ITSC 2023 Workshop Proposal
Co-Design and Coordination of Future Mobility Systems

Gioele Zardini, Andrea Censi, Dario Paccagnan, Maximilian Schiffer, Emilio Frazzoli

Abstract

Increasing urbanization and exacerbation of sustainability goals threaten the operational efficiency of current transportation systems and confront cities with complex choices with huge impact on future generations. At the same time, the rise of private, profit-maximizing Mobility Service Providers leveraging public resources, such as ride-hailing companies, entangles current regulation schemes. This calls for tools to study such complex socio-technical problems. In this workshop, we discuss methods and tools to study the co-design of future mobility systems and the interactions between stakeholders of the mobility ecosystem, modeling regulatory aspects such as taxes and public transport prices, as well as operational matters for Mobility Service Providers such as pricing strategy, fleet sizing, and vehicle design.

Accessible from any background and seniority level, the workshop will provide basic tools to reason about these complex problems. Keynote talks from renowned experts will demonstrate how such tools can be implemented to solve real-world problems, and provide insights for future research avenues.

1 General Information

Type and duration: Workshop, full day, September 24th, 2023, Hybrid
Title: Co-design and Coordination of Future Mobility Systems
URL: https://idsc.ethz.ch/research-frazzoli/workshops/futuremobilitycodesign-itsc23 (in preparation)

Note that this workshop proposal complements the homonym special session proposal. The combination of these two activities will substantially contribute to bringing these fundamental topics forward in the community. A first successful edition of this workshop has been organized at ITSC 2022.

2 Organizers

Gioele Zardini (primary point of contact): Ph.D. Candidate, Institute for Dynamic Systems and Control, ETH Zürich
Address: Sonneggstrasse 3, 8092 Zürich, Switzerland;
Phone: +41795737620
E-mail: gzardini@ethz.ch. Website: gioele.science

Bio: Gioele Zardini is a Ph.D. Candidate in Emilio Frazzoli’s group at the Institute for Dynamic Systems and Control, ETH Zurich. He received his BSc. and MSc. in Mechanical Engineering with focus in Robotics, Systems and Control from ETH Zurich in 2017 and 2019, respectively. He spent time in Singapore as a researcher at nuTonomy (then Aptiv, now Motional), at Stanford University (working with Marco Pavone) and at MIT (in 2020 working with David Spivak, and currently with Munther Dahleh). Driven by societal challenges, the goal of his research is to develop efficient computational tools and algorithmic approaches to formulate and solve complex, interconnected system design and autonomous decision making problems. His research interests include the co-design of complex systems, compositionality in engineering, applied category theory, planning and control, and game theory, with applications to intelligent transportation systems,
autonomy, and complex networks and infrastructures.

He is the recipient of a paper award at the 4th Applied Category Theory Conference, and of the Best Paper Award (1st Place) at the 24th IEEE International Conference on Intelligent Transportation Systems (ITSC).

**Dr. Andrea Censi**: Senior Researcher, Institute for Dynamic Systems and Control, ETH Zürich.

Address: Sonneggstrasse 3, 8092 Zürich, Switzerland;
E-mail: acensi@ethz.ch. Website: censi.science

Bio: Andrea Censi is deputy director of the Dynamic Systems & Control chair. He obtained a Ph.D. from Caltech. Previously, he has been a research scientist at MIT and Director of Research at Aptiv Mobility (now Motional). He is president of the Duckietown Foundation.

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**Prof. Dario Paccagnan**, Department of Computing, Imperial College London

E-mail: d.paccagnan@imperial.ac.uk

Address: Huxley Building, 180 Queen's Gate, London SW7 2RH, United Kingdom

Bio: Dario Paccagnan is an Assistant Professor at the Department of Computing, Imperial College London since the Fall 2020. Before that, he was a postdoctoral fellow with the Center for Control, Dynamical Systems and Computation, University of California, Santa Barbara. He obtained his PhD from the Automatic Control Laboratory, ETH Zurich, Switzerland, in 2018. He received a B.Sc. and M.Sc. in Aerospace Engineering from the University of Padova, Italy, in 2011 and 2014, and a M.Sc. in Mathematical Modelling and Computation from the Technical University of Denmark in 2014; all with Honors. Dario's interests are at the interface of game theory and control theory, with a focus on the design of behavior-influencing mechanisms for socio-technical systems. Dario was a finalist for the 2019 EECI best PhD thesis award and was recognized with the SNSF Early Postdoc Mobility Fellowship, the SNSF Doc Mobility Fellowship, and the ETH medal for his doctoral work.

