Executive Summary

ITRL's unique integrated approach - in which we aim to integrate research topics, system levels and stakeholders - has during 2020 resulted in many insights and has sparked several new ideas. The ideas and topics include but are not limited to behavioral aspects, policy questions, and technical demos. In 2020 we had 36 projects active: 15 in Seamless Mobility of People (MOP), 6 in Urban Good Distribution (UGD), 14 in End-to-End Freight Transport (E2E), and 1 in the research platform. This is the highest number of active projects since the establishment of ITRL in 2014.

In 2020 15 new projects started (excluding an additional 3 projects that was approved during 2020 and starts in the first month of 2021). Furthermore, in the project ITRL collaborated with 92 different partners from public and private sector and academia. During 2019 and 2020 ITRL researchers published 29 scientific journal articles, 15 conference publications and 6 book chapters and preprints.

Within the **Seamless Inclusive Mobility of People (MOP)** program, the program with the largest research budget in the ITRL research portfolio, 15 projects were active over the course of 2020. Two projects have been finished under 2020, leaving 13 active projects to continue in 2021. 3 of these projects are considered large projects (determined by budget) and the remaining 10 projects qualify as medium and small. The project within the MOP program focus on identifying and clarifying uncertainties of 1) mobility systems, 2) new technologic innovations and 3) about human behaviour.

The **Urban Goods Distribution (UGD)** program encompasses 6 primarily small research projects, which might give the wrong impression that UGD is not one of the core research areas of ITRL. As the UGD research program is a new explicit focus for ITRL and some of the important / large projects in it are also relatively new (e.g., HITS, CREATE), relatively few concrete results are produced so far. The UGD program is expected to expand deliver more concrete results in 2021 and will be expanded to cover the research challenges that so far have weaker coverage.

In 2020 14 projects were conducted within the **End-to-End Freight Transport (E2E)** program. 3 of those have been finished under 2020, leaving 11 projects to continue in 2021. The E2E research program has a good balance between a small number of large projects (2), and a larger number of smaller projects (5). The projects can roughly be grouped in four categories: 1) fossil fuel dependence, 2) low transport efficiency and sub-optimal flows, 3) unsound market structures and 4) changing transport demand.

ITRL is a fertile environment for students. ITRL hosts 9 PhD and 8 PhD students participate in the affiliation network. The PhD students are active in all three research programs and being in different stages of their PhD. During 2020 5 PhD students passed their licentiate seminar/ half-time seminar. 10 MSc students conducted their MSc thesis project at ITRL. The courses organized with support of ITRL attracted in total 97 BSc-, MSc- and PhD-students. ITRL hosted two student project teams: Formula Student Team and Hyperloop.

1 Towards a transport system in a sustainable society

Transport is a central aspect of human life. However, whilst transport systems can contribute towards well-being and prosperity, they can also create negative impacts. In order 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 the negative impacts of freight transport and the distribution of goods are limited. This is the challenge that drives us.

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.

1.1 Our integrated approach

At ITRL – the Integrated Transport Research Lab - we believe in an integrated approach. Therefore, in order 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.

- **Integrated research topics** Our aim is to study a challenge or a concept from multiple perspectives, acknowledging that each perspective uses different approaches and methods and contributes with valuable insights. Our team of multidisciplinary researchers focusses on six main themes, those are 1) Mobility services, 2) Infrastructure, 3) Efficient transport, 4) Policy & business, 5) Connected transport and 6) Users & society.

- **Integrated system levels** In our research projects, we try to achieve three distinct but interconnected levels of research. These levels should not be considered static, but rather interactive and constantly evolving.

  The lowest point of the cone represents the demonstration level, at which time a demonstration, test, or real-life experiment is performed and data & knowledge are collected in the form of measurements, surveys or interviews.

  The knowledge gained at the demonstration level is then used at the simulation level to scale up our learnings; we take the results obtained at the demo level and try to simulate, improve, and project their various use cases.

Finally, at the system level, our results from the previous levels are synthesized and presented in the context of “real world” applications. At this point we can continue to test, refine, and learn from our observations, but in more practical, real world use-cases or new projects related to the previous learning.

- **Integrated stakeholders** Projects at ITRL are multi-stakeholder activities, where academia, industry (including SMEs), public bodies and users participate. By integrating people with different competences, education forms, and experiences, knowledge is transferred and further strengthened.

These strategies are executed across our research projects, research platforms, living-labs, and demonstrations. Our projects are in turn organised by thematic area. These areas, or research programs, cover a broad range of transport questions, from the mobility of people, to the transportation of goods and waste management.

Each program area, as a starting point, considers the greatest challenges facing the sector and poses questions which, if answered, can contribute greatly to creating more sustainable transport systems. It is through this process that research projects are designed. These research programs are 1) seamless mobility of people, 2) urban goods distribution and 3) end-to-end freight transport.

1.2 Seamless Inclusive Mobility of People – ITRL contributions during 2020

In the research program Mobility of People (MoP), we have during 2020 further developed our roadmap for how to build knowledge and contribute to understanding seamless, accessible, just, and inclusive personal mobility systems that are emission-free. To continue to build this knowledge, our research projects address uncertainties in the three challenge areas namely mobility services themselves, effects of new technologies, and changing people's behaviours and practices. These are the areas where more sustainable transport systems are preferred and used, see Figure 1.1. An overview of how projects active during 2020 targeted the challenges is shown in Figure 1.2.

This report on the results of the MOP research program, has been a collaborative work, where researchers have met in several workshops and worked on defining mutual concepts and frameworks. The following subsections present how the projects target the MoP challenges. The work is ongoing and research activities and project results presented here are work in progress. We will continue to develop our capabilities in 2021 through more research, collaborative activities and co-writing scientific journal publications.

Focus questions Seamless Mobility of People

1. How can innovative mobility solutions using different technologies and mobility services including different types of vehicles be combined to fulfil both urban and non-urban mobility needs?
2. How can challenges in different geographical areas be addressed using shared mobility (carpools, MaaS, hybrid taxis, routed buses etc.)? How can those mobility service systems be designed and evaluated for maximum sustainability impact?
3. How can new technologies (digitalisation, connectivity, automation and electrification) be used to design mobility systems for people? What is needed to scale up such systems?
4. Which sustainability effects come with these technologies? Which gains are unlocked by these technologies and where are those effective and implementable over time?
5. How can drivers and barriers to people's acceptance of new mobility solutions be understood? Which technological solutions and policies can contribute to acceptance and adaptation?
6. How will new mobility solutions affect behaviour and practices of travellers? Which policies and regulations are needed to support more sustainable travel choices?

Figure 1.1 Focus questions for the Seamless Mobility of People program.

		Challenge 1 - focus on systems		Challenge 2 - focus on technologies		Challenge 3 - focus on people	
		Uncertainties of mobility systems		Uncertainties of effects of new		Uncertainties of how to change people	
		How can innovative mobility solutions, including different technologies, be combined to fulfil urban and rural mobility needs?	How can challenges in different geographical areas be addressed using shared mobility (carpools, MaaS, hybrid taxis, routed buses etc.)? How can those mobility service systems be designend and evaluated for maximum sustainability impact?	How can new technologies (digitalisation, connectivity, automation and electrification) be used to design mobility systems for peope? What is needed to scale up such systems?	Which sustainability effects come with these technologies? Which gains are unlocked by these technologies and where are those effective and implementable over time?	How can drivers and barriers to people's acceptance of mobility solutions be understood? Which technological solutions and policies can contribute to acceptance and adaptation?	How will new mobility solutions affect behaviour and practices of travellers? Which policies and regulations are needed to support more sustainable travel choices?
Project	PL						
ABE Södertörn	Zhao	(X)	X		X		
CREATE	Zhao			X	X		
KOMPIS	Zhao	(X)	(X)			X	X
MERGEN	Gidofalvi			X	X		
MMiB	Pernestål			X	(X)		
MOBY	Gidofalvi	X	(X)	(X)	(X)		
REDO	Nybacka			X	X		
SAMS1	Hesselgren	(X)	X	(X)	(X)	(X)	(X)
SAMS2	Hesselgren	(X)	X	(X)	(X)	(X)	(X)
SEAMLESS	Zhao	X	X		(X)	(X)	(X)
SLL SDV 2	Almlöf	X	X	X	(X)		(X)
SmartGov	Pernestål						X
SocRob	Pernestål			X	(X)		
SUSTEV	Gidofalvi			X	X	X	X
VMaRS	Zhao					X	X

Figure 1.2 Mapping of MOP active projects and projected ended under 2020 to focus questions in the roadmap.

1.2.1 Uncertainties of Mobility Systems

During 2020 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. These frameworks will be further developed and applied in more assessments in future research projects.

Frameworks

A framework, including key performance indicators and data collection methods (surveys and interviews), has been developed in the research project **KOMPIS**. This framework can be used to assess if, and to what extent, Mobility as a Service (MaaS) systems contribute to environmental, economic and social sustainability. 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 + organizations that adopt MaaS), and societal level (city, municipality, region). At each level, the models of B2C (business-to-consumers), B2B-E (employees) and B2B-T (tenants) are considered. Moreover, at the societal level all the accumulated impacts are measured including environmental, economic and social dimensions of sustainability.

To provide reference values for the impacts of MaaS, the **VMaRS** project has applied future scenario analysis to assist decision makers to adjust and develop policies and regulations for sustainable MaaS. Diffusion of innovation theories and Swedish travel data were used to evaluate KPI's on emissions, energy consumption, and private car usage. The actual outcome is highly dependent on the level of MaaS available and the uptake. For example, reductions in CO_2 emissions are expected in the range 2.5% to 50%.

Assessments

SEAMLESS is a research project that includes several different deliverables and 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). By focusing on assessments, SEAMLESS will generate knowledge on how MaaS can, for example, change travel behaviour, improve accessibility, reduce emissions, increase energy efficiency and financially sustainable business opportunities, and generate knowledge that can inform decision-making within both public organisations and among service developers.

In the research project **SMSS** (Sustainable Mobility Services Södertälje) we designed, developed, implemented and evaluated a corporate mobility service system together with the project partners. When assessing impacts of the implemented service system, we found that there were impacts on user travel behaviour, but since the service system was not connected with public transport these were only limited. Furthermore, we found that several factors hindered upscaling and further development of the system. Moreover, the impacts on societal level were difficult to assess and therefore it was difficult for the municipality to acknowledge the service system's potential outside the limited company context. There were different barriers on individual, organisational, and societal levels, but these were also highly intertwined and to resolve them an integrated system approach is needed.

E-micro mobility

In the **MOBY** project (within EIT Urban Mobility research), we have analysed existing service providers' business models for shared micro-mobility (primarily electric kick-scooters) in Stockholm, Tel Aviv, Barcelona and Munich. It was observed that the providers operate under three distinctive different city policy regimes (liberal, opportunistic-exploitive, and protective-conservative) with respect to the coexistence with public transport. Furthermore, it was found that these regimes affect the providers' business models and strategies but were all driven by the venture capital market. Many of the scooter providers still experiment with different kinds of pricing models, number of scooters, scooter designs, and collaborations with various types of actors in order to expand their value propositions and service offers. Services such as teleoperations and data-driven intelligence that provide improved vehicle utilization and unit economics via supply-demand balancing and dynamic pricing at the operational level are on the rise and are expected to disrupt the market.

Simulation tools

CREATE was a one-year pre-study project that focused on requirement analysis, state-of-the-art and feasibility analysis for building a collaborative platform for transport system simulations. The aim of such a platform is to support system level analysis by creating technical and collaborative mechanisms for co-creation of data, models and simulation scenarios, as well as to identify mechanisms to keep these updated, relevant and (re-)usable. Furthermore, the objectives were also to establish a consortium with industrial and academic partners. The results from the pre-study CREATE are currently used as input for collaborative development of a project proposal (CO-CREATE) which is expected to: 1) Set up scenarios for new mobility alternatives and identify KPIs to measure system effects from such alternatives. 2) Define open modelling and simulation toolchains. 3) Develop modular simulation guidelines for various scenarios. 4) Establish an open collaboration arena for private, public and academic actors to collaborate around common scenarios and common assets.

1.2.2 Uncertainties of effects of new technologies

During 2020 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. Understanding uncertainties of the effects that new technologies have on different levels is one of the challenge areas in the research program. 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, primarily on an individual passenger level but future work will also investigate effects on organisational and policy levels. Moreover, we have researched effects of electrification of private cars and public transport buses on policy level and we have researched effects of autonomous and shared transport systems on policy level.

