IVT Annual Report 2023

ETH zürich

IVT Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Annual Report 2023

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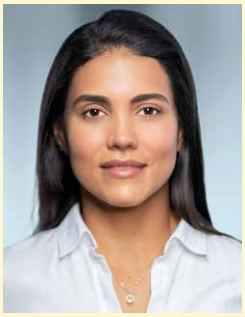

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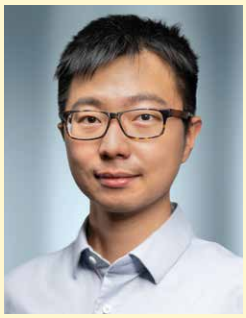

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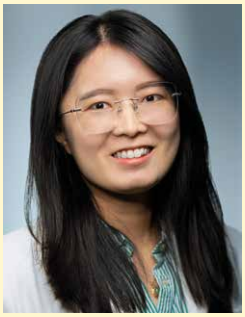

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1 Report of the director

Francesco Corman

I am happy to look back to 2023 as a year of change! Change is unavoidable, and we should understand how that results in opportunities. The biggest change is the change at the leadership of the institute, which makes me responsible for the operation of the machine, and the chance to write down those few words.

The other big change was the successful search for a successor for Prof. Axhausen. Prof. Eva Heinen will start in July 2024 taking on her duties of research and education in the domain of transport and mobility planning. Many challenges lie ahead of us, and many of them are due to planning and demand aspects, which can be answered scientifically and brought to attention of the policy makers and the sovereign.

This also means the imminent graduation of many doctoral researchers, and some reorganization for those remaining. Fortunately, the department and the school has accepted to keep Prof. Axhausen as leader of the E-Bike-City project, which given his enthusiasm and engagement can only bring further results to this relevant and useful idea.

A change from the normal routine was the successful organization of 11th hEART conference, which brought the attention of more than 200 international researchers to our research and our groups. The buildings and restaurants at Hönggerberg were very well suited to the conference. The support by PTV, aimsun, Bentley and the IVT-spin-off Transcality were extremely helpful. I am happy that staff from the entire IVT made the event smooth and enjoyable!

A further change is the restructuring of the IVT library, where many of the paper versions of many internal reports, the scientific / technical journals in their paper version, and multiple thousands of books about transport were stored. This is now reintegrated with the main Civil Engineering/ Architecture library to provide a seamless experience to those people willing to read or borrow them. Some books which were double in our library are remaining at our disposal. The room will be next refurbished to provide space for current and future needs.

The normal changes pertain people coming and leaving, and an increasing number of alumni. Moreover, the rearrangement of secretariat better matches the reorganizational challenges of a new professor joining. There will be one dedicated administrator for each group.

The vision of the IVT, of course will not change, but adapt, as the strategy of the department is adapting too. The pillars of IVT will remain the tri-partite division into road operation, (public) transport systems and transport planning, which we believe are able to tackle the grand challenges. Those are the increasing urbanization; future oriented infrastructure, and the changing environment. Those three pillars shape the opportunities and the challenge for mobility. The larger picture includes complex issues such as urban economics, sustainability of network infrastructures, socially inclusive design, analysis of the material and social changes and equity.

One very visible activity of the Institute is the E-Bike City project discussed last year. The project increased its momentum, and is now on-track with regular meetings of the principal investigators and all researchers involved. The second public event in the summer was a chance to engage the colleagues from the cities and consultancies in a series of workshops. The project website provides links to the videos of the event and links to the working papers and designs as the project unfolds. The most important is the initial draft for a redesign of Zurich's network, which can be studied in detail at https://ebikecity.ch/en.htm together with links to all the other workpackages.

In spite of those changes, or even through them, the IVT had a productive 2023. Its research and its monitoring is helping policy makers to formulate their strategy for a net-zero Switzerland, and operators to achieve it. We are sure that with the clearer long-term perspectives now in place we will continue to do so.

2 Mission

The mission of the IVT is the generation of new knowledge for the planning, design, and operation of transport systems, and its transfer through teaching, further education, and applied research. The focus is on land-based systems, i.e. rail and road-based modes of transport for freight and passengers. The interactions of the transport systems with society, industry and nature are fully integrated in our approaches. (See Figure 1.)

The institute is organized in three groups, which synergistically tackle demand aspects (understand, simulate, forecast and assess in welfare terms the outcomes of future travel demand and future transport technologies and policies), supply for roads (model, simulate, optimize and control traffic flow in all kinds of vehicular networks), and public transport (analyse, model, predict and optimize the performance of a network, based on the limited available resources).

We contribute to the following departmental grand challenges:

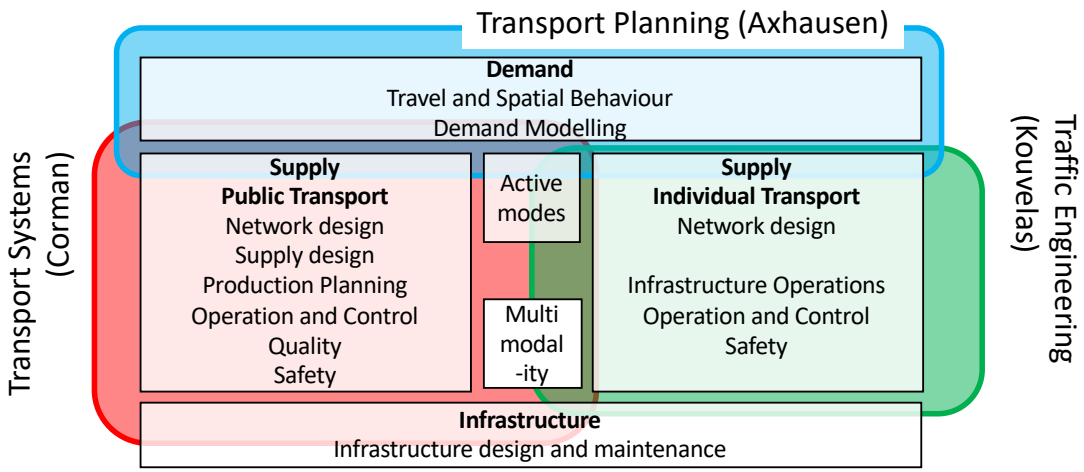
Urbanization, by planning the present and future of mobility, with links to spatial planning and sustainable development, by means of mobility policies and mobility management, for different forms of private and shared mobility. We seek to enable the potential of digitalisation for planning and controlling urban mobility systems, enabling sustainable and effective usage of infrastructure.

Future oriented infrastructure, by designing smart transport infrastructures, optimising real time control and of infrastructure and resource usage, given current needs and performance required; enabling the resiliency of the resulting transport system to changing needs and planned/unplanned unavailability.

Changing environment, by means of evaluation of policies and technologies for improved sustainability and energy efficiency of mobility; Impacts of changing environment on mobility systems.

Our teaching is system based, and the complex interactions of the transport system are our key examples for this systems approach. The graduate will able to manage all stages of the system life cycle and of their interactions with its contexts. We stress the domain and methodological basis for the planning, design, and operation of the transport systems.

Figure 1: Structure

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3 Research

3.1 E-Bike City: Designing sustainable streets

Lukas Ballo
Cooperation: D-BAUG Lighthouse Project (IBI, IfU, IKG, IRL, IVT) with TRANSP-OR (EPF Lausanne)

Reaching current climate targets requires a substantial reorganization of urban transport systems, far beyond the adoption of electric vehicles. However, transport planning in many developed countries is suffering from a dilemma between improving sustainability on one hand and retaining existing activities and accessibility structures on the other. As a result, the implementation of change is slow. Examples include lengthy discussions around transit investments, on-street parking, bike lanes, or future pricing of mobility.

As a way out of the dilemma, we build on decades of transport research to develop a tangible vision for a carbon-reduced urban mobility future. In a what-if approach, we envision a city where the transport system is getting closer to near net zero emissions within the next two decades – the *E-Bike City*. It must operate without major changes to the built environment and with technologies that are mostly already mature. A key assumption is that existing road space will be reallocated in favor of proven sustainable modes, such as transit, walking, and cycling. Already ongoing innovations in personal mobility vehicles like e-bikes serve as a key enabler for people with limited fitness, as well as longer trips in hilly terrains. However, despite prioritizing sustainable modes, motorized traffic will remain possible, guaranteeing mobility for those who need it.

An interdisciplinary team of researchers develops different aspects of this vision. The group for transport planning envisions the design and its implications on people's accessibility. Their network design shows the allocation of space on every street in Zurich, providing the maximum space for sustainable modes, while still guaranteeing access to every building by car. Precise street and intersection designs show the look and feel of living and traveling in such a city. An agent-based simulation is currently under development to show how such transformation will impact the accessibility and the activities of various people. The transport systems group shows how the operation of buses and trams needs to change to accommodate the changing travel needs. The transport engineering group tests the possibility of more efficient traffic organization by allocating road space dynamically.

Further knowledge is incorporated from researchers outside the institute. The Transportation and Mobility Lab at EPFL helps with predicting the impact of changing accessibility on people's activities. The Institute of Environmental Engineering investigates the real emissions from e-mobility, including the supply chains of vehicles and their batteries. The Institute of Cartography and Geoinformation contributes with advanced techniques for finding optimal street networks and evaluating them. The Institute of Construction and Infrastructure Management develops cost estimates and a plan for a stepwise implementation. And finally, the Institute for Spatial and Landscape Development provides insights on the public opinions toward such futures.

The E-Bike City project team aims to spur progress on decarbonizing urban mobility by providing an actionable vision of a low-carbon transport system. In addition, the tools used to generate the vision are being published as open-source software so that planners and other researchers can use them for envisioning and testing their variations and localizations.

A first draft E-Bike City Masterplan for Zurich, as well as more information about the project, can be found here: http://www.ebikecity.ch/en.htm

Further reading:

Ballo, L. and K.W. Axhausen (2023) Modeling sustainable mobility futures using an automated process of road space reallocation in urban street networks: A case study in Zurich, presented at the *103rd Annual Meeting of the Transportation Research Board (TRB 2024)*, Washington, D.C., January 2024.

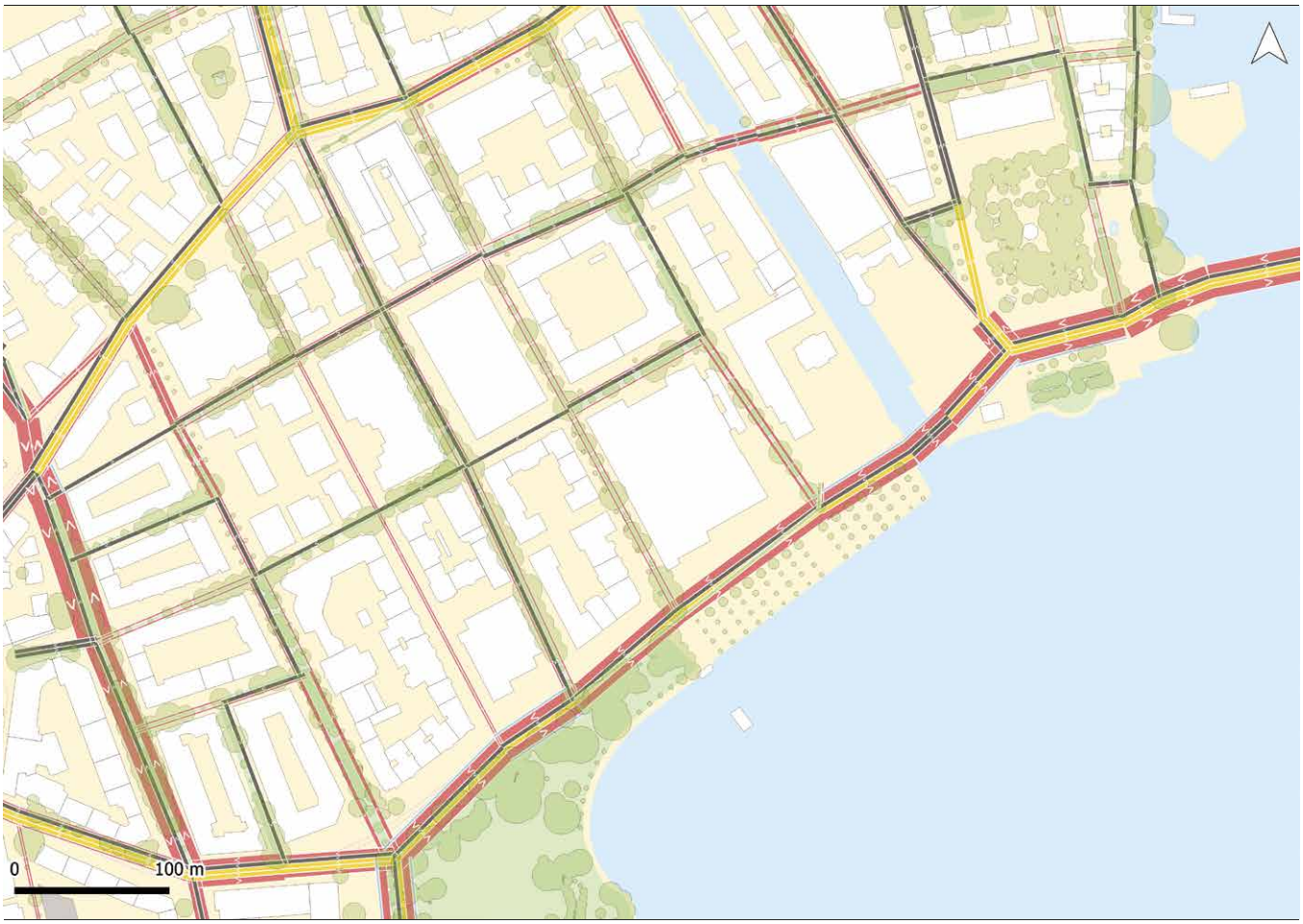
Ballo, L., L. Meyer de Freitas, A. Meister and K.W. Axhausen (2023) The E-Bike City as a radical shift towards zero-emission transport: Sustainable? Equitable? Desirable?, *Journal of Transport Geography*, **111**, 103663.

Axhausen, K.W. (2022) The dilemma of transport policy making and the COVID-19 accelerator, in Attard, M. and C. Mulley (eds.) *Transport and Sustainability, Transport and Pandemic Experiences, Volume 17*, 39–51, Emerald Publishing Limited, Bingley.

