lot of effort on making the Control Tower look better and more welcoming than ever before. We look forward to show the upgraded control tower and workspace during the upcoming demos and workshops throughout the year.

RESEARCH CONCEPT VEHICLES

The Research Concept Vehicles or RCVs at ITRL have as well been updated during the year since this is one strategic idea with the platforms to have them continuously updated and changed for coming research projects needs.

The larger RCV-E vehicle used currently in REDO2 project extensively have been further improved in terms of the vehicles remote driving capabilities with better antennas, sensors and software integration. During the year we have also had a collaboration with University of Malaga in Spain where the brake system of the RCV-E have been further developed to be able to do research on brake- blending and self-learning ABS systems using Spiked Neural Networks.

The RCV-Dynamic vehicle is a new and updated design from the old RCV platform which have been in development during 2022. This is a project that is funded by strategic faculty funding from the Vehicle Dynamics research group at SCI school.

This is a complicated updated design that require considerable iterations with the help from student projects and master thesis projects since the idea is to have a platform that can actuate steering, camber, vertical wheel movement and accelerate and brake individually on all four wheels and doing this in highly dynamic conditions.

SMART MOBILITY LAB AND SVEA VEHICLES FOR EVALUATING CONNECTED VEHICLE APPLICATIONS.

During 2023 we have designed and developed a testbed specifically for evaluating the real-life performance of advanced 5G-based C-V2X applications. Specifically, this means we designed the testbed to enable low-cost experimentation on advanced C-V2X applications with the ability to precisely evaluate the network, compute hardware, and software performance.

To make experimentation cheaper, we built the testbed around the use of 1/10th scale vehicles, called SVEA (Small VEhicle for Automation). Although 1/10th scale vehicles do not capture the full physics and dynamics of full-scale vehicles, they do provide the ability to cheaply evaluate V2X applications with real network, hardware, and software in the loop.

Additionally, 1/10th scale vehicles offer the ability to do preliminary studies with motion, providing some initial insight into how the results translate to full-scale vehicles. To provide a precise and reliable evaluation of the network performance, we develop the testbed in a private, fully controlled 5G network in the Kista Innovation Park, in collaboration with Ericsson. By developing the testbed in a private, fully controlled 5G network, we are able to test advanced 5G features such as time-critical communication, network slicing, and quality of service maintenance.

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Diane Holcomb, PhD
founder and CEO of Dogl
Teo Rizvanovic
founder and CTO of Aerit
dogl
KTH Innovation

Education

ITRL place great importance on our student engagement. Our students are key to solving the mobility challenges ahead and it is important for us to make sure they have the knowledge needed to enable a transition from the current transport system to a sustainable model.

ITRL established in 2018 its own PhD course, FSD3901 – Integrated Transport System, that will be running every second year. Since the start there have been more than 30 students participating and for the coming year in 2024 there is another 6 students expected to participate in the course. ITRL also established another PhD course in 2021, FMF3035 -System thinking and modelling of complex dynamic systems. The course provides an introduction to system thinking and modelling of complex, dynamic sociotechnical systems by using the modelling framework system dynamics.

JRC JUNIOR RESEARCH COMMUNITY OF ITRL

The Junior Research Community (JRC) of ITRL is a group of young researchers that study problems related to "sustainable transport systems" from different backgrounds, such as socio-technical system thinking, development of automation software, and robotics.

It includes 60 researchers, mostly Ph.D. students, but also postdocs, research engineers, and MSc thesis students from different departments and divisions (ITRL, Decision and Control Systems, Vehicle Dynamics, Energy Systems, Strategic Sustainability Studies, Transport Planning, Stockholm School of Economics, Geoinformatics, Network and Systems Engineering, Speech, Music and Hearing, Structural Engineering and Bridges). The activities organised by JRC are aimed at encouraging networking opportunities and integrated research collaborations between members and ITRL core partners.
In 2023, JRC organised the following activities:
•From Research to Reality: A Transportation Ideation Workshop: The Junior Research Community of ITRL had the pleasure of visiting KTH Innovation for a Transportation Ideation Workshop.

The event featured talks from two inspiring startups Dogl AB by Diane Holcomb and Aerit by Teo Rizvanovic, who previously graduated from KTH Innovation. They shared their journey and insights with the audience which was a great source of inspiration. After the talks, the workshop moved onto ideation, led by Hannes Eder, where participants brainstormed and discussed various innovative transportation ideas, it was fascinating to see the different ideas and perspectives.

