Corporate Relations

MOBILITY

AIR TRAVEL, AUTONOMOUS & AUTOMATED MOBILITY, TRANSPORTATION NETWORKS, URBAN MOBILITY, PUBLIC TRANSPORT...

RESEARCH SURVEY

Mobility

This survey by MIT's Industrial Liaison Program identifies selected projects and faculty/researcher expertise in areas related to mobility, as it relates to transportation. For some, mobility represents something more than just getting from one place to another, instead representing the idea that a person should be able to access all they care about easily, efficiently, and safely through a variety of modes of transportation. Nonetheless, transportation is at the heart of however broad or narrow of a definition for mobility one wants to use.

Therefore, this research survey focuses on MIT research on the systems and modes of transportation that are primarily used to move people. Topics covered include air travel, autonomous and automated transportation modes, and urban mobility, including public transit. The report also includes research related to the analysis and optimization of transportation networks. While these fields are treated separately, there is quite a bit of overlap. It should also be noted that while novel modes of transportation are examined here, research is limited to the use of these modes and its impact on mobility, not the development of the technology behind these modes.

Of note, in November 2019 the MIT Energy Initiative (MITEI) will present its **Insights into Future Mobility report** to members of the greater MIT community; it will then be presented in Washington DC (Nov 19, 2019). This report is the culmination of the three-year Mobility of the Future study that examined how the complex interactions between advanced drivetrain options, alternative fuels, refueling infrastructure, consumer choice, vehicle automation, and government policy may shape the future for personal mobility. Study leaders and researchers will share key findings, supported by detailed research involving advanced modeling; analysis of primary survey data; and interviews with government officials. They will provide insights into how evolving environmental policies, urban regulations, disruptive technologies, economics, and consumer behaviors and attitudes may transform mobility systems. See: http://energy.mit.edu/research/mobilityofthefuture/

Research and expertise in various aspects of mobility come from departments and labs and centers across the Institute, including the following:

- Aero / Astro
- AgeLab
- CEEPR
- Center for Transportation and Logistics
- City Science
- Civil and Environmental Engineering
- Civic Data Design Lab
- CSAIL
- Distributed Robotics Lab
- EECS
- Engineering Systems
- Future Urban Mobility
- Intelligent Transportation Systems Lab
- Institute for Data, Systems, and Society
- International Center for Air Transportation
- JTL Urban Mobility Lab
- New England University Transportation Center
- Norman B. Leventhal Center for Advanced Urbanism
- P-Rex lab
- Senseable City Lab
- Transit Lab
- Urban Studies & Planning

For more information, please contact us at +1-617-253-2691.

AIR TRAVEL

HAMSA BALAKRISHNAN

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Director, Transportation@MIT, https://transportation.mit.edu/about/leadership
Publications: http://web.mit.edu/hamsa/www/publications.html

Hamsa Balakrishnan is a professor of aeronautics and astronautics at MIT. Before joining MIT, she was at the NASA Ames Research Center, after receiving her PhD from Stanford University and a B.Tech. from the Indian Institute of Technology Madras. Her research is in the design, analysis, and implementation of control and optimization algorithms for large-scale cyber-physical infrastructures, with an emphasis on air transportation systems. Her contributions include airport congestion control algorithms, air traffic routing and airspace resource allocation methods, machine learning for weather forecasts and flight delay prediction, and methods to mitigate environmental impacts.

Simulation-based benefits and costs assessment of NASA's airspace technology demonstration-2

Saraf, A., Popish, M., Sui, V., Luch, N., Rose, M., Levy, B., Cardillo, J., Balakrishnan, H., Badrinath, S., Coppenbarger, R.
AIAA/IEEE Digital Avionics Systems Conference – Proceedings, Volume 2018-September, 7 December 2018, Article number 8569626, https://doi.org/10.1109/DASC.2018.8569626

This paper estimates the benefits and costs for an integrated arrival, departure, surface traffic management technology currently under operational evaluation at Charlotte Douglas International Airport. The technology under study is NASA's Airspace Technology Demonstration 2 (ATD-2) system. Using high-fidelity fast-time simulations of current-day operations (including modeling of current-day operational shortfalls) and future ATD-2 operations (including the modeling of associated ATD-2 benefit mechanisms), ATD-2 benefits were projected for three major U.S. airports. Individual airport benefits were then annualized (extrapolated to full year benefits) and nationalized (extrapolated to Core-30 FAA airports), to compute total projected monetary benefits per year. FAA-recommended cost assessment approaches were applied to compute projected ATD-2 implementation costs. Finally, costs were compared against National Airspace System (NAS)-wide benefits, and a projected return on investment was calculated. Our results estimate that the ATD-2 system can provide $2.6 billion in monetary benefits nationwide over the lifecycle of the program due to significant reduction in taxi delay as well as shifting of the delays from taxi to gate. The projected ATD-2 benefits significantly outweigh the projected implementation costs. Incorporation of ATD-2 into the FAA's planned Terminal Flight Data Manager (TFDM) system deployments is estimated to improve the benefit-cost ratio of the TFDM program from an earlier estimated 1.09 to 1.89 over the lifecycle of the program.

