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Introduction

The mobility sector is of paramount importance for a modern society. Economic and societal well-being relies heavily on safe, reliable, affordable, and high-capacity transport infrastructure that guarantees the efficient movement of people and goods at a local, regional, national, and global scale.

However, in Switzerland, mobility accounts for about 40% of the domestic Greenhaus gas (GHG) and even a higher percent of CO₂ emissions. This means that a radical overhaul in terms of energy sources, infrastructure and assets management and planning will be indispensable for maximizing efficiency and achieving sustainability. Moreover, the population is expected to increase and with it the demand for transport services. The decarbonization of the transport system compounded by the needed efficiency increase to adapt to increasing demand, is a key challenge to which ETH Zurich research activities and teaching should contribute to address.

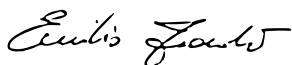
Within this context, we started in July 2021 our path towards establishing a competence center within the ETH Domain that aspires to become a reference in the field. The center addresses a wide variety of interrelated research topics around the transportation system. The center also aims to promote close collaboration with industry and with our strategic partners: SBB, AMAG, and Siemens Mobility as well as to establish and nurture intense dialogue and exchange with governmental institutions.

The establishment of the governance structures was completed this year, including the Advisory Board for the CSFM Digital Twin, that convened for the first time in January 2023. Also, within the framework of the **Digital Twin project**, the center was able secure additional funding and recruit two additional postdoctoral researchers as well as fund one additional collaborator located at the Swiss Data Science Center. Within the **ETH Mobility Initiative** Future Mobility research program five excellent new projects have been approved and started recently or are about to start.

This year the CSFM launched a new **Seminar Series**. The format attracted a variety of new stakeholders, also from outside ETH Zurich, and seems a promising concept worth continuing.

This reporting year also marked the completion of the mid-journey of this first phase of operation, with a formal takeover from the first center chairman, Prof. Kay Axhausen, to Prof. Emilio Frazzoli.

We summarize in this report the major highlights and developments of 2023 and we hope you enjoy the reading of these pages. The management office is always happy to receive suggestions, ideas, and feedback, so please do not hesitate to contact us!



Prof. Emilio Frazzoli
Chair



Dr Gloria Romera
Managing Director

1 CSFM Mission and Strategy

1.1 A center for interdisciplinary research on sustainable mobility at ETH Zurich

The Center for Sustainable Future Mobility (CSFM) consolidates and coordinates research efforts of about 40 research groups within ETH Zurich, Empa, and PSI. The center contributes to addressing the grand challenges of the transport sector and to deliver research-based solutions for the design and implementation of sustainable transport systems which will be safe, reliable, fast, socially desirable, environmentally friendly, and cost-efficient. In particular, the decarbonization of the transport system is a key goal to which the research activities should contribute significantly.

The mission

The Center for Sustainable Future Mobility (CSFM) aims at creating an internationally visible hub for research, education, and knowledge transfer towards the implementation of a sustainable mobility system in close cooperation with the Swiss industry and intense dialogue with the government and relevant policymakers.

Strategy

The CSFM's thematic scope extends beyond multidisciplinary to cross-sectoral functionality, exploiting innovation potentials across all modes and services (road, rail, air, waterborne, low-speed, non-motorized, etc.). Transferring insights, models, and methods from one sector/mode/service to the other and exploiting potential synergies whenever meaningful, can be a powerful tool to achieve system improvement.

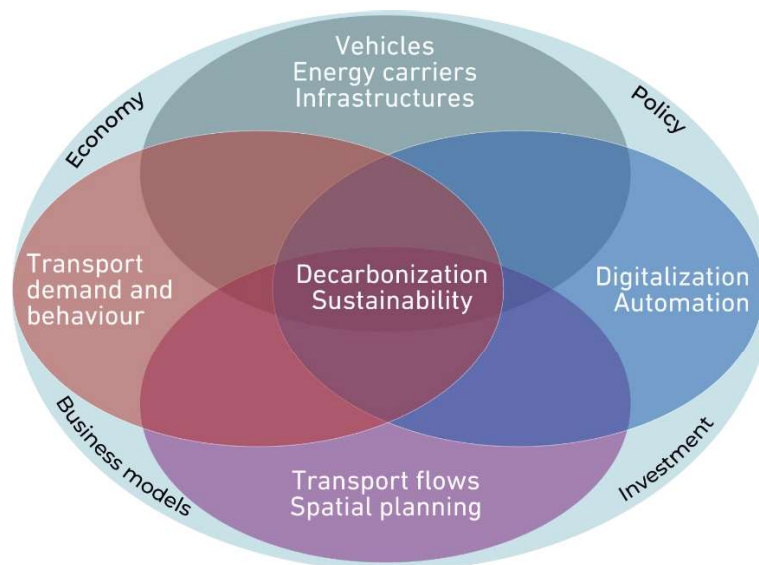


Figure 1: Center for Sustainable Future Mobility (CSFM) research areas

Research on new vehicles and energy carriers as well as the required infrastructure is critical to achieve a more sustainable transportation system and reduce emissions. The increased digitalization of modern society as well as the potential automatization of vehicles represent an opportunity to increase the efficiency of the system, for example, facilitating Mobility as a Service-related solutions. However, it also represents a risk in terms of inducing a higher transportation demand. The way cities and spaces are designed and built also influences the demand side. Research to understand the transportation demand is therefore needed as well.

These areas, as depicted in Figure 1, represent the major thematic blocks we attempt to address. However, transportation is a complex system with multiple interactions between all related socio-economic and policy factors. Major real issues and potential for improvement lay in the intersections between those mentioned thematic areas or overlapping research topics. The role of the center is to connect the different researchers and stakeholders to better address those real issues.