Effects of 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** 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, in order to acquire knowledge on the requirements on remote operation of autonomous vehicles. So far, we have 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. 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 to understand feasibility and impacts in transport systems' transitions towards autonomous vehicles and remote driving.

Effects of artificial intelligence and robots

Artificial intelligence offers new opportunities for 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 with self-driving buses in

Barkarby (for more details see section 1.2.3), we learned that bus passengers associate bus drivers with authority and some level of safety. In the research project **Social Robots accelerating the transition to sustainable transport**, 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 that will be performed during the coming years.

Effects of electrification of private cars and public transport buses

To combat negative effects of high up-front cost and 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 and shared mobility services. The project has developed a novel methodology for a travel adaptation survey to find travel-contextual adaptation patterns which have been applied in population-wide simulations to investigate the system-level impacts of the incentives that are discussed with stakeholders.

The **Tvärförbindelse Södertörn** project has investigated the potential for a self-driving bus service on the proposed highway connecting the southern parts of Stockholm County. Results of the projects are not finalised yet, but we have seen that there are economic advantages by integrating the bus traffic with other transport modes in the same system, e.g. that trucks can utilize the same digital infrastructure. Furthermore, the preliminary results show that the introduction of a bus service needs to integrate different actors, such as OEMs, operators, technology providers and authorities, and that some of these roles need to change.

Effects of autonomous and shared transport systems

The results from the **Public Transport and Self-driving technology - Barriers and Opportunities** project show that an autonomous public transport system provide large potential for economic savings. That the prospects of increasing ridership are smaller, except for in rural conditions, where the public transport service today is limited (e.g. one bus every two hours). The main impacts for the increased accessibility gains, due to the introduction of autonomous technology, were seen for leisure travel, and not for daily commutes, which questioned the “self-driving commute” as the major impact of autonomous technology. We also see a high risk for increased car usage in inner-city areas.

The research project **Smart Mobility Requires Smart Governance** investigated how the future transport system should be governed to achieve societal goals, such as equal access and sustainability. Smart Mobility refers to several trends, including digitalisation, autonomous driving and shared mobility, and it was explored how current and new governance tools could be used to steer towards societal goals. Main take-aways include: the need to clarify the societal goals, the need of collaboration between actors, that citizens are more customers, that many existing governance tools are still effective, and that smart mobility provides new and complementary tools (e.g. geofencing). The project also delivered a check list for authorities to work with governance of smart mobility.

1.2.3 Uncertainties how to change people

In 2020, we have conducted several research projects to understand how to shift people's behaviours and practices in sustainable directions. We have researched how a co-work hub located in Tullinge south of Stockholm influenced and changed transport behaviour and commuting trips. Furthermore, we have researched how the COVID-19 pandemic changed transport patterns in Sweden and Italy, and we have researched how the introduction of driverless buses changed transport behaviours and user acceptance of autonomous vehicles in Barkarby north of Stockholm.

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 the project partners, e.g. 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. We conducted interviews at various stages of the two-year operation and to complement the interviews we collected data from 29 travel diaries to further understand how the participants used the co-working space. We concluded that this co-work hub could lead to energy savings if there is a reduction of total travel time and distances together with an increased use of the co-working space.

Changes when COVID-19 pandemic came to Europe

During 2020, we carried out two different studies to investigate how individuals have **changed their activity-travel patterns** during the first wave of COVID-19 pandemic period (March - May 2020), and to understand how shopping activities were affected in two counterparts in Europe, Italy and Sweden. Based on 781 responses from an online survey, we found that the possibilities to change behaviour are different in different groups. External restrictions (e.g. closure of working places) and household composition (e.g. presence of elderly or kids) were found to be factors driving reductions in daily trips. However, the results did not show a strong correlation between the countries' restriction policies and respondents' likelihood to adopt new and online-based behaviours after the restriction period. The acceptance and long-term adoption of online alternatives were instead correlated with respondents' personalities and socio-demographics, which highlights the importance of promoting alternatives as a part of longer-term behavioural and lifestyle changes.

By using the same survey, but filtering out the 530 responses from Italy and Sweden, we analysed the **transition from physical to online shopping** activities. The results showed that there has been a larger increase in online shopping in Italy, and a larger decrease in physical shopping trips in Italy compared to Sweden. The main takeaways are i) in Italy the respondents tended to buy more work related items: respondents in Italy were less ready for remote working; ii) for grocery shopping, fewer people stopped (both online and physical store shopping) when compared with non-grocery shopping: people have different views of what is essential; iii) the density of population has significant influence on online shopping: people living in denser areas are more engaged in online shopping activities; iv) households without children have stopped going to the stores more compared to their counterparts.

Changes when autonomous buses were introduced

In the project **Modern Mobility in Barkarby**, we have explored the introduction of driverless vehicles in public transport from four perspectives: User acceptance and attitude, adoption over time, willingness to pay for automated bus services, and optimal routing.

We have learnt that an onboard steward significantly contributed to making people feel safe on board the autonomous bus. Autonomous bus services are expected to attract public transport users and younger people, and we learnt that income level and gender had no significant impact on the adoption of the service. However, income level had an influence on the willingness to pay for the service. During the first phase of operation, good information had a large impact on the adoption of the service, while later in the project we found that poor service level could demotivate users. We also found that, by optimising the complex network could double the numbers of users attracted to the service, compared to traditional public transport in the area.

1.3 Urban Goods Distribution – ITRL contributions during 2020

Challenges and focus questions identified for the Urban Goods Delivery (UGD) program are shown in Figure 1.3. A mapping of how the UGD projects active during 2020 targets the focus questions is shown in Figure 1.4.

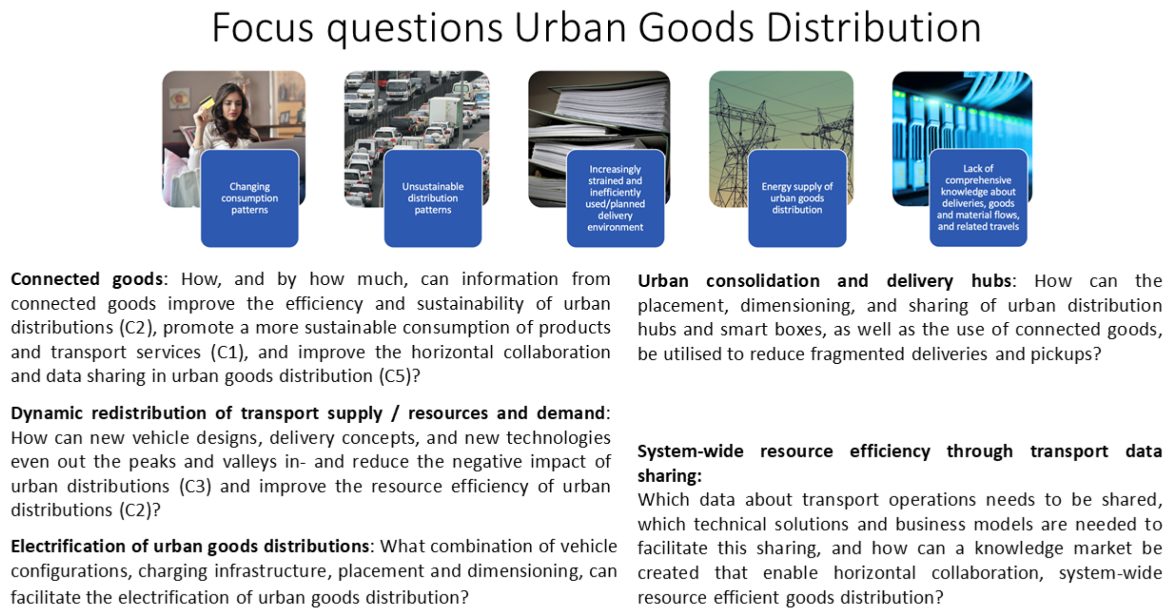


Figure 1.3 Focus questions for the Urban Goods Distribution program.

		Challenge 1 - Changing consumption patterns	Challenge 2 - Unsustainable distribution patterns	Challenge 3 - Increasingly strained and inefficiently used/planned delivery environment	Challenge 4 - Energy supply of urban goods distribution	Challenge 5 - Lack of comprehensive knowledge about deliveries, goods and material flows, and related travels
		E-commerce, circular economy; Delivery costs are often invisible to customers, and focus on customer convenience	Fragmented deliveries/pick-ups, less resource efficient vehicles, consolidations challenging due to business model	Dense city centers and urban sprawl creates congestions	Placement and dimensioning of charging stations; electrification of logistics	Lack of business models and technologies for sharing of business sensitive and private data
		How can "connected goods" promote a more sustainable consumption of products and transport services?	How can new efficient transport concepts improve the resource efficiency of urban distributions? How to allocate and share between different actors the consolidation and delivery hubs in order to reduce fragmented deliveries/ pickups?	How can efficient transport concepts even out the peaks and valleys in- and reduce the negative impact of urban distributions?	Which vehicle configurations are most efficient for urban distributions? How to organize (placement, dimensioning, logistics) the energy supply for electrified urban distributions?	How can private and business sensitive data base shared (technologies, standards, business models) to enable horizontal collaboration in and holistic optimization of the transport system?
Project	PL					
DS BM	Darwish	(X)	((X))			X
ECCENTRIC	Gidofalvi			X		
HITS2024	Pernestål	(X)	X	X	(X)	(X)
ICL 2	Gidofalvi	((X))	X	X	((X))	((X))
PREDICT	Gidofalvi	((X))	(X)			
ZEUS	Gidofalvi			X	((X))	

Figure 1.4 Mapping of UGD active projects and projected ended under 2020 to focus questions in the roadmap.

1.3.1 Program leader reflections

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. During 2020 in the UGD program has focused on further development of the road map of the program, see Figure 1.3. For the research program we have identified the following high level research topics:

- RT1: Connected goods
- RT2: Dynamic redistribution of transport supply / resources and demand
- RT3: Electrification of urban goods distributions
- RT4: Urban consolidation and delivery hubs
- RT5: Holistic resource efficiency through transport data sharing

In order to map the fit and coverage between the ongoing UGD projects and the its roadmap, individual researchers in the UGD projects have presented the ongoing and future research and the obtained research results and identified clusters and links in and between these and the UGD challenges and research themes. The subsections below are summaries of the results of this work.

As a reflection on the results of this work, one should note that UGD is a very important area of research given the fact that more than 50% of transport costs and the majority of inefficiencies are in last mile distribution. However, as the UGD research program is relatively new as an explicit focus for ITRL and some of the important / large projects in the area are also relatively new (e.g., HITS, CREATE), relatively few concrete results are produced so far. The UGD program is expected to deliver more concrete results in 2021 and will be expanded to cover the research challenges that so far have weaker coverage.

1.3.2 C1: Increasing and changing consumption patterns

As identified in the road map these patterns arise primarily due to trends in e-commerce, circular economy, integrated "invisible" delivery costs, larger focus on customer focused transport- then resource efficiency. The road map has also identified "connected goods" as a research topic / solution that among others has to potential to account for detailed (e.g., vehicle-delivery-route level) resource utilizations and *factual*- as opposed to standard costs at a package level allowing for identifying opportunities for improvements and promoting more sustainable consumption patterns. The InterCityLog2, HITS, and PREDICT projects mainly tackle the challenge, but shifting focus to resource efficiency by utilizing concepts like flow consolidation, modular multi-purpose vehicles, urban hubs / terminals, and connected goods. As concrete results, the **InterCityLog2** project developed a formal model for optimizing vehicles routes between a city terminal and customer locations for the distribution of goods and collection of recycling materials on the same vehicles routes. Current work is looking at the computation performance and the optimality of the solution of a heuristic routing method w.r.t. an exact solution and how these are affected by the distribution of transport demand. Similarly, in the **HITS** project an operators-user centric optimization model is formulated for combining passenger and freight flows using a fleet of multi-purpose modular vehicles. For both transport flow consolidation concepts the heuristic methods find the same optimal vehicles routes as the exact methods but beat the exact methods by orders of magnitude in running time. Finally, in the **PREDICT** project artificial intelligence methods are used to proactively reposition a fleet of varying-sized shareable vehicles according to a predicted shared / consolidated transport demand. The methods developed simultaneously aim to utilize the vehicles fleet (reduce the number of idling vehicles by up to 11%) while increasing the service quality (reduce customer delay by up to 68%) through intelligently matching the transport supply against the predicted demand. The methods can manage the minute-by-minute repositioning control of 1000s of vehicles and requests in real time and in a sense automatically find the balance between transport and resource efficiency for varying ratios of supply and demand.