•JRC Mentorship Program closing event: the successful conclusion of the JRC Mentorship Program, a one-year initiative that connected JRC members, primarily PhD students, with top industry experts in their respective fields. The program fostered meaningful discussions on research topics, career paths, and personal insights.

At the closing event, mentors and mentees came together to share their key takeaways from the program. Participants reflected on their journeys and highlighted the valuable lessons they learned. It was a truly inspiring moment that showcased the power of mentorship in shaping future leaders. The event concluded with a networking dinner.

•ITRL open house: JRC is actively involved in ITRL events. During the ITRL open house, JRC organised a poster session where members had the opportunity to present their work to other researchers, industrial and public sector representatives within the ITRL network.

JRC Mentorship Program closing event

Courses in collaboration with ITRL

ITRL

• Integrated transport system, 5 credits

• System thinking and modelling of complex dynamic systems, 6 credits

SCI | Aeronautical and Vehicle Engineering

•Vehicle Dynamics Project Course Part 1, 7.5 credits

•Vehicle Dynamics Project Course Part 2, 7.5 credits

EES | Automatic Control

•Automatic Control, Project Course, Smaller Course, 7.5 credits

ITM | Machine Design

•Advanced Machine Design, 18.0 credits

•Project Work, 6.0 credits

•Project Work in Mechatronics, 6.0 credits

•Mechatronics, Advanced Course Spring Semester, 9.0 credits

•Mechatronics, Advanced Course, Fall semester, 15.0 credits

• Systems Engineering 9.0 credits

Impact & Outreach

Events@ITRL

As a pioneer in realizing the future transport system, ITRL is aware of the importance that future users have. We therefore work actively with communicating our work to generate awareness and make sure the generated knowledge reaches relevant people.

14th February

BREAKFAST SEMINARS

Evaluation of bus networks designed by an algorithm: A case study in Södertälje

Anastasios Skoufas & Manuel Chala

16th March

BREAKFAST SEMINARS

Electrification of trucks – batteries, stationary charging, electric roads or all of them?

Jakob Rogstadius

29th March

VISITS TO ITRL

Introduce a Girl to Engineering Day

ITRL was proud to welcome 20 teenage girls as part of Introduce a Girl to Engineering day, organised by Womengineer. There were plenty of discussions among the group when the topic of trends and problems in transportation came up! Elisa then gave the high school students a tour of the lab and guided them in testing to remote operate vehicles.

30th May

BREAKFAST SEMINARS

The Virtual Lab Tour

Kaj Munhoz Arfvidsson, Pedro Roque, Mikael Nybacka, Xujing Song

2nd June

VISITS TO ITRL

The Awaken Sleeping Assets Project visits ITRL

ITRL walkthrough for the ASAP members organised by Claudia Andruetto

5th June

VISITS TO ITRL

Winners of Scania's Inovathon Visit ITRL!

Students, more importantly, the winners of Scania's Inovathon from Brazil were given a tour of ITRL during their trip to Sweden!

2nd July

VISITS TO ITRL

Transport attachés visit Integrated Transport Research Lab

ITRL hosted 71 EU attachés to showcase the hands-on cutting edge transport research being performed at the Lab.

30th August

ITRL PARTICIPATION

Kista Mobility Day

An end-to-end demonstration of a V2X scenario where traffic infrastructure ensures safety of pedestrians. Relating to the projects Future 5G ride & WASP Bridge.

31st August

ITRL OPEN HOUSE

Scania Group, Ericsson, Region Stockholm and Trafikverket as well as EIT Urban Mobility students, students, and academics from KTH dropped by to witness all the interesting projects and demos at ITRL

11th September

ITRL VISITS

Visit from officials at Regeringskansliet

Mikael Nybacka presents ITRL to officials from Swedish Government responsbible for research proposition within the transport sector

3rd October

ITRL VISITS

Visit from Tokyo University

Mikael Nybacka showcased ITRL to delegates from Tokyo university

5th October

ITRL PARTICIPATION

Nobel Calling Stockholm

ITRL had the opportunity to take part in the activities of the Nobel Calling event in Stockholm where we showcased the demos and presentations of our developing projects.