1.2 Organizational Structure and Governance

1.2.1 Steering Committee and Leadership

The Steering Committee is the operational governing body of the center. The members of the Steering Committee are elected by the general assembly for a period of four years. The Steering Committee appoints a chairperson and her/his deputy.

The center is jointly run by the Departments of Civil, Environmental and Geomatic Engineering (D-BAUG) and of Mechanical and Process Engineering (D-MAVT). As initially agreed between the two hosting departments the CSFM's administrative location transitioned from D-BAUG to D-MAVT last July. At the same time, Professor Emilio Frazzoli became the new chairperson of the center. He took over from Professor Kay Axhausen.

Chairperson Professor Emilio Frazzoli

Professor Frazzoli is a member of the Institute for Dynamic Systems and Control (IDSC). His main research interests are in the area of planning and control of mobile robotic systems, with a particular emphasis on autonomous vehicles and transportation networks. In recent years, he has been particularly interested in developing new approaches for smart urban mobility. Together with the CSFM steering committee, he will lead the development of the Center and define its future direction.

Deputy chairperson Professor Martin Raubal

Professor Martin Raubal is the new deputy chairperson. He is a professor of Geoinformation Engineering. He has been involved in the center since its inception as a member of the steering committee. He is also a member of the Future Resilient Systems (FRS) management committee at the Singapore-ETH Centre (SEC). His research interests focus on spatial decision making for sustainability, with an emphasis on mobile geographic information systems and location-based services.

Professor Kay Axhausen, who became chairperson of the center following the formal approval two years ago, has been responsible for getting the center up and running and implementing the proposed organisational structure. An important aspect of these first two years of operation was the integration of the Mobility Initiative into the structure of the new center. Professor Axhausen will retire in 2024. His farewell lecture held on the 7th December 2023, was part of a three-day colloquium hosted by the Network City and Landscape (NSL). We are very grateful for his dedication during this initial phase.

Christian Bach Steering Committee member

Massimo Filippini (D-MTEC) resigned in January 2023 from his duty as Steering Committee representative due to conflicting obligations. The CSFM acknowledges Professor Massimo Filippini for his valuable engagement. The Management Office proposed, at the occasion of the second General Assembly to appoint Christian Bach (APT, EMPA) as a new Steering Committee member, which was unanimously approved. Below is the list of current members of the Steering Committee.



Prof. E. Frazzoli

Dynamic systems and control
(D-MAVT)

Chair from July 2023



Prof. M. Raubal

Geoinformation Engineering
(D-BAUG)

Deputy Chair



Prof. U. Grossner

Advanced Power
Semiconductors (D-ITET)



Prof. A. Patt

Climate Policy (D-USYS)



Christian Bach

Head of the Automotive
Powertrain Technologies
Laboratory (APTL), EMPA



Prof. T. Bernauer

International Environmental
Policy (D-GESS)



Prof. K. Axhausen

Traffic Planning
Transport Modelling (D-BAUG)



Prof. C. Onder

Institute for Dynamic
Systems and Control (D-
MAVT)

1.2.2 New members in 2023

The CSFM welcomed in 2022:



Prof. Russell McKenna, Energy Systems Analysis at PSI and D-MAVT.

His research applies quantitative and qualitative methods to energy technologies and systems. Much of this research focusses on the transport sector, for example assessing decarbonization pathways for this sector, environmental analysis of alternative fuels and drive train concepts, and modelling of integration possibilities for electric vehicles into the energy system

1.2.3 Partnership Council

In 2018, ETH Zurich launched the ETH Mobility Initiative together with the Swiss Federal Railways (SBB) as first partner, followed by Siemens joining in 2019 and AMAG Group AG in 2020 to further expand research and education in mobility. These remain strategic partners of the Center for Sustainable Future Mobility.

The strategic long-term partners SBB, Siemens, and AMAG together with most relevant private donors constitute the Partnership Council. The Partnership Council gathers twice a year to engage in a strategic dialogue with the Steering Committee. It is one of the central competences of the Partnership Council to approve the thematic scope of the yearly calls of the Mobility Initiative program.

2 Research

2.1 Mobility Initiative Program

The *Future Mobility* program is a long-term research program established in 2018 and funded by the ETH Mobility Initiative partners. It focuses on research questions relevant to address the decarbonization, digitalization, and infrastructure development in the coming decades. Projects approved under this framework provide a unique opportunity for close collaboration with the Mobility Initiative industry partners which are AMAG, SBB, and Siemens.

2.1.1 Projects Approved in 2023

Aligning policies and business strategies with consumer and citizen (ALIGN, T. Bernauer)

Switzerland needs to increase transportation capacity, while simultaneously decreasing the ecological footprint of mobility. This can only succeed if future mobility systems are aligned with the attitudes, behaviors, and policy preferences of the Swiss population. This research will fill important gaps in scientific research on the mobility demand-supply nexus from a consumer and citizen perspective. It will also provide important insights for policy-makers and mobility services providers into consumer and citizen acceptance of various policy interventions and business strategies that are or might be used to make future mobility more sustainable.

Learning Railways for Better Schedules (LeRaBe, F. Corman)

Organising high-performant railway services is essentially a scheduling problem, assigning scarce infrastructure resources to a series of trains so that both the number of trains (capacity) and performance are maximized. Automated scheduling approaches exist; however, they face a hard trade-off between the speed of computation; the detail of the model and the scale of the instance solved. The team of Francesco Corman, proposes to use learning techniques at multiple stages to better understand what are the most critical performance indicators are, to provide faster solution approaches and to learn how practitioners implement in practice the solutions provided by automated scheduling tools, so that the scheduling algorithm learn to identify and anticipate the operator implicit preferences.

