ITRL — INTEGRATED TRANSPORT RESEARCH LAB

KTH ROYAL INSTITUTE OF TECHNOLOGY

ITRL

Annual Report 2021

Content

Towards a transport system in a sustainable society

Transport is a central aspect of the way that we, as humans, live. However, whilst transport systems can contribute towards well-being and prosperity, they can also create negative impacts. For societies to prosper, it is imperative that our transport systems are flexible, smart, and clean, that we offer mobility solutions to all and that we limit the negative impacts of freight transport and the distribution of goods. This is the challenge that drives us.

We believe in an integrated approach. Therefore, to achieve our mission of building and conveying knowledge that contributes to the transition towards sustainable road transport, we integrate disciplines, system levels and stakeholders in our research.

We are currently in a transportation paradigm shift driven by the introduction of new technologies and the crucial need to transition to a sustainable transport system. However, along with the potential for great success in this field, comes a number of challenges.

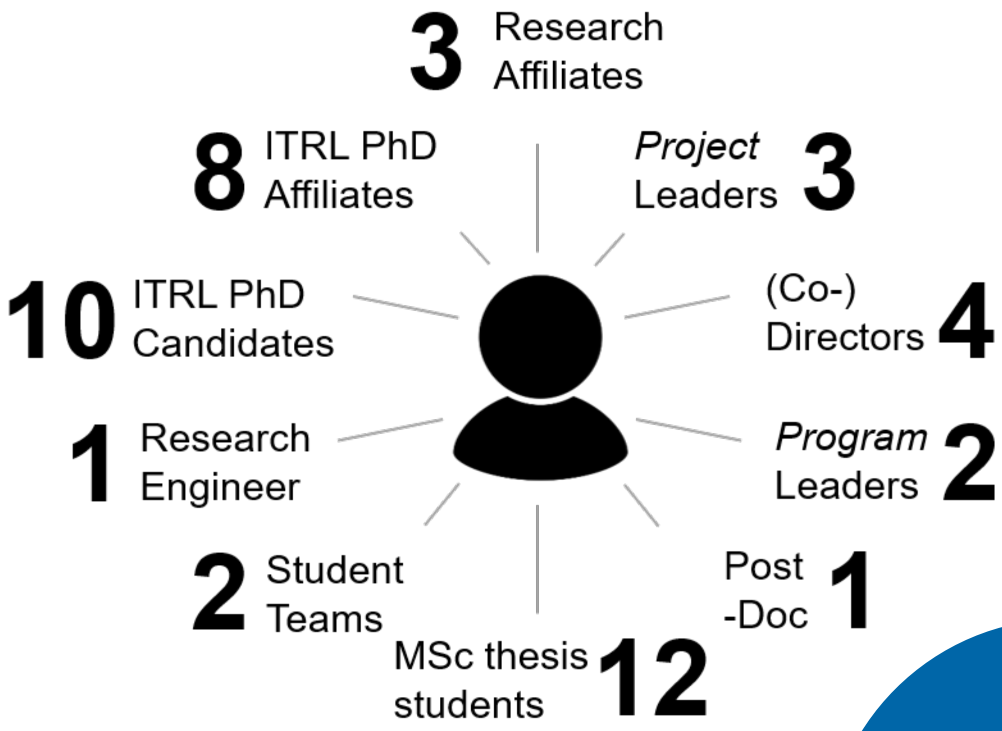
Vision

Our vision is of a world in which future generations have access to socially just, environmentally clean and efficient transport systems.

Mission

Our mission is to build and convey knowledge that contributes to the transition towards sustainable road transport. We do this by integration disciplines, system levels and stakeholders in our research.

ITRL in numbers



25
Core members of ITRL

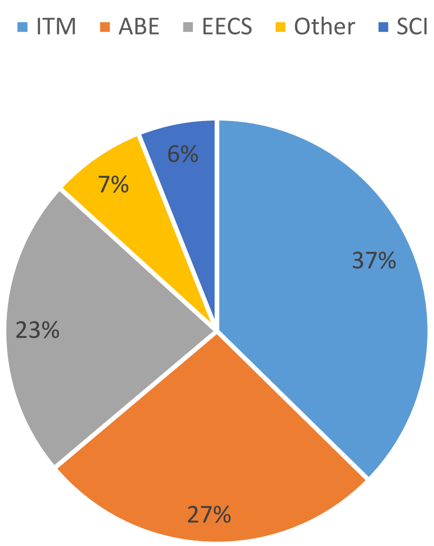
Staff

At ITRL researchers from various disciplines and industry come together to share knowledge, thoughts and experiences. The core team of ITRL, i.e. the people working most closely with ITRL, consists of 25 people, among which there are 48% women (12) and 52% men (13). The diagram above shows the core team of ITRL, plus the people that are considered closely working together with ITRL, for example our PhD affiliates and MSc thesis students.

Anna Pernestål stepped down as ITRL director in June, however she continues to work part time as a senior researcher. Jonas Mårtensson was then appointed deputy director and later made permanent director.

Two new PhD students joined, Zeinab Raoofi and Elisa Bin (previously research engineer). A new research engineer, Erik Stenemo, was also recruited. During the year ITRL welcomed a summer intern to work with Lin Zhao on the RCV, and an intern doing his master's degree project.

KTH School Involvement



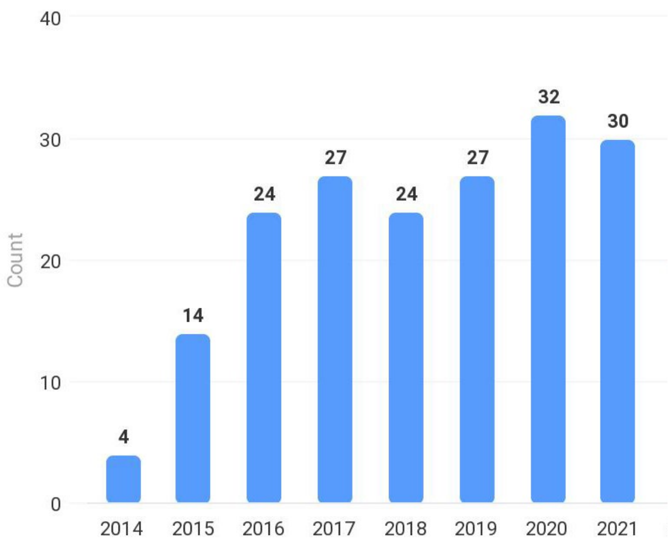
Social media statistics

Platform	*Followers 2020*	*Followers 2021*
LinkedIn	574	961
Facebook	546	636
Newsletter	644	655

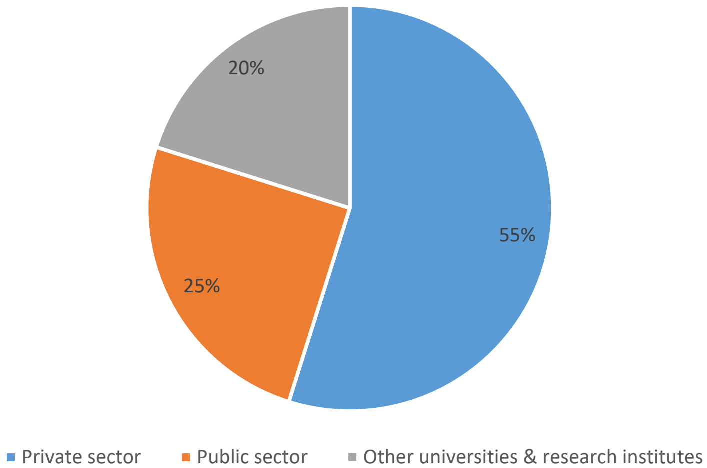
Most popular journals for ITRL

- European Transport Research Review
- Sustainability
- Travel Behaviour & Society