16th October

ITRL VISITS

Visit from Delgates of Technology & Innovation of Business, France

Mikael Nybacka showcased ITRL to delegates from Tokyo university

25th October

ITRL WEBINARS

Webinar on sustainable Freight in Stockholm – Results from the HITS-project

In this webinar, researchers involved in the HITS (Sustainable and Integrated Urban Transport Systems) project present and discuss midterm research results on the topic of Sustainable Urban Freight.

22nd November

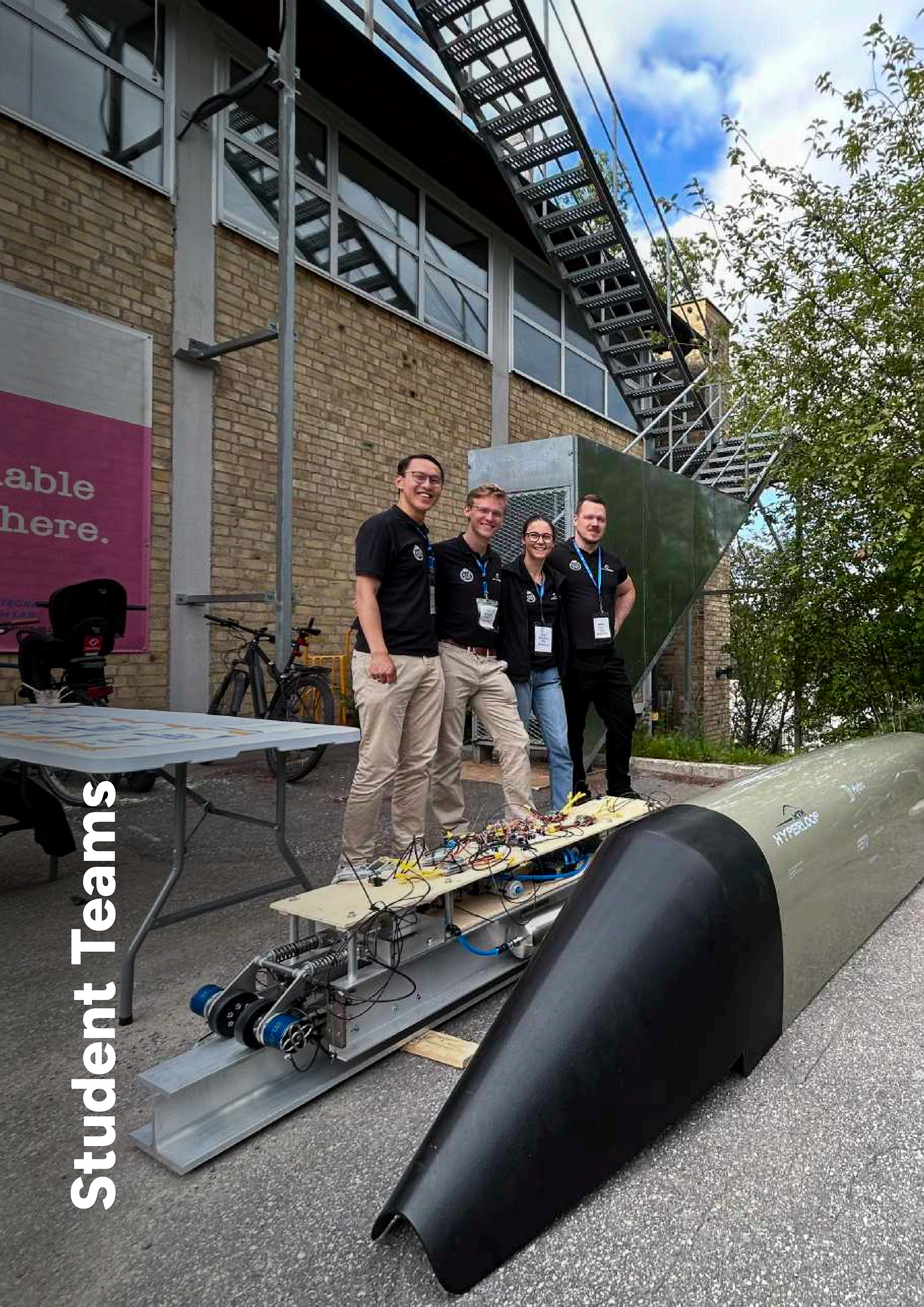
BREAKFAST SEMINARS

Methods for Managing Deep Uncertainty in Planning Sustainable Transport

In this seminar, esearchers involved in the MUST project presented Phase 1 findings, including a literature review on uncertainty in transport planning, insights from workshops, and a case study applying DMDU methods.