Integration of E-mobility Charging Infrastructure with the Grid (Intercharge, G. Hug, R. McKenna)

The project aims to provide a comprehensive assessment to what extent BeV may stress or support the Swiss net-zero energy transition and electric grid. This proposal aims to answer the questions: (1) How

does BeV and its electricity demand evolve and what are expected power spikes from charging infrastructure under different charging behaviors? (2) Are capacities at the different grid levels adequate to cope with the power spikes from home and public charging? (3) What strategies can avoid grid bottlenecks? (4) To what extent can BeVs support the integration of renewables and relieve the grid, during grid to vehicle or vehicle to grid operation?

Immersive Teleoperation with Robots for Inspection and Maintenance (INTRIM, M. Hutter)

The team for Marco Hutter will focus in this project on the use of NeRFs in real-time robot teleoperation for maintenance operations, e.g. switchboard cabinets in the Gotthard Base Tunnel. The team will benchmark this solution with other available teleoperation technologies in this application area and is convinced that the research findings can be extended to other domains that require immersive teleoperation and advanced robot capabilities. Some of these domains include industrial inspection and maintenance, space exploration, disaster response, and many others.

E-Mobility versus Synfuels in developing nations' road transport (ESYN, T. Schmidt, A. Patt, R. McKenna)

While the transition to battery-electric vehicles appears unambiguous in developed economies, the future of transport modes in developing countries remains uncertain. The interdisciplinary project proposed by member of three different ETH Departments, aims to address the role that battery electric vehicles or synthetic fuels can play in decarbonizing passenger road transport (i.e. cars) in developing countries, with a specific focus on Africa. The team will analyze the competition between electric vehicles and synthetic fuels, considering both existing vehicle stocks and new/used vehicle flows. The infrastructure development requirements for these technologies will also be assessed, including costs and feasibility as well as the complete environmental life cycle associated with different fuel supply pathways and vehicle technologies. The findings of this research will provide valuable insights for decision-makers in the public and private sector.

Additional information about the recently approved projects and the projects approved in previous calls can be found in the dedicated section of the CSFM webpage.

2.1.2 Projects finalized in this reporting period

On board Monitoring for Integrated Systems Understanding & Management Improvement in Railways (Call1 – 2018, E. Chatzi, F. Corman)

Switzerland's railway network usage has increased by roughly 40 % in the last 30 years. The amount of traffic per km of track is the highest worldwide, approaching 100 vehicle-km per km, per day, roughly double the amount of other European railway networks. Life-cycle assessment (LCA) and maintenance planning of infrastructure currently almost exclusively rely on inspections that are either carried out in regularly spaced intervals or are prompted by the onset of irregular or potentially unsafe behavior. The goal of this project was to shift the current condition assessment and monitoring paradigm for railways.

For that, the team exploited on board monitoring data obtained in a continual fashion from in-service trains for more accurately diagnosing conditions and faults of railway infrastructure, as well as providing complementary information regarding the state of the rolling stock.

The project was structure in two interlaced tracks:

- I. determine what quantities need be measured, i.e., which data is actually needed, complemented with mathematical/statistical models of the interacting system (pillar I),
- II. in order to determine processes and critical parameters that enable reduction in life cycle costs and performance improvement of the railway transport system (pillar II).

The team redefined the digital modelling of operations by moving from readily available measurements (push strategy), to quantities that reveal latent, yet salient, information on system performance (pull strategy). The work included defining intelligent and data-driven predictive tools to support operation and maintenance. To this end, data was merged with models of the dynamics and/or of the interaction of the vehicle/rail infrastructure, thereby maximizing the understanding of the system, and the ability to assess it.

Integrated intelligent railway wheel condition prediction (Call1 – 2018, O. Fink)

Railway wheels are safety-critical components that significantly impact performance and are major cost drivers for maintenance. The condition of the wheels also influences infrastructure condition and conservation. Furthermore, wheel defects cause noise and vibration emissions, impacting the environment and significantly reducing customer comfort.

While wheel defect detection with wayside monitoring devices based on strain gauges is state-of-the-art, predicting wheel deterioration and defect evolution over time under varying operating conditions is still not possible with current tools and knowledge. In this project, the researchers developed and tested a new methodology based on deep learning algorithms.

This project addresses challenges in applying data-driven methods to condition monitoring, focusing on domain generalization and adaptation. Key contributions include a framework for robust fault diagnostics, mitigating label noise through anomaly identification and dataset modification. It introduces a generative model for creating realistic faults in new operational contexts, enabling the transfer of fault diagnostics models for reliable use. The project also employs contrastive feature learning for robust fault detection and diagnostics under changing conditions, avoiding false alarms and ensuring sensitivity to novel faults. Additionally, an unsupervised approach is developed for learning informative health indicators, crucial for continuous monitoring of industrial assets' health evolution.

Towards commercial solar thermochemical production of sustainable drop-in fuels (Call4 – 2021, A. Steinfeld, A. Patt)

The production of sustainable drop-in fuels for the transportation sector - synthetic and completely interchangeable substitutes for conventional petroleum-derived hydrocarbons (e.g. gasoline, diesel, kerosene, methanol) - can be realized with the help of technologies that convert H₂O and CO₂ into fuels using solar energy. Developing scalable and economically viable solar fuel technologies has become a global energy challenge, but their technology readiness level (TRL) has largely been limited to benchtop laboratory studies. ETH researchers have developed the science and technology for solar fuels production and have recently demonstrated the entire process chain to solar fuels at the pilot scale.

To further advance the development, the team performed a comprehensive techno-economic feasibility study of the industrial-scale production of drop-in transportation fuels using concentrated solar energy. The technical evaluation was complemented by an economic and environmental assessment of the entire process chain.