Figure 2: Separated cycling paths in intersections (Birchplatz, Zurich)

Figure 3: Cycling facilities on major thoroughfares with limited space (Winterthurerstrasse × Letzistrasse, Zurich)

Figure 4: Excerpt from the E-Bike City Masterplan (General-Guisan-Quai, Zurich)



3.2 Insights on commuting behavior of travelers in the city of Zurich

Mariana de Almeida Costa

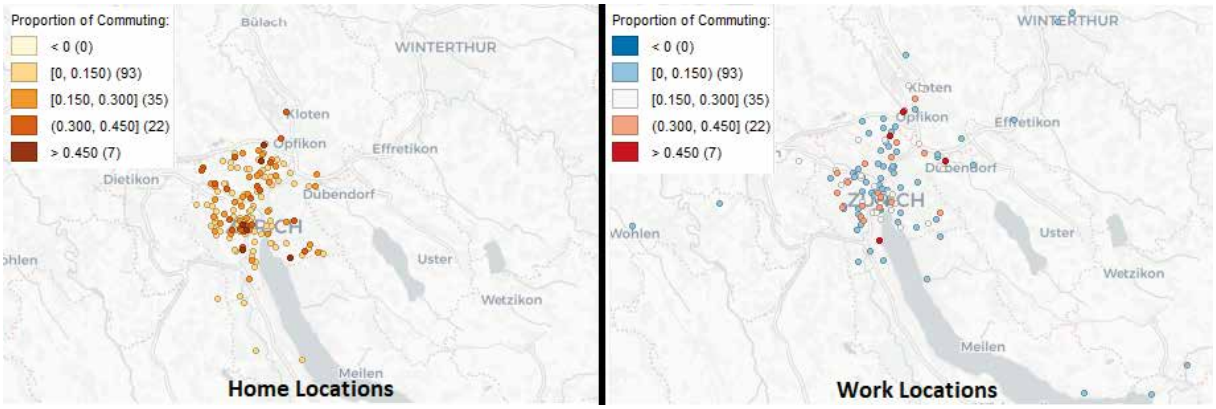
Investigating commuting patterns is key for enhancing urban networks, as they reflect the long-term and usual behaviour of individuals and have a considerable impact on mobility. Studies on commuting provide critical insights into how individuals move within and between environments, with significant implications for urban planning and transportation infrastructure. While high-quality public transportation (PT) links to employment centres have been shown to encourage switches away from car commuting, operators must identify opportunities to keep PT an attractive alternative. On the other side, car commuting has implications beyond road traffic congestion and high emissions: it also has spatial implications on urban centres by reducing walkability, transit accessibility, and community interactions.

In this work, we investigate the repeatability and patterns of demand for public and private transport users commuting between home and work. We propose an unsupervised approach to distinguish between commuting and non-commuting trips, and measure the regularity of the individual commuting travel behaviour. The research context is developed by using travel diaries collected by a smartphone application called *ETH-IVT Travel Diary* consisting of 6838 trips of 172 users in the city of Zurich (Switzerland). The application allowed (continuous) passive tracking, and activities, trips and modes were identified through a mode detection algorithm by Marra et al. (2019). This type of passive tracking requires imputation of the location labels where activities are performed. For that purpose, we used the unsupervised clustering method DBSCAN, which groups activity locations together based on the GPS coordinates along with some other parameters. Following one of the goals of this study to capture non-standard commuting trips (e.g. night-shifts, unusual departure times, etc.), an additional filter was proposed to include only locations with a minimum weekly visiting frequency of 2 days a week and a minimum activity length of 4 hours. Then, under these conditions, 'home' location was the most visited cluster and 'work' the second most visited, while all other clusters were labelled as 'other'.

After labelling locations, commuting trips from 'home' to 'work' and vice-versa can be studied. Figure 5 shows two panels where each dot is one user coloured according to their commuting proportion. In the left side the dots represent the home locations, and the work locations in the right side. The majority of users has a proportion of commuting trips in the range 10–30%, there is no indication of strong spatial commuting pattern existing in some specific area, although the figure suggests lower proportion of commuting for work locations far from the city centre.

Table 1 summarizes the results obtained for activities and trips by using this clustering strategy. About 16% of the trips are commuting trips, with home-work trips accounting for about 58% of them, indicating some more complex

Figure 5: Proportion of commuting according to home and work locations. Left panel: Home locations, right panel: Work locations.



trip chaining on the work-home trip side. It is interesting to notice that commuting trips, on average, take longer than the average of all trips, whereas work-home trips are, on average, longer than home-work trips.

Table 1: Summary of activities according to chosen clustering strategy.

Total Trips	6692	100.0%
Total Home-Work Trips	625	9.3%
Total Work-Home Trips	436	6.5%
Total Commuting Trips	1061	15.8%
Total Private Trips	2489	37.2%
Total PT Trips	2901	43.3%
Total Mixed Trips	1302	19.5%
Total Commuting Trips – Private	250	23.6%
Total Commuting Trips – PT	632	59.5%
Total Commuting Trips – Mixed	179	16.9%
Avg. Time Trip [minutes]	24.20	-
Avg. Time Home-Work Trip [minutes]	28.82	-
Avg. Time Work-Home Trip [minutes]	30.39	-
Avg. Time Commuting Trip [minutes]	29.46	-

In terms of mode share, figure 6 reveals that users change the mode preference when all trips are considered *vs.* when only commuting trips are considered. While private and mixed profiles seem to dominate over PT trips when all trips and non-commuting trips are considered, this pattern changes to PT dominance when only commuting trips are considered.

A complete assessment of some of those trip characteristics based on descriptive statistics, can be found in Costa et al. (2023). We limit this report to the main findings: (1) commuters have regularity of departure times (most commuting trips are realized within 15 minutes of the average departure time); (2) PT modes are preferred in commuting trips, while private and mixed are preferred in non-commuting trips; (3) line transfer is frequent for PT commuters, with the majority of PT trips having at least one line transfer, whereas non-commuting PT trips are characterized by majority of trips without transfers; (4) only for about 50% of the PT commuters there was at least one trip with an agreement between the lines used in both directions; (5) important differences between the duration of home-work and work-home trips arise in transfer and walking times, with longer times observed for work-home trips.

These analyses show recurrence from the perspective of departure times, mode/line choice, and trip duration, revealing interpersonal variability. However, a goal of our work was to measure intrapersonal variability, i.e. we wanted to measure which level of similarity was realized for each commuter. In other words, how much each user "sticks" to their usual travel choices. For this analysis, a grouping heuristics based on a similarity metric described in Costa et al. (2023) was applied. Figure 7 shows the results of the grouping heuristics in terms of three metrics, namely the total number of trips (orange bar), the average number of trips across all clusters (blue bar), and the size of the largest cluster (maximum number of trips grouped together, red

Figure 6: Mode share

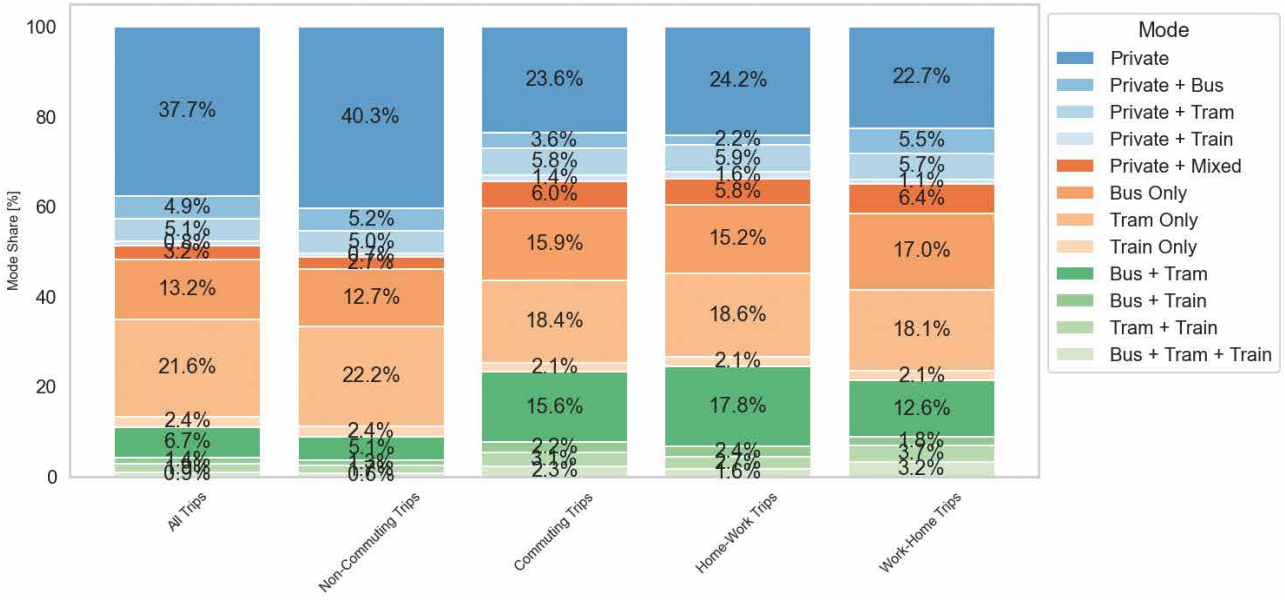
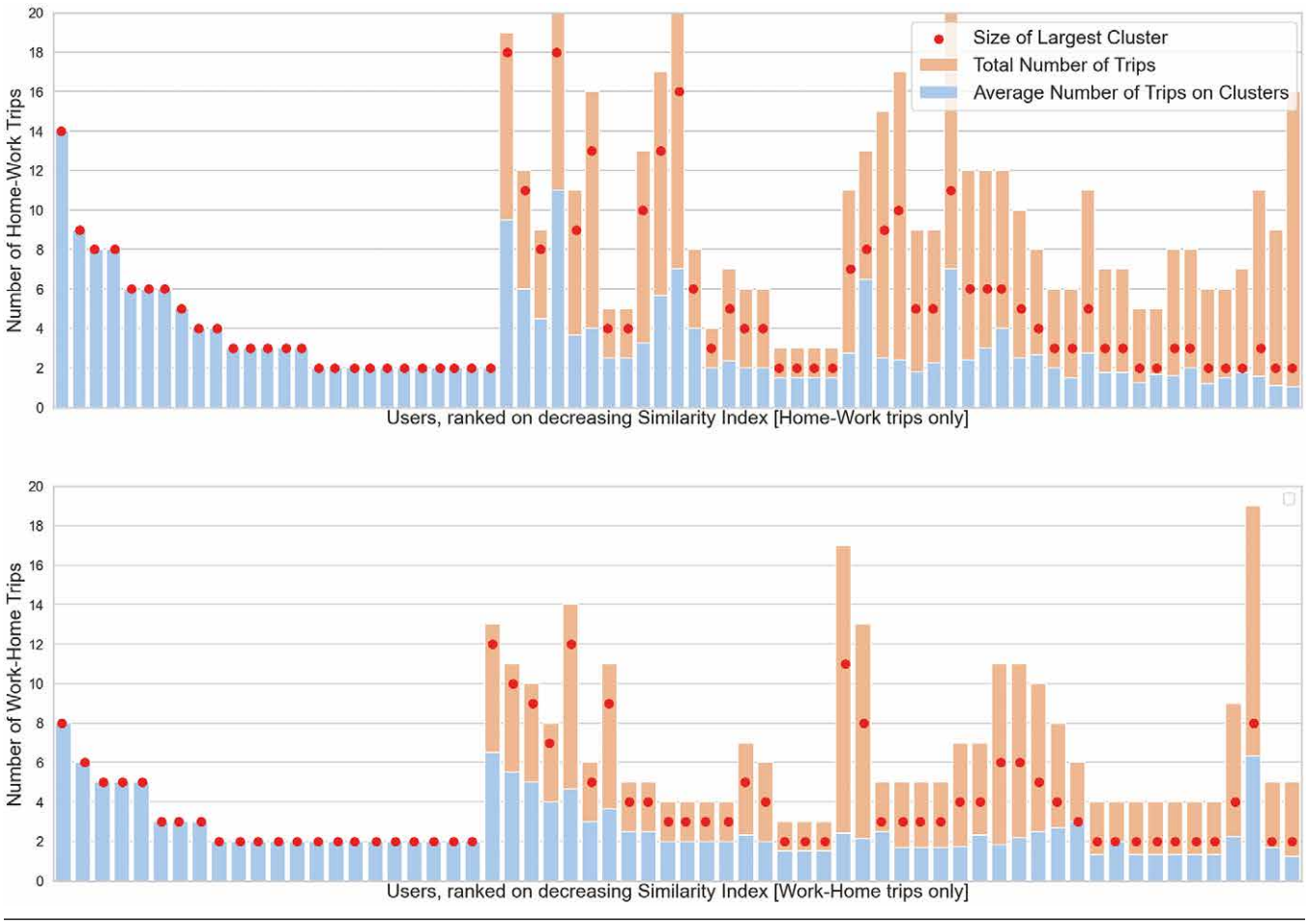


Figure 7: Similarity metrics for users with home-work and work-home trips (orange and blue bars are overlaid)



circle). Each bar represents one user and users are sorted in decreasing order of the similarity metric. Users with only one commuting trip are not plotted nor further analysed.

In Figure 7, the similarity metric corresponds to the size of the largest cluster (red circle) over the total number of trips (orange bar) or, in other words, to the relative position of the red circle with respect to the height of the orange bar. This metric equals one (or 100%) when the orange bars are not visible. The top panel shows the 73 users that had at least two home-work trips considered similar, whereas the lower panel shows the 64 users that had at least two similar work-home trips. In particular, both mean and median values for the similarity metric were high. For users where the orange bars are not visible, 100% of their commuting trips were made with the exact same line(s), and similar duration and departure times. Furthermore, median values exceeding 75% indicate that, for half of the users in home-work and work-home trips, at least 3 out of 4 of their commuting trips belong to their most frequent cluster.

The analyses conducted in this work yield three pivotal conclusions that hold significant potential for assisting policy-makers in delivering better services. The first conclusion is that the majority of users prefer public transport options when traveling between their homes and workplaces. Remarkably, a significant proportion of these commuters demonstrate a willingness to transfer more and utilise mixed modes during their commuting journeys. Additionally, the proportion of commuters using PT decreases noticeably for work locations situated farther away in the city. These observations strongly suggest that users are inclined to choose PT for their commutes when accessibility and reliability are adequately provided. In contrast to commuting trips, the mode share for non-commuting trips predominantly favours private modes of transportation.

The second main conclusion highlights the disparities observed between home-work and work-home trips in PT, where differences in walking times and transfer times indicate that the experience of commuters may differ depending

on the direction of their journey, with work-home trips exhibiting greater walking and transfer times and higher variability of departure times. Additionally, work-home trips were found to be less frequent than home-work trips, and for PT trips, there was limited agreement between the lines used for home-work and work-home journeys, suggesting a higher level of complexity in trip planning.