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**Prof. Maximilian Schiffer**, Operations and Technology Department, Technical University of Munich

E-mail: schiffer@tum.de

Address: Arcisstrasse 21 80333 München, Germany

Bio: Maximilian Schiffer is a tenured Professor of Business Analytics & Intelligent Systems in the School of Management and a Core Member of the Munich Data Science Institute at the Technical University of Munich. Moreover, Maximilian is an Associate Member of the GERAD. Before joining TU Munich, he was a visiting postdoctoral scholar at Stanford University and a postdoctoral scholar at RWTH Aachen University. He received a Ph.D. degree in Operations Research from RWTH Aachen University in 2017. As a scholar, Maximilian’s expertise lies in the fields of Operations Research, Prescriptive Analytics, Machine Learning, and Data Science applied to a variety of application fields, e.g., transportation problems, supply chains, production networks, and big data. His research currently focuses on electric vehicles, smart city logistics, autonomous systems, interpretable machine learning, as well as innovative applications in supply chain and production management. He is the recipient of several awards, among others the INFORMS TSL Dissertation Prize and the GOR Doctoral Dissertation Prize. His work has been recognized with a best paper awards from the IEEE Conference on Intelligent Transportation Systems and the INFORMS TSL SIG on Facility Logistics, and an Anna Valicek Medal from the AGIFORS. He is currently serving on the Editorial Boards of Transportation Science, OR Spec- trum, Transportation Research Part C & Part E, and Business & Information Systems Engineering.

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**Prof. Emilio Frazzoli**: Professor of Dynamic Systems and Control, ETH Zürich.

Address: Sonneggstrasse 3, 8092 Zürich, Switzerland;
E-mail: efrazzoli@ethz.ch. Website: idsc.ethz.ch/the-institute

Bio: Emilio Frazzoli is a Professor of Dynamic Systems and Control at ETH Zurich, and former CSO of Motional. His main research interest are in robotics, autonomous systems, and intelligent mobility. In acknowledgement of his seminal work in these fields, Emilio has received numerous awards, including the 2015 IEEE George S. Axelby Award and the 2017 IEEE Kiyo Tomiyasu Award, and has been named
an IEEE Fellow in 2019. Emilio has published more than 200 papers in the fields of robotics, autonomous vehicles, and drones. A former full professor at MIT, he directed the research group that first demonstrated an autonomous mobility ("robotaxi") service to the public, and performed the first analysis of the social and economic impact of such a service, based on real transportation data. In 2013 he founded nuTonomy with Karl Iagnemma, and served as its Chief Technology Officer until its acquisition by Aptiv in 2017.

3 Content

3.1 Motivation and relevance to the ITS community

In past decades, cities worldwide have observed a dramatic urbanization. Today, 55% of the world's population resides in urban areas, and in the next 30 years the proportion is expected to reach 68% [1].

A direct consequence of the population density growth is the increase of urban travel, and of the externalities it produces [2]. In this rapidly expanding setting, cities have to take important decisions to adapt their transportation system to welcome larger travel demands. This is a very complex task for at least three reasons. First, cities need to accommodate the changing travel needs of the population, by predicting them [3], and by ensuring fairness and equity [4]. Second, designed policies not only have to account for the citizens' satisfaction, but also for their impact on private Mobility Service Providers (MSPs) such as ride-hailing companies, micromobility (µM), and, in a near future, Autonomous Mobility-on-Demand (AMoD) systems [5]. Indeed, such services gained a considerable share of the transportation market in recent years; e.g., in NYC, ride-hailing companies have increased their daily trips by 1,000% from 2012 to 2019 [6]. While offering more choices to travellers, these systems operate benefiting from public resources (such as roads and public spaces), are profit-oriented, and often lead to potentially disruptive consequences for the efficiency of the transportation system and for society at large [7–9]. In this avenue, cities gain an important, onerous regulatory role. Third, policies have to be designed while meeting global sustainability goals. It is not surprising that cities are estimated to be responsible for 78% of the world’s energy consumption and for over 60% of the global greenhouse emissions (30% of which is produced by transportation, in US) [10]. Indeed, sustainability is central in policy-making worldwide: NYC plans to increase sustainable trips from 68% to 80% [6], and EU plans a 90% reduction of emissions by 2050 [11].

Taken together, the aforementioned perspectives highlight the complexity of this socio-technical problem, and imperatively call for methods to inform and drive policy makers\(^1\). In this context, developed methods need to inform the co-design of individual mobility solutions and the associated mobility systems, accounting for a range of heterogeneous stakeholders with conflicting objectives (Fig. 1).