1.3.3 C2: Changing and unsustainable/inefficient distribution patterns

Many of the same trends that cause the increase of consumption patterns also introduce fragmented deliveries and pickups, which are serviced by an increasing number of actors that use smaller and less resource effective vehicles to deliver. The methods developed in the **InterCityLog2**, **HITS**, and **PREDICT** projects contribute to a more dynamic and optimal redistribution of transport supply that make the distribution patterns more efficient. The same projects also use consolidation and urban hub concepts for improvements. In particular, where to place, how to dimension, and how to share between different actors the consolidation and urban hubs in order to reduce fragmented deliveries / pickups are investigated and tested in pilots in the **InterCityLog2** and **HITS** projects. In the **HITS** project the role and placement of hubs for goods and people transports as well as “service” hubs for multi-purpose modular vehicles is considered. In the **PREDICT** project consolidation in last mile transports is handled in a more demand-driven, predictive fashion and instead of hubs consolidations happens in the cargo space of dynamically routed mixed-sized vehicle fleets. In the **Drive Sweden Business Model Lab**, in an “incubator and learning space settings,” partners investigate some of these consolidation solutions within the area of logistics from a business perspective. Finally, a the **CREATE** pre-study has researchers have successfully integrated UGD into a larger project that aims to create comprehensive open data sets and define and demonstrate the viability of an open modelling and simulation tool-chain to support the holistic design and evaluation of transport systems.

1.3.4 C3: Increasingly strained and constrained and inefficiently used and planned delivery environment

Trying to cater for the increasing and changing consumption patterns and transport demand by adhering to old regulations and logistics requirements within the physical limitations of growing cities creates peaks and valleys in transport demand that ultimately lead to an unattractive and unsustainable environment for citizens as well as deliveries. Based on the previous ITRL led studies of the off-peak project delivery concept, the **ECCENTRIC** and **ZEUS** projects further investigate what are the benefit and limitations of off-peak delivery schemes. The projects also study how the peaks can be shifted in space and time by servicing some of the transport demand with off-peak deliveries via PHEV distribution trucks that switch to silent, electric operations in specific digitally geofenced areas (a.k.a., smart urban zones) in the city. The **ECCENTRIC** project’s evaluations have shown 1) a reduction of 30% in delivery time compared to the average daytime equivalents, 2) a reduction of 44% in carbon emissions due to electric operations compared to reference day-time deliveries operated with trucks running of renewable HVO, and 3) a driving noise emission reduction due to electric operations of 5 to 10 dB depending on the background noise. More importantly, **ECCENTRIC** laid the foundations for methods that from a combination of noise sensors mounted in the build environment and on the moving vehicles and the positions of the vehicles can accurately model both the driving noise and delivery noise of the operations that is separated from the background noise of the city. The **ZEUS** project has built on these modelling results and devised a comprehensive framework of models and evaluations tools to assess and make decisions about different zero emissions silent urban delivery scenarios the are defined by vehicle configurations, delivery locations, delivery times,). The framework with its models and tools is able to evaluate the how actual measured and modelled hypothetical driving and delivery operations' impact transport efficiency, carbon emissions, and the noise that citizens observe. Finally, the models can calculate relevant KPI for stakeholders and together with relevant business model aspects can evaluate alternative scenarios via a multi-actor multi-criteria analysis methodology. One concrete output of the **ZEUS** project is guidelines for the cities for the evaluating the conditions for suitable night-time deliveries. A significant **impact** of the **ZEUS** project is that the participants from the City of Stockholm are considering new guidelines for night-time deliveries.

1.3.5 C4: Energy supply of urban goods distribution

While most of the projects in the UGD project portfolio use electric vehicles, the need of solving the energy and power supply for the vehicles have been indirectly addressed, primarily from the energy demand side. In particular, the vehicles routing optimization methods in the **InterCityLog2** and **HITS** projects take into consideration the energy demand as a range limitation of electric vehicles. Notably, the **HITS** project that also utilizes off-peak electric urban delivery concepts aims to extend the **ECCENTRIC** and **ZEUS** projects by studying the provision of electric supply for these deliveries. Electric supply aspects of urban transports are also studied from a business perspective in the **Drive Sweden Business Model Lab** project. Realizing the knowledge gap in this challenge, the UGD program is actively being developed with projects that optimally incorporate charging times and range limits into the distribution operations as well as projects that investigate how to plan charging infrastructures for UGD considering the logistic operations.

1.3.6 C5: Lack comprehensive knowledge about deliveries, goods and material flows, and related travels

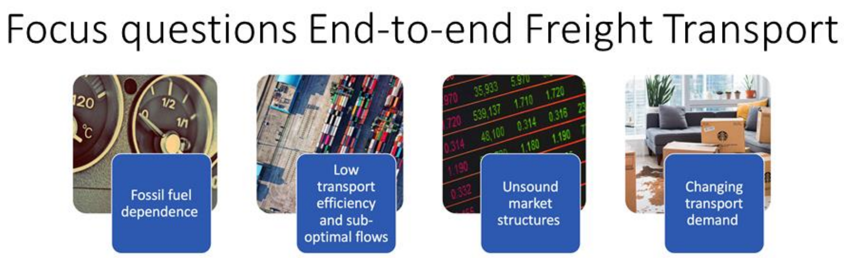
Transport data is a prerequisite for the evaluation and improvement of current transport operations and for the estimation, modelling, and simulation of future transport demands and scenarios. Yet transport data is fragmented in silos / systems of actors and is rarely shared. One notable exception is the **InterCityLog2** project where two transport suppliers / LSPs (Bring and Rang Sells) collaborate to consolidate their complimentary transport flows. While the project shows a good example of data sharing, the experiences in the project also show that while IT system integration is possible technologically it is costly and pilots of concepts do not warrant the high costs. Project experiences also show a difference in degree of digitalization of parts of the logistics of different transport flows, which is mainly due to the difference in processes and measurement and sensing technologies. In particular, in contrast to package/item-based transports, recycling materials are gathered in different kinds of containers (plastic sacks, bins and carts of varying size), volumes and weights are difficult to sense accurately on location and is often done at the terminal. The difficulty in digitalization in some flows naturally pose challenges when one has to reconstruct the operations from multiple partial and often noisy data sources (GPS tracks, delivery and pickup logs) to assess or improve the efficiency of logistics operations. The actors' willingness to share transport data in the InterCityLog2 project is more of an exception than the rule in the transport sector. To improve this, the **Drive Sweden Business Model Lab** project investigates business models that can promote data sharing. A particular challenge is to demonstrate a clear value proposition for data sharing between actors that are competing for the business of the same set of transport buyers. The **HITS** and **CREATE** projects aim to contribute to the lack of data challenge by creating comprehensive transport open data sets and demonstrating the value of data sharing.

1.4 End-to-end Freight Transport – ITRL contributions during 2020

1.4.1 Program leader reflections

In the End-to-end freight transport program (E2E) we have continued to work on the program roadmap. The vision is a fossil-free, 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. We have specified a set of focus questions associated with each of the challenges, see Figure 1.5. The questions not only exemplify the scope, but are also a support in the selection of projects for the program. An overview of how the E2E projects target the challenges and focus questions is shown in Figure 1.6.

In the following subsections present how different projects are related to the focus questions. These constitute steps towards our vision and much remains to be done. We will continue our journey in 2021 and beyond.



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?

Figure 1.5 Focus questions for the End-to-End Freight Transport program.

		Challenge 1 - Fossil Fuel Dependence	Challenge 2 - Low transport efficiency and sub-optimal flows	Challenge 3 - Unsound market structure		Challenge 4 - Changing transport demand	
		Up-scaled and optimal combination of biofuels and electrification	Right size of vehicles, or the right combination of a vehicle fleet, in order to improve transport efficiency and modal shifts	Reshaping logistic flow to make them sustainable by, for example, enabling horizontal optimization utilizing digitalization, connectivity, data sharing, and automation	Utilizing digital technologies to go beyond reducing CO2 emissions; having an impact on such issues as enabling fair trade, gender equality etc. in logistics	Requirements for the large-scale adoption of driverless vehicles that also meet changing transportation demands	System level impacts of circular economy principles and glocal logistics on long distance freight transport
Acronym	PL						
AVTCT 2	Mårtensson		(X)	(X)			
Campus 2030	Qureshi		(X)	X		(X)	
DigiGoods	Qureshi			X	(X)		
EL Construct1	Qureshi	X	(X)				
EL Construct2	Qureshi	X	X		X		
EL South Sthlm	Qureshi	X	(X)	X			
FoI platform	Gidofalvi	X					
IMPACT_AED	Pernestål	X		(X)		X	
LOLA	Gidofalvi	X					
RENO	Gidofalvi	X					
ResilientE2E	Qureshi	(X)	(X)	(X)	(X)	(X)	(X)
SL SDD	Pernestål	X				X	
TIFF	Pernestål					X	
TRACER	Gidofalvi	X					

Figure 1.6 Mapping of E2E active projects and projected ended under 2020 to focus questions in the roadmap.

1.4.2 Up-scaled and optimal combination of biofuels and electrification

Fossil fuel dependence in transport is one of the major contributors to the CO2 emissions. The projects in the E2E program can be divided into different categories depending on the objectives and assumptions. Answers to questions such as: how should the electric infrastructure be developed? Can we meet the 2030 target of CO2 reductions? etc, are answered by the projects with varying level of granularity. An overview of the results and findings are as follows.

Simulation and analysis platforms

At ITRL we aim to work on different abstraction levels. Software based analysis is essential for cases where physical implementation is not feasible. In the **System level impacts of driverless vehicles** project we have developed a system dynamics model of Swedish long distance freight. The simulation model includes electric and automated vehicles and can be used for evaluating transport demand, fleet size and composition, energy use, and CO2 emissions. In addition a tool for evaluating different kind of optimisation of electric infrastructure is developed in the **RENO** project.

Electric infrastructure

The projects **TRACER**, **COCAINE (LOLA)** and **RENO** address the optimisation of electrical infrastructure. Both TRACER and COCAINE are built on the results from RENO. In particular, the placement of charging infrastructure and selection of the roads to have the maximum as well as optimized utilization of electricity is considered. The optimization is achieved by considering several tuneable parameters, including movement patterns of the vehicles. Results show that by using the optimization algorithms we can electrify 3 times as much tonne-km compared to the intuitive solution of electrifying the main roads between Stockholm and Gothenburg to the same cost (5.26 Gtonne-km of goods transportation compared to 1.61 Gtonne-km, by considering a total of 300km of electric roads).

Electrification of “the ends”

Success in electrification also requires thinking beyond roads, i.e. considering the end points where the vehicles are loading or unloading goods. One examples is construction sites. **Charging stations for construction sites** is an example of project covering this aspect. The main scope is the vehicles as well as mobile machines within a construction site. The trucks within a construction site are special case which are used for both within and outside a construction environment. In the pre-study project we have found several areas of research including, but not limited to, energy optimisation to ensure smooth supply or power as well as aspects like digitalization and business models. In the phase 2 of the project **Med utsikt från förarplatsen – hur fungerar elfordon i systemet?** (Electrified construction sites from the electric truck driver's point of view) ITRL will be focusing on digitalization needs and business models for a fully electric construction site. The targeted area of the project is Norra Djurgården.

End-to-end electrification

In November 2020 a new project started related to the electrification of transport in the south of Stockholm. This project covers hub-to-hub transportation. The main work will be carried out from 2021.

Predictions for the achievability of climate goals

In the project **System level impacts of driverless vehicles** we have explored the impacts of electrification and automation of freight transport on the potential to reach the national goals of reducing CO2 emissions from freight transport in 2030 (compared to 2010). The simulations show that the even with the new technology, it is challenging to reach the goals. Main reasons are that the new technology reduces transport costs and induces new demand, and that there is a delay in the uptake of the cleaner technology due to the fleet turnover time. Therefore, measures to make transport more efficient (e.g. increasing fill rates) are crucial to reach the national goals.

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

The question related to the size and combination of vehicle fleet is addressed by several projects either directly or indirectly.

In the project **Charging stations for construction sites** and its continuation **Med utsikt från förarplatsen – hur fungerar elfordon i systemet?** (Electrified construction sites from the electric truck driver's point of view) ITRL is focusing on digitalization and connectivity. While the phase 2 has just started, in phase 1 we have identified several areas (such as optimization of electricity and digitalization of contracts between different stakeholders) which are necessary to maximize the benefits of electrification of construction sites. The project will also help us in evaluating the size of vehicles suitable for loading and unloading of construction material.