Finally, the third conclusion reveals that users exhibit consistency in their route choices for commuting trips. The proposed similarity metric demonstrates that a median of users has at least 3 out of 4 trips that can be considered equivalent from a route choice perspective. Understanding and leveraging this regularity can assist policymakers and service providers in several ways, for example, by allocating resources efficiently, optimizing schedules, and enhancing the overall travel experience for most users. Furthermore, these conclusions highlight the importance of ensuring accessibility, reliability, and convenience in PT options for commuting journeys, and they emphasize the need for policymakers to explore strategies that incentivize the use of PT modes in non-commuting scenarios to achieve a more balanced and sustainable transportation system.

References

Costa, M.A., A.D. Marra and F. Corman (2023) Public transport commuting analytics: A longitudinal study based on GPS tracking and unsupervised learning, *Data Science for Transportation,* **5** (3) 15.

Marra, A.D., H. Becker, K. W. Axhausen and F. Corman (2019) Developing a passive GPS tracking system to study long-term travel behavior, *Transportation Research Part C: Emerging Technologies,* **104**, 348–368.

3.3 Towards bicycle traffic flow modeling

Ying-Chuan Ni

This study envisions that cycling is one of the primary transport modes in an urban road network. A large amount of road space is allocated to bicycles to provide cyclists with a safe and efficient environment. Therefore, road networks need to be examined and redesigned to meet the growing cycling demand so that bicycle traffic congestion can be prevented despite the less road space occupancy of bicycles compared to cars.

However, traffic and transport modeling approaches nowadays often model the travel time of cycling based on assumptions and ignore its congestion dynamics. In the practical field, it has been regarded as a transport option for travelers but not yet a traffic mode. To the best of the author's knowledge, Paulsen and Nagel (2019) is the first research attempt to consider the congestion effect of bicycle traffic for the route choice problem of a bicycle traffic assignment model. Still, a universal understanding of bicycle traffic flow characteristics is lacking. Bicycle traffic dynamics at the corridor- or network-level influenced by traffic signal control in the urban context also has not been discussed before.

For decades, research related to car traffic management has been using the fundamental diagram (FD) and macroscopic fundamental diagram (MFD) to describe its traffic states. However, the shapes of bicycle flow FDs and MFDs in various conditions are not completely explored, which makes it rather difficult to facilitate further research related to bicycle traffic management. Therefore, this study aims to derive functional forms for bicycle FDs and MFDs.

Nevertheless, the scarcity of empirical data on bicycle flow has long been a problem. Due to the lack of empirical data, microscopic traffic simulation is a comparatively reliable method to study bicycle flow performance. The bicycle simulation function in PTV Vissim (PTV Group, 2023) is selected considering its ability to simulate non-lane-based bicycle flow. The parameter values calibrated in Kaths et al. (2021) are applied.

In the simulation environment, bike lanes with and without a narrowing bottleneck are simulated to compute traffic states on bicycle flow FDs. bike lane corridors are also created to generate bicycle flow MFDs. To derive functional form FDs, a curve-fitting approach is adopted. Wu's FD (Wu, 2002) is chosen as the basis for the function considering the similarity

Figure 8: Simulated bicycle flow FDs of lane width (a) 1.5 m (b) 2 m (c) 2.5 m and functional form bicycle flow FDs of lane width (d) 1.5 m (e) 2 m (f) 2.5 m

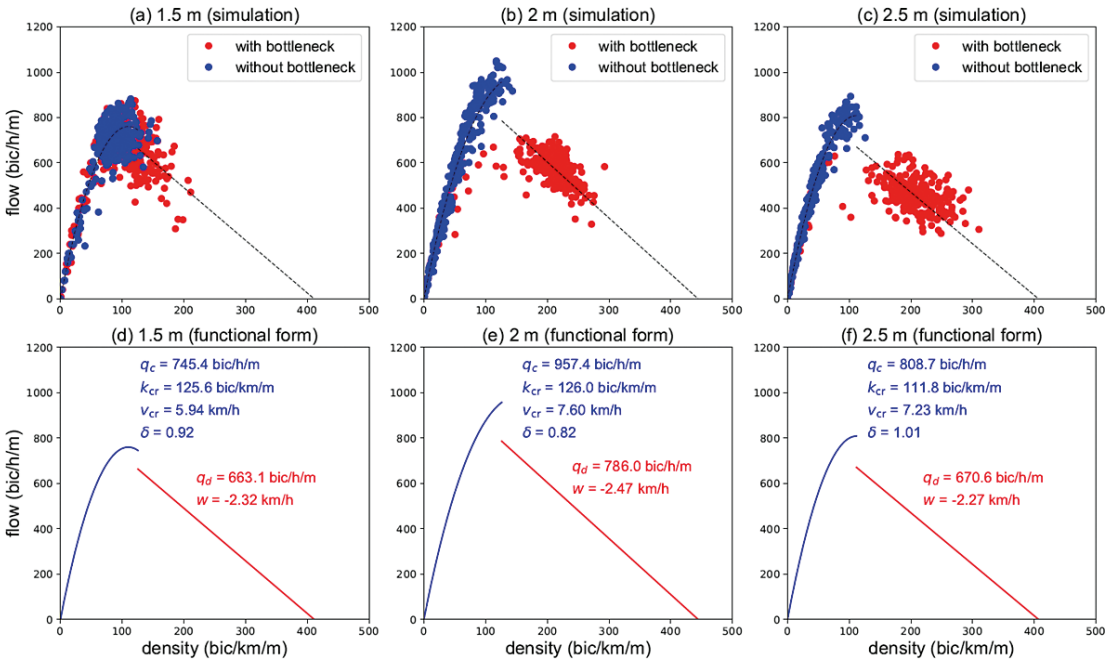
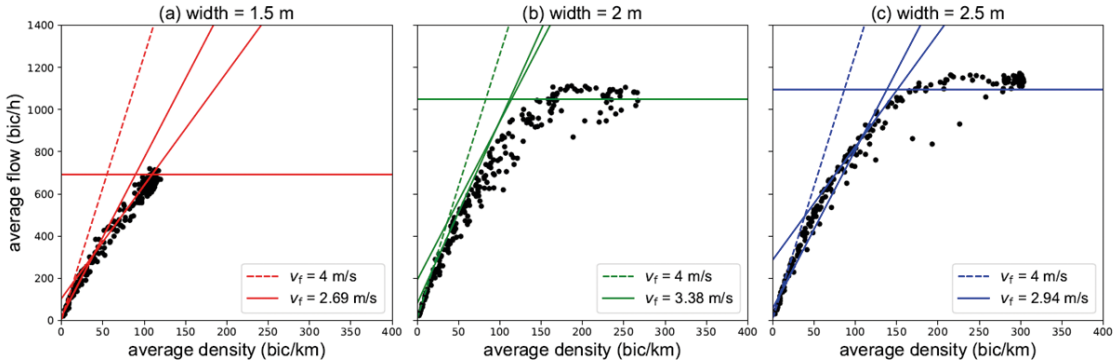


Figure 9: Free-flow and saturated MFD cuts in scenarios with lane width (a) 1.5 m (b) 2 m (c) 2.5 m



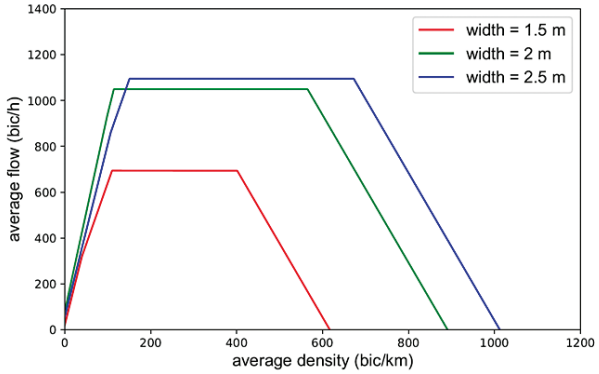
between the lane-changing behavior in multi-lane traffic and the overtaking maneuver in non-lane-based traffic. The functional form MFDs are derived using the variational theory (VT) method (Leclercq and Geroliminis, 2013). The functional form MFD would then be a piece-wise linear function formulated by a number of cuts on the flow-density plane.

The effect of several factors which influence the bicycle traffic flow performance, including lane width, overtaking incentive, and heterogeneity of the desired longitudinal speed, is investigated. The results of bicycle flow in scenarios with different lane widths are presented here. Figure 8 shows the simulated bicycle flow FDs and their fitted functional forms. The validity of the adopted theoretical MFD estimation approach is demonstrated in figure 9, while figure 10 compares the full MFD envelopes of bike lane corridors in scenarios with different widths.

The findings and methodological contribution in this study can serve as a preliminary exploration for bicycle flow from a traffic engineering perspective and pave the way for in-depth research regarding large-scale macroscopic bicycle traffic modeling in the future.

It is also worth noting that the results in this study may be affected by the parameter selection and the inaccuracy of the model in replicating the bicycle flow performance in high density conditions in the real-world. As mentioned in Ton et al. (2022), there is still no microscopic simulation model for bicycles which is ready to be applied to a wide variety of scenarios. Developing a microsimulation model which can better represent realistic bicycle movements should be an ongoing research endeavor. Empirical bicycle flow data which covers every traffic density regime is still required to provide insights into the cycling behavior in various conditions and aid the development of bicycle flow models.

Figure 10: Analytical bicycle flow MFD envelopes of scenarios with different lane widths



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3.4 BostonWalks study

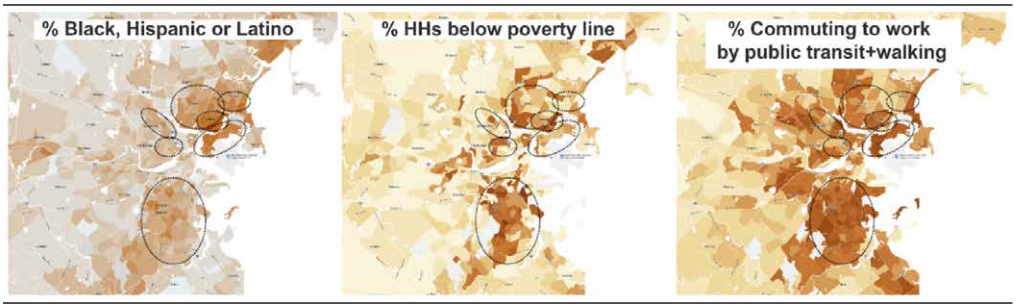
Adrian Meister
with Professor Andres Sevtsuk, City Form Lab, MIT

Transportation research and practice have inordinately focused on planning for automobiles and historically privileged demographic groups. Only in recent years has non-auto mobility, particularly active and public transport, started gaining traction in mainstream mobility research in the U.S. as a key pathway to reducing urban energy demand and CO_2 emissions. The City of Boston, for instance, has committed to reducing drive alone to work rates by 50% and increasing transit use by 33% by 2030, prompting a need for new timely research for meeting such goals. As in many US cities, race, income, and non-auto mobility are spatially related in Metro Boston, see Figure 11. Moreover, inequitable policies (i.e. redlining, zoning, and the frequent siting of freeways through minority neighborhoods) have resulted in residents of color (especially Black and Hispanic) facing disproportionate exposure to air pollution and pedestrian fatalities. Since the pandemic, we are witnessing a stronger drive from local municipalities to support equitable non-auto mobility access through fare-free transit pilots, dedicated bus/bike lanes, and pedestrian shared-street pilots.

A critical barrier for research and practice to address those problems is a lack of observed travel behavior data. Existing data sources fall short w.r.t. to richness and extent. No currently available data source for Metro Boston includes post-pandemic behavior as well as the recent uptake of active and shared mobility products and services. The last data collection efforts from the MPO dates from 2011 using phone-assisted interviews. While this method is widely used by most regional and national transport agencies, the corresponding research field has shifted to fully automated travel diaries based on smartphone GPS-localization. These type of data, i.e. GPS-recorded movement patterns, have much higher information contents and allow for much wider variety of analysis and integration into sophisticated transport planning frameworks. Furthermore, existing travel behavior data, including those for the Metro Boston area, typically either focus on commute trips (less than a third of all daily trips) or on a general (not race- or income-specific) 'representative' sample, which can conceal the specific needs and preferences of certain demographic groups.

The BostonWalks study aims to collect data on walking behavior of the population. The study uses a smartphone tracking app to uncover how and where respondents move through the city. The data of around 2,000 participants will help to better understand the walking behavior of the population and to derive important policy changes to make Boston more livable and equitable.

Figure 11: Race/ethnicity, income, and non-auto commute mode in Metro Boston (within I-95)

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4 Teaching

4.1 Degree programmes with IVT participation

The IVT contributes to a number of degree programmes of the department and across the school. We will introduce the main commitments below, excluding the BSc in Environmental Science, the MSc in Applied Mathematics or the BSc in Geography of the University of Zurich.
ETH has adopted the BSc/MSc system initiated by the Bologna – Treaty. The 6-semester BSc provides the student with the foundation to continue his or her education at ETH, where he/she can continue automatically, or elsewhere. ETH does not consider this degree to be a fully professional qualification.

4.1.1 Bachelor Civil Engineering

The BSc course starts with foundation courses in mathematics, mechanics, geology, systems engineering, management and surveying in the first year. A small group project gives the student a first idea of the professional questions and the challenges of teamwork. A comprehensive set of exams, which needs to be passed jointly, is scheduled for the summer of the first year.
The second and third year allow the student to add depth to his/her understanding and to prepare the student for his/her master's degree. Courses in physics, hydraulics, structural mechanics, materials, computer science are complemented with civil engineering courses in structural engineering, geotechnics, hydraulic engineering and construction management. The IVT offers a sequence of three courses introducing transport planning, traffic engineering and railway operations.

4.1.2 Bachelor in Geospatial Engineering

This BSc course offers the basis for a career in either geomatics or planning, including transportation engineering. It began in the academic year 2018/19 building on the earlier geomatics and planning BSc. In contrast to the previous course it allows the students more choices and requires them to engage more with statistics, machine learning and computing.
The IVT now offers a sequence of five courses introducing transport planning, traffic engineering and railways operations, of which only one introductory course on transport is compulsory for all of the students of this degree. Nevertheless, if chosen, the remaining four courses offer a better preparation for the students of the master's courses. The courses here and across the whole degree will coordinate the teaching of computing to make sure, that our students are well prepared for their future.