Privacy and stability in airport ground delay programs

Gopalakrishnan, K., Balakrishnan, H.
2017 IEEE 56th Annual Conference on Decision and Control, CDC 2017, Volume 2018-January, 18 January 2018, Pages 1199-1205, https://doi.org/10.1109/CDC.2017.8263819

Adverse weather can reduce airport capacity. When the number of arriving aircraft exceeds this reduced capacity, flights can get delayed. A Ground Delay Program (GDP) is a strategy by which aircraft landing slots can be redistributed so that the flights are delayed on the ground itself and not in the air. This increases safety, reduces the fuel consumption and hence the operating costs for airlines. In this paper, we present six algorithms that perform this slot reassignment. These algorithms differ in the extent to which slots can get re-arranged in real-time and the amount of information that the airlines must reveal to the central planner during the implementation. These two features of the algorithm are called as stability and privacy respectively. The efficiency of these six algorithms, measured in terms of the expected delay cost for flights, is compared using operational data for La Guardia Airport in New York. A two-step Receding Horizon Static (2-step RHS) model is shown to be a good compromise based on present expectations of privacy and stability in the system.

Evaluating the impact of uncertainty on airport surface operations

Badrinath, S., Balakrishnan, H., Clemons, E. Author, Reynolds, T.G.
2018 Aviation Technology, Integration, and Operations Conference, 2018, Article number AIAA 2018-4242, 22p, https://doi.org/10.2514/6.2018-4242

Flights spend significantly more time taxiing on the airport surface during periods when the departure demand exceeds airport capacity, resulting in excessive fuel burn. Departure metering by holding aircraft at the gate during periods of congestion has been shown to yield benefits by lowering the taxi-out time. However, an important aspect of this problem that has not been understood well is the impact of uncertainty in departure demand. Recently, some airlines are beginning to publish an expected time that the flights are ready to pushback, which is referred to as Earliest Off-Block Time (EOBT). Tactical decisions for departure metering need to be made with the EOBT information. However, the EOBT published by airlines is often found to deviate from the actual gate out time without departure metering, which represents an error in the EOBT estimate. Hence, it is important to consider errors in EOBT information while analyzing benefits from departure metering. In this paper, we present a queuing network model to predict aircraft taxi-times on the airport surface. The predictions from the queue model are used for departure metering with NASA's ATD-2 logic that is being used in field trials at Charlotte airport. The framework allows us to quantify the reduction in departure metering benefits due to errors in EOBT information. The analysis reveals that the benefits reduce significantly due to EOBT uncertainty which has important implications for future departure metering applications, such as through the Terminal Flight Data Manager (TFDM) platform.

CYNTHIA BARNHART

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Professor of Civil and Environmental Engineering and Engineering Systems

Appointed chancellor of the Massachusetts Institute of Technology in 2014, she is responsible for advising the president on undergraduate and graduate education and residential life policies. She plays a leading role in strategic planning, faculty appointments, resource development, and campus planning activities.

Her teaching and research is in the areas of large-scale optimization, airlines operations, the global airline industry, and transportation operations, planning, and control. She has supervised scores of graduate and undergraduate theses across a range of disciplines, and has published widely in the flagship journals of her field.

Robust optimization: Lessons learned from aircraft routing

Marla, L., Vaze, V., Barnhart, C.
Computers and Operations Research, Volume 98, October 2018, Pages 165-184,
https://doi.org/10.1016/j.cor.2018.04.011

Building robust airline scheduling models involves constructing schedules and routes with reduced levels of flight delays as well as fewer passenger and crew disruptions. In this paper, we study different classes of models to achieve robust airline scheduling solutions, with a focus on the aircraft routing problem. In particular, we compare one domain-specific approach and two general paradigms of robust models, namely, (i) an extreme-value based or robust optimization-based approach, and (ii) a chance-constrained or stochastic optimization-based approach. Our modeling and solution approach demonstrates the creation of data-driven uncertainty sets for aircraft routing using domain-specific knowledge and develops a completely data-driven simulation-based validation and testing approach. We first demonstrate that additional modeling, capturing domain knowledge, is required to adapt these general robust modeling paradigms to the aircraft routing problem, in order to meaningfully add robustness features specific to aircraft routing. However, we show that these models in their naive forms, still face issues of tractability and solution quality for the large-scale networks which are representative of real-world airline scheduling problems. Therefore, we develop and present advanced models that address these shortcomings. Our advanced models can be applied to aircraft routing in multiple ways, through varied descriptions of the uncertainty sets; and moreover, are generally applicable to linear and binary integer programming problems. Through our detailed computational results, we compare the performance of solutions arising from these different robust modeling paradigms and discuss the underlying reasons for their performance differences from a data-driven perspective.