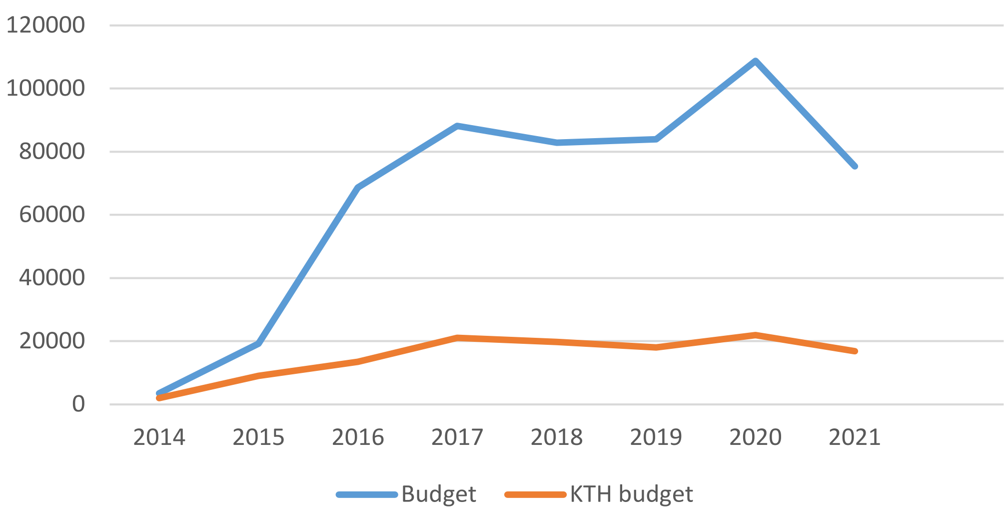
Active projects per year

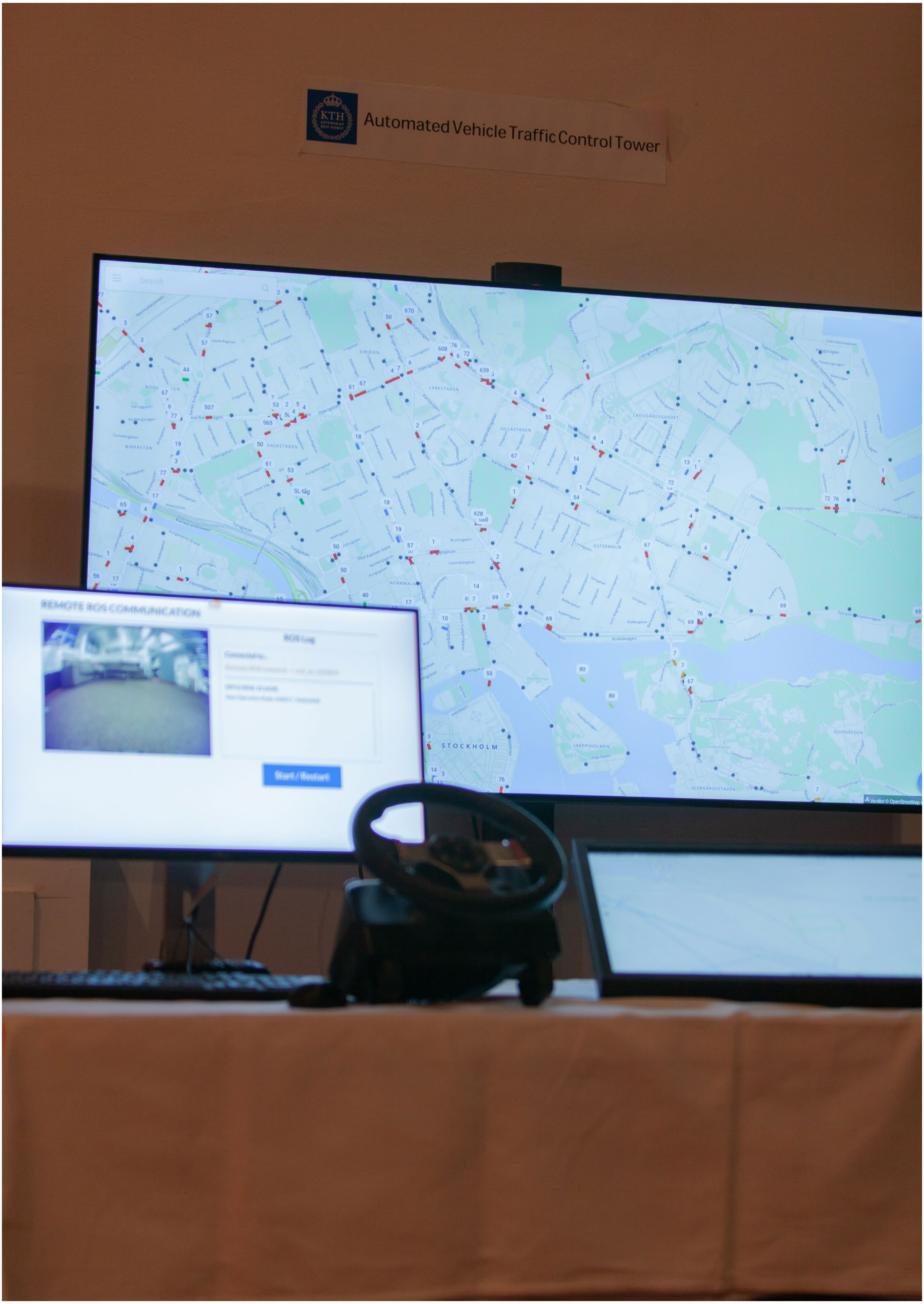


Collaboration Partners



Budget in active projects (kSEK)




KTH
VETENSKAP
OCH KONST
Automated Vehicle Traffic Control Tower
REMOTE ROS COMMUNICATION
ROS Log
Start / Restart
STOCKHOLM

Projects

Projects started:

- CORD - Cognitive Assessment of Remote Drivers
- PRESTO - Predictive Quality-of-Service Management for Enhanced Automotive and Transport Services
- RoSE
- Future 5g Ride
- FOKA - Operating unmanned autonomous buses
- TRACER - Accelerate the electrification of the Heavy Freight Transport (HFT) industry
- Mistra SAMS Living Lab 2
- PSSST - Investigate policies related to self-driven shared vehicles, especially public transport
- DS BM2 - Collaboration on business models with industrial partners
- MUST - methods for Managing deep Uncertainty in planning for Sustainable Transport
- SLICE-T - System level impacts of (cellular) connectivity-enhanced transport.

Ongoing projects:

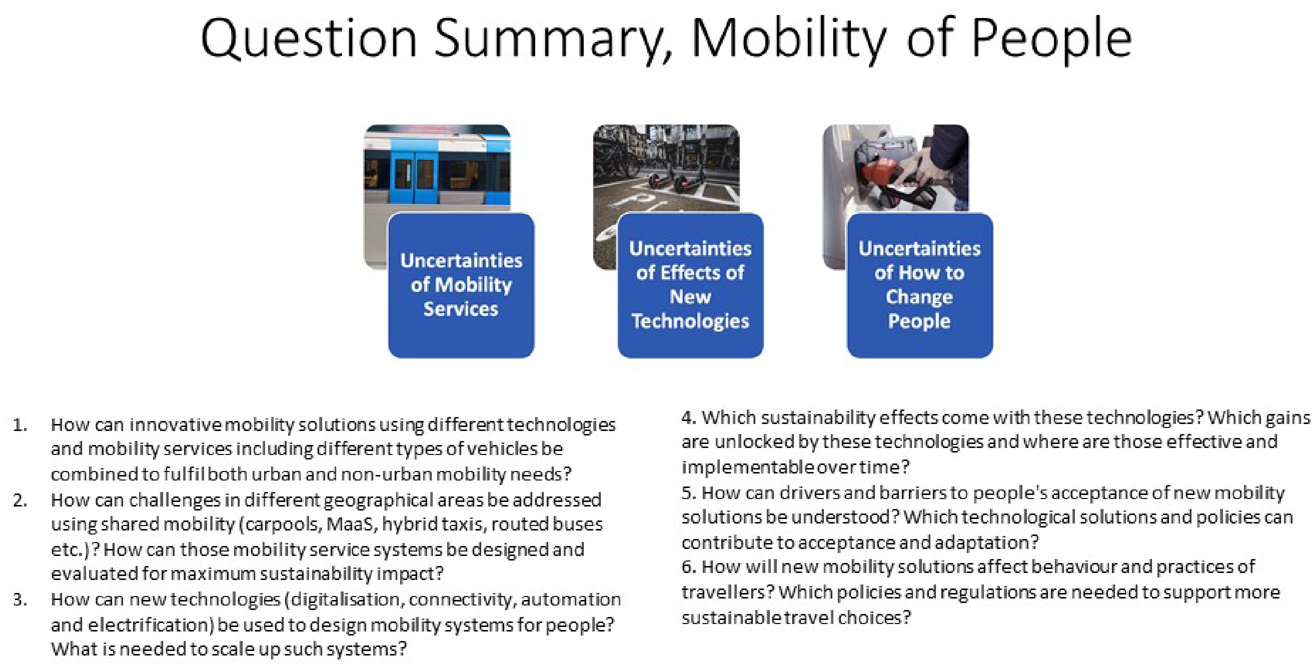
- Campus 2030
- LOLA - Cost-benefit Optimized Charging Infrastructure
- Drive Sweden Business Model Lab
- Electrified transport in South Stockholm
- HITS 2024
- InterCityLog2 - Minimize transport work with cross-border collaboration
- MERGEN – Multi-purpose biometric Evaluation Research tool Grounded in Emerging Network technologies
- REDO - Remote Driving Operation
- RoSE - Learning in Routing Games for Sustainable Electromobility
- SEAMLESS - Systematic Evaluations and Assessments of MaaS
- Social robots accelerating the transition to sustainable transport
- SUSTEV - Towards a sustainable use of electric vehicles
- Uptime for AV - How is vehicle diagnostics and fault handling affected when the driver is removed?

Finished projects:

- ResilientE2E
- ABE Södertörn
- DS BM
- KOMPIS
- System Level Impacts of Self-driving Vehicles
- AVTCT 2 - Exploration of actors and functionality of traffic control towers for AVs
- 5g Ride Control Tower

Mobility of People

The research program Mobility of People, have during 2021 built further knowledge in relation to the three challenge areas with different uncertainties of: mobility systems, effects of new technologies and how to change people's behaviours and practices in sustainable directions. The work is ongoing and the research activities and project results presented here are work in progress.