The solar thermochemical fuel production pathway utilizes a ceria-based redox cycle for splitting water and CO₂ into syngas – a tailored mixture of H₂ and CO – which in turn is converted into liquid hydrocarbon fuels for the transportation sector. The cycle is driven by concentrated solar heat and supplemented by a high-temperature thermal energy storage for round-the-clock continuous operation. The study examines three locations with high direct normal irradiation using a baseline heliostat field reflective area of 1 km² for the production of six drop-in fuels, namely: jet fuel and diesel via Fischer-Tropsch, methanol, gasoline via methanol, dimethyl ether, and hydrogen. Two scenarios are considered: the near-term future by the year 2030 and the long-term future beyond 2030.

The results demonstrate that, in the near-term future and in regions of high solar irradiation, e.g. Atacama Desert in Chile, the minimum fuel selling price is estimated at around 76 €/GJ (2.5 €/L) for jet fuel and diesel, 65 €/GJ for methanol, gasoline (via methanol) and dimethyl ether (DME), and 42 €/GJ for hydrogen (excluding liquefaction). In the long-term future, with advancements in solar receivers, redox reactors, high-temperature heat recovery and low-temperature direct air capture adsorption, the industrial-scale plant could achieve a solar-to-fuel efficiency of up to 13–19 %, depending on the target fuel, resulting in a minimum fuel selling price of 16–38 €/GJ (0.6–1.3 €/L) for jet fuel and diesel, and 14–32 €/GJ for methanol, gasoline, and DME, making these fuels synthesized from sunlight and air cost-competitive vis-à-vis e-fuels but also vis-à-vis advanced biofuels if optimal conditions materialize.

2.2 Digital Twin of the Swiss Mobility System

The “Digital Twin of the Swiss Mobility System” is an integrative project aiming to establish a platform to exchange mobility data and analytical tools to support research projects within the different CSFM research groups.

A dedicated Advisory Board was defined with the mandate to guide the project and connect this activity to other related activities within the ETH Domain and beyond. This Board convened for the first time in January 2023.

Open Digital Twin Platform for Research on the Swiss Mobility System (ODTPR-SMS)

A main achievement in this reporting period was the successful application for additional funding for this activity within the framework of the swissuniversities Open Research Data (ORD) program. This funding will allow to establish the first version of this Platform for the years 2023 and 2024 in collaboration with the Swiss Data Science Center (SDSC). The project entitled Open Digital Twin Platform for Research on the Swiss Mobility System, started in March 2023. Thanks to this grant, two additional scientists joined the CSFM in May and July respectively. A third scientist from SDSC at EPFL is also involved in the development of the initial version of this platform.

Open Digital Twin Platform for Research on Swiss Mobility System (ODTPR- SMS)

Objective: Promote and facilitate the efficient exchange of Mobility Data and Modeling tools

- Create an open-source platform that supports traceability, reusability, inspection, and querying of Mobility Digital Twins.
- Develop an online repository containing pointers to community products.
- Develop guidelines for the community to expand the repository with new data and tools.

Community:

- Center for Sustainable Future Mobility (CSFM), a network of 40 Chairs (ETH Domain)
- In discussion with: AMAG, SBB, Siemens, [tpg](#), City of Lausanne, Swisstopo, BAV,
- With the ambition to become a reference for public and private institutions in the transportation sector and beyond.

Next Steps:

- Development of a standard for open-source digital twins applied to mobility.
- Privacy and security solutions for dealing with highly sensitive data.
- Demonstrate usability and added value in different projects.

Box 1: Open Digital Twin Platform for Research on Swiss Mobility Systems (ODTPR-SMS) in a nutshell

The platform will consist of modular open software that allows to connect basic functional (core) modules and specific additional modules created to load datasets or to process data using specific analytical tools. Each user can create their own modules by adopting some basic guidelines. These modules may allow for example to analyze data, simulate scenarios or any other data transformation to extract information and insights from the data. These modules can then be connected within the platform to exploit its additional functionalities. The new modules can also be shared with the community, for example to allow reproducing published results or comparison of different tools or datasets. Therefore, this platform is meant to promote by design FAIR¹ principles among the Mobility Research community.

The first modular prototype based on eqasim and MATSim has been completed and is currently being tested. This prototype was presented last October to the CSFM community in a dedicated workshop. At this workshop, the architecture was explained as well as the expected functionality. Several CSFM members presented potential use cases.

The focus for the team in the next year will to enrich the current prototype with new features necessary to adapt to use cases from the CSFM community. Discussions with several CSFM members are ongoing to identify promising use cases that demonstrate the potential of the platform as well as provide the team with the information needed to improve the usability of this prototype.

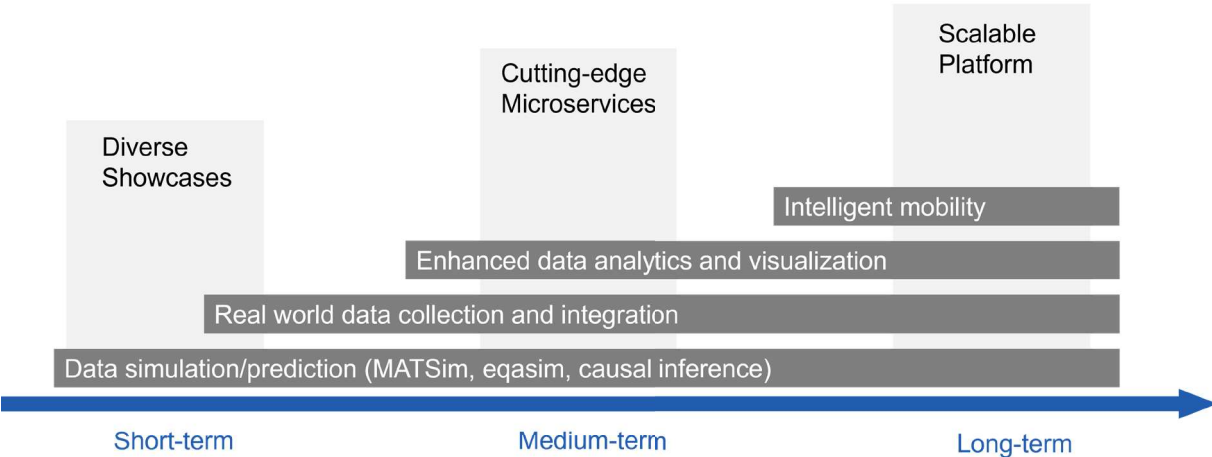


Figure 2: Roadmap of the Open Digital Twin Platform for Research on Swiss Mobility System

The team will also proceed this year with the initially planned data acquisition for the Digital Twin. Looking for publicly available datasets both on a recurring basis, such as government data on traffic, but also specialized collections that may have been performed previously in different research groups.