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Identification, Characterization, and Prediction of Traffic Flow Patterns in Multi-Airport Systems

Murca, M.C.R., Hansman, R.J.
IEEE Transactions on Intelligent Transportation Systems, Volume 20, Issue 5, May 2019, Article number 8373742, Pages 1683-1696, https://doi.org/10.1109/TITS.2018.2833452

Efficient planning of airport capacity is key for the successful accomplishment of traffic flow management. Yet, the dynamic and uncertain behavior of capacity-determining factors makes it difficult to estimate flow rates precisely, especially for strategic planning horizons. Metroplex systems impose additional challenges in this decision-making process because of relevant operational interdependencies between the closely located airports. This paper presents a data-driven framework to identify, characterize, and predict traffic flow patterns in the terminal area of multi-airport systems toward improved capacity planning decision support in complex airspace. Through the identification and characterization of patterns in the terminal area traffic flows, we learn recurrent utilization patterns of runways and airspace as well as relevant decision factors, and use that knowledge to develop descriptive models for metroplex configuration prediction and capacity estimation. The framework is based on the application of machine learning methods on historical flight tracks, weather forecasts, and airport operational data. A multi-layer clustering analysis is first performed to mine spatial and temporal trends in flight trajectory data for identification of traffic flow patterns. Based on this knowledge, a multi-way classification model is developed to generate probabilistic forecasts of the metroplex traffic flow structure for look-ahead times of up to eight hours. Finally, an empirical approach for arrival capacity estimation is proposed based on historical flow pattern behavior. The observed variability in throughput and terminal area delay performance emphasizes the importance of metroplex configuration predictability toward improved flow rate planning and ultimately better traffic regulation.

Development of vertiport capacity envelopes and analysis of their sensitivity to topological and operational factors

Vascik, P.D., Hansman, R.J.
AIAA Scitech 2019 Forum, 2019, https://doi.org/10.2514/6.2019-0526

This study develops an Integer Programming (IP) approach to analytically estimate vertiport capacity envelopes. The approach is used to determine the sensitivity of vertiport capacity to the number and layout of touchdown and liftoff pads, taxiways, gates, and parking pads (i.e. the vertiport topology). The study also assesses the sensitivity of vertiport capacity to operational parameters including taxi time, turnaround time, pre-staged aircraft, and approach/departure procedure independence, among others. Findings indicate the importance of balancing the number of touchdown and liftoff pads with the number of gates to achieve maximum aircraft throughput per vertiport footprint. Furthermore, simultaneous paired arrivals or departures provide significant throughput gains without the need for fully independent approach and departure procedures. The methodology and findings introduced in this paper support the development of concepts of operation to maximize throughput for a given vertiport footprint and demand scenario. While throughput has been extensively researched for fixed-wing operations, little research has been dedicated to the operation of infrastructure for Vertical Takeoff and Landing (VTOL) aircraft. The emergence of new VTOL aircraft to conduct a potentially large number of urban air mobility operations creates a need to better understand the operation and throughput capacity of vertiports, especially in space constrained inner-city locations. This paper reviews numerous existing heliport designs to derive four topology classes of vertiport layouts. The IP formulation of vertiport operations is readily adapted to represent the infrastructure and operations of these layouts.

Predicting and planning airport acceptance rates in metroplex systems for improved traffic flow management decision support

Murça, M.C.R., Hansman, R.J.

Transportation Research Part C: Emerging Technologies, Volume 97, December 2018, Pages 301-323, https://doi.org/10.1016/j.trc.2018.10.020

Efficient planning of Airport Acceptance Rates (AARs) is key for the overall efficiency of Traffic Management Initiatives such as Ground Delay Programs (GDPs). Yet, precisely estimating future flow rates is a challenge for traffic managers during daily operations as capacity depends on a number of factors/decisions with very dynamic and uncertain profiles. This paper presents a data-driven framework for AAR prediction and planning towards improved traffic flow management decision support. A unique feature of this framework is to account for operational interdependency aspects that exist in metroplex systems and affect throughput performance. Gaussian Process regression is used to create an airport capacity prediction model capable of translating weather and metroplex configuration forecasts into probabilistic arrival capacity forecasts for strategic time horizons. To process the capacity forecasts and assist the design of traffic flow management strategies, an optimization model for capacity allocation is developed. The proposed models are found to outperform currently used methods in predicting throughput performance at the New York airports. Moreover, when used to prescribe optimal AARs in GDPs, an overall delay reduction of up to 9.7% is achieved. The results also reveal that incorporating robustness in the design of the traffic flow management plan can contribute to decrease delay costs while increasing predictability.