Demos at the ITRL Open House 2023

Student Teams



ITRL is currently hosting two student teams, KTH Formula Student and KTH Hyperloop. This support can be for example providing facilities, mentorships, or financial.

DeV17

KTH FORMULA STUDENT

KTH Formula Student continues to develop their most innovative and complex car yet – DeV17. 2023 started with the qualifying for this year's competitions where the team succeeded qualify for Formula Student Germany, the biggest competition in Europe.

The new car was revealed in May during a full-day event which included demonstrations of the manufacturing process and individual systems. Shortly thereafter the team was invited by Lund Formula Student to the Nordic Test Event, where some of the Nordic Formula Student teams gather to exchange experiences and test their cars.

The summer turned difficult as multiple systems were not ready and the team was unable to get the car working in time for the competition in Germany. Since then the team has been working on getting the car in perfect condition for 2024 as well as started the work on building the next car, DeV18. The team have had continued strong sponsorship support during 2023 from Scania, Sanvik, ESSIQ, NCAB and Lenovo to mention a few.

KTH HYPERLOOP

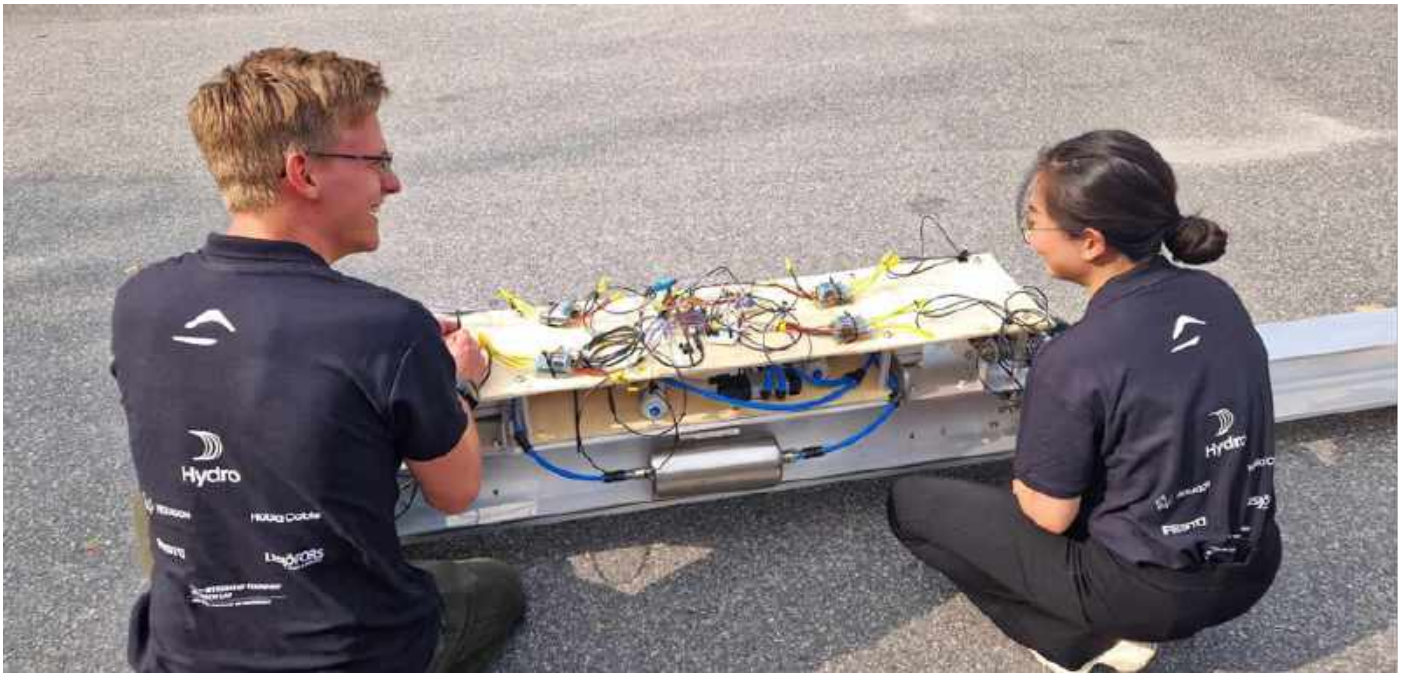
KTH Hyperloop is a student Hyperloop team from KTH Royal Institute of Technology that focuses on research and development of the Hyperloop concept. In 2023, the team achieved a significant milestone by successfully manufacturing its first functional Hyperloop pod.