¹ FAIR Data Principles: Findable, Accessible, Interoperable and Reusable

3 Communication and Outreach

3.1 Outreach and Networking Events

3.1.1 CSFM Symposium on June 6, 2023

The CSFM Symposium took place on the 6th of June at ETH Zurich and hosted over 100 participants. The symposium program in the morning was dedicated to presentations of the Mobility Initiative projects. The afternoon was dedicated to invited Keynotes speakers concluding with a panel discussion.

The three Mobility Initiative projects highlighted this year were:

- Long-Range Obstacle Detection for ADAS, Cornelius von Einem, Andrei Cramariuc, Cesar Cadena, Prof. Roland Siegwart, Autonomous Systems Lab.
- Augmented Reality - Towards a New Generation of User Support System in Maintenance Operation (IARMO), Dr. Julian Wolf, Prof. Mirko Mebold, Product Development Group (pd|z),
- Incentives for Electric Vehicles Adoption, Dr. Davide Cerruti, Prof. Maximo Filippini, Center for Energy Policy and Economics (CEPE).



The Keynotes from Kristin von Szadkowski from Volkswagen Group, Dr Gianluca Ambrosetti, CEO and co-founder of Synhelion, and Dr Roland Moser, Chairman of the European Rail Research Advisory Council (ERRAC), provided insights about the current technologies, innovation efforts and deployment activities that pave the way towards a more sustainable transportation system. The panel discussion around what we can learn from each other to move forward towards a more sustainable mobility system, across modes pointed to possible ways forward and synergies between activities towards decarbonization of transport among the different modes and different industrial sectors.

Best Poster Award

Georgia Pierrou and Christian Moretti were this year the winners of the Best Poster Award at the CSFM Symposium. The jury, consisting of Kristin von Szadkowski, Professor em. Konstantinos Boulouchos, Dr Andreas Mehlhorn, and Dr Roland Moser evaluated the posters based on the novelty of the content or results, applicability/impact towards the goals of the CSFM, and design as well as a 3-minute pitch in plenum by the corresponding candidates.

The presentations by external guests and CSFM members, the panel discussion, as well as the poster session, provided opportunities to present the latest research results and engage in discussions.



3.1.2 Mobility Initiative Workshop 2023

The Center launched the 6th call of the Mobility Initiative on a dedicated workshop organised at ETH Zurich last March. The workshop brought together about 45 researchers and partners to discuss project ideas for the Mobility Initiative call for proposal. 16 project ideas were presented and discussed at this occasion most of which were follow up after the event and resulted in applications to the Mobility Initiative call.

The workshop connected the domain experts and the Mobility Initiative partners. A particular asset of the workshop is that it allows to explore potential synergies between ideas proposed by different partners enriching considerably the project proposals.

3.2 Seminar Series

A seminar series was launched in the spring semester. With this series, we aimed at creating a new communication vehicle within the incipient CSFM network by addressing issues relevant to the rather interdisciplinary community, the centre's industry partners and other institutions active in the field of sustainable mobility. One of the objectives of this Seminar Series is also to facilitate the interaction and exchange between CSFM members that may not be aware of the research work being conducted in other groups. The initial idea that we have been testing in 2023 is to combine presentation from both academia and the praxis on a specific topic. In total we organized five events this year on the topics, data for sustainable mobility, Infrastructure and innovation for E-Mobility deployment, taxing E-Mobility in the future, external costs of transport and new regulations for Autonomous Vehicles in Switzerland.

3.2.1 Spatial data and data analytics for sustainable mobility

The first CSFM Seminar on Sustainable Transportation took place on March 23, 2023. The focus was on data analytics for sustainable mobility and the event attracted over 40 participants from industry and academia.

Martin Raubal, Professor of Geoinformation Engineering at ETH Zurich, discussed the importance of spatial data science and analytics in establishing a sustainable mobility system. He presented three projects addressed by his group: the first project, SBB Green Class studied the readiness of frequent customers of public transport to adapt to combined transport solutions including e-vehicles. Yumuv, analysed the impact on human mobility behaviour effects of mobility as a service bundle. Finally, solar power for e-cars addressed the potential of using a rooftop photovoltaic generation to cover the charging demands of individual electric vehicles under different smart charging strategies.

Thomas Hettlinger, data scientist at SBB, presented how data analytics is being applied to test the potential impact of new services. He also referred to the recently concluded project Yumuv. The findings will help SBB to decide about future services of this kind. An extension of the framework used in Yumuv (Trackintel framework) will be used to support decarbonization of the vehicle fleet. Currently, data analytics is mainly used to support decisions about whether a specific innovation project should move forward or be stopped. However, Thomas believes that data analytics should be used more in the other steps of the innovation process: from the initial phase of exploration of 'potential' to the very final 'rollout' of new products or services.

After the presentations, the audience could add comments and pose questions to the speakers. Throughout, the engaged audience ensured a lively and intense discussion.

3.2.2 E-mobility for last/first mile: Fleet innovation and charging infrastructure

CSFM Seminar with Dr Erik Wilhelm from Kyburz Switzerland and Professor Hua Cai from Purdue University on research on e-fleets.