4.1.3 Master in Civil Engineering

The MSc in Civil Engineering offers the student the option to choose two from six specialisations:

- Construction management
- Structural engineering
- Geotechnics
- Transport systems
- Hydraulic engineering
- Materials and mechanics

A rich set of courses gives the student the possibility to define his or her course. A major project in the third term trains independent professional work, while the four month MSc thesis focuses on the scientific aspect of the training.

4.1.4 Master in Spatial Development and Infrastructure Systems

This specialised MSc course is open to students from across the engineering and quantitative social sciences and aims to give them a common language and understanding of these two fields through three required courses and the joint professional team project in the third term, which addresses current large-scale planning issues.
The courses are offered mainly by our institute and the Institute of Spatial Development, but the students can and are encouraged to take classes from the wide ranging list of approved electives from architecture, economics, mathematics and statistics.
The students can choose to focus on either area, spatial development or transport engineering, or mix them to create a unique profile for themselves.

4.2 IVT courses

Course	Course number	Lecturers	Assistants
Active Mobility This course is about basics of pedestrian transport planning and planning of cycle traffic facilities, transport-related attributes of the human being, design of pedestrian and cycle traffic networks, pedestrian and cycle traffic facilities, microsimulation of pedestrian flows, and assessment of performance and level of service.	**101-0488-01L** Credits (ECTS): 6	Walter, Bosina, Meeder	Spanninger, Klasovita
Agent Based Modeling in Transportation This course provides an introduction to agent-based modeling in transportation. The lectures and exercises offer an opportunity to learn about agent-based models' current methodology, focusing on MATSim, how agent-based models are set up, and perform a practical case study by working in teams.	**101-0491-00L** Credits (ECTS): 6	Balac	Kagho
Basics of Java and Best Practices for Scientific Computing This course provides an introduction to programming in Java, version control, and cloud computing.	**101-0491-10L** Credits (ECTS): 1	Balac	(none)
Basics of RE&IS The course Basics of RE&IS provides essential skills and knowledge for the Master's degree program in Spatial Development & Infrastructure Systems. Students will know the basics of scientific writing with complementary use of human and artificial intelligence. Students will learn how to search for scientific literature, create graphs, and give a presentation while writing a literature review.	**103-0377-10L** Credits (ECTS): 3	Sailer, Corman, Kaufmann	Trepat
Doctoral Seminar: Data Science and Machine Learning in Civil, Env. and Geospatial Engineering Current research in machine learning and data science within the research fields of the department. The goal is to learn about current research projects at our department, to strengthen our expertise and collaboration with respect to data-driven models and methods, to provide a platform where research challenges can be discussed, and also to practice scientific presentations.	**101-0522-10** Credits (ECTS): 1	Ntertimani, Chatzi, Corman, Hajnsek, Kraus, Lukovic, Schindler, Soja, Van Strien	(none)
ETH Global Development Summer School The ETH Global Development Summer School provides young researchers with the opportunity to work on current and sustainability-related topics in interdisciplinary and intercultural teams. Focus is given not only to teaching theoretical knowledge but also to solving specific case studies.	**851-0655-00** Credits (ECTS): 3	Rom, Krütli, Makridis, Mertens	(none)

Course	Course number	Lecturers	Assistants
Frontiers in Machine Learning Applied to Civil, Env. and Geospatial Engineering This doctoral seminar organised by the D-BAUG platform on data science and machine learning aims at discussing recent research papers in the field of machine learning and analyzing the transferability/adaptability of the proposed approaches to applications in the field of civil and environmental engineering (if possible and applicable, also implementing the adapted algorithms).	101-0523-14 Credits (ECTS): 1	Van Strien, Chatzi, Corman, Hajnsek, Kraus, Vasileios, Lukovic, Schindler, Soja	(none)
Highway Geometric Design and Engineering Knowledge and application of the bases and connections of the geometric highway design. Identification of construction risks; Road construction an dimensioning incl. drainage systems; Principles and certification of safety and serviceability.	101-0428-00L Credits (ECTS): 6	Müller	(none)
Laboratory Transport and Spatial Planning This laboratory applies main transport planning methods based on land use types and patterns. Using a small scale case study, students implement a four-stage travel demand model based on real-world data and propose scenarios for improvements of transport and land use infrastructure.	101-0408-00L Credits (ECTS): 3	Vitins	Meyer de Freitas
Logistics and Freight Transportation Basics and concepts of logistics and freight transportation; Infrastructure and production processes of different transport systems (rail, road, intermodal, waterborne, and air); Interconnections between logistics requirements, market, transport services, operational processes, transport means and regulation in freight transport of all transport systems; Quantitative methods for solving practical logistics problems including cargo loading, facility location, network design and flow problems.	101-0459-00L Credits (ECTS): 6	Corman, de Almeida Costa	Jusup
Microscopic Modelling and Simulation of Traffic Operations The course introduces the basics of microscopic modelling and simulation of traffic operations, including model design and development, calibration, validation, data analysis, identification of strategies for improving traffic flow performance, and evaluation of such strategies. The aim is to provide the fundamentals for building a realistic traffic-engineering project from beginning to end.	101-0492-00L Credits (ECTS): 3	Makridis	(none)
Public Transport and Railways Teaches the basic principles of public transport network and topology design, to understand the main characteristics and differences of public transport networks, based on buses, railways, or other technologies.	101-0415-01 Credits (ECTS): 3	Corman	Trepat

Course	Course number	Lecturers	Assistants
Public Transport Design and Operations This course aims at analyzing, designing, improving public transport systems, as part of the overall transport system. Goal of the class is to understand the main characteristics and differences of public transport networks, their various performance criteria based on various perspective and stakeholders, and the most relevant decision making problems in a planning, tactical, and operational point of view.	101-0427-01 Credits (ECTS): 6	Corman	Yan, Fuchs, Martin-Iradi
Railway Infrastructures 1 Introduction in rail infrastructures, interoperability and technical standards, network development, infrastructure planning, design of rail infrastructures, planning and design of railway stations, introduction to rail technology, innovation of the rail system, beginning commissioning of rail infrastructures, strategies for cost optimization, operational aspects of maintenance.	101-0419-01L Credits (ECTS): 2	Weidmann	(none)
Railway Infrastructures 2 Track geometry including calculation and measuring as well as related data systems; clearance profiles; interaction between track and vehicles, vehicle dynamics, stress; track construction including special features of railway bridges and tunnels; environmental aspects in track construction; track diagnostics and forcast; track maintenance and related methods	101-0419-02L Credits (ECTS): 2	Weidmann, Güldenapfel, Kohler, Manhart	(none)
Readings in Transport Policy This course explores the issues and constraints of transport policy through the joint readings of a set of relevant papers. The class meets every three weeks to discuss the texts and the summaries written by the students.	101-0481-00L Credits (ECTS): 3	Axhausen, Meyer de Freytas	(none)
Risk Center Seminar Series This course is a mixture between a seminar primarily for PhD and postdoc students and a colloquium involving invited speakers. It consists of presentations and subsequent discussions in the area of modeling complex socio-economic systems and crises.	364-1058-00L Credits (ECTS): 0	Schernberg, Basin, Bommier, Bresch, Brusoni, Cederman, Cheridito, Corman, Gersbach, Hölscher, Paterson, Sansavini, Stojadinovic, Sudret, Teichmann, Wattenhofer, Wiemer, Zenklusen	
Road Safety The collection and the methods of statistical and geographical analysis of road accidents are important fundamentals of this course. Safety aspects in design of urban roads are discussed and measures for improving the safety situation are presented. Procedures of infrastructure safety management for administrations and police are another topic.	101-0469-00L Credits (ECTS): 6	Deublein, Eberling	(none)

Course	Course number	Lecturers	Assistants
Road Transport Systems The course covers road transportation technologies, network design, traffic flow theory, operations of private and public transport, management and control of intelligent transportation systems. This course gives the students an overview of topics involved in road transport systems and provides the background for Master's degree study.	101-0416-10L Credits (ECTS): 3	Makridis, Ambühl	Chavoshi Boroujeni
Survey Methods and Discrete Choice Analysis Comprehensive introduction to survey methods in transport planning and modeling of travel behavior, using advanced discrete choice models.	101-0478-00 Credits (ECTS): 6	Schmid	(none)
Traffic Engineering The course covers fundamentals of traffic flow theory and control, and it includes understanding of traffic data collection and processing techniques, as well as data analysis, traffic modeling, and methodologies for traffic control.	101-0437-00L Credits (ECTS): 6	Kouvelas	Chavoshi Boroujeni
Transport Basics Introduction to the fundamentals of transportation, developing an understanding of the interactions between land use and transportation, and introduction to the dynamics of transport systems, mainly daily patterns and historical developments.	103-0414-10 Credits (ECTS): 4	Makridis, Axhausen, Corman, Nold	Meyer de Freitas, Sun
Transport Planning (Transportation I) The lecture course discusses the basic concepts, approaches and methods of transport planning in both their theoretical and practical contexts. The course introduces the basic theories and methods of transport planning.	101-0414-00L Credits (ECTS): 3	Axhausen	Ballo
Transport Planning Methods The course communicates knowledge of methods and algorithms commonly used in transport planning. The students gain ability to independently develop a transport model.	101-0417-00L Credits (ECTS): 6	Axhausen	Meyer de Freitas
Transport Systems Introduction of the basic principles of the design and operation of transport systems (road, rail, air) and of the essential pathways of their impacts (investment, generalised costs, accessibilities, external effects), referring to relatively constant, and factors with substantial future uncertainty, in the past and expected evolution of transport systems.	101-0467-01L Credits (ECTS): 6	Axhausen, Ambühl, Marra	Meister, Martin-Iradi
Transportation Engineering Lab The goal is to integrate the contents of the lectures of the block "Transportation" through a joint set of exercises which will allow the students to understand how the parts come together in the design of transport systems. The exercise will be based on a Swiss city. The exercises will involve onsite work.	103-0230-00 Credits (ECTS): 6	Axhausen, Corman, Makridis	Fuchs, Sun

4.3 Student theses

Lastname, firstname	Title of thesis	Supervisor(s)
Bachelor's theses, BSc Civil Engineering and Geospatial Engineering		
de Luca, Dario	Potential impacts of automated vehicles: A global overview	Balac
Fuchs, Silvano	Periodic stability in the context of single-track networks	Fuchs
Grüniger, Fabian	Life cycle assessment of passenger cars – Which variables have an impact?	Meister, Axhausen
Raúl, Lara	Descriptive route choice analysis of cyclists in Zurich	Meister, Axhausen
Rhiel, Simon S.	Evalution of route choice models for a Zurich scenario	Meister, Axhausen
Sivakumaran, Sivahari	Navigating the transformative landscape: A comprehensive analysis of shared transportation services in Germany	Heimgartner, Makridis
Diploma theses, Diploma of Advanced Studies in Spatial Planning		
de Gottardi, Alessio	Making space: Regenerative scenarios of street and node transformation in Zurich	Livingston, Axhausen
Master's theses, MSc Civil Engineering and Spatial Development and Infrastructure Systems		
Bender, Joël	Combining line planning and timetabling to ensure equitable connections from origin to destination	Fuchs
Borgeaud, Aurélien	Modeling the different strategies between compliers and non-compliers in reducing CO2 emissions by 30%. Evidence from an MDCEV model.	Heimgartner, Mächler, Axhausen
Bottinelli, Kim	Profitability of using electric bus fleets: A case study of Kyoto	Corman; External supervisors: Schmöcker, Sun (Kyoto University)
Brunner, Johannes	A new microscopic bicycle simulation model considering non-lane-based traffic characteristics	Ni, Makridis, Kouvelas
Grossmann, Henri	Estimating multimodal capacity implications of radical transformations in the road network	Meyer de Freitas, Ambühl, Axhausen
Keller, Lisa	Swiss Metro: Alternative line plans maximising passenger and vehicle efficiency	Fuchs
Masmejan, Samuel	Application of ramp metering for the highway management in Switzerland	Chavoshi, Makridis, Kouvelas

Lastname, firstname	Title of thesis	Supervisor(s)
Matthias, Jan	Can we make it to the end? Combining line planning and timeta-bling to ensure connections	Fuchs
Meier, Fabio	Designing EBC intersections	Ballo, Axhausen
Pfaffen, Jerome	Deciphering movements in Zurich: Understanding trip purpose share with MATSim	de Almeida Costa
Pleisch, Anian	The impact of weather on urban transport demand	Marra
Ruf, Sven	E-Bike City network design	Ballo, Axhausen
Schütze, Till	Simulation of dynamic pricing for station-based bike-sharing systems using MATSim: A case study in Zurich, Switzerland	Balac, Axhausen
Sonnak, Miriam	Evaluation of E-Bike City networks	Balac, Ballo
Tanner, Sandro	Tradable mobility credits for long-distance travel in Europe – Impacts on the modal split between air, rail and car	Corman; External supervisors: Cats, Provoost (TU Delft)
Wu, Wenhui	Developing an adaptive car following model for microscopic simulation	Makridis, Kouvelas

Projects, MSc Civil Engineering and Spatial Development and Infrastructure Systems		
Halipchak, Oleksandr	Generalizing the insights from a Heckman-selection home-office model to the Swiss population	Heimgartner, Axhausen
Livio, Emma	Description of the disruption management process from the operational perspective	Marra
Maanna, Leila	What is micro-mobility? Defining micro-mobility for transport planning & systems by vehicles, users, and use cases	Livingston, Axhausen
Minakaki, Despoina	Description of the disruption management process from the operational perspective	Marra
Rieder, Max	E-Bike Campus	Livingston, Axhausen
Vescovo, Jacopo	Flexible line planning vs. rigid line planning	Klasovitá
Westermann, Katharina	What is micro-mobility? Defining micro-mobility for transport planning & systems by vehicles, users, and use cases	Livingston, Axhausen

5 Doctoral theses

5.1 Ongoing doctoral theses

Ballo, Lukas

Supervisors: Axhausen, Raubal

Rebuilding cities for human-scale mobility
Decarbonization, rapid growth of urban populations and growing equity concerns are urgent challenges for transport in cities. A radical shift towards bicycles, e-bikes, e-mopeds and similar human-scale vehicles is a possible solution, especially since current massive adoption of e-bikes helps overcome many barriers of cycling. In this work, we explore what would happen if we took away 50% of road space now occupied by cars and turned it into dedicated infrastructure for human-scale mobility.