Uncertainties of mobility systems

During 2021 we have conducted several research projects to understand the impacts of mobility systems at macro, meso and micro levels. Understanding uncertainties of developing, implementing, operating, and governing mobility systems is one of the challenge areas in this research program. We have developed frameworks to analyse impacts of systems at macro, meso and micro levels and we have used these frameworks to assess mobility service systems (see section Assessments).

Frameworks

A framework, including key performance indicators and data collection methods (surveys and interviews), has been developed in the research project KOMPIS. The framework enables evaluations that assess sustainability impacts of different types of MaaS services to suggest development and governance of sustainable service systems. The framework includes three levels: individual level (users), organizational level (organizations that develop and operate MaaS, as well as organizations that adopt MaaS), and societal level (city, municipality, region).

Assessments

SEAMLESS is a research project that includes several different deliverables and has just started during the fall 2020. SEAMLESS uses the framework developed in KOMPIS to assess environmental, economic, and social impacts at three levels: micro (traveller), meso (organisation) and macro (city, region, country). Quantitative and qualitative methods are used to analyze data collected from various types of MaaS pilots to explore how and to what extent MaaS would impact factors such as travel behavior, accessibility, emissions, and business opportunities to name a few. SEAMLESS has successfully conducted two stakeholder seminars during 2021 to introduce the SEAMLESS and KOMPIS assessment method as well as recruit MaaS pilots for data collaboration.

Uncertainties of effect of new technologies

During 2021 we have conducted several research projects to understand how to assess impacts of new technologies and what the impacts of new technologies are at macro, meso and micro level. We have researched effects of autonomous vehicles and remote driving on drivers from different perspectives and at different levels in several projects. Furthermore, we have researched effects of autonomous buses and artificial intelligence on an individual passenger level. Moreover, we have researched effects of electrification of private cars and public transport buses on policy level and effects of autonomous and shared transport systems on policy level.

Autonomous vehicles and remote driving

When moving to automated road transport systems there will be increased needs to manage fleets and their operations, as well as to solve problems that the autonomous vehicle might have, e.g. decision problems due to changing environment needing remote assistance. These could either be solved by giving the vehicle permission to proceed, give it a new safe path, or even taking over control, and remotely drive the vehicle. In the MERGEN research project we study the cognitive load of remote driving compared to real driving, as well as assess difficult scenarios for remote operators in traffic control towers, to acquire knowledge on the requirements on remote operation of autonomous vehicles. So far, we have carried out several tests and learned that our test methods work well to measure cognitive load.

In the REDO research project, the focus is 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 is different than what needed during real driving, so feedback cues for remote driving need to be designed specifically 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 REDO can be used for scale-up studies in AVTCT2 and future projects to understand feasibility and impacts in transport systems' transitions towards autonomous vehicles and remote driving.

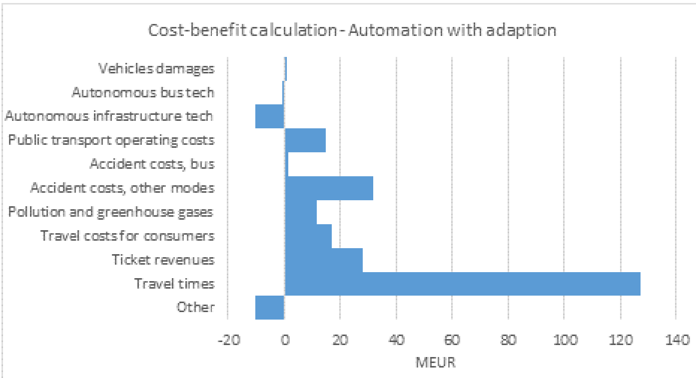
Autonomous buses and artificial intelligence

Artificial intelligence is booming and offers opportunities in self-driving public transport. Since self-driving vehicle technologies are becoming increasingly ready for wide implementation, it becomes more important to tailor it to users' needs. In the research project Social Robots, we investigate which function social robots might be able to fulfil in future driverless buses. To structure the unstructured, i.e. to provide real-time travel data, is what has been identified as a main potential of social robots according to the public transport industry and academic professionals. This increased level of convenience will be included in our experimental research, while also assessing how the introduction of social robots in driverless busses impacts passengers' level of comfort and feeling of safety.

Electrification of private cars and public transport buses

To combat negative effects such as increased congestion caused by low marginal operational costs of electric vehicles, the SustEV project has built models to evaluate impacts of possible packages of policies and incentives to drive more sustainable electric vehicle use. The investigated transport service incentives included dedicated or subsidized charging & parking, subsidized public transport and shared mobility services. The project has developed a novel methodology and a WebGIS based tool for a travel diary data collection and adaptation survey to find travel-contextual adaptation patterns through travel behaviour modelling. This will be followed up with the stakeholders' consultations to identify feasible incentives and strategies to help change people's behaviours and practices in sustainable directions.

The ABE Södertörn research project investigated the prospects of introducing full-sized autonomous buses on Crosslink ('Tvärförbindelse') Södertörn in southern Stockholm. The project was a collaboration between ITRL, Sweco, Trafikverket, Keolis, Volvo and Scania, financed by Trafikverket and ran from 2020 to 2021. Within the project, the requirements for physical and digital infrastructure were examined and an estimation of system level effects was provided. The project concluded that the vehicle technology was not yet ready for commercial use, but the substantial gains could be made from providing cheaper and more comfortable rides for passengers. However, infrastructure costs could be significant and separate road lanes may not be suitable for all cases and the infrastructure for autonomous buses should ideally be used for other modes of transport as well.



Cost-benefit calculation from project ABE Södertörn

Autonomous and shared transport systems

In the research project PSSST – Policies for sustainable, shared, and self-driving transportation – we investigate the potential for different policy tools given shared self-driving vehicles. The project is funded by Region Stockholm in collaboration between ITRL and the Division of Transport Planning at KTH and runs from 2021 to 2022. We use both quantitative and qualitative methods, to investigate how policies affect different sustainability goals and use input from public planners in the Stockholm region. During 2021 an analytical model has been developed which will be used to evaluate policy implications.

FOKA is a research project initiated in 2021 where ITRL together with Nobina Technology, Region Stockholm and Järfälla municipality, and ObservIT and Telia will design, implement, and test autonomous buses without operators onboard, but with support from a control tower. We explore barriers (technical, legal, data sharing, passenger attitudes and needs and up-scaling of business models) to extended use of autonomous and connected vehicles, and how such transport can support public transport to be attractive, sustainable, and encourage travel with shared resources.

Uncertainties in how to change people

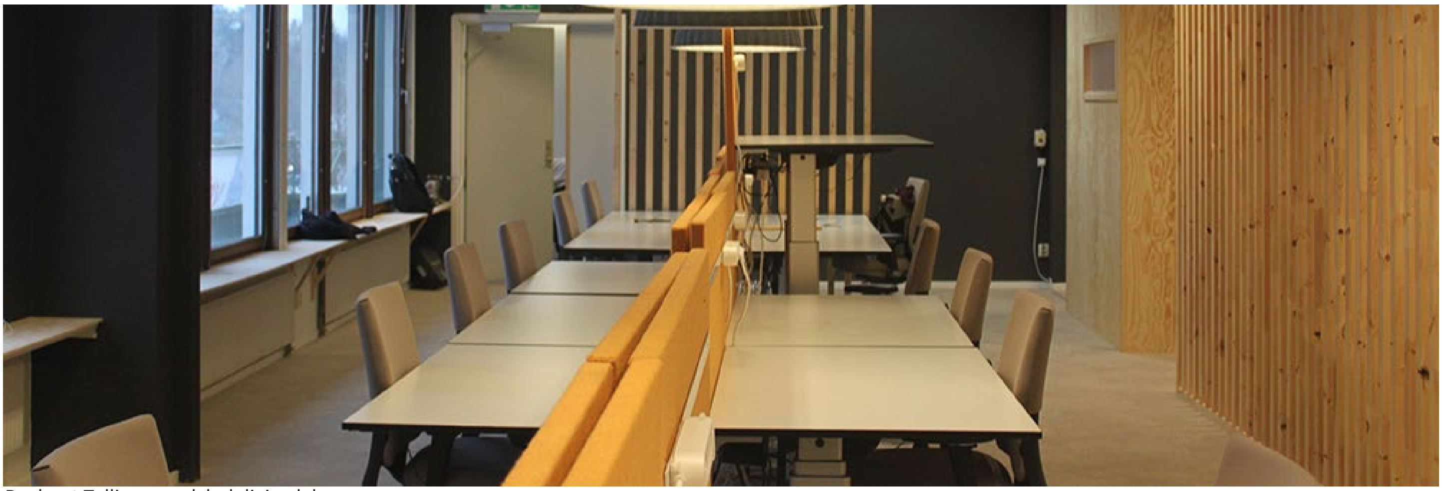
In 2021, we have continued to carry out research projects to understand how to shift people's behaviours and practices in sustainable directions. During 2021, we have researched how a co-work hub located in Tullinge south of Stockholm influenced and changed transport behaviour and commuting trips.