MIT INTERNATIONAL CENTER FOR AIR TRANSPORTATION

http://icat.mit.edu
Director: R. John Hansman
Projects: http://icat.mit.edu/current-projects
Publications: http://icat.mit.edu/research

The mission of the MIT International Center for Air Transportation is to improve the safety, efficiency and capacity of domestic and international air transportation and its infrastructure, utilizing information technology and human centered systems analysis.

Cruise Altitude and Speed Optimization Decision Support Tool

http://icat.mit.edu/current-projects

Changing weather, turbulence encountered en route, and air traffic constraints, among other factors, can result in airliners flying at suboptimal altitudes, creating significant fuel burn inefficiencies. However, current aircraft crews, working with flight plans and weather information that may be several hours old, have limited information to support replanning a flight en route when those situations are encountered. As a result, a decision support tool for cruise altitude and speed optimization is being developed for use in the cockpit, integrating an optimization framework, the most recent weather forecasts, and a graphical visualization interface to assist pilots in making strategic altitude and speed decisions in real time. The decision support tool is able to provide an optimized flight plan, as well as capabilities for rapidly assessing the impact of various flight plan options on fuel, time, and expected ride quality across the length of the flight.

Analysis of Urban Air Mobility Operational Constraints

http://icat.mit.edu/current-projects

Urban air mobility (UAM) refers to a set of proposed operations and technologies that aim to provide on-demand air transportation services within a metropolitan area. This project investigates potential operational constraints that could arise during the implementation, operation, or scale-up of a UAM system. Exploratory case studies in Los Angeles, Boston, and Dallas identified a set seven UAM operational constraints. The top three prioritized constraints concern aircraft noise, takeoff and landing area availability, and air traffic control scalability. These constraints directly aligned with previous literature from helicopter passenger networks and indicate new electric aircraft, automation, and telecommunications technologies may not directly address the significant operation constraints of UAM networks. Continued efforts are therefore investigating approaches to mitigate the impacts of these three constraints, particularity through a new concept of operations for low altitude air traffic control. The results of this project support NASA and FAA decision makers and may inform requirement definition for UAM aircraft and networks.

Non-stop versus connecting air services: Airfares, costs, and consumers' willingness to pay

Ennen, David; Allroggen, Florian; Malina, Robert
https://dspace.mit.edu/handle/1721.1/121459

Airlines provide both non-stop and connecting services. The airfare for each service type is determined largely by the willingness to pay (WTP) of passengers and the costs for airlines. This paper estimates the impact of itinerary characteristics such as number of stopovers, detour, layover time, and aircraft size on airfares using a novel demand and supply model. This model allows us to calculate both costs and markups for non-stop and connecting itineraries in U.S. domestic markets. We find that, on average, passengers have a higher WTP for nonstop flights and the WTP for connecting flights is driven particularly by the number of stopovers, in-flight time, and transfer time. As a result, we identify significant heterogeneity with regard to costs and mark-ups between markets. While in most U.S. domestic markets airlines incur higher costs for operating connecting routings, the indirect routing via a hub achieves lower costs in some markets, as the economies associated with the use of larger aircraft offset the costs of the stopover. Finally, we show that the presence of connecting services reduces fares for nonstop flights, in particular for itineraries with a longer market distance as detours and the significance of fixed costs associated with a stopover decrease.

Assessing Integration Between Emerging and Conventional Operations in Urban Airspace

Vascik, Parker D.; Hansman, R. John
https://dspace.mit.edu/handle/1721.1/121182

This paper investigates the use of low altitude airspace by conventional flight operations in proximity to the San Francisco, Boston, and Atlanta international airports. The purpose of the investigation is two-fold. First, the study presents an approach to develop lateral and vertical containment boundaries for arrival and departure flight trajectories. The boundaries describe the extent of the airspace actively used to support the flights. Second, the study develops containment boundaries for large transport aircraft operations at the three airports to demonstrate how these conventional operations may influence where and when emerging Unmanned Aircraft Systems (UAS) or Urban Air Mobility (UAM) networks may operate. 180 days of ASDE-X radar tracking data were analyzed to determine the location and traffic density of large transport aircraft, helicopters, and four other classes of operators. The flight trajectories for each operator class were sorted into arrivals, departures, and missed approaches to or from each runway. Containment boundaries were first developed for transport aircraft with greater than 100 passenger seats. Airspace that remained outside the containment boundary could potentially support simultaneous but non-interfering UAS or UAM operations. Variations in containment size due to airport-specific attributes were investigated. Containment boundary expansion to accommodate regional and commuter aircraft operations was assessed. Finally, airport access for UAM or UAS operators based upon conventional flight operations was considered.