3.2 Objectives

We believe that the problem described in Section 3.1 can be tackled by adopting a system-level perspective and by explicitly considering interactions between mobility stakeholders (both at the planning, and operational level, e.g., via game-theoretic tools) [12–18].

This workshop will gather experts from diverse engineering disciplines (including transportation, operations research, urban planning, and autonomy) to

- identify challenges and opportunities regarding the aforementioned problems;
- present promising tools to address such challenges;
- inform young researchers about such novel tools;

\(^1\)We treated these topics in [12], which was appreciated in the community during last year's ITSC, and awarded the best paper award.
• find interaction opportunities between diverse research communities to unite forces and tackle the problems.

3.3 Detailed Schedule

The full-day program consists of invited talks, followed by questions and discussions (30 minutes talks and 10 minutes of questions and discussion). The workshop will also be open for submissions, which, upon selection, will receive a slot for an oral presentation or a poster presentation (to be decided depending on the number of submissions). The schedule is reported in Table 1.

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:30-08:40</td>
<td>Gioele Zardini</td>
<td>Welcome and introduction to the workshop</td>
</tr>
<tr>
<td>08:40-09:20</td>
<td>Prof. Maximilian Schiffer (TUM)</td>
<td>TBD</td>
</tr>
<tr>
<td>09:20-10:00</td>
<td>Prof. Kenan Zhang (EPFL)</td>
<td>How would mobility-as-a-service (MaaS) platform survive as an intermediary?</td>
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<tr>
<td>10:30-11:10</td>
<td>Prof. Samitha Samaranayake (Cornell)</td>
<td>TBD</td>
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<tr>
<td>11:10-11:50</td>
<td>Prof. Saurabh Amin (MIT)</td>
<td>TBD</td>
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<tr>
<td>11:50-12:30</td>
<td>Prof. Alexandre Bayen (UC Berkeley)</td>
<td>TBD</td>
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<tr>
<td>14:00-14:40</td>
<td>TBD</td>
<td>TBD</td>
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<tr>
<td>14:40-15:20</td>
<td>Prof. Kaidi Yang (NUS)</td>
<td>TBD</td>
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<tr>
<td>15:20-16:00</td>
<td>Prof. Mahnoosh Alizadeh (UC Santa Barbara)</td>
<td>TBD</td>
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<tr>
<td>16:00-16:40</td>
<td>Prof. Panagiotis Angeloudis (ICL)</td>
<td>TBD</td>
</tr>
<tr>
<td>16:00-17:00</td>
<td>Final discussion and selected presentations</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Schedule for the workshop.

In the following, we report a list of invited speakers, as well as their biographies. All the speakers have confirmed their talks. We are particularly proud of the diverse set of speakers we have put together. Details
are available upon request.

**Maximilian Schiffer**  Maximilian Schiffer is a tenured Professor of Business Analytics & Intelligent Systems in the School of Management and a Core Member of the Munich Data Science Institute at the Technical University of Munich. Moreover, Maximilian is an Associate Member of the GERAD. Before joining TU Munich, he was a visiting postdoctoral scholar at Stanford University and a postdoctoral scholar at RWTH Aachen University. He received a Ph.D. degree in Operations Research from RWTH Aachen University in 2017.

As a scholar, Maximilian’s expertise lies in the fields of Operations Research, Prescriptive Analytics, Machine Learning, and Data Science applied to a variety of application fields, e.g., transportation problems, supply chains, production networks, and big data. His research currently focuses on electric vehicles, smart city logistics, autonomous systems, interpretable machine learning, as well as innovative applications in supply chain and production management. He is the recipient of several awards, among others the INFORMS TSL Dissertation Prize and the GOR Doctoral Dissertation Prize. His work has been recognized with a best paper awards from the IEEE Conference on Intelligent Transportation Systems and the INFORMS TSL SIG on Facility Logistics, and an Anna Valicek Medal from the AGIFORS.

He is currently serving on the Editorial Boards of Transportation Science, OR Spectrum, Transportation Research Part C & Part E, and Business & Information Systems Engineering.

**Kenan Zhang**  Dr. Kenan Zhang is currently a postdoctoral researcher at ETH Zurich, supervised by Prof. John Lygeros and Prof. Andreas Krause. She received her Ph.D. in Transportation Engineering and M.S. in Statistics at Northwestern University. She also holds B.S. in Civil Engineering from Tsinghua University and M.S. in Construction Management from Carnegie Mellon University. Her primary research interest falls in the modeling and optimization of urban transportation systems. She is also broadly interested in the applications of game theory and machine learning in transportation. In September 2023, she will join EPFL as an Assistant Professor in Transportation Engineering.