Changes when a co-work hub was introduced

As a part of Mistra SAMS Living Lab 2, we developed a co-working space in Tullinge, south of Stockholm. With help from our partners such as Ericsson, we recruited more than 60 participants who lived in and around Tullinge but worked elsewhere in the Stockholm region. The co-work hub offered a professional workspace with facilities that encouraged efficient and sustainable work and travel practices. Using this real-life experiment, we aimed to understand possible changes that a decentralized co-work hub could have on the participants' travel and work behaviour. Since February 2019, around 52 participants have been involved in various research activities such as a survey, in-person interviews, phone call interviews, and three-week time-use diaries covering information about their travel habits and preferences, characteristics of respondents' current working life, leisure activities and time use during the days they worked from the hub.

While the results of the data collected through the diaries and interviews indicated that participants merely exchanged working from home for working at the hub, for some participants the hub triggered significant lifestyle changes as they walked to the hub, used the e-bicycles to make trips during the day, and ran errands more locally. While most of the participants expressed immense interest in working from the hub more often, the diaries stated that they could not achieve that. We investigated some of the possible conditions that hindered participants from spending more time at the hub. The most significant conditions that we found were workplace regulations together with norms and expectations. However, due to the onset of the COVID-19 pandemic, changes have been observed in the attitudes towards remote working, which might effectively reduce the hinderance for participants to work at the hub more often hence reducing their commuting trips and saving.

Many participants expressed the need for the hub during this period, believing that they would use one more often after the pandemic. As of October 2021, we have invited the participants of the living lab to resume working at the work hub (in accordance with the Swedish Public Health Agency regulations). As a follow up to previous research at the hub, during the months of October 2021 to January 2022, we designed and conducted another round of interviews of about 10 interviews (including the quitters and the regulars). A summary report based on the results collected through these interviews is currently underway and concrete qualitative analysis will be conducted and published as a journal article late next year.

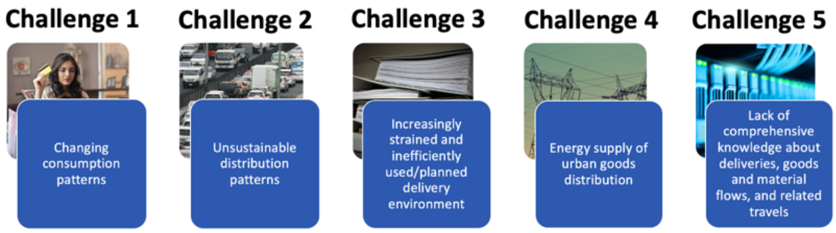


Desks at Tullinge work hub living lab.

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. The UGD program road map, established in 2020, identified the following five challenges and five groups of research questions that were coupled to possible technological trends and solutions that can potentially address the challenges.



Connected goods: How, and by how much, can information from connected goods improve the efficiency and sustainability of urban distributions (C2), promote a more sustainable consumption of products and transport services (C1), and improve the horizontal collaboration and data sharing in urban goods distribution (C5)?

Dynamic redistribution of transport supply / resources and demand: How can new vehicle designs, delivery concepts, and new technologies even out the peaks and valleys in- and reduce the negative impact of urban distributions (C3) and improve the resource efficiency of urban distributions (C2)?

Electrification of urban goods distributions: What combination of vehicle configurations, charging infrastructure, placement and dimensioning, can facilitate the electrification of urban goods distribution?

Urban consolidation and delivery hubs: How can the placement, dimensioning, and sharing of urban distribution hubs and smart boxes, as well as the use of connected goods, be utilised to reduce fragmented deliveries and pickups?

System-wide resource efficiency through transport data sharing: Which data about transport operations needs to be shared, which technical solutions and business models are needed to facilitate this sharing, and how can a knowledge market be created that enable horizontal collaboration, system-wide resource efficient goods distribution?

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.

Organizing for collaboration and sharing

With a focus on Challenge 2 and 3, in this research topic, our KTH researchers investigate possibilities of re-configuring and re-organising sociotechnical systems through studying trials of off-peak deliveries in Stockholm, Sweden. We have found that the efficient use of resources was considered the main business and societal value of implementing off-peak deliveries and that barriers to overcome included uncertainties regarding costs, lack of regulations and trust which requires collaboration, re-organisation and re-configuration. Some takeaways from the study include:

- Actors need to agree on sensible outcomes and be incentivised by perceived value.
- System thinking is beneficial to develop such incentives
- Actions taken by the respondents in this study often only intervene at lower system levels.
- To really change systems (such as transport systems), the system goals and purpose need to be agreed upon.

Environmental assessment of city distribution

With a focus on Challenge 2 and 3, in this research topic, our colleagues from IVL, with the help of stakeholder workshops/interview and measurements and simulations investigate 1) what the external costs of delivery traffic that enters Södermalm today are and 2) how large the reduction potential by freight consolidation systems and 'off peak'-solutions is. We have found that the current external costs are approximately 80 000 € per day of which 80% is due to congestion and that the consolidation scenarios studied can reduce the costs by 75% and that external consolidation hubs can lead to largest reductions. Some takeaways from the study include:

- Congestion is largest contributor to external costs
- Consolidation system yield large potentials for reduced external costs
- Suburban consolidation required to achieve the higher consolidation potential
- Mobile lockers show higher external costs compared to fixed lockers

Sustainable vehicle design
With a focus on Challenge 2 and 3, in this research topic, our industrial PhD student (Raphael Andreolli) from Scania supervised by KTH researchers and Scania supervisor Eric Falkgrim investigate how autonomous modular vehicles (AMV) should be configured, designed and operated to give the most benefit with respect to sustainability and performance, taking both vehicle and system level perspectives. Autonomous modular vehicles are flexible vehicles that can transport people, goods and waste during daily and nightly operations without human drivers. Our research results for 2021 is a vehicle model that can be used to compute vehicle: energy consumption, range, battery pack, battery discharging, payload capacity and vehicle performance measures (startability, gradeability, accelerationability, and maximum speed). Our future research will include how to connect the vehicle model and optimize AMVs for higher system level logistics functions (i.e., UGD with AMV fleets).

Impacts of modular multi-purpose vehicles
With a focus on Challenge 2 and 3, in this research topics, our PhD student (Jonas Hatzenbühler) supervised by KTH researchers investigate how to solve the pickup and delivery problem with AMV fleets. We have solved a series of use case scenarios using an exact optimization algorithm and an adaptive large neighborhood search algorithm and found that AMV fleet based UGD can lead to 1) cost savings of up to 15%, 2) additional savings due to collaboration, 3) higher utilization of vehicle capacity, 4) reduction of empty kilometers, 5) similar unserved demand, 6) reduction of fleet size of up to 34%, and 7) reduction of trip duration of up to 32%. Our proposed models can be used by companies and policy makers to identify required fleet sizes, optimal vehicle routes and cost savings due to different types of operation and vehicle technologies.

System level effects of urban logistics concepts
With a focus on Challenge 2 and 3, in this research topic, our PhD student (Claudia Andruetto) supervised by KTH researcher investigate how to model and design a urban freight transport system use system dynamics modelling and design of an urban freight transport system that minimize transport-related externalities that negatively affect the liveability of the urban environment and the health of citizens. In 2021, our work was focused on city hubs, which by enabling collaboration can reduce congestion and pollution through increased consolidation and shift to smaller, less carbon-intensive vehicles.
The output of our study so far includes 1) a visual representation of a framework, tool for sustainability performance assessment, 2) evaluation of sustainability performance of concepts based on the literature, and 3) a system dynamics model with a validated structure, with implementation of city hubs. Some takeaways from the study include:

- Even if sustainability is measured in most of the companies, this is not always a priority.
- Achieving more consolidation decreases congestion and emissions.
- The main barriers to the implementation of city hubs are competitiveness and the branding of the vehicles and the drivers. These barriers are from a transport company perspective.
- It is unclear whether city hubs higher potential in low- or high-density areas.

Data sharing
With a focus on Challenge 5, in this research topic, our visiting researcher 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.

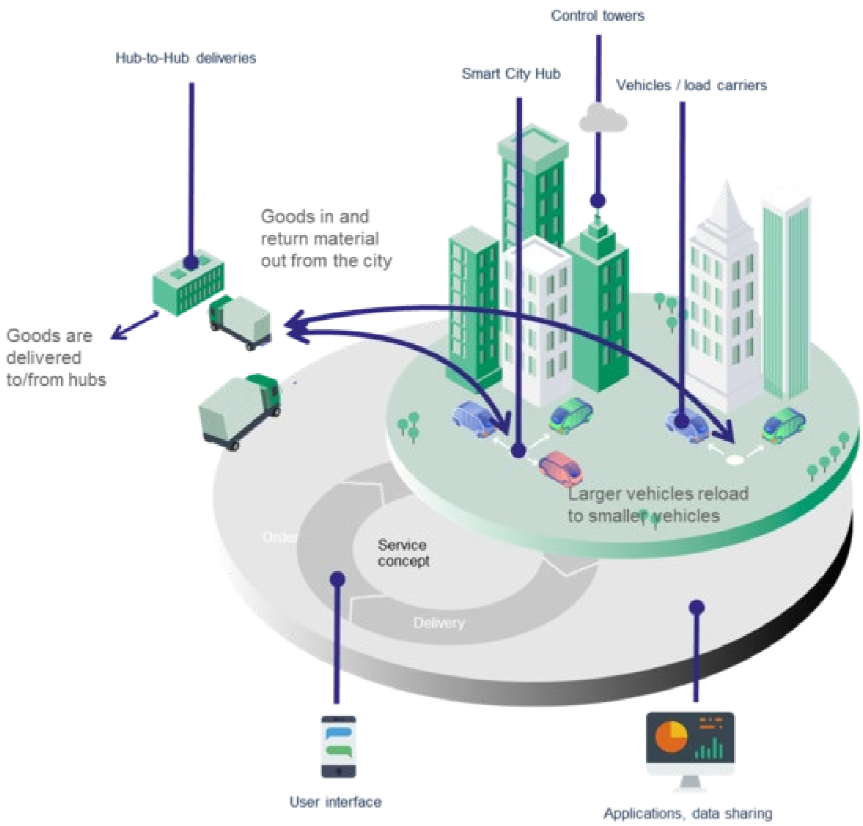
Policy, legislation, and regulation
With a focus on Challenge 5 and 3, in this research topic, our colleague from Uppsala University (Kristina Andersson) primarily investigate the current and expected legal obstacles or enablers of data sharing and off-peak deliveries. We have found that lots of legislation 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.