Recognizing the rapid advancements in the technology, the team initiated the development of a research paper titled "Cargo-Hyperloop: Acceptance and Integration in Scandinavia." in the third quarter. As the year concluded, KTH Hyperloop qualified for the European Hyperloop Week 2024, an international event where top student Hyperloop teams present their research to a panel of judges and an international audience.

This marks the team's third representation at the event but will be the first time the team competes for a complete system demonstration award and in the societal impact and socio-economic interactions research paper categories. Moving into 2024, the team enters the testing phase for their Hyperloop pod and will see the construction of a non-vacuum test-track.

The KTH Hyperloop pod shell.

The KTH Formula Student team poses for a picture after the reveal of their new car.



Two KTH Hyperloop mechanical engineers are dismantling the pod after a successful public test run.

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Center Partner: Scania

Scania is one of the founders of ITRL and is still one of its core partners contributing with funding, expertise and in-kind in projects

Scania engagement in ITRL is driven by the objective that we together can drive the shift to a sustainable transport system. Integrated system research and innovation is necessary in order to better understand the transformation of transport systems and to reach the goals of the decarbonisation of the transport system in time.

We are convinced that a strong partnership is a must for driving the shift and to gather competences from different disciplines, schools, industries and public sector is one of the key capabilities of ITRL. Scania is involved in a number of ITRL projects but during the year no new projects have been started. The focus has instead been on the shaping of ITRL 2.0 on the projects already running.

Regarding ITRL 2.0 Scania has during the autumn made the decision to continue to fund ITRL for another four years from 2025 to 2028. The largest project engagement with ITRL is the HITS projects. During the year Scania and ITRL together with partners continued doing research and innovation actions. Besides HITS Scania engagement in ITRL projects has also been in project like SLICE-T, Future 5G Ride and STIFF.

The project STIFF has been ongoing at a reduced pace during the spring because Lina Rylander, industrial PhD student at Scania, has been on parental leave. However, Xin Tao, a former ITRL Ph.D. student, finished her working package exploring an integrated vehicle health management scheme applied to automate the decision-making process for driverless vehicles.She presented her thesis Application of Integrated Vehicle Health Management in Automated Decision-making for Driverless Vehicles in May. STIFF started at full speed after the summer vacation, and during the initial month, the project work mostly consisted of planning the research activities. Before Christmas, the project's first workshop was conducted with a group of Scania experts. This group will be involved in the project during the entire research process, and the first get-together proved to be much appreciated by the participants. Moreover, during the fall, two master thesis projects were initiated, and they will start at the beginning of 2024. The vision of the project HITS is to "Understand and create conditions for a sustainable transportation system in the city."

The project explores and tests efficient freight distribution in cities during off-peak hours, pooling in urban environments with sustainable transport services, and envisions a sustainable transportation system for 2030 and beyond. Additionally, the project conducts research on system effects and the design of sustainable systems. Schematically, one could describe the project structure as follows, where digitization, understanding of policy, and business development are central to all sub-areas. Research demonstrates that significant improvements in urban freight can be realized, both in reducing emissions and traffic by modifying existing structures and patterns. The key to such transformation lies in the power of collaboration among customer, supplier and shipper, were the lecturers' common message.

Scania Partner at ITRL
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Center Partner: Ericsson

Ericsson is an active core partner of ITRL contributing with expertise in wireless mobile connectivity to initiate and drive research projects leading the transition to a safe and sustainable transportation industry.

Selected Ericsson focus projects and their progress during 2023:

SLICE-T (System Level Impacts of Cellular Connectivity-Enhanced Transport) takes a horizontal perspective on 5G and 6G connectivity and cost requirements imposed by different service types and investigates how novel connectivity techniques can fulfill these requirements in a cost-efficient manner. One goal of the project is to sum up the requirements from difference services and to propose deployment best practices that meet requirements in a cost and energy efficient manner. During 2023 the SLICE-T project has been focusing on implementing optimization models for budgeted cell-planning and deployment and an associated simulator to test and verify the performance of the developed optimization schemes in realistic vehicular scenarios.