AVTCT (Phase 1 & 2) indirectly addresses the question under consideration. It aims to understand the role and responsibilities of different kinds of traffic control towers for automated road vehicles (AVTCTs). The platform can later be utilized to simulate and visualize different vehicle flows or combinations of vehicles in fleets. In 2020 we have continued to develop the platform supporting the supervision, control and management of AV’s. In the recent developments we have started systematic architecture development, and also included the Voysys software.

1.4.4 Reshaping logistic flow to make them sustainable by, for example, enabling horizontal optimization utilizing digitalization, connectivity, data sharing, and automation

DigiGoods and **Campus 2030** are two projects with sole focus on digitalization and connectivity. DigiGoods targeted goods transport, horizontal & vertical integration and investigating whether one, by using state of the art sensors, can get hold of additional information that can improve overall visibility in the supply chain. In DigiGoods we have studied processes from different supply chains and identified the factors which limit the possibility of the optimisation of the supply chains. The identified factors include, but are not limited to, missing information, which requires new sensors and leads to integration issues with existing IT infrastructure. In addition, an architecture comprising of a data model, functional interfaces and sequence of operations has been developed in the project. One result inferred from the project is that many improvements are required on vertical chains, which is one of the factors limiting the realization of horizontal integration.

In Campus 2030 the aim is to develop a live platform in the form of a digital twin of the KTH campus. The digital twin will open a wide range of possibilities such as analysis to improve vehicle operations from data from the road infrastructure and vice versa.

1.4.5 Utilizing digital technologies to go beyond reducing CO2 emissions; having an impact on such issues as enabling fair trade, gender equality etc. in logistics

In **Charging stations for construction sites** a great emphasis is being placed on improving the design and services to attract more female workers in an traditionally male dominated industry.

In the newly started project **Resilient and sustainable good transport systems in an uncertain future (Resilient E2E)** we will be looking at sustainability aspects beyond CO2 emissions. Project results are expected during 2021.

1.4.6 Requirements for the large-scale adoption of driverless vehicles that also meet changing transportation demands

Driverless vehicles can be one way to improve transport efficiency. However, a challenge is to ensure that driverless vehicles have at least as good uptime as a human driven vehicles, and poor uptime is one of the factors that can hinder large-scale adoption of driverless vehicles. The **TiFF (Uptime of driverless vehicles)** targets this aspect. So far, we have the following results.

- A map of roles and information flows when trouble shooting
- An analysis on how design methods can be used
- Algorithms for risk based decision making

Another factor which can affect the adoption of driverless vehicles is the total cost of ownership. In the project **System level impacts of driver-less vehicles** ITRL researchers have found that the total cost of ownership can be reduced between 15-35% when using driverless trucks. Thereby motivating the usage or driverless vehicles. On the other hand it was found that driverless vehicles can lead to an increase of 22% of on-road and 5% of hub-to-hub (H2H) transport, caused by a shift from rail and sea freight transport.

The above mentioned projects targets general aspects of driver-less vehicles. In future projects the work can be extended by increasing focus on aspects specific to transportation demands.

1.4.7 Special note on the Resilient E2E project

The **Resilient E2E** project addresses many of the questions in the program. The project started in Q4 2020. It is a pre-study with the vision of a transport system which is both sustainable and resilient to future crises. Results are expected by mid of 2021. These will include but not limited to the usage of methods and tools for companies and government to make informed decisions and an overview of events during Covid-19 pandemic, trends & patterns as well as underlying mental models which are required to change for the envisioned future.

1.5 Key Performance indicators - KPIs

In 2020 ITRL reached an "all time high" in number of active projects. During the year ITRL had 36 active projects (whereof 34 have external funding) that was led by ITRL or where ITRL contributes significantly. The increase in this number is mainly the result of the increase in the number of small projects (<1000 kSEK KTH funding), implying that the overall size of the research budget has remained largely unchanged since 2019. Various projects for the coming years have already been secured and we remain initiating new projects.

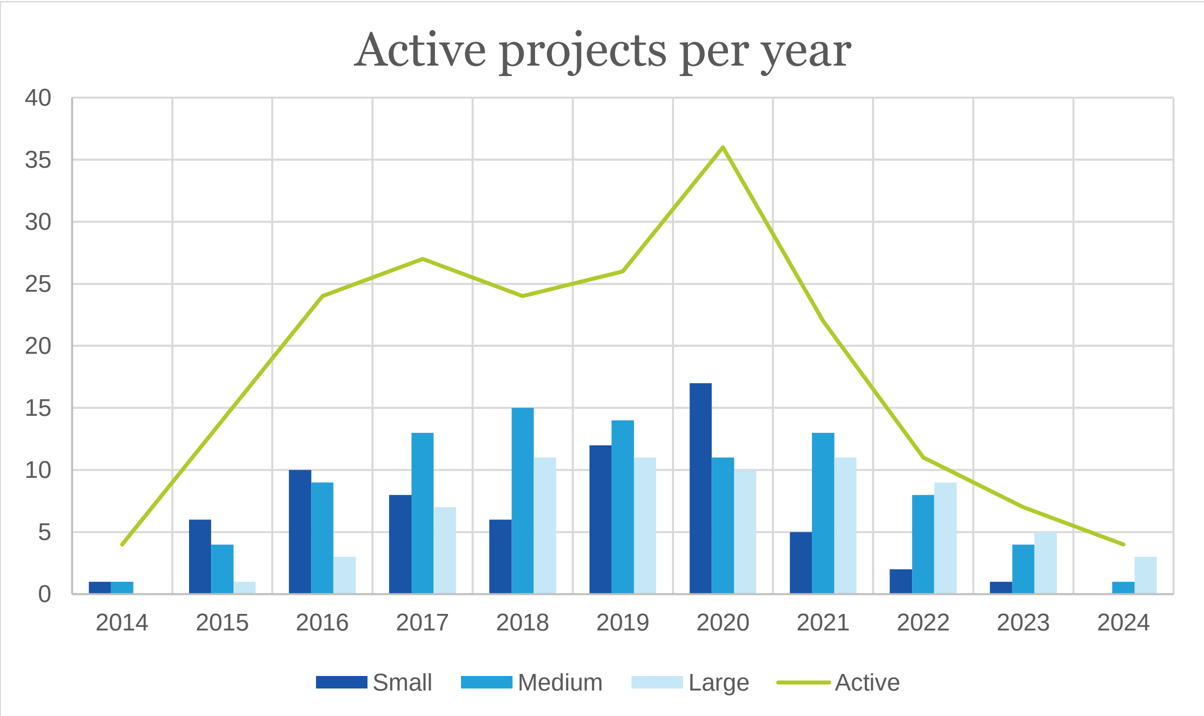


Figure 1.7 Active projects per year, grouped by size (*small*: KTH budget < 1000 kSEK, *medium*: 1000 kSEK < KTH budget < 3000 kSEK, *large*: KTH budget > 3000 kSEK) and the accumulated number.

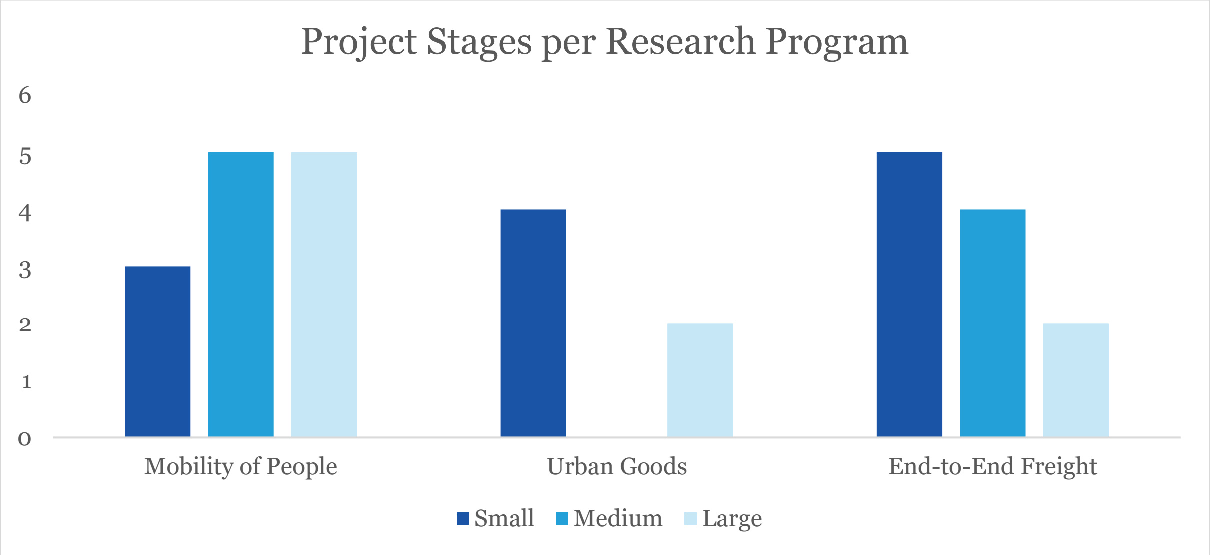


Figure 1.8 Active projects, grouped by size and research program, data taken on 31 december 2020.

92 different organisations (academia, public sector and private sector) are engaged in the 36 ITRL projects, see Figure 1.9.

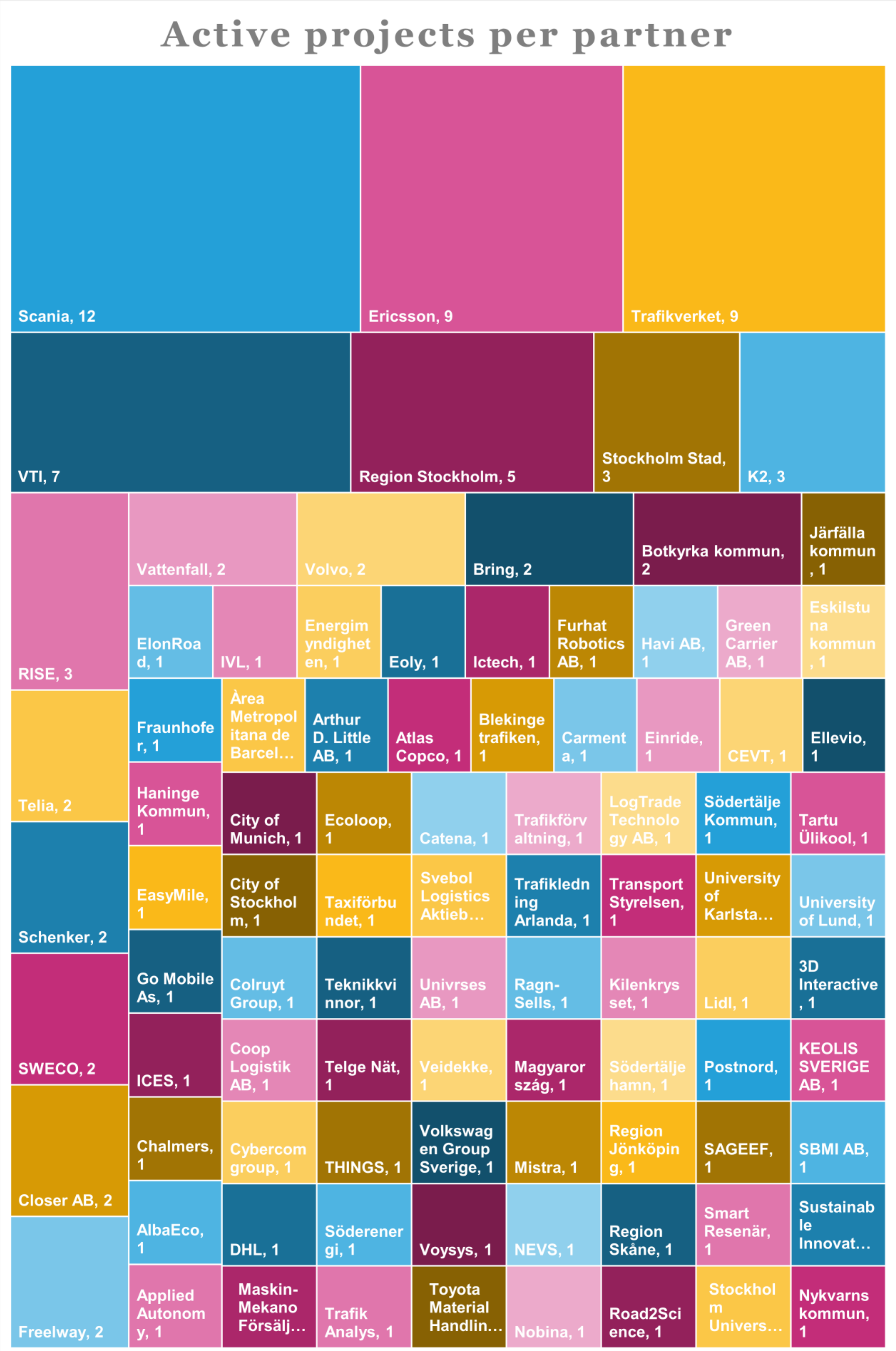


Figure 1.9 Number of active projects in relation to ITRL partners, data taken on 31 december 2020.