InterCityLog2 - Minimize transport work with cross-border collaboration

With a focus on Challenge 2 and 3, in this research project, together with partners, our PhD student (Ehsan Saqib) supervised by KTH researcher investigate how to assess the energy efficiency potential in solutions identified as unutilized potential for collaborative and consolidated low emission transport solutions in cities. In practice, this means that we study and collect data about the current operations of ÄlskadeStad in Stockholm and devise methods that assess the energy, business, and environmental costs of the current shared city hub based consolidated package delivery and recycling material pickup logistics operations of partners Bring and Ragn-Sells. For this purpose, we perform transport work, energy use, and delivery and handling time measurements of the current operations and compare it to traditional non-collaborative delivery and pickup operations as well as optimized operations that are found by a heuristic optimization model that determines the optimal fleet size and routes for consolidated delivery and pickup operations. Already in our prior studies (InterCityLog), we have seen that the current operations that share a city hub, drivers, and small electric trucks reduce the cost by up to 50% compared to traditional non-collaborative operations. With the optimization model, we see a potential for improvement by combining/sharing the routes for the deliveries and pickups. Some barriers that we find for capitalizing on this potential are other logistic operations that require tight process- and system integrations in addition to data sharing. Specifically, the presorting of packages in the terminal outside of the city according to the consolidated routes in the city is difficult. In the future, we plan to use the model that we developed to evaluate the potential of such collaborative and consolidated low emission transport solutions in other cities and geographies to enable the scaling on the operations.

Outlook

Building on our off-peak delivery experiences in the pilots, ECCENTRIC, ZEUS, and HITS 2024 projects, from 2022 our KTH researchers and PhD students will in the project "DATASETS: exploring DynAmic environmental Taxation for a Sustainable, Efficient urban Transport System" create 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. Based on these models and tools, we plan to generate projects that create a multi-actor framework for dynamic smart urban zone simulations and AI-optimizations for sustainable urban goods deliveries. Finally, we hope to continue our research on how to create a sustainable and integrated urban transport system in the continuation of our light-house project HITS 2024.



HITS 2024.

Research

End-to-End Freight Transport

The vision of the End-to-end freight transport program (E2E) is a fossil-free, socially just and efficient transport system. The main challenges addressed by the program are 1) fossil fuel dependence, 2) low transport efficiency and sub-optimal flows, 3) unsound market structures and 4) changing transport demand.

Focus questions End-to-end Freight Transport

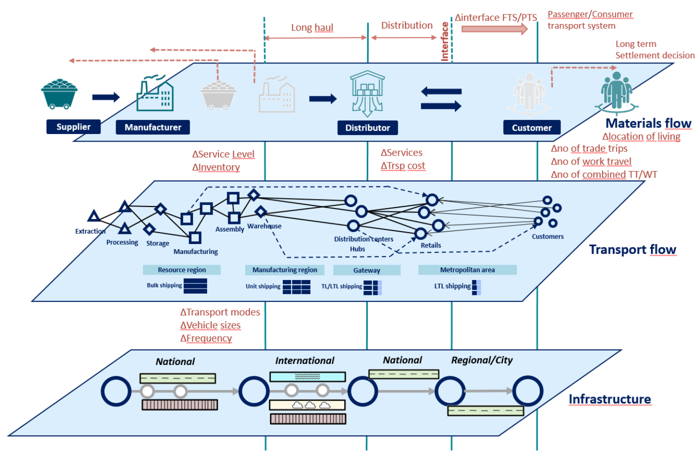
1. How can an up-scaled and optimal combination of biofuels and electrification be achieved for long distance freight?
2. What is the right size of vehicles, or the right combination of a vehicle fleet, in order to improve transport efficiency and modal shifts?
3. Can logistics flows be reshaped to make them sustainable by, for example, enabling horizontal optimization utilizing digitalization, connectivity, data sharing, and automation?
4. How can digital technologies be utilized to go beyond reducing CO2 emissions; having an impact on such issues as enabling fair trade, gender equality etc. in logistics?
5. What are the requirements for the large-scale adoption of driverless vehicles that also meet changing transportation demands?
6. What are the system level impacts of circular economy principles and global logistics on long distance freight transport?

Up-scaled and optimal combination of biofuels and electrification

Fossil fuel dependence in transport is one of the major contributors to the CO2 emissions. Electrification is receiving increasing attention, both in terms of battery-electric vehicles and in terms of continuous electrification (electric roads). Battery-electric heavy vehicles were (almost) considered infeasible just some five years ago but now there are massive investments in this technology. ITRLs work on electric infrastructure is summarized in the specific section on Electrification.

The IMPACT-AED project aims to facilitate a systematic discussion on the impact of Automation, Electrification, and Digitalization (AED) on the freight supply chain using a System Dynamic (SD) model. The problem is structure using the three-layered Wandel model (Wandel et al., 1992) in the freight supply chain, which includes material flow, transport flow, and infrastructure. Then, for each layer, we attempt to identify critical variables and key performance indicators (KPIs) to translate them into a System Dynamics conceptual model.

Electrified Transports Stockholm South, funded by TripleF, aimed at exploring the required ecosystem of actors needed to enable the electrification of transports



Wandel model.

with connections to the emerging logistics hub in Stockholm South, focusing on key value propositions. Interviews and focus groups were conducted, engaging representatives from different key stakeholders in the emerging ecosystem, such as truck manufacturer, electricity network operator, facility providers, charging infrastructure manufacturer, transportation company, etc. The analysis found potentially critical bottlenecks that may challenge the transition to electric trucks. It distinguishes between challenges in the near and distant future as well as between closed and open logistic systems. Providing a map of the interlinkages between key ecosystem actors, the results contribute to a holistic understanding of the business model related challenges and uncertainties that different actors are facing and how they are connected.

Right size of vehicles, or the right combination of a vehicle fleet, to improve transport efficiency and modal shifts

Some related results are reported under HITS 2024 - Impacts of modular multi-purpose vehicles in Section Urban Goods Distribution.

Reshaping logistic flow to make them sustainable

The DigiGoods prestudy project studied three different logistic chains from manufacturing, postal services and grocery. The investigated aspects were: Business models (identification of actors, challenges, appropriate solutions and value propositions); System architecture (architecture and semantics for sharing data between actors); Critical aspects and bottlenecks for shared data. The main findings are: 1. There are several parts of supply chain with missing data. In cases with heavy equipment, the generation of the missing data requires sensors with high level of robustness to sustain different kind of physical shocks. In cases with high volume new innovations are required to enable fast and low-cost sensing. 2. IT system integration is one of the main challenges in sharing data between different parts of the supply chains.

Requirements for the large-scale adoption of driverless vehicles

The TIFF project studies the service market system for trucks (maintenance, repair, and vehicle monitoring services) when indroducing driverless vehicles (SDVs). Lina Rylander, industrial PhD student at Scania, proposes a new design of the service market system for SDVs. The questions that have been explored are how the system is affected by removing the driver and which considerations are needed when redesigning the system. The study showed that the driver has a significant role in the service market system considering five theme aspects 1) Fault detection, 2) Decision-making, 3) Information exchange, 4) Information retrieval, and 5) Tacit knowledge and experience. These five theme aspects can exist singly, but they often exist jointly. The information exchange and information retrieval are essential for decision making; however, experience is often needed when interpreting information. This interpretation of the theme aspects can be illustrated by a sensemaking process, where the system actors use experience and knowledge to, for example, decide upon suitable actions. Part of the solution might be to introduce better decisions support systems and automated descicion-making. Models for this have been developed by PhD student Xin Tao.