Dr Wilhelm is the Head of Research at Kyburz Switzerland and is responsible for data analytics in self-driving system engineering. He earned his PhD from ETH Zurich while studying multicriteria vehicle design, data analytics and control optimization. During his stay in Zurich he co-founded a startup in vehicle telematics for reducing on-road energy use. His post-doctoral research was performed at the Massachusetts Institute of Technology (MIT) in the Field Intelligence Lab. Dr Wilhelm has held an assistant professorship at the Singapore University of Technology and Design where he contributed to robotics and large-scale data collection research areas.

he contributed to robotics and large-scale data collection research areas.

Innovation for sustainable last mile delivery: The innovations Kyburz brings to the area of last mile delivery steadily contribute to lower well-to-wheel emissions in Switzerland, Australia, and 14 other countries all over the world. In this short presentation, Erik examined some of the insights gained through Kyburz data-driven approach to engineering design and highlighted how these processes can be scaled to other problems. He touched on activities relating to the circularity of material flows and autonomous driving for on-road energy use reduction that is critical for decarbonisation of the sector.

Hua Cai, by the time Visiting Professor at ETH Zürich, is an Associate Professor at Purdue University, holding a joint appointment in Industrial Engineering and Environmental and Ecological Engineering. Her research interests include data-driven system modelling and optimization, prospective environmental assessment of emerging technologies, complex adaptive systems, and decision making for sustainable consumptions. Specifically, her research has focused on the environmental impacts of shared mobility and micromobility, autonomous vehicles, electric vehicles, and infrastructure optimization to support the mixed adoption of these emerging transportation technologies for urban sustainability.



Vehicle charging infrastructure for the future transportation system: Electric vehicle charging infrastructure development needs vary depending on different pathways of adopting electric vehicles, autonomous driving, and shared mobility. A fleet of human-driven electric vehicles and a fleet of shared autonomous electric vehicles would have different charging needs and different infrastructure support requirements. These considerations are critical for users, service providers, and fleet operators. In this presentation, Professor Cai shared her group's research on using integrated simulation and optimization models to inform electric vehicle charging infrastructure development.

3.2.3 The transition to electric vehicles: Implications for public revenues and funding of roads

The mineral oil tax generates billions in revenue, which are mainly used to finance road construction and maintenance. The gradual introduction of electric vehicles (EVs) in the Swiss fleet aims to mitigate the considerable CO2 emissions of the transport sector. This transition creates a significant funding gap in transport infrastructure. In this seminar we aimed to convey different perspectives which are also part of the research within the sustainable mobility community at the CSFM and which, in our opinion, should be part of the current dialogue and decision-making process.



Roman Rosenfellner from the Federal Roads Office presented the main pillars as well as the outstanding questions around the decision-making basis for a new financing model. The central element of this model is the replacement of mineral oil taxes by a distance-based charge. The controversial side effects

of replacing mineral oil taxes, the different strategies of introduction and the technical and privacy issues associated with the recording of distance travelled are relevant aspects of the debate.

Betsy Sandoval Guzmán, from EMPA, provided evidence of possible disparities between actual energy consumption and linear pricing models, which typically consider indicators such as empty weight, engine power, and distance travelled. The methods presented are based on vehicle energy models and machine learning-based segmentation of passenger cars and have been successfully applied in several decarbonisation projects.

Bessie Noll of the Energy and Technology Policy Group (EPG) addressed how to balance the need for revenue with the urgency of accelerating the EV transition. Using techno-economic models of adoption, they conclude that distance-based taxation works better than purchase taxes and can help avoid substantial delays in the transition.

Finally, Alessio Levis from International Political Economy and Environmental Policy presented studies on public support and political feasibility assessment, as they are crucial to reach the goal of zero net emissions by 2050. In this respect, the Swiss Mobility Panel, currently in its 5th wave of surveys, provides a unique and high-quality basis to support the decision-making process.

The lively discussion revealed that further connecting all these knowledge fields and improving the cooperation between research and the governmental institutions is needed.

3.2.4 External costs of transport as a tool to achieve sustainable mobility

The benefits of transport are plenty and obvious, particularly for those that take part in it; however, there are also costs associated with the use of any transportation means. A part of these costs is generally covered by the users, but there is also a part of the costs which is covered by the general public. These are the external costs regularly assessed by ARE, primarily related to environmental and health damage, as well as a portion of the costs induced by accidents.

At this seminar, Josephine Leuba and Nicole Mathys explained in detail the methodology and scope of the national calculations of external costs of transport. These costs amount to a total of about 14 billion CHF (in 2019), of which only around 5% are currently internalized, with the majority of the internalization taking place via the performance-related heavy vehicle charge (HVC).

The annual external cost estimates for all modes of transport in Switzerland form the basis for calculating transport costs and compensation for heavy goods traffic, as well as shaping the country's transport policy. These estimations are used to assess cost-benefit analyses of road and rail infrastructure projects, and therefore contribute to paving the way for more sustainable decisions in the long run.

The methodology is constantly being updated. The next planned developments involve: the integration of congestion costs, the improvement of the database, the definition of critical parameters, as well as a better differentiation between urban and rural areas.

Thomas Heck, from the Laboratory for Energy Systems Analysis at Paul Scherrer Institute (PSI), presented the results of the life cycle-based assessment of environmental externalities of transport. The method used by the PSI's team is a bottom-up approach for impact pathways, combined with a semi-regional approach that allows differentiation of drivetrain technology and level of development. It also enables simulation of future technological development.