The PRESTO (Predictive Quality of Service Management for Transport Services) project focuses on cellular quality of service prediction along roads to enable improved support for a variety of transport services. PRESTO has during 2023 been focusing on comparing the performance of different AI-based prediction techniques (a summarizing paper will appear in IEEE Communications Magazine) and developing AI-aided channel prediction schemes (is summarized in a book chapter to appear in 2024).

The Future 5G Ride project has during 2023 continued the work on use cases related to connected infrastructure sensors and how these contribute to better environment perception aiding driverless vehicles' efficiency and safety. KTH and Ericsson have jointly evaluated the feasibility of vehicles receiving time sensitive traffic environment information from infrastructure sensors via a 5G network.

KTH enhanced their SVEA platform with a framework for data packet latency measurements and Ericsson contributed with their private 5G test network in Kista. The results showed that the Quality-of-Service mechanism enabled in the 5G network sufficiently protected the time sensitive sensor data when the 5G network was overloaded with data traffic from other non-prioritized users.

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Center Partner: Region Stockholm

Region Stockholm is responsible for healthcare, public transport, regional planning and culture across 26 municipalities in the capital city region. Region Stockholm contributes with support for research in healthcare, transport, technology, social sciences and natural sciences.

By funding research, making the region's infrastructure accessible and welcoming researchers to Region Stockholm's operations, the new knowledge that research creates can contribute to improving quality and efficiency. Region Stockholm's commitment to research and development are intended to create the right conditions for the region's inhabitants to have access to operations and services that are constantly improving and developing. Region Stockholm contributes to the financing of KTH/ITRL and supports with test arena. The region is actively taking part in different research projects when the research is of interest for the region's responsibilities.

During 2022 Region Stockholm participated in projects FOKA, PSSST, 5G Ride, and ElSouth. Collaboration is organized by a coordination group for innovation, which prepares and produces proposals for decisions on joint strategic innovation initiatives for Region Stockholm. The purpose is to strategically create the right conditions for innovation projects, to raise the level of understanding and expertise in innovation and to increase opportunities for systematics, collaboration, dissemination and implementation.

With strong universities, many research institutes and a wide range of business actors with highly skilled labor in the Stockholm Region, research and innovation is a policy area of particular importance. The public transport authority of Stockholm County, SL, carries out comprehensive shared transportation, mainly for people.

The public transport system is commonly ranked as second best in the world. Based on the development program Region Stockholm is constantly seeking new efficient and environmentally friendly solutions. Trains, trams, metro and buses in Stockholm have been using 100% renewable energy since 2017 and the aim is to provide the most sustainable public transport in the world. Next steps for the Stockholm region are continued electrification of buses and boats as well as automation.

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Publications

19
publications

7 **conferences attended**
in North America; South America & Europe

3 **publications in conference proceedings**

4 **theses**
1 master thesis, 2 licentiate thesis, 1 doctoral thesis

1 **project report**

11 **journal publications**
prominently in IEEE based journals & Transportation Research Part A

JOURNAL PUBLICATIONS

Title: A Survey of Teleoperation: Driving Feedback;
Authors: Lin Zhao, Mikael Nybacka, Malte Rothhämel;
Year: 2023;
In: IEEE Intelligent vehicle symposium

Title: Safe Teleoperation of Connected and Automated Vehicles;
Authors: Frank J. Jiang; Jonas Mårtensson; Karl H. Johansson;
Year: 2023
In: Cyber-Physical-Human Systems: Fundamentals and Applications

Title: Rollout-Based Charging Strategy for Electric Trucks With Hours-of-Service Regulations;
Authors: Ting Bai, Yuchao Li, Jonas Mårtensson; Karl H. Johansson;
Year: 2023
In: IEEE Control Systems Letters

Title: SA-BiGCN: Bi-Stream Graph Convolution Networks With Spatial Attentions for the Eye Contact Detection in the Wild;
Authors: Yancheng Ling; Zhenliang Ma; Bangquan Xie; Qi Zhang; Xiaoxiong Weng;
Year: 2023;
In: IEEE Transactions on Intelligent Transportation Systems.