Data-Driven Modeling of Air Traffic Flows for Advanced Air Traffic Management

Condé Rocha Murça, Mayara; Hansman, R. John
https://dspace.mit.edu/handle/1721.1/121155

The Air Traffic Management (ATM) system enables air transportation by ensuring a safe and orderly air traffic flow. As the air transport demand has grown, ATM has become increasingly challenging, resulting in high levels of congestion, flight delays and environmental impacts. To sustain the industry growth foreseen and enable more efficient air travel, it is important to develop mechanisms for better understanding and predicting the air traffic flow behavior and performance in order to assist human decision-makers to deliver improved airspace design and traffic management solutions. This thesis presents a data-driven approach to modeling air traffic flows and analyzes its contribution to supporting system level ATM decision-making. A data analytics framework is proposed for high-fidelity characterization of air traffic flows from large-scale flight tracking data. The framework incorporates a multi-layer clustering analysis to extract spatiotemporal patterns in aircraft movement towards the identification of trajectory patterns and traffic flow patterns. The outcomes and potential impacts of this framework are demonstrated with a detailed characterization of terminal area traffic flows in three representative multi-airport (metroplex) systems of the global air transportation system: New York, Hong Kong and Sao Paulo. As a descriptive tool for systematic analysis of the flow behavior, the framework allows for cross-metroplex comparisons of terminal airspace design, utilization and traffic performance. Novel quantitative metrics are created to summarize metroplex efficiency, capacity and predictability. The results reveal several structural, operational and performance differences between the metroplexes analyzed and highlight varied action areas to improve air traffic operations at these systems. Finally, the knowledge derived from flight trajectory data analytics is leveraged to develop predictive and prescriptive models for metroplex configuration and capacity planning decision support. Supervised learning methods are used to create prediction models capable of translating weather forecasts into probabilistic forecasts of the metroplex traffic flow structure and airport capacity for strategic time horizons. To process these capacity forecasts and assist the design of traffic flow management strategies, a new optimization model for capacity allocation is developed. The proposed models are found to outperform currently used methods in predicting throughput performance at the New York airports. Moreover, when used to prescribe optimal Airport Acceptance Rates in Ground Delay Programs, an overall delay reduction of up to 9.7% is achieved.

Feasibility Study of Short Takeoff and Landing Urban Air Mobility Vehicles Using Geometric Programming

Courtin, Christopher; Burton, Michael; Butler, Patrick; Yu, Alison; Vascik, Parker D.; Hansman, R. John
https://dspace.mit.edu/handle/1721.1/116863

Electric Short Takeoff and Landing (eSTOL) vehicles are proposed as a path towards implementing an Urban Air Mobility (UAM) network that reduces critical vehicle certification risks and offers advantages in vehicle performance compared to the widely proposed Electric Vertical Takeoff and Landing (eVTOL) aircraft. An overview is given of the system constraints and key enabling technologies that must be incorporated into the design of the vehicle. The tradeoffs

between vehicle performance and runway length are investigated using geometric programming, a robust optimization framework. Runway lengths as short as 100-300 ft are shown to be feasible, depending on the level of technology and the desired cruise speed. The tradeoffs between runway length and the potential to build new infrastructure in urban centers are investigated using Boston as a representative case study. The placement of some runways up to 600ft is shown to be possible in the urban center, with a significant increase in the number of potential locations for runways shorter than 300ft. Key challenges and risks to implementation are discussed.

Scaling Constraints for Urban Air Mobility Operations: Air Traffic Control, Ground Infrastructure, and Noise

Vascik, Parker; Hansman, R. John
https://dspace.mit.edu/handle/1721.1/116860

The scalability of the current air traffic control system, the availability of aviation ground infrastructure, and the acceptability of aircraft noise to local communities have been identified as three key operational constraints that may limit the implementation or growth of Urban Air Mobility (UAM) systems. This paper identifies the primary mechanisms through which each constraint emerges to limit the number of UAM operations in an area (i.e. the scale of the service). Technical, ecosystem, or operational factors that influence each of the mechanisms are also identified. Interdependencies between the constraints are shown. Potential approaches to reduce constraint severity through adjustments to the mechanisms are introduced. Finally, an effort is made to characterize the severity of each operational constraint as a function of the density of UAM operations in a region of interest. To this end, a measure of severity is proposed for each constraint. This measure is used to notionally display how the severity of the constraint responds to UAM scaling, and to identify scenarios where efforts to relieve the constraint are most effective. The overall purpose of this paper is to provide an abstraction of the workings of the key UAM operational constraints so that researchers, developers, and practitioners may guide their efforts to mitigation pathways that are most likely to increase achievable UAM system scale.