**Samitha Samaranayake**  Samitha is an Assistant Professor in the School of Civil and Environmental Engineering and a Graduate Field Faculty in the School of Operations Research and Information Engineering, the Center for Applied Math and the Systems Engineering Program at Cornell.

His primary research interest is in mathematical modeling and algorithm design for large-scale transportation network problems, and his current focus is on problems at the intersection of public transit and ride-sharing. In particular, he is interested in hybrid transit systems—services that are designed from the ground-up to fully integrate traditional fixed-line public transit and agile, demand-responsive modes.

He looks at these problems through the lens of Algorithm Engineering, which focuses on developing theoretical insights from successful data-driven and heuristic approaches, and vice-versa (heuristics from theory). While the general formulations of the underlying technical questions in this domain typically lead to complex optimization problems with known hardness results, tractable solutions can sometimes be obtained by exploiting domain-specific characteristics that arise in specific transportation systems. He also works closely with public transit agencies and private shuttle operators to gain domain-specific practical insights, calibration of models using real-data, and validation through simulation and real world deployment of our algorithms.

**Saurabh Amin**  Saurabh Amin is an Associate Professor in the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology (MIT). He is a PI in the Laboratory of Information and Decision Systems. He is also affiliated with the Operations Research Center, and the Center for Computational Science and Engineering at MIT.
Since joining MIT in 2011, he has pursued research in the design of inspection and control algorithms for infrastructure systems. His work builds on foundations in control theory, game theory, and optimization in networks. His papers have addressed problems in resilient network control, information systems and incentive design, and optimal resource allocation in large-scale infrastructure systems. By focusing on the domains of highway transportation, electric power distribution, and urban water networks, he develops new theory and design tools for improving the performance of critical infrastructure systems in the face of disruptions, both stochastic and adversarial.

Amin has supervised 7 doctoral and 19 Master students. His mentees have secured tenure-track positions at major universities, including Cornell University, Georgia Tech, New York University, USMA West Point, and University of Texas at Austin. His work has been supported by NSF CPS FORCES Frontiers project, NSF CAREER award, Google Research award, DoD-Science of Security Program, AFOSR, Siebel Energy Institute, and C3.ai Digital Transformation Institute.

Amin received his B.Tech. degree in civil engineering from Indian Institute of Technology Roorkee, M.S. in transportation engineering from University of Texas at Austin, and Ph.D. in systems engineering from University of California, Berkeley.

Alexandre Bayen  Alexandre Bayen is the Liao-Cho Professor of Engineering at UC Berkeley. He is a Professor of Electrical Engineering and Computer Science (link is external), and Civil and Environmental Engineering (link is external). He is currently the Director of the Institute of Transportation Studies (link is external) (ITS). He is also a Faculty Scientist in Mechanical Engineering, at the Lawrence Berkeley National Laboratory (link is external) (LBNL). He received the Engineering Degree in applied mathematics from the Ecole Polytechnique, France, in 1998, the M.S. and Ph.D. in aeronautics and astronautics from Stanford University in 1999 and 2004, respectively. He was a Visiting Researcher at NASA Ames Research Center from 2000 to 2003. Between January 2004 and December 2004, he worked as the Research Director of the Autonomous Navigation Laboratory at the Laboratoire de Recherches Balistiques et Aerodynamiques, (Ministere de la Defense, Vernon, France), where he holds the rank of Major. He has been on the faculty at UC Berkeley since 2005. Bayen has authored two books and over 200 articles in peer reviewed journals and conferences. He is the recipient of the Ballhaus Award from Stanford University, 2004, of the CAREER award from the National Science Foundation, 2009 and he is a NASA Top 10 Innovators on Water Sustainability, 2010. His projects Mobile Century and Mobile Millennium received the 2008 Best of ITS Award for ‘Best Innovative Practice’, at the ITS World Congress and a TRANNY Award from the California Transportation Foundation, 2009. Mobile Millennium has been featured more than 200 times in the media, including TV channels and radio stations (CBS, NBC, ABC, CNET, NPR, KGO, the BBC), and in the popular press (Wall Street Journal, Washington Post, LA Times). Bayen is the recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE) award from the White House, 2010. He is also the recipient of the Okawa Research Grant Award, the Ruberti Prize from the IEEE, and the Huber Prize from the ASCE.