2 Scientific publications 2019-2020

During 2019 and 2020 ITRL researchers published (at least[1]) 29 journal papers, 15 conference papers and 6 other publications (including book chapters and reports), see Figure 2.1. For a full list of publications (including links) see Appendix A.

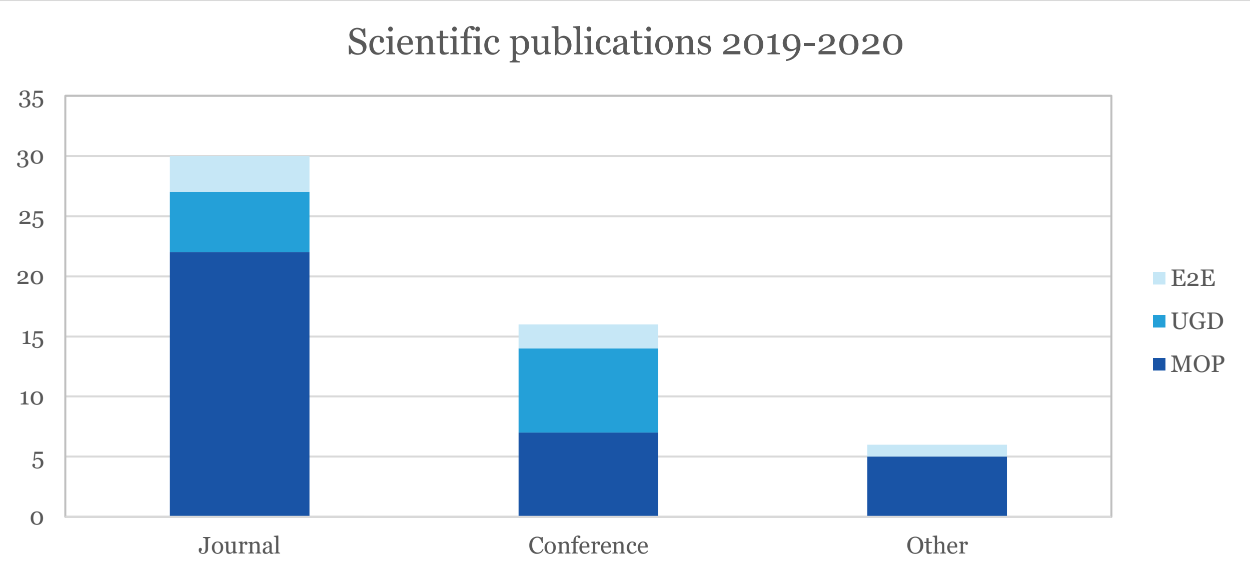


Figure 2.1 Number of scientific publications of ITRL research, divided over scientific journal publications, conference proceedings and other (such as book chapters or preprints). (MOP = Seamless Mobility of People, UGD = Urban Goods Distribution, E2E = End-to-end Freight Transport)

Under 2019-2020, ITRL has published three papers in each of the following journals – resulting in these journals being the most popular for ITRL research:

- ***Sustainability*** is an international, cross-disciplinary, open access and peer-reviewed journal for studies related to sustainability and sustainable development. The journal provides a platform for publishing experimental and theoretical findings from natural sciences, social sciences and humanities, promoting scientific predictions and impact assessment of global change and development. (source: SJR)

- ***Transport Research Procedia*** is an open access journal publishing full sets of conference proceedings, in order to assure fast and word-wide dissemination of knowledge. The journal is non peer-reviewed, leaving the responsibility of peer-review to conference organisers. The journal accepts papers focussing on any social science are of transportation research. (source: SJR)

- ***Transportation Research Part A: Policy and Practice*** is an international, peer-reviewed journal intended for publishing of papers with general interest in all passenger and freight transportation modes. The journal places equal emphasis on the problem of industrialized and non-industrialized regions. *Part A* is complemented by *Part B – F* (where ITRL research has also been published in), the complete set forming a cohesive and comprehensive reference of current research in transportation science. (source: SJR)

[1] Tracking all papers from ITRL researchers is challenging, due missing tags in data bases and delays in the publication process. The publications listed here include publications listed in DiVA (with ITRL as affiliation or funding organisation) and/or reported to us.

3 Activities

3.1 Breakfast seminars

During 2020 ITRL held 8 Breakfast seminars (webinars), see Table 3.1

Title	Speakers	Date	#registrations	#attendees	#online rewatch	Research program
When Walking Becomes Wandering:Enriching Automated Travel Diaries Using Biometric Information	Robin Palmberg (ITRL) and Emilia Schwertner (KTH)	18/02/2020	30	24	102	MOP
Sustainable Urban Innovation: The Promise and Peril of Laboratories, Experiments, and Testbeds	Andrew Karvonen (KTH)	24/03/2020	51	41	506	MOP
Will public transport be relevant in a self-driving future?	Erik Almlöf (ITRL/Stockholm Public Transport Authority)	21/04/2020	102	82	55	MOP
How can gaming technology be used to better understand, communicate and implement future transportation?	Christer Lindström (CEO 4Dialog and co-founder of the International Institute of Sustainable Transportation)	19/05/2020	42	28	118	E2E
Mobility Ecosystem Sprawl: Innovating for Decarbonization	Liridona Sopjani (KTH)	09/06/2020	44	27	186	MOP
An overview of transport system resilience	Erik Jenelius (KTH)	20/10/2020	78	75	86	MOP, UGD, E2E
Key barriers in MaaS development and implementation: Lessons learned from testing Corporate MaaS (CMaaS)	Mia Xiaoyun Zhao (ITRL) & Mia Hesselgren (KTH)	17/11/2020	38	30	41	MOP
How can we understand electric roads – five questions and (probably more than) five answers	Karin Ebbinghaus (Elonroad), Magnus Höglund (Scania), Maria Bratt Börjesson (VTI, Linköping Universitet), Győző Gidofalvi (ITRL, KTH), Mats Engwall (KTH), Björn Hasselgren (Trafikverket)	15/12/2020	126	98	90	MOP, UGD, E2E

Table 3.1 Overview of breakfast seminar/webinar attendance. Recordings can be rewatched on Youtube (#views) and/or Facebook (#displays). Data on youtube video viewing taken on 19 january 2021.

3.2 Communication

3.2.1 Media attention

As 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.

- **Podcast Stadsutvecklerna** How do traffic issues relate to Urban Development? How do traffic and mobility affect people's living environment in a newly built district? These are some of the questions that are addressed in this episode of the podcast Stadsutvecklerna, featuring ITRLs director Anna Pernestål. The episode also features Kristoffer Tamsons, Regional Minister for Transport in Stockholm and David Mothander, Head of Public Policy for Nordics and Delivery Services at Bolt.

  Stadsutvecklarna is a podcast about the development of Stockholm and the capital's newest district, Värtahamnen. Program leader of the podcast is Kristina Alvendal, who gathers knowledgeable and future-looking guests to talk about urban development from different perspectives.

- **KTH Interview** In 2020 ITRL has started a new project about how social robots can accelerate the transition to sustainable transport. KTH has interviewed one of the co-PI's in this project, Gabriel Skantze, about the idea behind the project and the challenges that we face.

- **Framtiden runt hornet** In the Swedish TV-series Framtiden runt hörnet (The future around the corner) produced by SVT – the Swedish national public television broadcaster-, the technology of the future is discussed. What cutting-edge research from today in technology, medicine, psychology and artificial intelligence will be crucial for tomorrow? For the episode about Automation, ITRL director Anna Pernestål is interviewed about her experiences on how automation is influencing transport nowadays and what her vision is for the future.

- **Solcellskollens Podcast** In this episode Anna joins Solcellskollens founder and podcast host Erik Wallnér to give an overview of the challenges involved in putting self-driving cars on the roads, as well as how the technology has progressed in 2020. Solcellskollens podcast talks about renewable energy systems, and invites entrepreneurs, researchers and others who are working on the technology of tomorrow.

- **Mitti Stockholm** In this news article Erik Almlöf is interviewed about his research into how socioeconomic factors explain travel behaviour in Stockholm under the Covid-19 pandemic. He explains the actual findings, and how these findings can be useful for the future with regards to transport system planning.

3.2.2 LinkedIn

The number of followers almost doubled, increasing from 294 to 574 during 2020. LinkedIn continues to be ITRLs main social media platform.

Best performing posts:
(In terms of engagement rate)

Content	Created	Views	Clicks	Likes	Comments	Shares	Engagement rate
Register link: Electric roads webinar	01/12/2020	1031	206	25	7	9	24%
Popular Science: Bhavana Vaddadi	25/06/2020	699	89	14	0	0	14,7%
Popular Science: Albin Engholm	31/08/2020	1337	123	31	1	2	11,7%
Lars Svensson, Adaptive motion planning	18/06/2020	601	39	23	3	5	11,6%
Popular Science: Robin Palmberg	03/04/2020	635	53	14	1	2	11%

A total of 49 posts were made during 2020, with each post on average being viewed 628 times and liked by 15 people. The most liked post of the year was the announcement of new webinars (6/10/2020) with 54 likes. Due to the increase in followers posts made during the second half of the year received a significantly higher rate of reach, likes, comments and shares.

The most successful posts were the ones highlighting the individual researchers at ITRL, especially in the Popular Science series. Webinars also received a higher level of engagement, as well as research and news relating to Covid-19.

The least successful posts are were ITRL reposting itself. Reposting other organizations or people also seemed to cause a lower engagement.

Circa 50% of ITRLs followers are based in the Stockholm region.

3.2.3 Facebook

In 2020 ITRLs followers went from 439 to 546. Both reach and the number of posts has decreased since 2018 (no reach data for 2019).

	2017	2018	2019	2020
Number of posts	15	58	30	26
Total reach	5161	15861	n/a	13411

Similar to LinkedIn, posts regarding webinars were more popular, receiving more reactions and reach. Since Facebook ranks videos higher in users feed, the Breakfast Webinars streams and other videos achieved the biggest reach. The top performing posts are:

- Breakfast Webinar with Andrew Karvonen video (24/03/2020)
- Covid-19 transport survey (22/04/2020)

- Announcement of Breakfast Webinar with Andrew Karvonen (20/03/2020)

The majority of ITRLs audience on Facebook are men in the ages of 25-34, primarily located in the Stockholm and Gothenburg region.

3.2.4 Twitter

ITRLs Twitter account is currently inactive since 2019, but will be restarted during 2021.

3.2.5 Website

Updates regarding projects, news articles, breakfast seminars. Several sections need to be updated with current information, this project has started and will continue in 2021.

News posts: 30 in total.

3.2.6 Newsletter

A total of 10 campaigns (emails) were sent from ITRL, with 4 of them being newsletters sent out quarterly. The newsletter currently has 644 subscribers. About 43% of recipients are considered highly engaged and often open and click on emails.

4 ITRL Staff & Students

ITRL is a research hub where researcher from various disciplines and industry come together to share knowledge, thoughts and experiences. The core team of ITRL, i.e. the people that are employed by ITRL, consists of 20 persons, among which there are 50% females and 50% males. The diagram below 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.

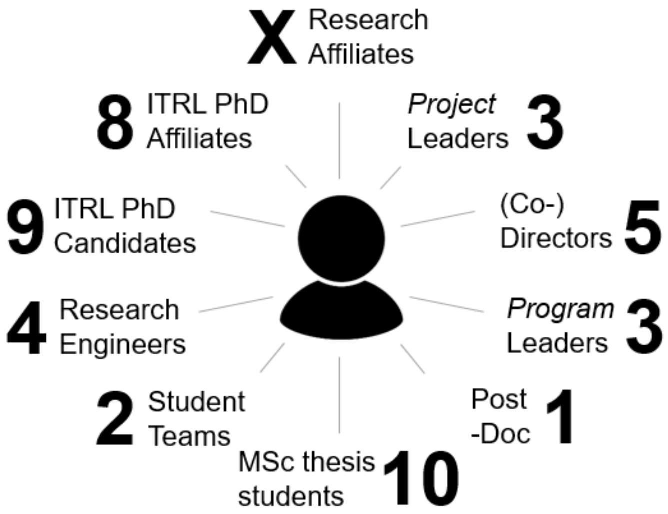


Figure 4.1 Statistical overview of the people working at ITRL. We currently have exact data on the number of research affiliates, but estimate that to be above 50.