AUTONOMOUS AND AUTOMATED MOBILITY

ALAN M BERGER

Norman B (1938) and Muriel Leventhal Professor of Urban Design and Landscape Architecture, http://dusp.mit.edu/faculty/alan-berger, https://www.alanmberger.com
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Alan M. Berger is Professor of Landscape Architecture and Urban Design at Massachusetts Institute of Technology where he teaches courses open to the entire student body. He is founding director of MIT's P-REX lab, a research lab focused on environmental problems caused by urbanization, including the design, remediation, and reuse of waste landscapes worldwide. He is also Co-Director of MIT Norman B. Leventhal Center for Advanced Urbanism (LCAU). All of his research and work emphasizes the link between our consumption of natural resources, and the waste and destruction of landscape, to help us better understand how to proceed with redesigning around our wasteful lifestyles for more intelligent design and development outcomes. Unlike conventional practice, there are no scalar limits in his outlook or pedagogy: Projects are defined by the extent of the urban and environmental problems being addressed. He coined the term

"Systemic Design" to describe the reintegration of disvalued landscapes into our urbanized territories and regional ecologies.

P-Rex lab

https://www.alanmberger.com/

P-REX lab is a research group focused on environmental issues caused by urbanization, including the design, remediation, and reuse of landscapes worldwide. All of our research and work emphasizes the link between our consumption of natural resources, and the waste and destruction of landscape, to help us better understand how to proceed with redesigning around our wasteful lifestyles for more intelligent design and development outcomes. Unlike conventional practice, there are no scalar limits in our outlook or pedagogy: projects are defined by the extent of the urban and environmental problems being addressed. We coined the term "Systemic Design" to describe our approach to urbanization, which considers the entire urban enterprise as one holistic system that can be improved through design thinking.

Autonomous Transportation and Its Potential to Transform Suburban Life

http://toyotamobilityfoundation.org/en/research/suburban.html

As global populations grow, cities are expanding beyond their core and out to lower-density suburban neighborhoods. In the United States, almost two-thirds of these suburban areas have non-existent or limited public transit options. This results in a dependence on individually-owned vehicles and associated challenges of traffic, parking, affordability, and environmental impact. With this in mind, the autonomous driving revolution has the potential to radically transform life in suburban communities.

To explore the possibilities, TMF has partnered with the MIT Norman B. Leventhal Center for Advanced Urbanism. Together, and with the collaboration of urban planners and landscape urbanists, we will expand prior research to develop scenarios and plausible suburban configurations that will explore autonomous mobility options. The work will evaluate real-world typologies and create guidelines for future land use and new Optimized Suburban Units (OSUs). TMF will also work to develop best practices for policy development and implementation.

JOSEPH F COUGHLIN

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Publications: https://longevityeconomy.com/publications

Joseph F. Coughlin, PhD is Director of the Massachusetts Institute of Technology AgeLab. He teaches in MIT's Department of Urban Studies & Planning and the Sloan School's Advanced Management Program. Coughlin conducts research on the impact of global demographic change and technology trends on consumer behavior and business strategy.

Special Series: Social Science of Automated Driving

Coughlin, J.F., Raue, M., D'Ambrosio, L.A., Ward, C., Lee, C.
Risk Analysis, Volume 39, Issue 2, February 2019, Pages 293-294,
https://doi.org/10.1111/risa.13271

[No abstract available]

The Influence of Feelings While Driving Regular Cars on the Perception and Acceptance of Self-Driving Cars

Raue, M., D'Ambrosio, L.A., Ward, C., Lee, C., Jacquillat, C., Coughlin, J.F.
Risk Analysis, Volume 39, Issue 2, February 2019, Pages 358-374,
https://doi.org/10.1111/risa.13267

Self-driving vehicles will affect the future of transportation, but factors that underlie perception and acceptance of self-driving cars are yet unclear. Research on feelings as information and the affect heuristic has suggested that feelings are an important source of information, especially in situations of complexity and uncertainty. In this study (N = 1,484), we investigated how feelings related to traditional driving affect risk perception, benefit perception, and trust related to self-driving cars as well as people's acceptance of the technology. Due to limited experiences with and knowledge of self-driving cars, we expected that feelings related to a similar experience, namely, driving regular cars, would influence judgments of self-driving cars. Our results support this assumption. While positive feelings of enjoyment predicted higher benefit perception and trust, negative affect predicted higher risk and higher benefit perception of self-driving cars. Feelings of control were inversely related to risk and benefit perception, which is in line with research on the affect heuristic. Furthermore, negative affect was an important source of information for judgments of use and acceptance. Interest in using a self-driving car was also predicted by lower risk perception, higher benefit perception, and higher levels of trust in the technology. Although people's individual experiences with advanced vehicle technologies and knowledge were associated with perceptions and acceptance, many simply have never been exposed to the technology and know little about it. In the absence of this experience or knowledge, all that is left is the knowledge, experience, and feelings they have related to regular driving.