The project System level impacts of driver-less vehicles was concluded during 2021 and Albin Engholm presented his Licentiate thesis: Driverless trucks in the Swedish freight transport system: An analysis of future impacts on the transport system and the emerging innovation system. The main findings are: 1) Driverless trucks could enable cost reductions of around 30%-40% per ton-kilometer. A key determinant of the cost reduction is to what extent reduced driver costs will be offset by other forms of human labor that may be required for driverless truck operations. 2) The impacts of driverless trucks on road transport demand, utilization of different truck types, modal split, and total logistics costs are studied. The analysis shows that driverless trucks could reduce total costs for Swedish freight transport in the range of billions of SEK per year. Road transport demand and truck traffic volumes may increase significantly through modal shifts from rail and sea. 3) There are several favorable factors for a successful introduction of driverless trucks, but also that the innovation system is characterized by a 14 high degree of uncertainty related to what infrastructure will be required and available, what business models will be emerging, and which actors will be able to capitalize on the development and which actors that become marginalized in a future with driverless trucks.

Research

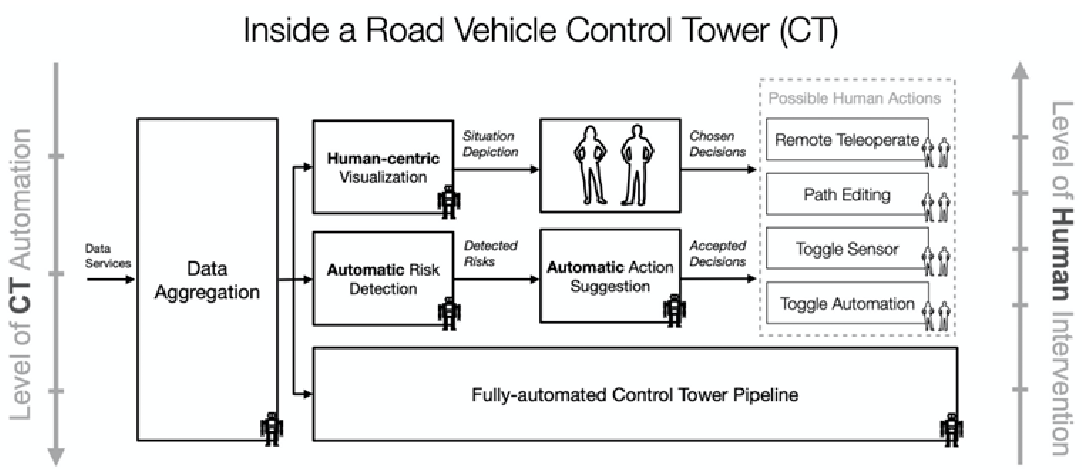
Connected Transport

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 to handle complex situations and coordinate decisions. These systems will bring new demands on reliability, latency, and efficiency.

ITRL has recently started the project SLICE-T together with Ericsson, Scania, Telia and Trafikverket, where we will study system-level technical, societal, and environmental impacts of providing mobile connectivity to transport systems and services. Various classes of connected transport services will be analyzed to quantify their relevance over time for transport system sustainability (defined in a broad sense, comprising environmental impact, safety, efficiency, and business models). The connectivity requirements of the most relevant service types will be analyzed and used to assess the required network performance along different types of roads, and how those networks can be deployed. 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 be investigated. Based on the technical and economic analysis, the project will identify hurdles and possibilities for deployment, adoption, and usage. The project will identify technical and business solutions for mobile network operators, transport service providers and road infrastructure operators that contribute to a sustainable transport evolution.

Remote decision-making, operation and control of automated vehicles has been the topic of several projects. In the AVTCT project we have begun to define, conceptualize, and implement control towers for automated vehicles. We investigated definitions, architectures and required technologies and we have developed a demonstration platform using the Smart Mobility Lab and simulations integrated with the systems from our collaboration partners (Carmenta, in particular). An interesting aspect is the increasing level of automation and the decreasing level of human intervention in the control tower, where AI and automated decision-making plays a central role. This is depicted in the figure below.

The 5G Ride projects implements and demonstrates control towers for automated vehicles from T-engineering and Scania, connected to the Ericsson Innovation cloud. The new phase of this project will focus on connected infrastructure sensors from Viscando that would improve the situational awareness for operating automated vehicles. The aim is to analyse and experimentally validate the use of 5G connectivity for this safety-critical high-demand use-case of connected vehicles and sensors.



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 challenges of the electrification research program have not yet been explicitly defined in a roadmap, but given the multiple stakeholders (OEMs for vehicles, battery, and chargers; logistics / mobility service providers and users; grid operators, charging network operators, governments and state), their multiple objectives and constraints, the multiple transport electrification solutions and applications, and their interactions, it is clear that the integrated approach of ITRL to researching the topic is needed. The aims and results of current electrification project below give a good indication of the problem complexities and the approaches needed.

Electrified Transport in South Stockholm

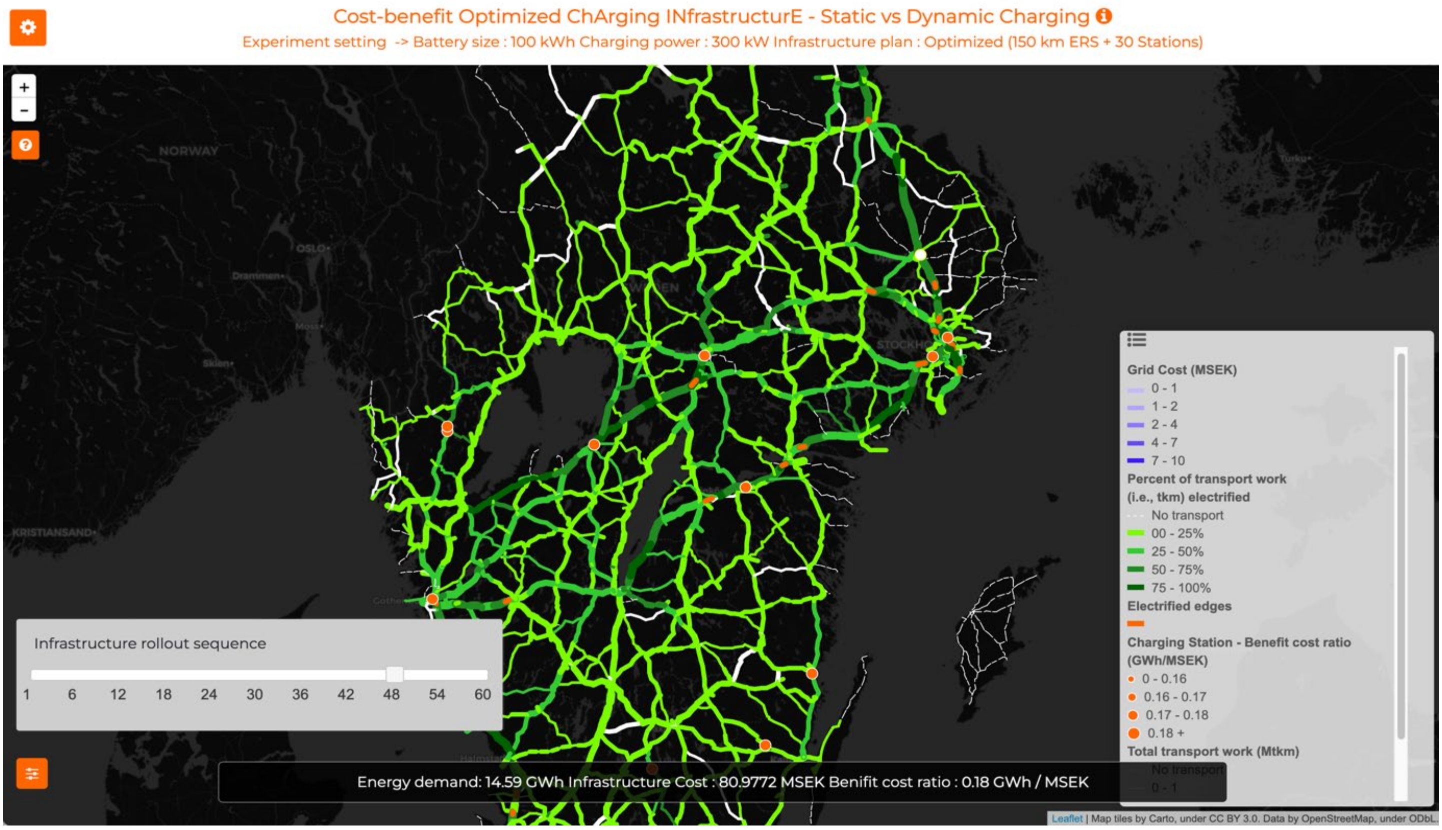
This study, funded by TripleF, aimed at exploring the required ecosystem of actors needed to enable the electrification of transports with connections to the emerging logistics hub in Stockholm South, focusing on key value propositions. Interviews and focus groups were conducted, engaging representatives from different key stakeholders in the emerging ecosystem, such as truck manufacturer, electricity network operator, facility providers, charging infrastructure manufacturer, transportation company, etc. The analysis found potentially critical bottlenecks that may challenge the transition to electric trucks. It distinguishes between challenges in the near and distant future as well as between closed and open logistic systems. Providing a map of the interlinkages between key ecosystem actors, the results contribute to a holistic understanding of the business model related challenges and uncertainties that different actors are facing and how they are connected.