Chavoshi Boroujeni, Kimia

Supervisor: Kouvelas
External examiner: Ferrera (University of Pavia)

Coordinated control for highway networks
The research has two chapters, that correspond to different aspects of traffic on highways. In the first chapter, a control solution to reduce congestion in highway traffic systems is presented. The aim is to produce a control strategy characterized by low computational cost, so that real-time implementation can be attained. The adopted model to describe traffic dynamics is the METANET model. A particular spatio-temporal derivative relationship, describing how control signals (ramp metering and variable speed limits) and disturbances effects propagate along the highway system, is highlighted in the research. This relationship is the basis of a proposition providing the essential tool for relative degree calculation in generic highway systems. Utilizing this proposition, a feedback linearization-based control law is developed. The control design is completed by employing a linear MPC, which allows for complying with the physical constraints. The performance of the proposed method is evaluated by conducting comprehensive simulation studies, also considering a real-world traffic system. The computational costs are analyzed by comparing the developed methodology with a nonlinear MPC-based approach. Simulation evidence confirms that the proposed method can provide satisfactory solutions for coordinating RM and VSL in highway systems. Such solutions are compatible with real-time implementation. The second chapter is devoted to coordination of the connected and automated vehicles traffic. The research suggests a new consensus paradigm, where vehicles have variable influences on the final consensus. These influences are the output of the stationary Nash equilibrium of a modified Karma game for a proportional resource allocation problem. Each agent influence is dependent on the urgency level and Karma value. The research evaluates fairness and general performance of the designed consensus problem.

ElBaklish, Shaimaa

Supervisors: Corman, Makridis

Physics-informed traffic management in intelligent transportation systems
Data-driven methodologies and machine learning offer new opportunities for optimal traffic management strategies but often they lack physical intuition, which creates obstacles towards large-scale deployment and public acceptability. The motivation is to explore physics-informed solutions, combining established knowledge from modeling approaches with the capability of machine learning to capture complex patterns observed in real-world cases. The goal is the development of robust traffic management strategies for highway networks focusing on minimizing the time that users spend in the network and their energy consumption, while homogenizing traffic flows.

Fuchs, Florian

Supervisor: Corman

New approaches for integrated optimal planning for public transport
This PhD project aims to develop tools and techniques for integrated planning and optimisation of public transport systems, focusing on railways. By considering all aspects of the transport system, including lines, timetables, and vehicle schedules, it aims to create a cohesive and efficient system

that meets the needs of all users while also addressing challenges such as declining funding, increasing demand, and the need for reliability, efficiency, and accessibility.

Ghandeharioun, Zahra

Supervisors: Kouvelas, Makridis

Optimization of shared on-demand transportation
The main goal of this research is to optimize on-demand autonomous ride-sharing services. In the scope of this project, an event-based simulator will be developed and different optimization methods will be studied. Furthermore, with the help of the simulator, various ride-sharing strategies will be considered and compared. In the next stages of the research, the results will be integrated with other modes of transport.

Gramsch Calvo, Benjamin

Supervisors: Axhausen, Grêt-Regamey

Socially motivated travel and the micro-dynamics of segregation: Integrating the Schelling model in travel behavior
The problem of segregation has been a recurring topic in the scientific literature as it can have multiple sources and components. One of these components is individual choices. The individual decision to perform leisure activities in a social environment modifies the social composition of said location, attracting similar individuals. The described process can generate segregation patterns that can't be acknowledged through individual decision modelling. This dissertation will propose a destination choice model using a discrete choice approach followed by an agent-based model. Currently, the thesis is in the choice modelling process, in which the main motivations to perform socially motivated travel are disentangled to analyze what are the main characteristics of the social environment when leisure is performed.

Heimgartner, Daniel

Supervisors: Bierlaire (EPFL), Hess (University of Leeds)
External examiners: Bierlaire (EPFL), Hess (University of Leeds)

Towards structural choice modeling – Methods and applications
As part of the project Multimodality in the Swiss New Normal, we investigate the impact of home office on transport demand. The hypothesized causal chain embodies the following adjustment channels: Home office frequency choice, mobility tool ownership choice, and changes in daily activity chains, where the first two will be the focus of the thesis. Understanding the home office frequency is a multi-faceted problem: Who can work from home in the first place? The frequency choice is only observed if access is guaranteed. Therefore, two dimensions need to be estimated simultaneously. On the other hand, mobility tool ownership is expected to be a function of this modeled frequency. Hence, there is a structural relation between the two model components and thus potential error correlation. This thesis discusses the arising difficulties holistically and puts them into the perspective of the current state of art (e.g., the relation to hybrid choice modeling, where the observed choice is conditional on the latent continuous variable). Suitable modeling and simulation techniques are presented with both artificial data and real-world applications.

Jusup, Matej

Supervisors: Corman, Krause

Real-time railway rescheduling under uncertainty using learning algorithms
Railway operations are often affected by unexpected disturbances, causing train delays, which can then propagate through the railway network. This project aims to find real-time rescheduling decisions in case of delays or disruptions that explicitly account for the unfolding of future uncertainty. To this end, we first model train delays and their propagation using random variables or stochastic processes. We then formulate a dynamic stochastic optimization problem for train rescheduling that includes retiming, rerouting, and order-swapping decisions. Finally, we develop a multi-agent reinforcement learning algorithm for efficiently solving this problem. By directly accounting for future uncertainty, our solution approach has the potential to reduce train delays and to advance the state-of-the-art in railway traffic management, which is currently dominated by deterministic models.

Klasovitá, Viera

Supervisor: Corman
External examiner: Zenklusen (IFOR ETH Zurich)

Deterministic and stochastic optimisation approaches in public transport planning problems
This research focuses on using and applying tools from mathematical optimisation to problems in the public transport industry. In particular, we plan to include uncertainties in the optimisation process. We want to determine methods that solve or approximate the problem and compare them

to the solutions obtained from equivalent deterministic problems. Thus, we want to find out whether adding uncertainties to the problem improves the solution or just makes the problem harder to solve.

Lordieck, Jan

Supervisors: Corman, Sansavini

Increasing railway performance in real-life by understanding capacity consumption and improving disruption management

Current disruptions in railway systems lead to capacity losses and affect service quality. The research aims to develop a data-driven decision support tool for dealing with railway disruptions. Using complex system representations and control methods, high-level disruption management strategies should be derived and transformed into microscopic dispatching actions. The final goal is a comprehensive disruption management framework for different types of disruptions.

Meister, Adrian

Supervisor: Axhausen
External examiners: Bierlaire (EPFL),
Sevtsuk (City Form Lab / MIT)

(Another) bicycle revolution?

Cycling is becoming an increasing popular mode of transport in many regions of the world. It is a healthy, quiet and efficient mode of transport. Its advantages show to be of growing importance to counteract several long-term, systematic problems and challenges faced by current urban transport around the globe. The COVID-19 pandemic has generated a surge in global bicycles sales and cycling activity. The goal of this thesis it to shed light on the current and possible future state of cycling in Switzerland. The thesis will review the historical development and evaluate drivers of currently observed cycling behavior. The MOBIS/COVID and TimeUse+ dataset will be used to estimate route and mode choice models which reflect the behavioral adaptions to recent environmental conditions (pandemic, climate change, congestion, technological change). Finally, the choice models will be incorporated into the MATSim environment, which will allow to simulate the cost and benefits of current and planned infrastructure and policy measures around cycling.

Mesaric, Raphael

Supervisor: Axhausen
External examiner: Erath (FHNW)

Change of daily patterns of travel during an epidemic

The COVID-19 pandemic has demonstrated the need for models to accurately simulate and predict the spreading of infectious diseases and to assess the potential impact of policy measures aimed at the containment of the disease. The effectiveness of these measures depends heavily on the everyday behavior of the population and on how people adjust their travel patterns. This thesis analyzes the behavioral changes during the pandemic by applying multiple discrete-continuous extreme value (MDCEV) models on Swiss GPS tracking data. In a second step, the MATSim-EpiSim framework is used to simulate the spread of the COVID-19 pandemic by tracking the interactions of agents and subsequently identifying infections by following their contact network. The model is applied to the trinational region around Basel and calibrated against real world data at different spatial resolutions, with particular attention on spatially varying aspects such as border closures and containment measures. The objective is to assess the suitability of this modeling approach for forecasting the progression of an infectious disease. In addition, the simulation results provide information about the right time to implement measures and therefore have the potential to support the decision-making of the authorities in charge.

Meyer de Freitas, Lucas

Supervisor: Axhausen

Net-zero transport futures: Policies and methods for influencing and assessing behavioral changes

The goal of this doctoral thesis is to first assess the necessary mobility behavioral changes needed to achieve net-zero emissions in the transport sector, given possible technological developments reducing GHG-emissions in the transport sector. In a second step, policy packages are derived that are able to achieve these goals. In this context, a focus is laid on developing behavioral models that account for behavioral changes in face of radical interventions in transport supply, especially the role of personal and environmental attributes for cycling in mode choice models, as well as the modelling of the "new normal". Given that the evaluation of transport supply interventions is strongly focused on reductions of travel times, a final part of this project focuses on developing and applying assessment methodologies that question current ones and put personal wellbeing into focus rather than utility maximization. Here, the differential changes between urban, suburban and countryside residents is highlighted

as well. For a comprehensive analysis of the effects of radical transformations in mobility, activity-based models are employed and adapted to evaluate the changes in daily behavioral patterns of individuals.

Ni,Ying-Chuan

Supervisors: Kouvelas, Makridis

Bi-modal urban traffic modeling, road space allocation, and control

To foster active mobility, more urban road space should be allocated to slow modes. However, the feasibility of such a large-scale road space transformation is questioned due to the possibility of induced traffic congestion. In this research, the traffic flow performance before and after the road space redesign will be assessed using macroscopic fundamental diagrams (MFDs) and MFD-based traffic simulation. In a network with a large volume of cyclists, bicycle traffic congestion is likely to happen. Macroscopic traffic dynamics of bicycle flow has not been studied compared to the research effort car traffic flow has received in past decades. Therefore, studying macroscopic bicycle traffic dynamics and developing models to describe bicycle traffic state is the first crucial step in this research. Afterward, the bi-modal (cars and bicycles) urban traffic system will be developed. The transmission of vehicles and bicycles between corridors is simulated. Urban road space is often not fully utilized by road-users. A simulation-based optimization approach, which incorporates the mentioned simulation model, will be proposed to increase the road space utilization efficiency and hence mitigate the traffic congestion. Dynamic allocation strategies can be designed considering the different trip patterns in the morning and evening peak hours. Network-level urban traffic control strategies, e.g., route guidance and perimeter control, for the traffic performance of both cars and bicycles has not been discussed before. With the help of the developed simulation model for the bi-modal urban traffic system, these novel strategies are interesting future work directions. In addition, bi-modal demand-responsive traffic signal control techniques can be developed to further ensure a good level-of-service in the road network.

Nold, Michael

Supervisor: Corman

Advanced railway network operation by integration of virtual and dynamic coupling

New technologies are going to be soon allowing to couple and decouple trains while driving at operational speeds. This enables completely new operational railway concepts. It has an influence on timetables, network structures, energy consumption, and infrastructure capacity. The goal of this holistic investigation is to work out operational examples of this new technology, also compared with existing railway operational concepts, considering the advantages for operators and passengers.

Riehl; Kevin

Supervisors: Corman, Makridis

Fair and efficient transport systems using non-monetary, economic resource allocation

Conventional traffic management control systems focus on optimizing global objectives such as minimization of travel time or maximizing the throughput of the system. However, the question of fairness enjoyed little attention so far. This doctorate project analyses the interplay between efficiency and fairness, and aims to answer questions like "Are fairness and efficiencies contradicting each other?", "Is there an efficient, optimal level of unfairness?", "How can we trade-off fairness and efficiency when implementing traffic control systems?". Based on lessons learned in economics, game theory, control and resource allocation, we will novel, fair & efficient control algorithms using resource allocation schemes in the realm of traffic management.

Sallard, Aurore

Supervisors: Axhausen, Balać

Bayesian approaches for travel demand generation

In this doctoral thesis, I propose to explore more in depth the potential of Bayesian Networks for travel demand generation, linking population synthesis and activity plan generation in one single step. The methodology will be tested by generating a full-size population of Switzerland. To analyze the results, studies will be conducted about the spatial and temporal transferability of the model. The framework will be expanded towards multi-day activity scheduling and a case study will focus on work-from-home preferences. This doctoral thesis aims to be a contribution towards the development of interpretable, flexible and behaviorally rich travel demand generation models.

Sun, Linghang

Supervisors: Kouvelas, Makridis

Designing anti-fragile large-scale traffic frameworks

Past decades have witnessed an ever-growing traffic volume. This rise in traffic demand has caused more frequent

congestion and traffic accidents. In this research, we propose to adopt the cutting-edge concept of antifragility to tackle such challenges, so that the traffic systems can thrive under growing volatility and randomness. RL algorithms are applied to better induce antifragility regarding traffic control in a cordon-shaped network. The next step of this research would be to adapt and implement the algorithms into a multi-regional setting.

Trepat Borecka, Jacob

Supervisor: Corman
External examiner: Besinovic (TU Dresden)

Optimization and decomposition approaches in large-scale railway transport planning problems
The growth in demand for railway passenger and freight traffic is pushing the utilization of the available infrastructure towards its capacity limits. In this context, several planning and operational problems arise in railway networks, such as the need of optimizing the usage of the existing infrastructure in order to increase the transported demand, the phenomena of power peaks caused by railway traffic, as well as many resource management problems (e.g. rolling stock scheduling, maintenance or shunting). In this thesis, we aim at developing high-quality decision support algorithms to solve large-scale optimization problems to make rail transport systems smarter and ultimately more efficient, i.e. increased capacity, lower costs and increased punctuality. For this, we exploit mathematical optimization, decompositions, heuristic techniques and uncertainty.

Winkler, Caroline

Supervisor: Axhausen
External examiners: Bierlaire (EPFL), Ahrend (TU Berlin)

Measuring and modeling time use patters in Switzerland
This research involves developing a tool for time use, travel, and expenditure behavior data collection. The tool has spent this year in the field to test its components and to proof the study concept as a whole. Now in its main data collection stage, we are aiming at 1,000 study participants who are each to use the app over the course of one month. We will apply these longitudinal GPS and diary data to choice models to investigate how individuals use and value their resources of time and money.

Yan, Tzu-Hao

Supervisor: Corman
External examiner: Chatzi (ETH Zurich)

Optimal scheduling of rail maintenances and inspections
For railway companies, there is an ongoing trend of developing on-board monitoring techniques due to increasing traffic demand and lacking time of performing inspections. This triggers the need for developing novel approaches for scheduling rail inspections and maintenance. Therefore, the aim of this research is to develop an optimization model for the scheduling problem with consideration of various factors, such as life cycle cost, safety, comfort, reliability and accessibility. Particular attention is given to the usage of data acquisition from on-board monitoring sensors.