Thomas Heck's presentation emphasized the high importance of indirect impacts induced by the associated life cycle (e.g., vehicle manufacturing, fuel production, etc.) when calculating environmental

impacts and externalities. In the past, the direct emissions of the vehicle, were the main source of environmental issues and externalities, when compared to the indirect life cycle emissions. However, technological improvements, and especially the electrification of the fleet, will lead to a completely different distribution of direct and indirect emissions. The method described by Thomas Heck allows to calculate the impact caused in regions far away from where the vehicles are used. Moreover, for electric vehicles, the impacts associated with electricity generation are particularly important.

3.2.5 New regulations for autonomous vehicles in Switzerland

With the latest developments in autonomous driving and a multitude of pilot tests going on in different cities, it seems critical to develop the necessary regulations also in Switzerland. In this seminar, we discussed the challenges posed by these technologies to regulators and society with **Professor Emilio Frazzoli**, Institute for Dynamic Systems and Control (ETH Zurich), **Stephen Milford**, University of Basel, on ethical aspects of regulating Autonomous Vehicles, **Professor Thomas Probst**, Chair of Law of Obligations, European Private Law and Comparative Law, University of Fribourg, on the legal framework an overview of key issues, **Armin Jost** from the Federal Roads Office, on the current mandate and status of the regulation, **Xilin Zhou**, from SwissRe on the crucial role of insurance for autonomous vehicles and finally the perspective of operators on safety and cybersecurity regulations for AV presented by **Amin Amini** from Loxo.

3.3 Digital Twin workshop

The 1st technical workshop of the Open Digital Twin Platform Project took place on October 10, 2023. The first part of the event was held in hybrid mode, allowing remote participants to get a first impression of the tool.



The workshop hosted also presentations showcasing potential use cases for the platform. The team collected valuable feedback and ideas, which are currently being evaluated to plan the final phase of the project.

3.4 Other dissemination and communication Measures

The primary platforms for disseminating information about the Mobility Initiative call for proposals, as well as news and events from CSFM, are currently the CSFM webpage and LinkedIn channels. To enhance communication effectiveness, particular emphasis has been placed on refining existing channels, notably the web news section and LinkedIn presence. The website's news section has undergone systematic curation, tailoring content to resonate with our audience. In the past year, we successfully published 20 articles, with 10 originating from the center management office. We also

regularly publish news highlighting member achievements which are published also in other channels, and relevant funding opportunities.

LinkedIn has emerged for CSFM too as a pivotal platform for sharing corporate news and allowing scientists to showcase their accomplishments and activities. A concerted effort has been made to increase the frequency of posts to approximately one per week, resulting in a substantial rise in followers. This channel has proven instrumental in not only engaging a broader international audience but also strengthening our connection with the scientific community. The strategic development of these communication channels reflects our commitment to fostering transparent, engaging, and impactful interactions within the CSFM community and beyond.

Below a selection of news and dissemination activities not mentioned in previous sections.

- Info event on Swiss participation on Europe Rail Joint Undertaking, co-organized with the Swiss Federal Office of Transport at ETH Zurich on 06.02.2023. With: Carlo Borghini, Director Europe Rail JU, Thomas Gugler and SBB, Riccardo Scarinci, EURESEARCH.
- Emilio Frazzoli is a member of the Board of Swiss Association for Autonomous Mobility. <https://www.saam.swiss/de/>
- Contributed to AV legislation debate with ASTRA
- Einstein Episode on Autonomous Driving featuring Centre for Sustainable Future Mobility members: Emilio Frazzoli, Miriam Elser and Dejan Milojevic from Empa
- Heavy trucks likely not zero-emission in the near future (ETH News), Professor Tobias Schmidt and Bessie Noll from the Energy and Technology Policy Group at ETH Zurich. [\(10.10.2023\)](#)
- CSFM was present with posters, presentation, and an info-stand:
 - ETH Industry Day (06.09.2023)
 - SFOE Mobility Research workshop (12.09.2023)
- Support organization & representation at the ETH Zurich & GreenBuzz event: The future of sustainable mobility (05.10.2023)
- Carbon-neutral solar fuels (ETH Industry News) – promoted by CSFM, article and video by Tünde Kirstein [\(27.04.2023\)](#)

Web news-articles on approved and completed Mobility Initiative projects

- Scheduling methods for automated railway timetabling. ETH Zurich together with SBB addressed the issue in a project funded by the ETH Mobility Initiative. [\(14.04.2023\)](#)
- Towards commercial solar production of sustainable transportation fuels (Mobility Initiative). ETH Zurich, jointly with industrial partners Synhelion, SBB, and AMAG, recently completed a comprehensive technical, economic and environmental analysis of the solar thermochemical production of drop-in fuels. [\(18.09.2023\)](#)
- New Mobility Initiative projects approved [\(25.09.2023\)](#)
- INTERACT: Deep learning algorithms for improved predictive railway wheel maintenance [\(15.12.2023\)](#)

4 Outlook

Research promotion

Our platform is committed to fostering innovation and research in sustainable future mobility. To achieve this, we regularly organize a thematic call for project proposals together with our strategic partners. This Future Mobility research program approved so far 29 research projects which are funded by ETH Zurich and the Mobility Initiative. The next Call has been already scheduled and it will promote those projects that not only fulfill scientific excellence criteria but also relevance for the future mobility systems. A workshop has been also scheduled to connect researchers and practitioners toward defining high impact and relevant research and innovation challenges.

Outreach and Networking Events

In line with our dedication to sustainable future mobility, we actively engage in outreach activities. This year we will host again a Symposium that aims at disseminating research results and connect researcher and practitioners serving as a dynamic forum for the exchange of ideas, the presentation of cutting-edge research, and the exploration of emerging trends in the field.

At the center and particularly on the occasion of the Symposium, we recognize the pivotal role that young scientists play in shaping the future of sustainable mobility. We believe in providing a dedicated platform for them to showcase their work and foster meaningful connections within the community. Through this inclusive approach, we aim to amplify the voices of the next generation, catalyzing collaboration and knowledge exchange to drive advancements in sustainable future mobility. By offering this unique opportunity, we empower young scientists to contribute significantly to the ongoing discourse and collective efforts towards a greener and more sustainable transportation landscape.