Title: Designing for change in complex socio-technical systems;
Authors: Lina Rylander and Magnus Eneberg;
Year: 2023;
In: Expanding the Frontiers of Design: Critical Perspectives

Title: Modular vehicle routing for combined passenger and freight transport;
Authors: Jonas Hatzenbühler, Erik Jenelius, Gyözö Gidófalvi, Oded Cats;
Year: 2023;
In: Transportation Research Part A: Policy and Practice

Title: Adding Cyberphysical Systems to the Engineering Education "Pi";
Authors: Claudia Andruetto, Rafia Inam, Martin Törngren;
Year: 2023;
In: Computer

Title: Rollout-Based Charging Strategy for Electric Trucks With Hours-of-Service Regulations;
Authors: Ting Bai, Yuchao Li, Jonas Mårtensson; Karl H. Johansson;
Year: 2023
In: IEEE Control Systems Letters

Title: Platoon Cooperation Across Carriers: From System Architecture to Coordination;
Authors: Alexander Johansson; Ting Bai; Karl Henrik Johansson; Jonas Mårtensson;
Year: 2023;
In: IEEE Intelligent Transportation Systems Magazine

Title: Transition from physical to online shopping alternatives due to the COVID-19 pandemic: A case study of Italy and Sweden;
Authors: Claudia Andruetto, Elisa Bin, Yusak Susilo, Anna Pernestål;
Year: 2023;
In: Transportation Research Part A: Policy and Practice

Title: Using vignettes to explore policy tools for a self-driving transport future;
Authors: Erik Almlöf;
Year: 2023;
In: Transportation Research Interdisciplinary Perspectives

CONFERENCE PROCEEDINGS

Title: How can we structure the future development of automation, electrification, and digitalization in the transportation sector by using morphological analysis?;
Authors: Zeinab Raoofi, Erik Stenemo, Albin Engholm, Anna Pernestål;
Year: 2023;
In: 2022 Conference Proceedings Transport Research Arena, TRA Lisbon

Title: Categorization of urban logistics concepts according to their sustainability performance
Authors: Claudia Andruetto, Jonas Mårtensson, Anna Pernestål;
Year: 2023;
In: 2022 Conference Proceedings Transport Research Arena, TRA Lisbon

Title: A review on real vehicle usage modelling of driverless multipurpose vehicles in vehicle routing problems;
Authors: Raphael Andreolli, Mikael Nybacka, Ciarán J. O'Reilly, Erik Jenelius;
Year: 2023;
In: Proceedings of the International Conference on Engineering Design, ICED 2023

CONFERENCE PRESENTATIONS

Title: Investigation of system-level impacts of electrification on the road freight transport system: a System Dynamics approach;
Authors: Zeinab Raoofi, Maria Huge-Brodin, Anna Pernestål;
Year: 2023;
Presented at: The Nordic Logistics Research Network 2023

Title: Activity and time-use diary for a Neighborhood Telecommuting Centre in Stockholm, Sweden;
Authors: Bhavana Vaddadi, Chengxi Liu, Yusak Susilo;
Year: 2022
Presented at: 16th International Conference on Travel Behaviour Research (IATBR) 2022, Santiago, Chile

Title: How to teach a machine to drive?;
Authors: Erik Almlöf;
Year: 2023;
Presented at: Euro Working Group Transport (EWGT) in Santander, Spain

Title: Influence of sound, vibration, and motion-cueing feedback on driving experience and behaviour in real-life teleoperation;
Authors: Lin Zhao, Mikael Nybacka, Malte Rothhämel, Lars Drugge;
Year: 2023;
Presented at: The 28th IAVSD International Symposium on Dynamics of Vehicles on Roads and Tracks, August 21-25, 2023, Ottawa, Canada.

Title: A city hub system dynamics model - A case study in Stockholm;
Authors: Claudia Andruetto; 2023;
Presented at: European Transport Conference 2023 in Milano

THESES & REPORTS

Title: Trajectory Optimization of Smart City Scenarios Using Learning Model Predictive Control;
Authors: Mustafa Al-Janabi; 2023; Master Thesis

Title: Designing for Change in Complex Systems: Design Considerations for Uptime in a Transportation System with Driverless Vehicles;
Authors: Lina Rylander, 2023; Licentiate thesis

Title: Teleoperation and the influence of driving feedback on drivers' behaviour and experience
Authors: Lin Zhao, 2023; Licentiate thesis

Title: Application of Integrated Vehicle Health Management in Automated Decision-making for Driverless Vehicles; Authors: Xin Tao; 2023; Doctoral thesis

Title: Results for the comparison between e-scooter trips and their public transport and walking equivalent in the city of Gothenburg;
Authors: Erik Almlöf, David Micallef, Henry Acosta Carrascal; 2023; Report on: The ELKOLL project, KTH DIVA

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Thank you all for a great 2023!

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