IYAD RAHWAN

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The Moral Machine

http://moralmachine.mit.edu/

Adoption of self-driving, Autonomous Vehicles (AVs) promises to dramatically reduce the number of traffic accidents. But some inevitable accidents will require AVs to make tradeoffs about potential risk, such as risk to pedestrians on the road versus risk to the passenger in the car. Even if these "moral dilemmas" are rare, defining algorithms to make such decisions is a challenge, since people may be uncomfortable with the idea of Artificial Intelligence making life-and-death decisions without human oversight. Experimental ethics can help manufacturers and regulators understand the psychological challenges that may undermine trust in driverless cars, and our ability to exercise oversight over their behavior. This may be a necessary pre-condition to the wide adoption of autonomous transportation.

The trolley, the bull bar, and why engineers should care about the ethics of autonomous cars

Bonnefon, J.-F., Shariff, A., Rahwan, I.
Proceedings of the IEEE, Volume 107, Issue 3, March 2019, Article number 8662742, Pages 502-504, https://doi.org/10.1109/JPROC.2019.2897447

Everyone agrees that autonomous cars ought to save lives. Even if the cars do not live up to the most optimistic estimates of eliminating 90% of traffic fatalities [1], eliminating at least some traffic fatalities is one of the key promises of automated driving. Indeed, the first two principles of the German Ethics Code for Automated and Connected Vehicles lead with this goal as a normative imperative [2].The primary purpose of partly and fully automated transport systems is to improve safety for all road users. The licensing of automated systems is not justifiable unless it promises to produce at least a diminution in harm compared with human driving [ ].

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Bryan Reimer, Ph.D., is a Research Scientist in the MIT Center for Transportation and Logistics, a researcher in the AgeLab, and the Associate Director of The New England University Transportation Center. His research seeks to develop theoretical and applied insight into driver behavior by fusing together traditional psychological methods with big data analytics in computer vision, deep learning, and predictive modeling. His work leverages laboratory experimentation, driving simulation, field testing, and naturalistic driving studies to develop a comprehensive understanding of visual, physiological, behavioral, and overall performance characteristics associated with how drivers respond to the increasing complexity of the modern operating environment. His work aims to find solutions to the next generation of human factors challenges associated with driver attention management, distraction, automation and the use of advanced driver assistance systems to maximize mobility and safety. He is an author on over 200 technical contributions in transportation and related human factors areas....

The Relative Impact of Smartwatch and Smartphone use while Driving on Workload, Attention, and Driving Performance

Perlman, D., Samost, A., Domel, A.G., Mehler, B., Dobres, J. & Reimer, B. (2019). Applied Ergonomics, 75, pp. 8-16. https://doi.org/10.1016/j.apergo.2018.09.001

The impact of using a smartwatch to initiate phone calls on driver workload, attention, and performance was compared to smartphone visual-manual (VM) and auditory-vocal (AV) interfaces. In a driving simulator, 36 participants placed calls using each method. While task time and number of glances were greater for AV calling on the smartwatch vs. smartphone, remote detection task (R-DRT) responsiveness, mean single glance duration, percentage of long duration off-road glances, total off-road glance time, and percent time looking off-road were similar; the later metrics were all significantly higher for the VM interface vs. AV methods. Heart rate and skin conductance were higher during phone calling tasks than "just driving", but did not consistently differentiate calling method. Participants exhibited more erratic driving behavior (lane position and major steering wheel reversals) for smartphone VM calling compared to both AV methods. Workload ratings were lower for AV calling on both devices vs. VM calling.

A user study of semi-autonomous and autonomous highway driving: An interactive simulation study

Park, J., Iagnemma, K., Reimer, B.
IEEE Pervasive Computing, Volume 18, Issue 1, January-March 2019, Article number 8705036, Pages 49-58, https://doi.org/10.1109/MPRV.2018.2873850

The aim of this study is to explore user acceptance of semi-autonomous and fully autonomous vehicles on a highway through the use of an interactive simulator. Participants were asked to experience driving modes with three different levels of autonomy and complete questionnaires with items selected from traditional and automotive-specific technology acceptance models. The three levels of automation included manual driving (no-automation as a baseline condition), semi-autonomous driving where drivers were able to indicate lane change decisions, and fully autonomous driving. Results indicate that within the limited experience of the interactive simulation, users grew to like the automated system as much as manual control during later portions of the study. Overall, this work suggests that the driver will quickly grow to like automated driving features and may rapidly become less anxious about the loss of control experienced.