4.1 PhD Students at ITRL

ITRL hosts a variety of PhD students that are very eager to contribute the sustainable transport modes of the future. Some of the PhD students dedicate their full work to this purpose, others participate in the ITRL PhD affiliation program and use the fertile environment of ITRL to expand their network and seek collaborations.

During 2020 three new PhD students started at ITRL. Claudia Andruetto already worked at ITRL as research engineer and started her PhD in the HITS program in June. In October Tim Selimi also started his PhD in the HITS project while Lin Zhao kicked off his PhD regarding the RCV (Research Concept Vehicle).

In 2020 five of our PhD students have performed their licentiate or half-time seminar. Xin, Robin, Jonas, Matej and Alexander received presented their research results so far and received green light and valuable feedback to continue with their projects.

In 2020 ITRL started a **PhD student affiliation program**, open for PhD students at KTH and industrial PhD students with our partner organizations. Currently the network engages 16 PhD students from KTH (from four different schools at KTH), and two students from Stockholm School of Economics. This is an informal network for students interested in multidisciplinary research for sustainable transport systems. The students will form a diverse network of researchers with different competences and backgrounds, who use different methods to analyse and design sustainable solutions for transportation of goods and people. Unfortunately the Corona pandemic has limited the number of activities this year, but we have had two internal conferences and we hope that 2021 will give more opportunities for networking.

In Appendix B a short summary of the individual work of the PhD students together with their personal reflection is included.

4.2 Master students at ITRL

Student are an integral part of ITRL staff is included in various courses, we host numerous MSc thesis students and the ITRL facilities are used by two KTH student teams: the Formula student team and the Hyperloop team.

4.2.1 Courses

In total 97 BSc, MSc and PhD students have participated in the courses hosted by ITRL.

Course number & name	ITRL responsible	Description	#students	#ECTS/ credits
AH1025 Public Transport Systems, Buses and Rail (BSc)	Erik Jenelius	The course provides a basic knowledge of the **condition, design, management and control** of a public transportation system. Environmental impact, market, vehicle systems, planning, financing and organization are treated on a general level.	20	7.5
AH2173 Public Transport (MSc)	Erik Jenelius	Attractive, efficient and reliable public transport systems are fundamental in **promoting sustainable growth developments** in metropolitan areas. The need to integrate and operate increasingly complex, diverse and technology-oriented transit services poses challenges to both planners and operators. The course provides knowledge on **planning and operations of public transport systems** and their analysis and evaluation through various measures of performance.	26	7.5
SD2229 Vehicle Dynamics Project Course Part 1 +2 (MSc)	Mikael Nybacka	This course is designed to give the students a chance to use their gained knowledge during past courses on **real life projects** connected to **vehicle technology or vehicle dynamics** for both road and rail. The projects in this course will either be tied to a company or to a research project at KTH.	9 (related to ITRL)	7.5 + 7.5
FAH3460 Topics in Transport Science Part 1 (PhD)	Erik Jenelius	The course helps doctoral students to situate themselves in the broad field of transport science. The students obtain **broad knowledge** through overview lectures and interact on more **detailed topics in seminars**, taking various roles (presenter, opponent, listener).	7	3.5
FSD3901 Integrated	Mikael Nybacka	To solve the challenges that the transport area is facin,g there is a need for an **integrated way of thinking** with systems perspective. No single research area can solve effectively and in a	10	5.0

transport system (PhD)		**sustainable way** the challenges that we are facing. The idea behind this course is to give the PhD students a systems perspective on transport research and a wider understanding of different research areas.		
EL2425 Automatic Control (MSc)	Jonas Mårtensson	The overall purpose of the course is to give the student **practical knowledge and experience** of project work in design and implementation of control systems. The students get to consolidate their previously acquired knowledge in control theory by solving a problem on a **laboratory system**. The student also gets experience in project work and **technical communication**.	25	7.5

4.2.2 MSc Thesis Projects

Under 2020 10 MSc students graduated under (partial) ITRL supervision. This amounted to a total of 8 MSc thesis projects. Three projects relate to the Mobility of People research program, End-to-End Freight Transport hosted two projects and three projects were conducted in relation to the RCV and AVTCT (Research Concept Vehicle and Automated Vehicle Traffic Control Tower). In Appendix B an overview of the MSc thesis project is given, along with a reflection of the students on their work.

4.2.3 Formula student

In 2020 we have been working on developing our new driverless electric vehicle, DeV17, which is aiming to partake in competitions 2021. DeV17 will be a completely new platform, moving to a composite monocoque from a tubular steel one, for the first time using four wheel drive, and incorporating a brand new design language in the shape of performance and reliability. Our aim is to bring a competitive and reliable platform to the future KTH Formula Student members, which can easily be improved upon in order to be a championship winning vehicle.

Unfortunately have all competitions and testing events been cancelled this year as a result of the pandemic. However, we did qualify to Formula Student Germany, an event notorious for its difficulty to get into. We managed our qualification with a large margin to the cut-off line, outperforming many other top level European teams and universities - which is something we're incredibly proud over.

During the first half of 2021, we plan to once again qualify for competitions. Furthermore, we look to manufacture and assemble our DeV17 - which will hopefully get valuable track testing time prior to the summer in order to prepare for competitions. Depending on the situation with the pandemic, we aim to compete in Germany for Formula student 2021.

4.2.4 Hyperloop

Many things have happened during the span of a year. At the end of 2019, it was still in consideration that the SpaceX pod competition - the quintessential Hyperloop event for all student teams - might take place in the summer of 2020. After a quite successful first entry in the competition one year earlier, we were eager to prove ourselves once more, now with a pod design reaching up to 550km/h.

As a result of the pandemic we were forced to divert our attention from manufacturing towards rethinking our design approach. Along the way, a significant amount of knowledge and experience was gained, resulting in new and improved subsystems. For instance, the Linear Induction Motor has increased its force with almost 50%, enabling a higher top speed to be achieved. Accompanying the motor, a new and lighter design of the chassis was also made. The new target speed brought a new iteration of the brakes, vertical suspension and lateral guiding system to be proceeded. For the latter, an initial design has been completed as recently as in November. As a final example, large strides for the communication within the pod, including the control and sensor system, have been made.

Looking forward, we focus our attention on Valencia as it will host the first EHW - European Hyperloop Week - an event where we plan to display our latest accomplishments in some of our sub-systems. Although the technical design will still be the main focus in our team, our long-term goal has for a long time been to make the Hyperloop system in its entirety a reality in Sweden. By devoting some time and effort into studying the full-scale concept of Hyperloop, we hope to soon have a much better view of how this can be achieved. As part of this, the ambition is to get involved as a representative for Sweden in the newly started standardisation process for Hyperloop in the EU.

2020 proved to be a period when we kept pushing the boundaries for what we as students can develop in the world of Hyperloop, and at the same time kept a reasonable sense of community throughout the year. This is, after all, a point of light for all our members to be proud of in these challenging times.

5 Appendix A: Scientific publications

5.1 Mobility of People

Journal articles

Abenozo, R.F., Cats, O., Susilo, Y.O. (2019). Determinants of traveler satisfaction: Evidence for non-linear and asymmetric effects. *Transportation Research Part F: Traffic Psychology and Behaviour, 66,* 339-356. doi.org/10.1016/j.trf.2019.09.009

Abenoza, R.F., Liu, C., Cats, O., Susilo, Y.O. (2019). What is the role of weather, built-environment and accessibility geographical characteristics in influencing travelers' experience? *Transportation Research Part A: Policy & Practice, 122*, 34-50. doi.org/10.1016/j.tra.2019.01.026

Alhassan, I.B., Matthews, B., Toner, J., Susilo, Y. (2020) The Movingo integrated ticket: seamless connections across the Mälardalen region of Sweden. *Transportation Planning and Technology*, *43*(4), 404-423. doi.org/10.1080/03081060.2020.1747204.

Alhassan, I.B., Matthews, B., Toner, J., Susilo, Y. (2019) Revisiting public transport service delivery: exploring rail commuters' attitudes towards fare collection and verification systems. *European Journal of Transport and Infrastructure Research, 19*(4), 310-331. doi.org/10.18757/ejtir.2019.19.4.4283

Almlöf, E., Nybacka, M., Pernestål Brenden, A. (2020). Will public transport be relevant in a self-driving future? A demand model simulation of four scenarios for Stockholm, Sweden. *Transportation Research Procedia, 49*, 60-69. doi.org/10.1016/j.trpro.2020.09.006

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Chengxi, L., Wang, Q., Susilo, Y.O. (2019). Assessing the impacts of collection-delivery points to individual's activity-travel patterns: A greener last mile alternative? *Transportation Research Part E: Logistics and Transportation Review, 121*, 84-99. doi.org/10.1016/j.tre.2017.08.007

Guo, J., Susilo, Y., Antoniou, C., & Pernestål Brenden, A. (2020). Influence of Individual Perceptions on the Decision to Adopt Automated Bus Services. *Sustainability*, *12*(16), 6484. doi.org/10.3390/su12166484

Johari, F., Peronato, G., Sadeghian, P., Zhao, X. (2020). Urban building energy modeling: State of the art and future prospects. *Renewable & sustainable energy reviews, 128,* 109902. doi.org/10.1016/j.rser.2020.109902

Hesselgren, M., Sjöman, M., Pernestål, A., (2020). Understanding user practices in mobility service systems: Results from studying large scale corporate MaaS in practice. *Travel Behaviour and Society, 21*, 318-327. doi.org/10.1016/j.tbs.2018.12.005

Langbroek, J.H.M. and Hagman, J. (2020). Coping with a growing number of e-taxis in Greater Stockholm: A stated adaptation approach. *Case Studies on Transport Policy, 8*(2), 576-585. doi.org/10.1016/j.cstp.2020.03.006

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Liu, C., Susilo, Y.O. and Ahmad Termida, N. (2020) Weather perception and its impact on out-of-home leisure activity participation decisions. *Transportmetrica B: Transport Dynamics, 8*(1), 219-236. doi.org/10.1080/21680566.2020.1733703

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Stead, D., Vaddadi, B. (2019). Automated vehicles and how they may affect urban form: A review of recent scenario studies. *Cities, 92*, 125-133. doi.org/10.1016/j.cities.2019.03.020

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Xylia, M., Leduc, S., Laurent, A.-B., Patrizio, P., Meer, Y. van der, Kraxner, F., Silveira, S. (2019). Impact of bus electrification on carbon emissions: The case of Stockholm. *Journal of Cleaner Production, 209*, 74-87. doi.org/10.1016/j.jclepro.2018.10.085

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Zhao, X., Vaddadi, B., Sjöman, M., Hesselgren, M., Pernestål, A. (2020) Key barriers in MaaS development and implementation: Lessons learned from testing Corporate MaaS (CMaaS). *Transportation Research Interdisciplinary Perspectives, 8,* 100227. https://doi.org/10.1016/j.trip.2020.100227

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Vaddadi, B., Pohl, J., Bieser, J., Kramers, A. (2020). Towards a conceptual framework of direct and indirect environmental effects of co-working. *ICT4S2020: Proceedings of the 7th International Conference on ICT for Sustainability, Bristol, United Kingdom, June 2020* (p. 27-35). doi.org/10.1145/3401335.3401619

Zhao, X., Susilo, Y., Pernestål, A. (2020). The long-term acceptance pattern of automated public transport service: Evidence from Stockholm. *MFTS 2020 The 3rd Symposium on Management of Future Motorway and Urban Traffic Systems, Online, 6-7 July 2020*

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Almlöf, E., Rubensson, I., Cebecauer, M., & Jenelius, E. (2020). Who Is Still Travelling by Public Transport during COVID-19? Socioeconomic Factors Explaining Travel Behaviour in Stockholm Based on Smart Card Data. Preprint available at dx.doi.org/10.2139/ssrn.3689091

Bin, E., Andruetto, C., Susilo, Y., & Pernestål, A. (2020). The Trade-Off Behaviours between Virtual and Physical Activities during COVID-19 Pandemic Period. Preprint available at doi.org/10.2139/ssrn.3698595