5.2 Completed dissertations

Kagho, Grace O. (December)

Planning for the future of transport: The role of on-demand mobility services

Supervisors: Axhausen, Balać
External examiners: Osorio (HEC Montréal), Bogenberger (TU Munich)

Today's urgent need for climate change solutions makes it critical to push for more sustainable transport solutions in our cities. Autonomous vehicle technology combined with Mobility on-demand (MoD) services, also known as shared automated vehicles (SAVs), are being considered as a potential way of creating an efficient and sustainable transport system. In particular, ride pooling can combine the benefits of public transport and private vehicles. Agent-based simulation models are extensively used to simulate these systems in order to capture the dynamics between demand and supply. Thus, policies and operational decisions that could directly impact travellers can be modelled and tested to manage travel demand. However, modelling such a system requires rich data and complex strategies that consider the interactions between behavioural parameters and model components that affect the system. This means that there is no perfect simulation approach that can provide a complete model of the real world. Therefore, this dissertation aims to develop and test strategies for effective simulation of on-demand mobility services and to define best practices for using such models, which in turn should enable the creation of useful models that are representative of the real world and valuable for policy planning and forecasting. The studies in this dissertation examine different agent-based simulation strategies for MoD services, addressing issues related to data availability, model richness, decision-making reliability, and the influence of equity policies on MoD simulations.

Schatzmann, Thomas (December)

Measuring change in behavior: Stated choice experiments in transportation

Supervisor: Axhausen
External examiners: Hess (University of Leeds), Hintermann (University of Basel)

This thesis is motivated by the desire to understand how to effectively measure and predict changes of individual mode choice behavior in the realm of transportation. The demand for passenger transport is derived from our travel behavior, which in essence boils down to the choices (to travel) we make and hence inherently links our preferences to behavior. Transport planners not only rely on revealed preference (observed) data to estimate travel demand models but often use stated preference data to do so in response to a fast changing transport environment. Within that context, this thesis employs two key methods in order to investigate how people change their behavior in the light of hypothetical mode choice scenarios: stated choice experiments and choice models. For the purpose of this work, a web-based approach to implement and conduct such experiments was developed. The framework should not only be helpful to researchers and practitioners in the transport planning community, but generally to everyone undertaking stated choice experiments. Each of the chapters in this thesis approached a unique aspect of mode choice by applying those two methods. A first case study examined how choice behavior would change if a long-distance bus service were introduced in Switzerland, competing with cars and public transportation. According to the findings, and given the assumption of a liberalised Swiss transport market, such a service would be difficult establish, but even more to sustain due to an inelastic demand pattern. The bus market share was estimated at around 8.5%, which likely represents an upper bound based on the dense bus stop network assumed. The estimated value of travel time for the bus is similar to the car, but higher than for public transportation, which indicates that the participants prefer the comfort level of the latter over the bus. Furthermore, long-distance buses mainly attract younger individuals who are particularly price-sensitive. The second case study investigated the preferences for the use of urban ridepooling in Hamburg, Germany, exemplified by MOIA, a subsidiary of Volkswagen Group. The key drivers in choosing a ridepooling service like MOIA are primarily travel cost, travel time, trip purpose and distance. While for commutes, in terms of value of travel time, MOIA can not compete with public transport and cars, the results indicated similar values for MOIA and public transport for leisure trips of distances up to 6 km, which can be attributed to comfort-related effects. For longer distances, however, this effect vanished and got compensated by comparatively higher travel costs, leading to increasing values. An important finding for MOIA, as the results support the main use case of MOIA in Hamburg, although only for shorter distances. The last case study delved into the idea of a Tradable Mobility Credit Scheme in the city of Munich, Germany, and how it could help to promote the

shift to more sustainable modes and internalize external costs. On top of the usual (internal) travel costs, a monthly mobility budget in the form of MobilityCoins was hypothetically introduced, which accounted for both the external costs and benefits associated with the modes under consideration. With respect to these coins, the results indicated that respondents showed greater cost sensitivity the lower the remaining budget was and the fewer days they were into a given month. Regarding the values of travel time, the largest variance in the values was observed for cars, presumably induced by higher external costs that were imposed and influenced the perceived overall cost, potentially shifting users away from using it. However, the approach did not allow an investigation into real-world trading of these MobilityCoins in the market.

Spanninger, Thomas (November)

Probabilistic data-driven train delay predictions

Supervisor: Corman
External examiners: Kliewer (FU Berlin),
Palmqvist (Lund University)

Railway systems are a backbone of global transportation, connecting communities and fostering economic growth in a sustainable way. Punctuality is a key railway service quality. As delays can occur due to a number of reasons anyhow, real-time traffic management is crucial to minimize their cascading network consequences. Train delay predictions are central to optimizing traffic flow in real-time and also provide important information for passengers, reducing anxiety. In this thesis a review of train delay prediction methodologies is presented, categorizing approaches into data-driven and event-driven. Analyzing prediction inputs, assumptions, and prediction horizons allows a discussion of the benefits and shortcomings of the diverse approaches. Motivated by the limitations identified in current approaches, this thesis introduces a novel Markov chain-based stochastic model for real-time train delay predictions. Using process time deviations as underlying variable and an elastic state space definition, the proposed model achieves enhanced accuracy. Furthermore, an uncertainty-aware neural network is proposed to incorporate uncertainty within an emerging AI prediction framework for train delays. A temporal dynamic study on prediction performance suggests an exponential decay for the phenomenon-inherent predictability of train delay with increasing prediction horizons.

5.3 Awards and prizes

Axhausen, Kay W.

World Conference on Transport Research (WCTR 2023)
• Transport Policy Prize 2023

Ballo, Lukas

Exchange at the Massachusetts Institute of Technology (MIT)
• ETH Doctorate Mobility Fellowship

Becker, Felix

World Conference on Transport Research (WCTR 2023)
• Transport Policy Prize 2023

Becker, Henrik

World Conference on Transport Research (WCTR 2023)
• Transport Policy Prize 2023

Brunner, Johannes

Schweizerischer Verband der Strassen- und Verkehrsfachleute
• VSS Price

Fuchs, Florian

Schweizerischer Verband der Strassen- und Verkehrsfachleute
• VSS Price

Meister, Adrian

102nd Transportation Research Board Annual Meeting (TRB 2023)
• Outstanding Paper Award

Ni, Ying-Chuan

ASB Meet and Share Event
• Best Presentation Award

Tanner, Sandro

Prix LITRA 2023
• Prix LITRA

Zwick, Felix

European Transport Congress (ETC 2023)
• Friedrich-List-Peis

6 Projects

6.1 Completed projects

Agent-based tracking of disease spread with dynamic models of travel behaviour in a pandemic (NFP78)

Group: VPL
Active from: 05/2020 until: 06/2023
IVT staff: Kagho, Sallard, Penazzi, Balac
Principal investigator: Axhausen
Project partners: FH Nordwestschweiz, Swiss Tropical and Public Health Institute, Gesundsheitsgeographie und Politik ETH

This project aimed to optimize the response to COVID-19 by exploring complex and spatially-heterogeneous policies (Cantons and tri-national regions with border effects and disease import from outside). Moreover, our results should also be relevant for preparedness against other pathogens with pandemic potential. Finally, this project aimed to address a fundamental question in disease modeling: what are the merits and limitations of the 'traditional' equation-based models vs. 'new' agent-based models regarding projection accuracy, parametrization, and computational cost?

Automated driving in road tunnels – Opportunities, risks and ideal routes

Group: SVT
Active from: 03/2022 until: 12/2023
IVT staff: Makridis, Chavoshi
Principal investigators: Kouvelas, Makridis, Amstein + Walthert
Project partners: CETU, ASTRA

Rising traffic numbers and increasingly scarce traffic areas mean that the traffic of the future must become safer and more efficient. What do automated vehicles mean for special infrastructures such as road tunnels in the Swiss national road network? Will this have an impact on safety risks? Will there be new opportunities, and to what extent will technical and operational operations have to adapt to the new situation? Pilot/test routes are needed to enable automated driving. An important prerequisite for initial test applications under real traffic conditions is the identification of ideal routes. The research project is based on the hypothesis: Tunnels on high-performance roads (national roads) are predestined infrastructures for promoting highly and fully automated driving.

Consumption and travel after the smartphone revolution (TimeUse+)

Group: VPL
Active from: 01/2020 until: 12/2023
IVT staff: Winkler, Meister
Principal investigator: Axhausen

The TimeUse+ study was designed to collect data to understand daily patterns in travel, time use, and expenditure behavior. Study participation involved completing an initial questionnaire that collected personal and household level characteristics along with information on mobility tool ownership. Next, participants spent 28 days using the TimeUse+ smartphone application to track their movements, which were then displayed to them as a continuous timeline. Participants were required to validate (i.e., annotate) their passively recorded events with all of the activities performed at each location or during travel. For each activity, some or all of the following attributes had to be validated: duration, social partners, and expenditures. The TimeUse+ app was developed specifically for this project and its tracking capabilities rely on the software development kit from MotionTag (www.motiontag.com). After a successful tracking period, participants completed a final questionnaire that was mainly concerned with long-term expenditure information, and also included questions regarding values, attitudes, and travel preferences. A total of 1,300 individuals participated in the study between July 2022 and February 2023. The data have been archived so that researchers may access the rich, longitudinal time use, travel, and expenditure data. Descriptive results computed by the research team reflect reasonable shares in terms of time and money spent at different locations and during travel. These findings have been summarized in a working paper, as have lessons learned throughout the entire study process, including design considerations, configurations tested, and the data collection protocol. The research team is currently applying the data to investigate a range of topics, from variability in daily travel to time use patterns regarding working from home and leisure.

Interdisciplinary agent-based models for evacuation (SNF 191164)

Group: VPL
Active from: 06/2022 until: 02/2023
Principal investigator: Axhausen
Project partners: Oregon State University, National Technical University of Athens

This project applies an interdisciplinary agent-based model (ABM) of wildfire evacuation to the devastating 2018 wildfire in Mati, Greece, where the second-deadliest wildfire of the 21st century took place. This model integrates the natural hazard system (wildfire propagation) with the sociotechnical response system comprising social (population response) and engineered (transportation network and shelter location) components. The research objective was to investigate the effects on wildfire casualties of the risk area population's decisions about (1) whether to leave and how long to wait (i.e., departure time); (2) what transportation mode to use (e.g., walking or driving); and (3) how fast to travel. Analysis of several evacuation scenarios shows that the absence of children, multi-modal travel, staged evacuation, and increased shelter capacity lead to a more successful wildfire evacuation. These analyses can help emergency managers improve the effectiveness of their communities' wildfire evacuation plans.

Real-time traffic estimation and control in a connected environment (RECCE)

Group: SVT
Active from: 11/2019 until: 10/2023
IVT staff: Chavoshi
Principal investigator: Kouvelas

This project developed integrated control solutions for managing congestion on motorway networks, specifically it focused on co-ordinated ramp metering (RM) and variable speed limits (VSL). The real-time solution involves advanced control methodologies combining feedback linearization and Lyapunov stability. An optimal controller is designed through convex optimization, addressing sensor configurations and potential hardware failures. The online closed-loop system enhances flexibility, accommodating sparse measurements and hardware failures. In a future connected environment with Vehicle-to-X (V2X) technologies, the project anticipates access to different traffic data, considering the increasing presence of autonomous vehicles (AV). Pilots with AVs are ongoing, requiring the integration of V2X and AV data with current traffic models for accurate estimates. The VSL infrastructure in Zurich is recognized for improving safety, reducing emissions, and minimizing delays. The proposed dynamic and automatic control approach aims to enhance efficiency and digitize traffic infrastructure, with plans to implement it at a traffic control center on a Swiss highway.

Scheduling methods for automated railway timetabling improving the efficiency of smartrail (SMARTIES)

Group: TS
Active from: 08/2018 until: 01/2023
IVT staff: Leutwiler
Principal investigator: Corman

Future demand in public transport is prognosticated to increase significantly. To manage the additional demand in transportation the Swiss Federal Railway SBB has launched the SmartRail 4.0 program. In the context of SmartRail 4.0 the capacity of the Swiss railway network shall be increase by up to 30%. Changes in the infrastructure of the network to increase its capacity are generally very expensive and often strongly limited in possibilities. SmartRail 4.0 targets to increase the capacity by means of new technologies. New tracking technologies allow to densify the traffic on the network by precise localization of all trains on the railway network. Densification of the traffic demands accurate and efficient scheduling of all trains over the entire network. In context of this project, mathematical techniques are developed to tackle the very complex problem of railway traffic scheduling. A major challenge in scheduling of the Swiss railway traffic is the size and complexity of the network in combination with a large amount of traffic. New methodologies need to be developed to cope with networks of such complexity and handle the large demand of traffic. ETH Zurich is working together with SBB to develop new algorithmic solution to achieve the ambitious goals of SmartRail 4.0 and shape the public transport of tomorrow in Switzerland.