TRACER - Transport Demand Centric Decision Support for Electric Charging Infrastructure Planning and Operations

In this Trafikverket / TripleF funded industrial PhD project, with the support of academic and industrial supervisors from KTH and Scania and in collaboration with experts from Trafikverket, investigate how to accelerate the electrification of the heavy freight transport 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. As the first step in the project, in 2021, to better understand the problem, we have 1) identified main actors to be vehicle owners, grid operators, charging infrastructure owners and vehicle manufacturers, 2) studied truck statistics from Sweden and Germany to better understand how trucks operate (mileage, mass utilization, emissions etc.), 3) conducted interviews with grid operators in Sweden and Germany to gather knowledge about challenges and costs of charging BEV with special emphasis on high-power charging, and 4) identified economics to be important, in particular, Total Cost of Ownership (TCO) for truck owners.

LOLA - Cost-benefit Optimized Charging Infrastructure

In this SEC funded pre-study, KTH researchers are extending the route-based charging infrastructure planning model of the prior RENO project and are investigating how to incorporate charging stations as an electrification option and how to effectively model and consider the charging infrastructures costs, including the cost of grid connections that is required to supply the charging demand, in the cost-benefit optimization of charging infrastructure plans. In 2021, we naturally extended the route-based evaluations based on the observation that charging at stations will take a relatively long time hence will be most attractive at locations where the driver can use the time during charging for other activities. These locations will most likely be at the start and end of the route and around five hours into the route when loading, unloading and mandatory rest stops usually take place. Thus, as with electric roads, the charging needs and the charging utilities along the routes should primarily depend on the routes and not the traffic counts. This route-based model is then used to optimize charging infrastructure plans that maximize these charging utilities and corresponding revenues per unit charging infrastructures costs. Preliminary results show that the optimized charging stations may have a larger return on investment for some scenarios than the optimized electric roads. However, for the large-scale electrification scenarios, the charging demand on charging stations



An interactive web map for the exploration of the return on investments of an optimized charging infrastructure roll-out plan for 150 lane-kms of electric road and 30 charging stations.

is well into the double-digit MW ranges, something that requires large charging infrastructure and grid reinforcement investments. In addition, while charging stations may appear to be a more feasible and a better infrastructure investment option than electric roads now, the opposite might be true in an autonomous transport future when stopped vehicles are considered "waste" from an operational efficiency perspective.

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 with partners from MIT investigate how to make traffic routing for commercial operators more sustainable by accounting for electromobility, operational costs, infrastructure condition deterioration, and environmental externalities. In 2021, we have created a simulation for the cost of the interaction between vehicles and the infrastructure especially the charging congestion, demand peaks, and travel delays that this can lead to in scenarios where the electrified vehicle's charging demand exceeds the charging supply. We have also created a game theoretic framework that mimics the route and vehicle choices (BEV vs ICEV) that individual operators will adopt under given charging costs, delay costs due to the shared nature of charging facilities, and the pollution cost levied by regulatory agency on the use of ICEVs. Next, we will look at how to set prices that allow the agents to learn and converge to a desirable social optimum.

ePREDICT: electric PREDIctive Consolidated Transportation

In this ERASMUS+ MSc thesis project, visiting researcher (Jesper Provoost) together with supervisors for KTH and University of Twente, have devised simulation and machine learning based algorithms that exploit the idle time of vehicles and optimize charging decisions for a fleet about when, where and for how long to charge vehicles while taking into consideration other operational decisions, i.e., dispatching and repositioning. The demonstrated benefits of the approach on ridepooling application include: 25% reduction in charging costs, 45% lower peaks, more even utilization and higher availability of chargers in time and space, and improved logistics efficiency / reductions due to optimized dispatching and repositioning which include 68% customer delay, 11% idle time, and 20% fleet size.

Outlook

While the LOLA project has successfully integrated charging stations as an electrification option and has included infrastructures costs (including estimates for the grid costs) into a charging infrastructure optimization model, we plan to further investigate how to provide decision support to further minimize the risk of lost assets of Distribution Service Operators (DSOs) like Vattenfall, EON, Ellevio, Stadskraft etc. and Charging Point Operators (CPOs) like InCharge etc.

We also 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.

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 20 students participating and for the coming year in 2022 there is another 10 students participating in the course.

Two PhD students, Albin Engholm and Bhavana Vaddadi, successfully defended their licentiate and half-time seminar. The ITRL facilities continues to be used by two student teams, KTH Hyperloop and KTH Formula Student.

Junior Research Community

Relaunched after the pandemic, the Junior Research Community of ITRL, or JRC, 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 consists of mostly Ph.D. students, but also postdocs, research engineers, and MSc thesis students are. The goal of the JRC is twofold: get to know fellow young transportation researchers in a rather informal way, create a strong networking channel, and encourage research collaborations (to effectuate ITRL's aim of integrated research).

We organise events throughout the whole year, both formal and informal, to achieve these goals. In 2021, we had a virtual meeting on June 18 and then an ITRL tour on October 27 and a mini conference on November 30 with the contribution of 35 multidisciplinary groups of junior researchers 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 (TMH), Structural Engineering and Bridges). We are looking forward to extending this potential community in the following year.

Project Courses

The following KTH student courses are held in collaboration with the Integrated Transport Research Lab – ITRL.

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

Junior Research Community conference

Impact & Outreach

As a pioneer in realizing the future transport system, ITRL is aware of the importance that future users have. We therefore actively participate in media, to generate awareness and make sure the generated knowledge gets dispersed outside our niche.

Webinars

Seven editions of ITRL Breakfast Webinars were organized, averaging around 50 people per webinar. The webinar dealt with a wide array of topics, such as social justice in mobility as a service, how Covid-19 impacted transportation, autonomous vehicles, and battery recycling. Additionally, ITRL hosted three webinars for the HITS project and one for Fordonsdalen, a collaboration between KTH and Region Stockholm.

Media Attention

We are aware of the importance that future users have. We therefore actively participate in media, to generate awareness and make sure the generated knowledge gets dispersed outside our niche.

ITRL was mentioned or had a researcher interviewed in five articles, with the most common paper being Dagens Industri. Three interviews with ITRL researchers were published on kth.se and on KTH's social media. One radio interview was conducted as well.

Jonas Mårtensson was interviewed by a Spanish journalist before the royal visit in November, and several photographers and journalists attended during the visit. Anna Pernestål was interviewed in Dagens Industri (twice) and Hem & Hyra, on autonomous vehicles and the project KOMPIS.

The 5g Ride project was spread through both domestic and international industry press, highlighting the projects demonstration day in November and the multi-million investment in the continuation of the project (Future 5g Ride).

The paper " Who continued travelling by public transport during COVID-19?" was also picked upp by Forskning och Framsteg and Dagens Nyheter.

Newsletter

During 2021 five newsletters were sent out to over 650 subscribers, as well as four emails to promote Breakfast Webinars.

Spanish and Swedish royal visit

On November 25th the kings of Spain and Sweden visited ITRL and were given a demonstration of a remote control safety systems for self-driving cars. After a presentation of ITRL by director Jonas Mårtensson, PhD student Frank Jiang demonstrated a safety system where AI aids humans in avoiding unsafe driving, as well as introducing the kings to ITRL and our research. King Felipe VI of Spain tested the system and successfully parked one of the vehicles in the Smart Mobility Lab. During the event ITRL also welcomed KTH president Sigbritt Karlsson, Swedish Minister for Energy and Digital Development Anders Ygeman, plus representatives from the Swedish and Spanish enterprise sectors, accompanied the royal party. ITRL also welcomed KTH president Sigbritt Karlsson, Swedish Minister for Energy and Digital Development Anders Ygeman, Ericssons CTO Erik Ekudden, plus representatives from the Swedish and Spanish enterprise sectors.

PhD student Frank Jiang demonstrating remote control safety systems for the kings of Sweden and Spain. Photo: Fredrik Persson

Visits to ITRL

- March – June, University of Malaga, guest PhD student, Javier Perez from, worked with RCV-E and collaborated with Lin Zhao and Mikael Nybacka.
- August, Campus 2030 student visit
- September, student visit from master program Urban Mobility
- November, Mikael Nybacka had WS with Scania, RVC group, (Concept vehicles), on remote driving and RCV-E design and design considerations regarding bi-directional vehicle. Resulted in a jointly supervised MSc Thesis student project.
- November, Spanish and Swedish royal Visit.

Conferences & Events

- **Jonas Mårtensson, Gyözö Gidofalvi & Malin Danielsson**: Scania Innovation Day
- **Lina Rylander**: Paper presented at 2021 Global Reliability and Prognostics and Health Management (PHM-Nanjing)
- **Elisa Bin**: AVTCT2 Project presented at Drive Sweden Forum 2021. AVTCT2 Project presented at TRB Automated Road Transportation Symposium (ARTS21) - Breakout session Remote Support for Automated Vehicle Operations. Paper presented at TRB 2021 ITF Pre-Summit Research Day: Transport Innovation for Sustainable Development: Re-shaping Mobility in the Wake of Covid-19. Pink Programming Deep Learning Camp (ITRL sponsor).
- **Erik Almlöf**: Paper presented at TRB 2021: Who continued travelling by public transport during COVID-19? Socioeconomic factors explaining travel behaviour in Stockholm 2020 based on smart card data
- **Lin Zhao**: “Study of different steering feedback models influence during remote driving”, In proceedings of 27th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks, St. Petersburg, Russia, August 18th, 2021.
- **Mikael Nybacka and Frank Jiang**: Presented ITRL at Sensible Stockholm Lab meeting, 7th of October, KTH and MIT researchers as well as startu-ps and Stockholm city officials was present.
- **Frank Jiang:** 5g Ride Demonstration Day

Center partner

Scania

Photo: Scania

Scania was the founder of ITRL together with KTH and is still a core partner of ITRL.