5.2 Urban Goods Distribution

Journal articles

Joubert, J.W., Trenta, N.M., Gidofalvi, G. and Kordnejad, B. (2020). A matching algorithm to study the evolution of logistics facilities extracted from GPS traces. *Transportation Research Procedia*, *46*, 237-244. doi.org/10.1016/j.trpro.2020.03.186

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Sopjani, L. et al. (2020). Unlocking the Linear Lock-In: Mapping Research on Barriers to Transition. *Sustainability*, *12*(3), 1034. doi.org/10.3390/su12031034

Conference

Gidofalvi, G., Yang, C. (2020). The potential of route based ERS network optimization: Transport demand optimized electric road placement. *Transportforum 2020, Linköping, Sweden, 8-9 January 2020*, p. 362. Retrieved from URL

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G. Gidofalvi (2019). Trajectory and Mobility Based Services: A Research Agenda. In Gartner, G., Huang, H. (Eds.), *Adjunct Proceedings of the 15th International Conference on Location-Based Services, Vienna, Austria, 11-13 November 2019,* p. 123-128*.* Retrieved from URL

Guo, J., Cumbane, S., Gidofalvi, G., Susilo, Y (2019). Towards a Sustainable Use of Electric Vehicles: The Design of a Stated Adaptation Web Survey Tool. *Proc. of 24th International Conference of Hong Kong Society for Transportation Studies, (HKSTS 2019), Hong Kong, Hong Kong, 14-16 December 2019,* p. 409-417. Retrieved from URL

5.3 End-to-End Freight Transport

Journal articles

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Engholm, A., Björkman, A., Joelsson, Y., Kristoffersson, I., Pernestål, A. (2020). The emerging technological innovation system of driverless trucks. Transportation Research Procedia, 49, p. 145-159. doi.org/10.1016/j.trpro.2020.09.013

Langbroek, J.H.M., Cebecauer, M., Malmsten, J., Franklin, J.P., Susilo, Y.O., Georén, P. (2019). Electric vehicle rental and electric vehicle adoption, *Research in Transportation Economics, 73*, 72-82. doi.org/10.1016/j.retrec.2019.02.002

Conference

Held, M., Flärdh, O., Roos, F. and Mårtensson, J., Implementation of an Optimal Look-Ahead Controller in a Heavy-Duty Distribution Vehicle, *2019 IEEE Intelligent Vehicles Symposium (IV)*, *Paris, France, 9-12 June 2019,* p. 2202-2207, doi.org/10.1109/IVS.2019.8813851

Li, Y., Johansson, K. H., Mårtensson, J., A hierarchical control system for smart parking lots with automated vehicles: Improve efficiency by leveraging prediction of human drivers, *2019 18th European Control Conference (ECC), Naples, Italy, 25-28 June 2019*, p. 2675-2681, doi.org/10.23919/ECC.2019.8796055.

Other

Pernestål, A., Engholm, A., Kristoffersson, I. and Hammes, J.J. (2020), The Impacts of Automated Vehicles on the Transport System and How to Create Policies that Target Sustainable Development Goals. Paulsson, A. and Sørensen, C.H. (Eds.) *Shaping Smart Mobility Futures: Governance and Policy Instruments in times of Sustainability Transitions*, Emerald Publishing Limited, p. 37-53. doi.org/10.1108/978-1-83982-650-420201003

6 Appendix B Students at ITRL

6.1 ITRL PhD students

Albin Engholm

At the end of this year I am almost halfway into my PhD project on how driverless vehicles may impact the transport system with a focus on freight transport. My plan is to present my Licentiate thesis during the spring 2021. So far, the majority of my research has been carried out within the research project System level impact of self-driving vehicles. As for most of us, 2020 has been a different year also for me. During the spring semester I had the great privilege to be on parental leave with my daughter Rakel at 80%. My working hours were spent on developing climate models for freight transport, revising papers and reading.

During the autumn I have been focusing on analysing the impacts of large-scale driverless truck adoption on the freight transport system by using the Swedish national freight transport model Samgods. This has been very interesting work which I aim to publish in a scientific journal in a not too distant future. I have also been working with developing dynamical simulation models to analyse the long-term impacts of driverless and electric trucks on transport system performance and climate targets and how it relates to transport climate policies.

The following research papers, which I have contributed to, have been published during this year:

Cost Analysis of Driverless Truck Operations
The Impacts of Automated Vehicles on the Transport System and How to Create Policies that Target Sustainable Development Goals
The emerging technological innovation system of driverless trucks

Some of my research was presented at the European Transport Conference by my colleague Claudia Andruetto and at Nationell Konferens i Transportforskning by myself.

Next year holds several stimulating challenges, such as:

- Presenting my Licentiate thesis
- Synthesizing the results from System level impact of self-driving vehicles which ends in Q3
- Continue developing and working with dynamical transport simulation models. In particular within a pre-study with the Swedish Transport Administration in which we investigate how different scenarios for the development of automation, digitalization and electrification within transport can impact the current transport system prognosis.

Thank you all in the ITRL ecosystem for this year. I hope to meet many of you during next year, hopefully in person!

Bhavana Vaddadi

I am working on understanding the System-level effects of New mobility and accessibility services for my PhD thesis. By exploring this topic, I wanted to highlight the importance of having a holistic outlook when assessing new innovations and technology. I have been involved in writing multiple papers on how to employ a holistic assessment framework to anticipate the effects of these new mobility and accessibility services.

One particularly interesting and yet challenging one being- Key barriers in MaaS development and implementation: Lessons learned from testing Corporate MaaS (CMaaS). So far, as I come close to defending my Licentiate thesis, I have understood how challenging it can be to take a holistic view and/or employ an interdisciplinary approach. I am sure it will only get more challenging over time but, I believe that it is a very important factor when studying innovations in mobility and accessibility.

One of the key factors of my work are the Key Performance Indicators (KPIs) to assess these new services. I presented some of my work on constructing the assessment framework as well as the KPIs in multiple conferences so far. With these presentations, I understood two things. One, a large sum of people is working with different individual aspects of new mobility and accessibility services but, a holistic view is lacking. This seems to be of peak interest to a majority of the research community. Second, the KPIs I have worked on are derived from generic literature studies on smart, sustainable mobility. Hence, there is a need to derive KPIs that are specific for new mobility and accessibility services.

Here, ITRL has been of great support. Due to my involvement in different projects, I have been able to learn from different real-life experiments of these new services. After my licentiate, I am really looking forward to two things. One, to build a better foundation for the deriving KPIs with the help of a series of workshops involving key actors in new mobility and accessibility services. Two, with the data gathered from different real-life cases, employ a stronger system thinking approach (for example, using system dynamics) to build a large flexible assessment framework which can be used as a decision-making tool for better development, implementation and operation for new mobility and accessibility services.

Claudia Andruetto

I have just started my PhD this year, in May. So far I have been mainly planning my research (writing a research plan) and reading about my research field. I have defined my research questions, and I have started addressing all of them through different methodologies (i.e. literature review, group model building and system dynamics modelling). Moreover, I have attended a summer school in system dynamics and that really opened my mind to this “new” research field and inspired me to study it even further.

I have contributed to two publications, one that is still in progress of finalization and one that is under review and will be re-submitted before the end of the year. These are

Potential Values of MaaS Impacts in Future Scenarios (Xiaoyun Zhao, Claudia Andruetto, Bhavana Vaddadi, Anna Pernestål)

The Trade-Off Behaviours between Virtual and Physical Activities during COVID-19 Pandemic Period (Bin, Elisa and Andruetto, Claudia and Susilo, Yusak and Pernestål, Anna)

A part from these, I currently working on two publications, one is an extension of the covid-19 work, and will be submitted before the end of the year. Moreover I also aim at presenting at the VREF conference next year the results of my ongoing literature review.

I have attended the European Transport Conference 2020, which was held online in the beginning of September, where I presented a work that I have previously done together with Albin Engholm and Anna Pernestål. The presentation was titled Fleet and transport system impacts of the diffusion of driverless and electric trucks and has been presented successfully. It has been very interesting to participate to the conference, since we got different comments on the work that we have done and how to improve it, and I have been able to listen to many other presentations and get inspiration from them.

I am very excited to study more about urban freight transport systems and how to apply system dynamics methodology to them, and I am looking forward to the next year and to the challenges that will bring ☺

Erik Almlöf

I've finished the work for the Self-driving public transport project (F8943) for SLL which has concluded with an article submitted to Transportation Research Part A. The research was presented at a breakfast seminar during the spring with a large attendance and several people reaching out with afterwards. We've also gotten an approval of a continuation of the project for the coming two years.

Secondly, I've been working on the Tvärförbindelse Södertörn project for Trafikverket where we're investigating the system impacts of a self-driving electrified bus line on a highway in southern Stockholm. The work is planned to conclude with an article submitted during early 2021.

Thirdly, I initiated a project together with Trafikförvaltningen and the Transportation Planning Department where we investigated who had stopped travelling by public transport due to the pandemic. We are currently revising a journal article for the project but have already gotten significant dissemination of the research through a preprint posted in the early autumn. Furthermore, the work was covered by the local newspaper Mitt I in early November and we've received a lot of questions from the transportation community. The paper will also be presented at the TRB conference in January.

The overall PhD progress is running a bit behind schedule with the current plan to have a licentiate seminar during late spring of 2021. My personal reflection is that I feel that I've become more assertive in my researcher role, with the COVID-19 paper as a fun and good example of a research project that we were able to achieve quickly. It wouldn't have been possible to do without the cooperation (and encouragement!) of ITRL management, Trafikförvaltningen and the Department of Transport Planning!

Jonas Hatzenbühler

My progress in my PhD goes according to my time plan. The Covid pandemic did luckily not affect my progress. I could defend my licenciate thesis in June this year and I am planning to graduate with the PhD end of next year.

At the beginning of the year, I have been working on finalizing my licenciate thesis. Including submitting two journal paper. The work was themed around transition towards autonomous bus public transport systems.

During the summer I have mainly explored vehicle routing problems and urban logistic concepts. In parallel I have worked on developing an interactive and web-based visualization tool to present my research results better.

In the last months I have shifted my focus from autonomous buses in public transport systems towards future mobility concepts like the NXT vehicle concept (see pictures) from Scania. Now I am developing an optimization model to explore the use and impact of such vehicle concepts on urban passenger and freight transport.

I have published one paper in Transportation Research Part A: Policy and Practice Journal (see below). It analyses the impact autonomous buses have on line-based public transport systems and in what order the buses should be replaced from conventional to autonomous buses in order to maximize the benefit for passengers and operator. The second paper is not yet published but in the last review phase. I expect a positive response within this year. It is submitted to Transportation. The main concept of the paper is the investigation of public transport network design for conventional and autonomous buses. Basically, exploring the differences between the vehicle technologies.

This year I did not attend any conferences since they all got cancelled or postponed to the next year. I am attending Transportforum beginning of next year.

I liked to see the new project (HITS) to get started. I felt like I could give nice input in the project perspective and my field of research and interest is really captured by the project scope. I like to be able to explore more in the field of transport related optimization problems and working on more sustainable transportation systems, mainly through the combination of passenger and freight transportation.

I am mostly looking forward in next year to produce some interesting and exciting insight into the use of the NXT vehicle concept. And of course, going towards the termination of my PhD degree makes me excited and keeps me motivated.

Lin Zhao

Now I mainly responsible for the REDO project. At the beginning of the project we have constructed the remote driving platform based on RCV-E and Control Tower. We realized the RCV-E remote driving function now. In order to transmit more real world information to remote driver, different kinds steering feedback model including physical model, modular model and current model have been constructed and they are all verified by RCVE vehicle data. By analyzing the results, we find that the characteristics are different between different models, so we assume that these models have different influence on remote drivers. Our next plan is to organize the remote driving experiment in Arlanda test track and recruiting subjects for taking part in the REDO Test. The main purpose of the coming experiment is to investigate the influence of feedback model on driver's brain wave, heart rate, driving performance, intuitive feeling and so on. Until now we have almost finished the test plan and are preparing for the coming experiment.

After the experiment, we plan to contribute a paper to the IAVSD conference. What I like most about my PhD this year is I begin experiencing a totally new research way and it is high efficiency and meaningful. I am looking forward to do deep research in my project and I think it is a meaningful research for improving future vehicle's safety and comfort performance. The following figures are the remote driving testing and steering feedback model verification separately.

Lina Rylander

This year, I have worked on data analysis, preparing workshops to perform concept development and the demonstrator. During the fall, I had planned to perform the workshops to explore the diagnosis and troubleshooting system of conventional trucks and develop concepts for a self-driving system. However, the pandemic's current situation forced us to re-plan, and therefore I have been working on the demonstrator instead. The work with the demonstrator has mainly focused on understanding the lab-platforms (AVCT and SVEA-cars) to comprehend how we can use them in the project.