Kaidi Yang  Kaidi is an Assistant Professor in Transportation in the Department of Civil and Environmental Engineering at the National University of Singapore (NUS). Prior to this, he was a postdoctoral scholar with the Autonomous Systems Laboratory in the Department of Aeronautics and Astronautics at Stanford University. He obtained a Ph.D. in Intelligent Transportation Systems from ETH Zurich in 2019. Prior to this, he received a BEng. in Automation, a BSc. in Pure and Applied Mathematics, and an MSc. in Control Science and Engineering from Tsinghua University. He aims to develop efficient and trustworthy algorithms for the design and operation of future mobility systems, with a particular focus on advances in vehicular technology (e.g., connected and automated vehicles, electric vehicles, etc.) and shared mobility. He is currently focusing on the following research areas: (1) connected and automated vehicles, (2) multimodal transportation systems, (3) risk-aware control of transportation systems, and (4) blockchain applications in transportation.
Mahnoosh Alizadeh  Dr. Alizadeh joined the UCSB electrical and computer engineering department in January 2017. Prior to that, she spent two years at Stanford University as a postdoctoral scholar. She received her PhD degree in Electrical and Computer Engineering from the University of California Davis in 2014 and her B.Sc. degree in Electrical Engineering from Sharif University of Technology in 2009. Dr. Alizadeh has been the recipient of the National Science Foundation CAREER award.

Panagiotis Angeloudis  Dr. Panagiotis Angeloudis is Reader and Head of the Transport Systems and Logistics Laboratory at Imperial College London. His research focuses on the intersection of autonomous vehicles, multi-agent systems modelling, network optimisation and their applications to freight distribution and passenger transportation. His research group specialises in developing high-performance, scalable models that capture the interactions between users, providers, infrastructure and operating regimes. Recent TSL projects have focused on the design of deployment strategies for safe and efficient autonomous transport systems (AVs, drones) for passenger and freight mobility.

3.4 Topics of interest

Topics of interest listed in the conference focus points include: Advanced Road Transportation Management, Social Transportation, Parallel Transportation Systems, Traffic Theory for ITS, Human Factors in ITS, Intelligent Logistics, Connected and Automated Vehicles, Shared Mobility, Education in ITS, Public Policy, Regulatory, and Societal Issues in ITS, New Trends in ITS.

4 Plan to solicit participation

The organizers have proven experience in organizing workshops at conferences and international seminars. We have become skilled in soliciting participation beyond mailinglists. Usually our advertising strategy includes:

- Direct marketing: inviting research groups directly to send their interested students.
- Marketing via organizers and keynote speakers: We have direct reach to ETH Zurich, Imperial College London, Technical University of Munich, MIT, UC Berkeley, EPFL, Cornell University, NUS, and UC Santa Barbara.
- Facebook, LinkedIn, Twitter, and other social media advertising.

Estimate of the number of attendants  Similar workshops which we organized in the past are expected to attract 70-100 persons. Virtual editions of our workshops involved over 250 participants, and were carried out online on Zoom, with interactions happening on GatherTown. However, as this edition will be physical (maybe even hybrid), it is hard to estimate the number of participants, as there might be travel restrictions due to the current pandemic and some of our colleagues around the world could experience difficulties in joining in person. Online participation is not the absolute solution, because it suffers from the time zone difference between Europe and the country of residence.

Our strategy is to maximize the number of people that can benefit from the workshop, even though they might not be able to attend in person, or online at the specific time in which it takes place. Because of this, we plan to have an hybrid workshop, recording, and possibly streaming it.

Additionally, we plan to disseminate the recordings after the workshop, if possible.

https://www.gather.town
5 Plan to encourage interaction among participants

The interaction among participants is the key ingredient of the proposed workshop, which already includes very diverse communities. Workshop participants will be able to continuously interact in person or virtually, via GatherTown. We designed the sessions to be highly interactive and not targeted to participants with a specific background (we expect a diverse mix of junior and senior researchers, from heterogeneous backgrounds), being more similar to guided interactive lectures. In between talks we scheduled 10 extra minutes that shall serve to answer questions and stimulate the conversation among participants. In the case of a virtual edition, participants will be able to join thematic virtual rooms. Interactions will be facilitated through:

- The possibility to ask questions by physical attendees at any time.
- In case of a virtual/hybrid edition, questions will be collected by a moderator over zoom-chat and will be answered at the end of the talk.
- Question spaces at the end of each talk.
- The open submission talks shall foster interactions between young researchers presenting work, and more experienced ones.

6 Dissemination

We will compile a “learning packet” that can be used as a study guide and for the benefits of people who might not be able to attend in person or at the specific time.

The learning packet will contain:

- **Recordings of the talks** will be provided after the workshop.
- **Pointers to curated literature**.
- **A summary of highlighted open challenges and tools to solve them**.

All of the above will be available for download on the official website.

7 Materials and equipment needed for the workshop

For the session we have minimal requirements, including a projector, audio system (microphone and speakers), and some chairs.

References