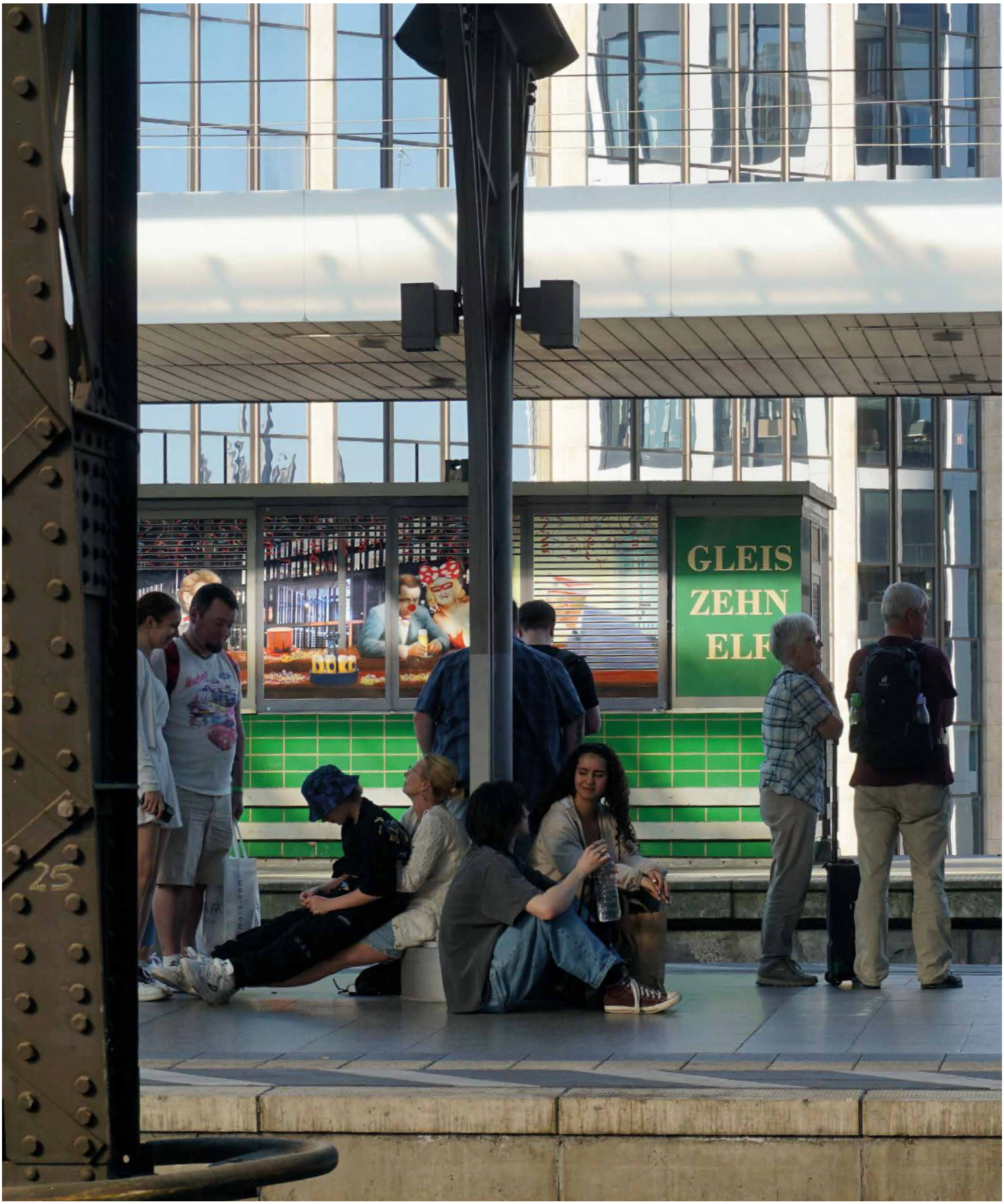
Transcality – Scalable digital transportation twin for cities (PIO-0721-1)

Group: VPL
Active from: 01/2022 until: 06/2023
IVT staff: Ambühl
Principal investigator: Ambühl
Project partner: Transcality

Transcality addresses the challenges in urban environments, like rapid growth, sustainability goals, and constant changes in infrastructure. Our web tool simplifies the task of urban traffic planning by simulating the immediate impacts of construction and other disruptions. This enables city planners to make faster, informed decisions. Our approach streamlines the traditional traffic simulation process, providing a more efficient, reliable, and cost-effective solution for traffic management.

6.2 Ongoing projects

Title	Group	IVT staff	Principal investigators	Project partners	Start
Antifragile optimization of nonlinear large-scale systems (ANTIGONES)	SVT	Kouvelas, Makridis, Sun	Kouvelas, Makridis	Huawei Munich Research Center	10/2022
Dependable ubiquitous automation (NCCR)	TS	Fuchs	Corman		08/2020
Difference-oriented urban planning (DiffUrb)	VPL	Gramsch	Axhausen, Kaufmann, Cattacin, Grêt-Regamey	EPFL	05/2021
Dynamic data driven approaches for stochastic delay propagation avoidance in railways (DADA)	TS	Huang, Jusup, Spanninger, Trivella	Corman		07/2019
Dynamic scheduling of mobile workforce (DYNAMIC)	TS	Corman	Corman		01/2018
E-Bike City: Designing sustainable streets (EBC)	SVT, TS, VPL	Elliot, Moussavi, Ballo, Chavoshi, Fuchs, Livingston, Meister, Meyer de Freitas, Ni	Axhausen, Corman, Makridis	IBI, IfU, IKG, IRL, ETH Zurich and EPFL	07/2022
E-Biking in Switzerland (EBIS)	VPL	Meister, Meyer de Freitas	Axhausen, Hintermann	Motiontag GmbH	05/2022
Learning real-life constraints and objectives to determine timetables optimised for robustness interactively (SORRI)	TS	Fuchs	Corman		06/2023
MOIA – A ridepooling service in Hamburg (DE) (MOIA Hybrid)	VPL	Zwick, Schatzmann	Axhausen	MOIA GmbH	06/2022
Multimodality in the Swiss new normal (SNN)	VPL	Balac, Sallard, Heimgartner	Axhausen	SBB, AMAG, City and Canton of Zurich	10/2021
Passenger-oriented railway traffic management and smart passenger information provision (P-O RTM)	TS	Zhu	Corman		01/2021
Pooling and its behavioral foundations	VPL	Kagho, Balac	Erath, Axhausen		11/2021
Power and energy for the future railways (RailPower)	TS	Nold	Corman		01/2020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7 Conferences and events

Event	Venue	Date	Organizor(s)
IVT Seminar: Redefining transport planning through a transport justice lens	Zurich	February 2023	IVT, ETH Zurich
IVT Seminar: Cycling in Switzerland	Zurich	March 2023	IVT, ETH Zurich
IVT Seminar: Advances in transportation & Mobility planning	Zurich	June 2023	IVT, ETH Zurich
E-Bike City Colloquium	Zurich	June 2023	D-BAUG, ETH Zurich
IVT Seminar: Energy-efficient optimization strategies for electric and connected mobility	Zurich	June 2023	IVT, ETH Zurich
MATSim User Meeting (MUM'23)	Zurich	September 2023	IVT, ETH Zurich
Workshop: Public Transportation – (Low) fares, equity and policy	Zurich	September 2023	IVT, ETH Zurich
11th Symposium of the European Association for Research in Transportation (hEART 2023)	Zurich	September 2023	IVT, ETH Zurich
Risk Center Seminar Series: Insights on propagation of congestion in urban transportation networks	Zurich	November 2023	Risk Center, ETH Zurich
D-BAUG Spotlight Seminar: The future of mobility – The quest for smart and sustainable transportation systems	Zurich	November 2023	D-BAUG, ETH Zurich
IVT Seminar: Complex approaches for resilient transport systems	Zurich	November 2023	IVT, ETH Zurich
IVT Seminar: Parameter identification of commercially implemented ACC systems	Zurich	November 2023	IVT, ETH Zurich
Public dissertation presentation: Uncertainty-aware predictions of train delay in real-time	Zurich	November 2023	IVT, ETH Zurich
Public dissertation presentation: Planning for the future of transport with agent-based modelling: The role of on-demand mobility services	Zurich	December 2023	IVT, ETH Zurich
NSL Colloquium: Transport Planning – Where do we go now?	Zurich	December 2023	NSL and IVT, ETH Zurich


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8 University and professional services

8.1 Academic committees ETH

Organization	Committees	Function	Lastname(s)
D-BAUG	ASB – Association of scientific staff	Co-president	Winkler
D-BAUG	MSc Spatial Development and Infrastructure Systems	Deputy director	Corman
ETH Zurich	CSFM – Centre for Sustainable Future Mobility	Member	Axhausen, Corman, Kouvelas
ETH Zurich	IVT – Institute for Transport Planning and Systems	Deputy	Axhausen
ETH Zurich	IVT – Institute for Transport Planning and Systems	Director	Corman

8.2 Members in advisory commitees

Organization	Committees	Function	Lastname(s)
AIRO-OPTSM – Italian Operation Research Society	Chapter: Optimization in public transport and shared mobility	Member	Corman
ATS – Asian Transport Studies	Advisory board	Member	Axhausen
Big Data Analytics in Transportation	Advisory editor	Member	Axhausen
Internationales Verkehrswesen	Editorial board	Member	Axhausen
IRSE – Institution of Railway Signal Engineers	Scientific committee	Fellow	Corman
JTLU – Journal of Transportation and Land Use	Editorial advisory board	Chair	Axhausen
STRC – Swiss Transport Research Conference	Management committee	Member	Axhausen, Corman, Kouvelas
Transportation	Editor in chief	Chair	Axhausen
Transportation Research A	Editors' advisory board	Member	Axhausen
Travel Behaviour and Society	Editors' advisory board	Member	Axhausen

Organization	Committees	Function	Lastname(s)
TRB – Transportation Research Board	Committee ADB10: Traveler behavior and values	Member	Axhausen
TRB – Transportation Research Board	Committee AED60: Statistical methods	Member	Corman
TRB – Transportation Research Board	Committee AR030: Railroad operating	Member	Corman
UITP – The International Association of Public Transport	Academic network	Chair	Corman
VEHITS – International Conference on Vehicle Technology and Intelligent Transport Systems	Programme committee	Member	Kouvelas
VSS – Schweizerischer Verband der Strassen- und Verkehrsfachleute	Scientific committee	Member	Corman

9 Publications and presentations

9.1 Reviewed journal papers

Ahmed, S.S., F. Corman and P.C. Anastasopoulos (2023) Accounting for unobserved heterogeneity and spatial instability in the analysis of crash injury-severity at highway-rail grade crossings: A random parameters with heterogeneity in the means and variances approach, *Analytic Methods in Accident Research*, **37**, 100250.

Apostolakis, T., M. Makridis, A. Kouvelas and K. Ampountolas (2023) Energy-based assessment and driving behavior of ACC systems and humans inside platoons, *IEEE Transactions on Intelligent Transportation Systems*, **24** (11) 12726–12735.

Ballo, L., L. Meyer de Freitas, A. Meister and K.W. Axhausen (2023) The E-Bike City as a radical shift towards zero-emission transport: Sustainable? Equitable? Desirable?, *Journal of Transport Geography*, **111**, 103663.

Bramich, D.M., M. Menéndez and L. Ambühl (2023) FitFun: A modelling framework for successfully capturing the functional form and noise of observed traffic flow–density–speed relationships, *Transportation Research Part C: Emerging Technologies*, **151**, 104068.

Chavoshi, K., A. Ferrara and A. Kouvelas (2023) A feedback linearization approach for coordinated traffic flow management in highway systems, *Control Engineering Practice*, **139**, 105615.

Ciuffo, B., M. Makridis, V. Padovan, E. Benenati, K. Boriboonsomsin, M.T. Chembakasseril, P. Daras, V. Das, A. Dimou, S. Grammatico, R. Hartanto, M. Hoelscher, Y. Jiang, S. Krilasevic, S. Liu, Q.N. Nguyen Le, C. Rosier, P. Ruan, Z. Wei, G. Wu, X. Zhao and Z. Zhao (2023) Robotic competitions to design future transport systems: The case of JRC AUTOTRAC 2020, *Transportation Research Record*, **2677** (2) 1165–1178.

De Almeida Costa, M., A.D. Marra and F. Corman (2023) Public transport commuting analytics: A longitudinal study based on GPS tracking and unsupervised learning, *Data Science for Transportation*, **5** (3) 15.

Du, Y., M. Makridis, C.M.J. Tampère, A. Kouvelas and W. ShangGuan (2023) Adaptive control with moving actuators at motorway bottlenecks with connected and automated vehicles, *Transportation Research Part C: Emerging Technologies*, **156**, 104319.

Gallo, F., N. Sacco and F. Corman (2023) Network-wide public transport occupancy prediction framework with multiple line interactions, *IEEE Open Journal of Intelligent Transportation Systems*, **4**, 815.

Genser, A., M. Makridis, K. Yang, L. Abmühl, M. Menendez and A. Kouvelas (2023) A traffic signal and loop detector dataset of an urban intersection regulated by a fully actuated signal control system, *Data in Brief*, **48**, 109117.

Ghandeharioun, Z. and A. Kouvelas (2023) Real-time ridesharing operations for on-demand capacitated systems considering dynamic travel time information, *Transportation Research Part C: Emerging Technologies*, **151**, 104115.

Heimgartner, D. and K.W. Axhausen (2023) Modal splits before, during and after the pandemic in Switzerland, *Transportation Research Record*, DOI: 10.1177/0361198123121219.

Hess, J., A. Meister, V.R. Melnikov and K.W. Axhausen (2023) Geographic information system-based model of outdoor thermal comfort: Case study for Zurich, *Transportation Research Record*, **2677** (3) 1465–1480.

Hintermann, B., B. Schoeman, J. Molloy, T. Schatzmann, C. Tchervenkov and K.W. Axhausen (2023) The impact of COVID-19 on mobility choices in Switzerland, *Transportation Research Part A: Policy and Practice*, **169**, 103582.

Hong, Y., H. Martin, Y. Xin, D. Bucher, D.J. Reck, K.W. Axhausen and M. Raubal (2023) Conserved quantities in human mobility: From locations to trips, *Transportation Research Part C: Emerging Technologies*, **146**, 103979.

Hörl, S. and K.W. Axhausen (2023) Relaxation–discretization algorithm for spatially constrained secondary location assignment, *Transportmetrica A: Transport Science*, **19** (2) 1982068.

Huang, P., Z. Li, Y. Zhu, C. Wen and F. Corman (2023) Train traffic control in merging stations: A data-driven approach, *Transportation Research Part C: Emerging Technologies*, **152**, 104155.

Huang, Z., B.P.Y. Loo and K.W. Axhausen (2023) Travel behaviour changes under work-from-home (WFH) arrangements during COVID-19, *Travel Behaviour and Society*, **30**, 202–211.

Iliopoulou, C. and M. Makridis (2023) Critical multi-link disruption identification for public transport networks: A multi-objective optimization framework, *Physica A: Statistical Mechanics and its Applications*, **626**, 129100.

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9.3 Papers in professional magazines

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9.4 Books, published research reports, patents, norms and official guidelines

Meyer de Freitas, L. and S. Blum (2023) High-speed rail in Europe: A review of ex-post evaluations and implications for future network expansion, *Case Study 5*, **MOVE/B1/2018 – 516**, IVT, ETH Zurich and EBP Schweiz, Zurich.

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9.5 Invited contributions in books and proceedings

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9.6 Dissertations

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9.7 Working and conference papers

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Brunner, J., M. Makridis and Y.-C. Ni (2023) An integrated microscopic bicycle simulation model considering non-lane-based traffic characteristics, paper presented at the *23rd Swiss Transport Research Conference (STRC 2023)*, Ascona, May 2023.

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Ni, Y.-C., M. Makridis and A. Kouvelas (2023) Three-dimensional macroscopic fundamental diagrams for dedicated bicycle and car traffic in an actuated signal control network, paper presented at the *23rd Swiss Transport Research Conference (STRC 2023)*, Ascona, May 2023.