I am currently working on a paper regarding design thinking and how to involve experts and stakeholders in the design work, focusing on a systemic design approach. The work with the paper has enhanced my understanding of integrating actors in the design process and the designer role. I believe this learning will be very useful in the continuation of the project.

In October 2020, I did my first formal presentation at the Swedish Transportation Research Conference, and I also participated in the TRAIL summer school at Delft University. Both experiences were very informative and inspiring. I was overwhelmed with the complexity of the autonomous vehicles' field and all the different challenges we need to overcome. However, it gave me a lot of new insights I will bring with me to the project.

This year has been very challenging as the pandemic has touched us all and has also affected the automotive industry in Sweden, and I am looking forward to 2021 and hope we will be able to meet with people in real life soon again. However, the new prerequisites have forced me to face problems in new ways and re-think how I do things, which I believe will be instructive and influence my future work.

Robin Palmberg

My PhD studies took a small hit from the current pandemic. As we are performing studies which are using sensors attached to the body, and some which are close to the eyes, we opted to push experiments forward until we knew a bit more about the situation and possible strategies for preventing contagion. Because of this, I focused on finishing all my courses and papers that I had in my backlog, so that now that we are preparing to perform the experiments, I do not have to think so much about courses and writing about old studies.

During 2020, we wrote the paper “Towards a better understanding of the health impacts of one’s movement in space and time” with the authors Yusak O. Susilo, Györö Gidófalvi and Fatemeh Naqavi. The paper was presented by me at MobileTartu2020 and was later submitted to “Journal of Location Based Services” awaiting review responses. The presentation seemed well received, and I can see that there is quite some interest in psychophysiological data analysis regarding built environments and transport based on the questions after the presentation.

The paper “Built Environment Characteristics, Daily Travel, and Biometric Readings: Creation of an Experimental Tool based on a Smartwatch Platform” with the same authors was revised and submitted to “Personal and Ubiquitous Computing”. Both papers revolve around using psychophysiological data as a measurement of how people are affected by their surroundings when travelling through urban environments.

The things I liked most during the past year is probably the MobileTartu2020 conference, the Aalto University Summer School on Transportation – EIT Urban Mobility Edition and the data collection that we managed to do under very controlled conditions out at Arlanda Test Track 2. During 2021 I look forward to performing my final experiments, finishing my thesis and then defending it so that I can (hopefully) get my doctoral degree. Oh yeah, and also finishing the course “Introduction to PhD studies in Machine Design”, which for some reason became my last course.

Tim Selimi

Xin Tao

I was previously at the Mechatronics Division of ITM. I joined ITRL and had the half-time seminar in May 2020. I was previously working on ‘Systems functions for situation-awareness of advanced Cyber-Physical Systems under uncertainty.' After joining ITRL, my research has shifted towards 'Fault Diagnosis System of Driverless Vehicles for Uptime'. This project is related to the PhD project of Lina Rylander, while I am researching from more technical perspectives. So far, more details on my research project is to be explored, including specific research questions, methods and case scenarios.

I have been involved in 6 papers in total. Five of them were published before I joined ITRL. Afterwards, I wrote one journal paper at ITRL, which has been submitted to the journal Reliability Engineering and System Safety in November. This paper is about the short-term maintenance planning of autonomous trucks for minimizing economic risk. I didn't attend any conference after joining ITRL.

This year is an unusual year for everyone, especially for me. Joining ITRL is a significant experience for me. I like the enthusiastic atmosphere here and I like the interaction with colleagues, who are professional and dedicated. I am looking forward to gain more youthful spirit of ITRL and make more progress in research.

6.2 ITRL PhD Affiliation program

Alexander Johansson

A truck platoon refers to a group of trucks that drive on the road in a formation with small inter-vehicular distances. There are many benefits related to platooning, both environmental and commercial. My research is focused on platoon coordination in large-scale road networks. Especially, I am interested in cases when trucks are owned by different transportation firms that cooperate in the form of platooning.

Frank Jiang

I am working on formally verifiable approaches to managing vehicle fleets remotely. Currently, the existing approaches for creating tasks for a vehicle fleet and remotely operating vehicles do not include guarantees on whether the vehicles can complete the task or will be safe throughout the task. I am implementing approaches with guarantees in the form of a control tower for automated vehicles at ITRL.

Marie Bemler

Marie's research focus on how expectations on self-driving vehicles affect organizations and technology development. For self-driving vehicles to become a part of the infrastructure many different actors needs to work together. Marie studies the visions in the sociotechnical system that surrounds the self-driving vehicle to explain how creation of new paths are affecting inertia and lock-ins and how that effects goals, organizations and the technology that is developed.

Matej Cebecauer

In his doctoral project, Matej uses data-driven approaches, machine-learning, and spatio-temporal clustering for revealing travel patterns in large urban transport networks. This includes loop detectors on highways, vehicles GPS data, toll gate data, and public transport smart card data. Matej am building a methodology framework with reasonable performance and easy application in the practice for multimodal transport planning, traffic and disruption management, and prediction. The ITRL affiliation program for him is about networking and identifying potential collaborations. Recently, he has been involved in studying the changes in public transport ridership during Covid-19.

Mathias Larson Carlander

Mathias Larsson Carlander is a PhD student at the House of Innovation Stockholm School of Economics and member of the ITRL PhD affiliation program. Mathias research focuses on organizations acting in system of systems and include digital ecosystems, digital innovation, product development, and digital platforms.

Mladen Cicic

As the connected vehicles enter the public roads, new opportunities for sensing and controlling the traffic flow are becoming available. Mladen's research deals with using connected vehicles, such as truck platoons acting as moving bottlenecks, as traffic flow actuators, in order to reduce the traffic congestion. Since it is hard to directly measure the traffic conditions everywhere, methods for traffic state reconstruction using local measurements from connected vehicles are also developed and employed in the traffic control loop.

Wenliang Zhang

Wenliang's research focuses on the active safety of vehicles by utilising various means of over-actuation and optimisation-based control methods. When considering his research topic from a higher level, e.g. a vehicle platoon, the safety of individual vehicles and the transport system as a whole can be further enhanced, as information regarding road condition, traffic situation, whether, etc. can be shared among vehicles.

Xiao Chen

Xiao's PhD work is on different levels of control and management of automated vehicles, with a focus on traffic coordination and control at a region of conflict such as free way on ramp and intersections by adapting optimization control framework, with an possible extension to handle mixed traffic environment with both human driven and automated vehicles.

6.3 MSc thesis projects

Designing public transport networks using big data

Student: Philip Svensson
Supervisor: Erik Almlöf

The aim of the thesis was to make use of real-world travel time and demand data and implement an algorithm which designs bus networks. Thereafter answering the questions: How well does the algorithm perform when applied to Södertälje, Sweden? Can the proposed method assist in the network design stage of real bus network planning?

Working on a larger project with individual responsibility was truly a great learning experience, both personally and academically. I was introduced to reading scientific papers in a greater extent than which I had encountered before. This experience is also something I value now in my current position as trainee patent attorney at Ericsson.

Transport solutions and how they will look in the future is an extremely important topic I believe, both in regards to mobility in our everyday lives and creating an environmentally sustainable future. Currently my aim is to broaden my knowledge within different areas of technology and become a European patent attorney.

Driving Autonomous Heavy Vehicles into the Future: A Business Model Perspective

Students: Anna Saibel, Gabriel Kitzler
Supervisor: Rami Darwish

Our thesis was about future business models for autonomous heavy vehicles and how manufacturers can survive this imminent technology shift by adapting their business models and core competencies. The study was carried out as an exploratory case study at the heavy vehicle manufacturer Scania and the findings helped us formulate a viable future service-based business model for an autonomous heavy vehicle manufacturer. We also managed to study and give examples of core competencies that can be leveraged dynamically after the shift.

We learned a lot from this master thesis project, not only about the heavy vehicle manufacturing industry and the technology shift itself, but also about working for longer periods of time in a close-knitted team as well as how to combine the interests of academia with the interests of a large company, which is where we found an excellent middle ground in ITRL. We are very grateful to ITRL for allowing us to utilize their offices and workspace and especially to Rami Darwish for providing us guidance and valuable insights.

Our plans for the future include working as recent graduates with technical project management and business development.

Design and analysis of an electric over-actuated vehicle suspension

Student: Ankith Suresh Athrey
Supervisor: Mikael Nybacka

For my thesis, I worked on improving the performance of the Research Concept Vehicle (RCV). My focus was on improving the performance of the steering and active camber actuation systems. This was achieved by building a simulation model of the respective systems, analysing the current performance, deciding on the hard points for the new, improved systems, and building new simulation models of these systems. I also worked on accommodating a new 100V battery system along the length of the vehicle, on the baseplate. I redesigned the frame to accommodate these changes and added more cross members to reduce flex in the base plate during operation and performed analysis on the new frame of the vehicle.

This master thesis has significantly contributed to my understanding of electric cars. I have learned the use of various software. I wish to continue in the field of design of electric cars, in the future.

Design and implementation of brake and steering control functions for an over-actuated vehicle platform

Student: Tao Liu, Ziwei Lu
Supervisor: Mikael Nybacka

Environmental impact assessment of different truck types

Student: Abhinav Maithani
Supervisors: Claudia Andruetto

My thesis topic was 'Environmental impact assessment of different truck types'. The thesis was about the analysing the environmental impacts of different trucks types i.e. IC engine Manual truck, IC engine Driverless truck, Electric Manual and Electric Driverless truck from their lifecycle point of view. The thesis was carried out to find the hotspots of environmental impacts during different life cycle stages of the trucks. The study can help to further improve the design of trucks to reduce the environmental impacts. It also evaluates the impacts of driverless technology and give an idea whether it is suitable to use this technology.

From this project I learned about the technicalities of different truck types and the new technologies that are used in the vehicle industries and how it is impacting the environment. This project also helped me learn more about the use of life cycle assessment as a tool to evaluate the environmental impacts and to make sustainable decisions.

For the future, I am looking for PhD (hopefully with ITRL) to learn more about these technologies and to carry out the research on how we can reduce emissions from the vehicle manufacturing phase. As it contributes almost half of the total emissions of the vehicle.

Life Cycle Assessment (LCA) of Lightweight Electric Motorbikes

Student: Savitri Engert
Supervisor: Miguel Brandao, Mia Hesselgren, Robin Karlsson

The project is performed to assess the potential environmental impacts of Kalk&, an off-road electric motorcycle model also certified for on-road use, designed, and manufactured by CAKE 0 Emission AB. For this purpose, an Attributional Life Cycle Assessment was chosen as the methodology to study the impacts of one whole motorbike over a lifetime of 500 charging cycles of the battery, used by a hypothetical example user in Stockholm, Sweden. The potential environmental impacts are focused on 12 categories using the ReCiPe Midpoint (H) method.

Measuring Complexity of Built Environments

Student: Periandros Papamarkos
Supervisors: Robin Palmberg

During the spring semester of the academic year 2019-20, I completed my Master Thesis, which in cooperation with ITRL. The study formed part of the MERGEN project, in which we try to better understand by what factors, and how, remotely operating drivers are affected by their surroundings and situations. In my Thesis' case, the focus was on how the level of car traffic and the presence or not of traffic signs and lights affect the drivers' perception of stress emotion and aims to introduce HCI techniques in order to prove that these techniques can bring valuable and credible results when substituting the conventional means of carrying out experiments.

The main takeaway from the whole process was that the use of remote HCI techniques for testing can bring valuable and credible results, something that can be proved of great help for researchers especially during periods with special restrictions such as a pandemic.

My plan for the future after the completion of my HCID studies, is to apply what I have learned in an innovative context.

Shared automation in control towers for automated vehicles

Student: Anton Björnberg
Supervisors: Jonas Mårtensson & Frank Jiang

In the thesis I examined a novel method for teleoperation of semi-autonomous vehicles to enhance safety and operability. The main drawbacks of existing solutions are signal transmission latency and limited situational awareness for the remote operator. To circumvent this, the thesis explores a method where the operator does not control the vehicle directly, but rather demonstrates their intentions by maneuvering a virtual vehicle locally. The motion of the virtual vehicle is communicated to the real one, which is then made to mimic that behavior with additional safety overlays. It was all very interesting, and I gained many insights into the problems and methods that are common in autonomous driving. My current goal is to find a full-time job related to robotics where I can apply what I have learned at KTH and continue to develop as an engineer.