Tony Sandberg is chairman in steering group and Ulf Ceder is co-director and member of ITRL management group.

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 reach the goals of 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 capablities of ITRL. Scania's ITRL project engagement in 2021 has been mainly focusing on the HITS project in exploring and researching innovative urban logistics solutions that can solve the urban last mile challenges.

Besides HITS Scania engagement in ITRL has mainly been in new project like SLICE-T, Future 5G Ride and TIFF.

Center partner

Ericsson

Ericsson is a core partner of ITRL, and contributes with cash funding, with project forming efforts, with leadership contributions including Mats Norin as member of the steering group and Håkan Olofsson as ITRL co-director in the leadership team, and with in-kind contributions as partner of selected research projects.

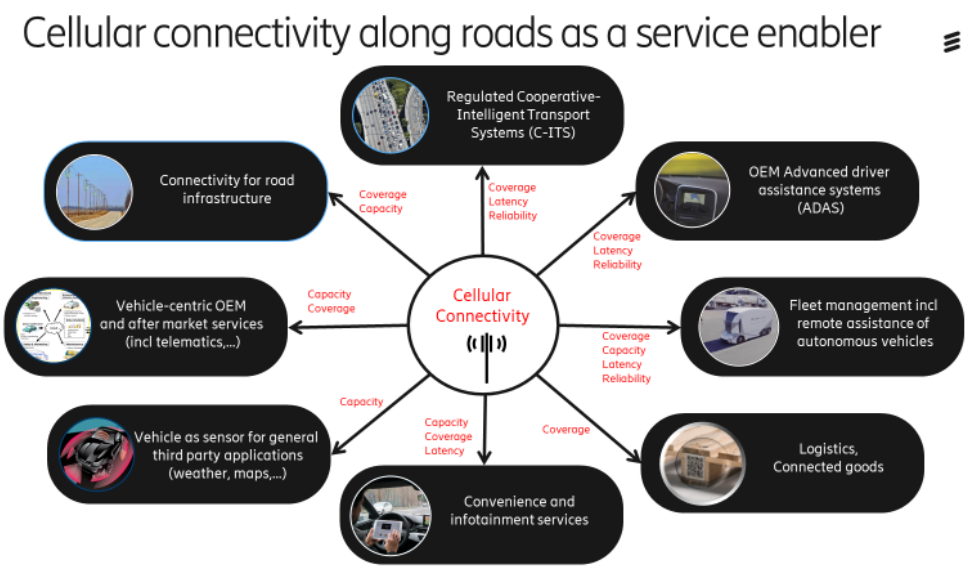
Our engagement in ITRL is driven by the insight that the ICT sector including 4G/5G connectivity can contribute to numerous efficiency gains in digitalizing different industry sectors, including 15% reduction in CO2 emissions [Malmodin et al, 2015]. Since the transportation sector is a major contributor to today's challenges but also sees strong transformational momentum, we view ITRL as a prioritized opportunity to gather researchers from multiple disciplines, both the transportation sector itself and connectivity-focused experts, from both KTH's different schools, from the industry and from the public sector, to find opportunities and solutions and accelerate the system transformation.

Ericsson's ITRL project engagement in 2021 has been selective, focusing on substantial engagement in the project 5G RIDE Control Tower, that investigated remote supervision needs of driverless vehicle fleets. The project revealed several insights in traffic tower use case needs (see Section X). Plenty of research is however still needed to fully understand which requirements exist on connectivity between vehicles and traffic towers, including the likely adoption pace in different transportation scenarios, which in turn will govern the needed connectivity evolution along different types of roads and streets.

Ericsson has spent substantial effort in helping to form new interesting ITRL-connected projects. These include:

- PRESTO, focusing on coverage and capacity prediction along roads, based on AI/ML (see Electrification);
- SLICE-T, which takes a horizontal perspective on 4G/5G connectivity needs across different service types, illustrated in Figure X, and aims to quantify efficiency and sustainability gains of each type, and based on these insights sum up the total need of evolving connectivity along roads and streets (see Connected Transport);
- (Future) 5G RIDE, the continuation of previous 5G RIDE projects which continues the paper research and trial efforts on remote supervision from traffic towers, and further adds the perspective of fixed connected infrastructure sensors and how these contribute to better environment perception aiding driverless vehicles' efficiency and safety. This project includes demonstrations in Kista (See Connected Transport).

Further, Ericsson has been speaking at ITRL's Breakfast Seminars, and CTO Erik Ekudden was part of the expert panel session at the Spanish royal visit at KTH/ITRL in November (see Impact & Outreach).



Center partner

Region Stockholm

Photo: Ana Bórquez on Unsplash

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 is 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 parts when the research is of interest for the region's responsibilities. During 2021 Region Stockholm participated in projects ElSouth, FOKA, PSSST, and Resilient E2E (completed).

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 and highly skilled labour 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 environmental work, based on the environmental program of Region Stockholm, and is constantly seeking new, environmentally friendly solutions. Trains 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. For light rail, commuter trains, metro lines and other electric powered transportations SL procures and uses only electricity from renewable sources. Next step towards zero-emissions in the Stockholm region is the transition to electric buses. The goal is also to contribute to better air quality and reduced noise for the inhabitants.

Publications

Journal articles

- E. Almlöf et al., ”Who continued travelling by public transport during COVID-19? : Socioeconomic factors explaining travel behaviour in Stockholm 2020 based on smart card data,” European Transport Research Review, vol. 13, no. 1, 2021.
- J. C. T. Bieser et al., ”Impacts of telecommuting on time use and travel : A case study of a neighborhood telecommuting center in Stockholm,” Travel Behaviour & Society, vol. 23, pp. 157-165, 2021.
- E. Bin et al., ”The trade-off behaviours between virtual and physical activities during the first wave of the COVID-19 pandemic period,” European Transport Research Review, vol. 13, no. 1, 2021.
- P. N. E. Chee, Y. O. Susilo and Y. D. Wong, ”Longitudinal interactions between experienced users' service valuations and willingness-to-use a first-/last-mile automated bus service,” Travel Behaviour & Society, vol. 22, pp. 252-261, 2021.
- A. Chiche et al., ”Feasibility and impact of a Swedish fuel cell-powered rescue boat,” Ocean Engineering, vol. 234, 2021.
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- J. Hatzenbühler, O. Cats and E. Jenelius, ”Network design for line-based autonomous bus services,” Transportation, 2021.
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- R. Palmberg et al., ”Built Environment Characteristics, Daily Travel, and Biometric Readings : Creation of an Experimental Tool Based on a Smartwatch Platform,” Sustainability, vol. 13, no. 17, 2021.
- A. Pernestål et al., ”How Will Digitalization Change Road Freight Transport? : Scenarios Tested in Sweden,” Sustainability, vol. 13, no. 1, 2021.
- P. Sadeghian, J. Hakansson and X. Zhao, ”Review and evaluation of methods in transport mode detection based on GPS tracking data,” Journal of Traffic and Logistics Engineering, vol. 8, no. 4, pp. 467-482, 2021.
- A. Engholm, I. Kristoffersson and A. Pernestal, "Impacts of large-scale driverless truck adoption on the freight transport system", Transportation Research Part A: Policy and Practice, vol. 154, pp. 227-254, 2021.
- X.Zhao et al., "Potential values of MaaS impacts in future scenarios", Journal of Urban Mobility, vol. 1, 2021

Conference

- L. Zhao et al., "Study of different steering feedback models influence during remote driving", In proceedings of 27th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks, St. Petesburg, Russia, August 18th, 2021.
- L. Rylander et al.,"Design of diagnosis service system for self-driving vehicles - Learnings from the driver's role today", in IEEE 2021 Global Reliability and Prognostics and Health Management (PHM-Nanjing)

Other

- A. Engholm, "Driverless trucks in the Swedish freight transport system : An analysis of future impacts on the transport system and the emerging innovation system" (Licentiate dissertation, KTH Royal Institute of Technology), 2021.
- T. Sjöström et al., ”Självkörande fullängsbuss på Tvärförbindelse Södertörn, final report of project Självkörande eldriven stombuss på Tvärförbindelse Södertörn – En skalbar fallstudie, 2021”
- J. Hultén et al., Att styra det nya, final report of project Smart mobilitet kräver smart governance, K2 Outreach 2021:1, 2021
- B.Vaddadi, X. Zhao, C. Andruetto, "Values of MaaS potential impacts based on representative scenarios" Technical report for the VMaRS project within KOMPIS - Kombinerad Mobilitet som Tjänst i Sverige, December 2020

Preprints

- C. Andruetto et al., "Transition from physical to online shopping alternatives due to the COVID-19 pandemic". CoRR, abs/2104.04061. arXiv: 2104.04061.

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KTH ROYAL INSTITUTE OF TECHNOLOGY

Thank you all for the great year!

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