Nold, M. and F. Corman (2023) A simulation-based approach for determination of the traction chain efficiency for multiple train trajectories, paper presented at the *23rd Swiss Transport Research Conference (STRC 2023)*, Ascona, May 2023.

Sallard, A. and M. Balać (2023) A comparison between Bayesian networks and statistical matching for travel demand generation, paper presented at the *23rd Swiss Transport Research Conference (STRC 2023)*, Ascona, May 2023.

Schatzmann, T., F. Zwick and K.W. Axhausen (2023) Investigating the preferences for the use of urban ridepooling, *Arbeitsberichte Verkehrs- und Raumplanung*, **1815**, IVT, ETH Zurich, Zurich.

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Winkler, C., A. Meister, U. Isenschmid, K. Lerdo de Tejada Acosta, B.A. Le and K.W. Axhausen (2023) TimeUse+ main study: Data and variable description, *Travel Survey Metadata Series*, **90**, IVT, ETH Zurich, Zurich.

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Yan, T.-H. and F. Corman (2023) Scheduling tamping actions with consideration of drivers' response failures, paper presented at the *23rd Swiss Transport Research Conference (STRC 2023)*, Ascona, May 2023.

9.8 Newspaper contributions, interviews and similar

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Winkler, C. and K. W. Axhausen (2023) How do the Swiss spend their time and money? A longitudinal smartphone diary study with GPS: TimeUse+, *NSL Newsletter*, **58**.

Zheng, S.-T., M. Makridis, A. Kouvelas, R. Jiang and B. Jia (2023) A multi-objective calibration framework for capturing the behavioral patterns of autonomously-driven vehicles, *NSL Newsletter*, **59**.

9.9 Public presentations and other invited talks

Apostolakis, T., M. Makridis, A. Kouvelas and K. Ampountolas (2023) Commercially implemented adaptive cruise control systems are not evil, poster presentation at the *102nd Annual Meeting of the Transportation Research Board (TRB 2023)*, Washington, D.C., January 2023.

Axhausen, K. W. (2023) Could an e-bike (+ walking, transit, scooter) city work?, headline presentation at the *5th Bridging Transportation Researchers Conference (BTR5)*, online, August 2023.

Axhausen, K. W. (2023) E-Bike City und das Dilemma der Verkehrsplanung, presentation at the *62. Deutscher Kongress für Geographie*, Frankfurt am Main, September 2023.

Axhausen, K. W. (2023) E-Bike City: A way out of our planning dilemmas?, keynote presentation at the *Chang'an University International Symposium*, Xi'an, July 2023.

Axhausen, K. W. (2023) E-Bike City: An answer to our transport dead-end?, presentation at the *SUMO User Conference*, Berlin, May 2023.

Axhausen, K. W. (2023) E-Bike City: Verifying a vison, guest lecture at the *University of Sydney*, Sydney, October 2023.

Axhausen, K. W. (2023) GPS travel behaviour survey experiences and future implication, presentation at the *Seminar at Chalmers University*, Gothenburg, September 2023.

Axhausen, K. W. (2023) How many can we track?, presentation at the *Academic Summit Forum on Integrated Transportation and Urban Connectivity*, Shenzen, July 2023.

Axhausen, K. W. (2023) How to model the E-Bike City?, presentation at the *Seminar: From Traffic Modeling to Smart Cities and Digital Democracies*, Zurich, October 2023.

Axhausen, K. W. (2023) How to recruit participants for GPS tracking?, presentation at the *Seminar at Yangzhou University*, Yangzhou, July 2023.

Axhausen, K. W. (2023) Insights for practice from the NFP75, presentation at the *Workshop*, Berne, February 2023.

Axhausen, K. W. (2023) Micro-simulation of travel behaviour and digital cities – MATSim and open-source agent simulation: Recent experiences, presentation at the *Transport Area of Advance – Lunch seminar*, Gothenburg, September 2023.

Axhausen, K. W. (2023) Mobilität für Morgen, presentation at the *Parteien in Baden*, Baden, March 2023.

Axhausen, K. W. (2023) Projekt E-Bike-City, presentation at the *DAV-Personalversammlung*, Zurich, April 2023.

Axhausen, K. W. (2023) What dilemmas are we facing when planning the future public mobility and which transport solutions could play a role the future?, presentation at the *Seminar of the Expert Committee in Public Mobility in Copenhagen*, online, September 2023.

Axhausen, K. W. (2023) Zukunft der Mobilität: Nie wieder Stau?, presentation at the *Treffpunkt Science City*, Zurich, November 2023.

Ballo, L. (2023) E-Bike City: Masterplan for Zurich, webinar at the *Elcykelkommunen – en vej til klimavenlig og sund mobilitet?*, online, December 2023.

Ballo, L. (2023) Modeling transport networks resulting from alternative allocations of road space, poster presentation at the *2023 Symposium of the Center for Sustainable Future Mobility*, Zurich, June 2023.

Ballo, L. (2023) Street designs for an E-Bike City, presentation at the *Brown Bag Seminar*, Zurich, May 2023.

Bernauer, T., K.W. Axhausen, E.K. Smith and F.M. Lichtin (2023) Swiss mobility panel, poster presentation at the *2023 Symposium of the Center for Sustainable Future Mobility*, Zurich, June 2023.

Corman, F. (2023) Power peaks in railway networks: Analytics, modelling and optimization, keynote lecture at the *Seminar: Modelling, Optimization and Analysis of Railway Transport*, Delft, June 2023.

Corman, F. (2023) Sometimes wrong, but useful: Integrating information in public transport., keynote lecture at the *Hot Topic Workshop: Integrated Planning in Public Transport*, Münchweiler, March 2023.

Heimgartner, D., A. Sallard, M. Balać and K.W. Axhausen (2023) Home office frequency and mobility tool ownership choices, poster presentation at the *2023 Symposium of the Center for Sustainable Future Mobility*, Zurich, June 2023.

Livingston, C. (2023) E-Bike City: A vision of sustainable transport, presentation at the *GreenBuzz Thematic Event: Driving Towards Zero Emissions – The Future of Sustainable Mobility*, Zurich, October 2023.

Livingston, C. (2023) Weshalb eine E-Bike-City?, presentation at the *Switzerland's Congress for Light Electric Mobility (SLEM)*, Berne, September 2023.

Makridis, M., A. Laverde Marín, G. Fontaras, M.J. Ramírez Quintana and A. Kouvelas (2023) Autonomous driver identification using vehicle trajectory data, poster presentation at the *102nd Annual Meeting of the Transportation Research Board (TRB 2023)*, Washington, D.C., January 2023.

Meyer de Freitas, L. and K.W. Axhausen (2023) Evaluating mode-shift potentials to cycling based on individual capabilities, poster presentation at the *102nd Annual Meeting of the Transportation Research Board (TRB 2023)*, Washington, D.C., January 2023.

Meyer de Freitas, L. and K.W. Axhausen (2023) Route choice preferences of cyclists in Switzerland: A SP-survey as part of the EBIS project, presentation at the *23rd Swiss Transport Research Conference (STRC 2023)*, Ascona, May 2023.

Ni, Y.-C. (2023) Traffic flow in a bicycle-centric city, presentation at the *ASB Meet & Share Your Research Day*, Zurich, October 2023.

Nold, M. and F. Corman (2023) RailPower – Power and energy for the future railways: Calibrated simulation of railway networks, poster presentation at the *2023 Symposium of the Center for Sustainable Future Mobility*, Zurich, June 2023.

Siam, M.R.K., H. Wang, M.K. Lindell, E. Vlahogianni and K.W. Axhausen (2023) Wildfire preparedness and resilience: Evacuation logistics and household preparation time estimations, poster presentation at the *102nd Annual Meeting of the Transportation Research Board (TRB 2023)*, Washington, D.C., January 2023.

9.10 Software and datasets

Winkler, C., A. Meister, U. Isenschmid, K. Lerdo de Tejada Acosta, B. Schmid and K.W. Axhausen (2023) TimeUse+ main study: Anonymized data, *dataset*, IVT, ETH Zurich, Zurich, Zurich.

Winkler, C., A. Meister, U. Isenschmid, K. Lerdo de Tejada Acosta, B. Schmid and K.W. Axhausen (2023) TimeUse+ main study: Restricted data, *dataset*, IVT, ETH Zurich, Zurich, Zurich.

Winkler, C., A. Meister, U. Isenschmid, K. Lerdo de Tejada Acosta, B. Schmid and K.W. Axhausen (2023) TimeUse+ pretest: Anonymized data, *dataset*, IVT, ETH Zurich, Zurich, Zurich.

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9.11 IVT in the news

Aeberli, M. (2023) Verkehr der Zukunft in Zürich – ETH plant Velo-Stadt voller Einbahnstrassen, *Tages-Anzeiger*, https://www.tagesanzeiger.ch/zuerich-eth-plant-velo-stadt-voller-einbahnstrassen-149015041899.

Baumann, F. (2023) ETH skizziert die Velostadt der Zukunft, *Velojournal*, https://www.velojournal.ch/aktuell/nachrichten/detail/eth-skizziert-die-velostadt-der-zukunft/.

Baumer, M. (2023) Autobahn-Hotspot auf der A1 – Widerstand gegen Acht-Spur-Ausbau im Grauholz wächst, *SRF Rendez-vous*, https://www.srf.ch/news/schweiz/autobahn-hotspot-auf-der-a1-widerstand-gegen-acht-spur-ausbau-im-grauholz-waechst.

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Faust, A. (2023) Bist du fit für die Mikromobilität?, online news, *Blick*, https://www.blick.ch/auto/news_n_trends/mobilitaetsmesse-e-nova-unterwegs-mit-e-bike-und-co-bist-du-fit-fuer-die-mikromobilitaet-id18710121.html.

Holler, D. (2023) Wie könnte eine E-Bike Stadt aussehen?, webpage, *oekonews.at*, https://www.oekonews.at/?mdoc_id=1184929.

Joller, S. (2023) E-Bike – Die Schweiz baut um, *SRF Wissen*, https://www.srf.ch/wissen/mobilitaet/mobilitaet-im-wandel-e-bike-die-schweiz-baut-um.

Meyer, F. (2023) Beim Blick beginnt's. Wie ETH-Forschende zur nachhaltigen Campusmobilität beitragen, webpage, *ETH Staffnet*, https://ethz.ch/staffnet/de/news-und-veranstaltungen/intern-aktuell/archiv/2023/06/beim-blick-beginnts-wie-eth-forschende-zur-nachhaltigen-campusmobilitaet-beitragen.html.

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Mickein, I. (2023) Meet Professor Francesco Corman, online news, *D-BAUG News*, https://baug.ethz.ch/en/news-and-events/news/2023/06/meet-professor-francesco-corman.html.

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Studer, R. (2023) Fünf Projekte auf dem Prüfstand, *AUTOMOBIL REVUE*, https://automobilrevue.ch/2023/02/08/fuenf-projekte-auf-dem-pruefstand.

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ZVG (2023) Vortrag von Professor Axhausen, *Rundschau Süd*, April 6, 2023.

10 Personnel and finances

10.1 Staff entry and departure – total number of employees

At the turn of the year 2023 the institute had 43 employees, which is an expression of the strength of our research program.

Found new responsibilities:

Mr Dr Lukas Ambühl, Mr Matteo Felder,
Mr Dr Alexander Genser, Mr Dr Alessio Marra,
Ms Dr Shimaossadat Mousavi, Mr Thomas Schatzmann,
Ms Valerie Willimann, Ms Dr Yongqiu Zhu

Joined the IVT in 2023:

Ms Andrea Bauer MBA, Ms Shaimaa ElBaklish,
Ms Dr Catherine Elliot, Mr Jan Lordieck,
Mr Dr Bernardo Martin Iradi, Mr Kevin Riehl,
Ms Dr Yifan Zhang

Student assistants

Name	Work agreement	Name	Work agreement
Baumann, Raphael	fall	Le Bao, An	spring
Buring, Simon	fall	Lerdo de Tejada, Acosta	spring
Chen, Zixuan	fall	Lotz, Samatha	spring
Fricker, Noëmi	spring	Martl, Escofet	spring
Heinonen, Sanelma Meri	spring	Nelissen, Henrike	spring
Hu, Zhiyuan	fall	Piller, Beatriz	spring
Hurni, Maylis	spring	Schönhari, Anna Michelle	spring
Isenschmid, Ueli	spring	Studerus, Andrea Jolanda	spring

Visitors and sabbatical stays

Role	Name	Affiliation / origin	From / until
Guest Professor	Dr Akbarzadeh, Meisam	University of Technology, Iran	24.04.2023–31.03.2024
Academic guest	Cai, Mengchi	China	01.02.2022–31.01.2023
Exchange student	Falbel, Eduardo	Brazil	23.08.2022–31.07.2023
Academic guest	Gong, Congcong	China	01.02.2022–31.01.2023
Academic guest	Hu, Yue	Tongji University Shanghai, China	01.07.2022–30.06.2023

Role	Name	Affiliation / origin	From / until
Academic guest	Illiopolou, Christina	Greece	01.09.2022 – 31.08.2023
Academic guest	Li, Junyi	Zhejiang University, China	01.10.2023 – 31.07.2024
Guest Professor	Dr Meloni, Carlo	Sapienza University Rome, Italy	15.06.2023 – 15.07.2023
Academic guest	Zhang, Jiarui	China	15.11.2023 – 14.11.2024
Academic guest	Zheng, Liang	China	01.07.2022 – 19.08.2023
Academic guest	Zhou, Qishen	Zhejiang University, China	01.11.2023 – 30.10.2024

10.2 Finances

The annual budget of the IVT was 4.3 mio SFr, of which about 37 % were from third parties.

Still, as before the IVT is drawing on a wide range of sponsors:
- Swiss National Fund (SNF)
- Bundesamt für Energie
- Transport research of the Federal Road Office (ASTRA with VSS and SVI)
- ETH internal grants
- Industry

This broad base of ETH and external funds gives the institute its stability and academic independence. The third party funding creates a substantial number of further posts, which not only conduct research, but benefit the teaching of the IVT.

IVT finances by source

Source	2020	2021	2022	2023	Average 2020–2023
ETH staff budget	2'456'331	2'323'728	2'306'756	2'502'681	2'397'374
ETH operational budget	164'002	105'000	150'953	190'996	152'738
ETH ICT funds	62'083	59'600	59'204	57'840	59'682
Third party funds	3'115'062	1'105'995	1'853'202	1'581'659	1'913'980
Total	5'797'478	3'594'323	4'370'115	4'333'176	4'523'773
Share of third party funds					42.31%

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March 2024

Abstract
This annual report describes the activities of
the Institute for Transport Planning and Systems (IVT)
during the year 2023.