The Seminar Series has emerged as a highly effective platform for the dissemination of knowledge and ideas within the realm of sustainable future mobility. Over the course of the five events organized to date, we have witnessed the successful engagement of practitioners and scientists from diverse backgrounds, extending beyond the boundaries of ETH Zurich. These gatherings have not only facilitated the exchange of insights but have also forged valuable connections and sparked enriching discussions. In 2024, we are enthusiastic about continuing the Seminar Series, and exploring new and relevant topics in the ever-evolving landscape of sustainable mobility. By doing so, we aim to build upon the momentum generated thus far, expanding our reach and impact.

The Center for Sustainable Mobility will collaborate with the initiative of the Federal Office of Transport and the State Secretariat for Education, and other related Swiss institutions, to curate a joint booth at the upcoming Transport Research Arena (TRA). This synergistic effort aims to showcase cutting-edge research, innovation, and sustainable solutions within the area of transportation. The joint booth should serve as a platform, exemplifying the collaborative spirit of Swiss institutions dedicated to advancing mobility research. Visitors can expect to explore a diverse array of projects, ranging from state-of-the-art technologies to impactful policy initiatives, all of which underscore Switzerland's commitment to shaping the future of transportation. Through this unified presentation, the Center and its partner institutions seek to foster dialogue, encourage knowledge exchange, and contribute collectively to the broader discourse on sustainable mobility at this conference which is a major event in the field of transportation research and innovation in Europe.

Digital Twin

In the upcoming year, the Digital Twin project, housed at the CSFM Management Office, is poised for significant advancements and accomplishments. The project team plans to not only drive development but also to communicate its breakthroughs and the profound value it offers to the wider community. A focal point of next year's commitment is a dedicated workshop, designed to spotlight the project's achievements, provide hands-on insights, and engage with stakeholders. Moreover, the team will amplify its outreach through the publication of comprehensive tutorials and other communication materials.

This multifaceted approach reflects our commitment not only to pushing the boundaries of innovation within this emerging Digital Twin technology, but also to ensuring that its potential impact resonates widely, creating a ripple effect of transformative possibilities throughout the research community.

Through strategic dissemination efforts, the management office aims to actively promote the adoption and utilization of the Digital Twin platform, positioning it as an indispensable tool for innovation and problem-solving across various sectors.

Entrepreneurship

The CSFM supports the inception of the recently approved Innovation Booster focused on "New Mobility." This initiative, backed by Innosuisse, is anticipated to ignite the entrepreneurial enthusiasm among researchers within the CSFM network. The CSFM is actively engaged in promoting this initiative across its members, extended network, and ETH Zurich, encouraging students and researchers to take on the challenges presented and develop ideas that have the potential to evolve into impactful commercial solutions. By fostering a spirit of innovation and collaboration, the CSFM aims to contribute significantly to the success of the Innovation Booster and the advancement of pioneering solutions toward sustainable future mobility.

Annex

Publications

Arcieri, G., C. Hoelzl, O. Schwery, D. Straub, K.G. Papakonstantinou and E. Chatzi (2023) Bridging POMDPs and Bayesian decision making for robust maintenance planning under model uncertainty: An application to railway systems, *Reliability Engineering & System Safety*, 239, 109496.

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Financial summary 2023

Material costs	Budget	Expenditure	Saldo
Management Office (Office, IT)	13'310	10'789.60	2'520.40
Rep., Coordination, Gov	5'200	2'522.98	2'677.02
KTT, Communication	28'750	21'774.81	6'975.19
Mobility Initiative - Events	2'700	4'394.33	-1'694.33
TOTAL material costs	49'960.00	39'481.72	10'478.28

Personnel costs	Budget	Expenditure	Saldo
Total MO	234'750.00	222'010.60	12'739.40
Digital Twin	90'574.00	58'257.00	32'317.00
TOTAL Personal costs	325'324.00	280'267.60	45'056.40

TOTAL costs	375'284	319'749.32	55'534.68
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Revenues 2023:	
Mobility Initiative:	200'000.00
ETH Zurich Executive Board:	120'000.00
CSFM Membership fees:	28'000.00
TOTAL Revenues	348'000.00

Difference yearly expenditure / revenues	28'250.68
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transferred from 2021(reserve)	44'727.65
transferred from 2022(reserve)	65'000.00
ETH Rat project - SPEED2ZERO	8'500.00

ODTPR-SMS

ODTPR-SMS	2023			2024		
	Budget	Expended	Saldo	Budget	Expended	Saldo
Material costs						
Total	5'000.00	3'899.57	1'100.43	5'000.00	-	-
Personnel costs						
Total	204'815.00	157'831.35	46'983.65	275'185.00	-	-
Funds transfered to 2024			48'084.08			

Budget and financial status of the ETH Zurich part of the ODTP-SMS grant (swissuniversities)

Members

DEPARTMENT/ Name	Institute / Lab
BAUG	
Brian Adey	Infrastructure Management
Kay W. Axhausen	Traffic Planning, Transport Modelling
Eleni Chatzi	Structural Mechanics and Monitoring
Francesco Corman	Transport Systems
Stefanie Hellweg	Institute of Environmental Engineering
David Kaufmann	Institute for Spatial and Landscape Development
Anastasios Kouvelas	Traffic Engineering and Control
Martin Raubal	Institute of Cartography and Geoinformation
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Russell McKenna	Energy Systems Analysis
Christopher Onder	Institute for Dynamic Systems and Control
Roland Siegwart	Autonomous Systems Lab
Aldo Steinfeld	Institute of Energy and Process Engineering
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