DANIELA L RUS

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Publications: http://danielarus.csail.mit.edu/index.php/about-daniela-2/publications-2/

Daniela Rus is the Andrew (1956) and Erna Viterbi Professor of Electrical Engineering and Computer Science and Director of the Computer Science and Artificial Intelligence Laboratory (CSAIL) at MIT. Rus's research interests are in robotics, mobile computing, and data science. Rus is a Class of 2002 MacArthur Fellow, a fellow of ACM, AAAI and IEEE, and a member of the National Academy of Engineering, and the American Academy for Arts and Science. She earned her PhD in Computer Science from Cornell University.

Distributed Robotics Lab

https://www.csail.mit.edu/research/distributed-robotics-laboratory

Our work spans: computational design and fabrication of robots; algorithms for perception, planning reasoning and control with guarantees; algorithms for auditable machine learning; and algorithms for collaborating machines and people. Our innovations enable new applications in smart living, transportation, healthcare, manufacturing, monitoring, exploration, and much more.

We focus on developing the science of network, distributed, and collaborative robotics by asking: how can many machines collaborate to achieve a common goal? Our research addresses the development of algorithms and systems that enable collaboration, increase autonomous capabilities, and rethink the ways in which we design and interact with the physical world.

Self-Driving Vehicles

https://www.csail.mit.edu/research/self-driving-vehicles

The Toyota-CSAIL Joint Research Center is aimed at furthering the development of autonomous vehicle technologies, with the goal of reducing traffic casualties and potentially even developing a vehicle incapable of getting into an accident.

Led by CSAIL director Daniela Rus, the new center will focus on developing advanced decision-making algorithms and systems that allow vehicles to perceive and navigate their surroundings safely, without human input. Researchers will tackle challenges related to everything from computer vision and perception to planning and control.

Planning in Congestion for Autonomous Vehicles

https://www.csail.mit.edu/research/planning-congestion-autonomous-vehicles

As autonomous vehicles populate the road, they need to interact with other autonomous and human drivers. In urban environments, these vehicles will need to navigate dense traffic situations, thus creating a need for planning in congestion. Our approach creates a dynamic control law that scales with the varying traffic density. We generate a cost function for the vehicle, which incorporates the density, occupancy, and risk level within the environment. By choosing vehicles actions only below a certain cost value, we demonstrate the vehicle remains safe while avoiding the common “freezing robot” problem.

Autonomous Vehicle Navigation in Rural Environments Without Detailed Prior Maps

Ort, T., Paull, L., Rus, D.
Proceedings - IEEE International Conference on Robotics and Automation, 10 September 2018, Article number 8460519, Pages 2040-2047, https://doi.org/10.1109/ICRA.2018.8460519

State-of-the-art autonomous driving systems rely heavily on detailed and highly accurate prior maps. However, outside of small urban areas, it is very challenging to build, store, and transmit detailed maps since the spatial scales are so large. Furthermore, maintaining detailed maps of large rural areas can be impracticable due to the rapid rate at which these environments can change. This is a significant limitation for the widespread applicability of autonomous driving technology, which has the potential for an incredibly positive societal impact. In this paper, we address the problem of autonomous navigation in rural environments through a novel mapless driving framework that combines sparse topological maps for global navigation with a sensor-based perception system for local navigation. First, a local navigation goal within the sensor view of the vehicle is chosen as a waypoint leading towards the global goal. Next, the local perception system generates a feasible trajectory in the vehicle frame to reach the waypoint while abiding by the rules of the road for the segment being traversed. These trajectories are updated to remain in the local frame using the vehicle's odometry and the associated uncertainty based on the least-squares residual and a recursive filtering approach, which allows the vehicle to navigate road networks reliably, and at high speed, without detailed prior maps. We demonstrate the performance of the system on a full-scale autonomous vehicle navigating in a challenging rural environment and benchmark the system on a large amount of collected data.

AGELAB

http://agelab.mit.edu
Research: http://agelab.mit.edu/research
Publications: http://agelab.mit.edu/2019-publications

The MIT AgeLab is a multidisciplinary research program that works with business, government, and NGOs to improve the quality of life of older people and those who care for them. The AgeLab applies consumer-centered systems thinking to understand the challenges and opportunities of longevity and emerging generational lifestyles to catalyze innovation across business markets.

The Advanced Vehicle Technology Consortium (AVT)

http://agelab.mit.edu/avt

The Advanced Vehicle Technology (AVT) Consortium was launched in September 2015 with the goal of achieving a data-driven understanding of how drivers engage with and leverage vehicle automation, driver assistance technologies, and the range of in-vehicle and portable technologies for connectivity and infotainment appearing in modern vehicles.

Using advanced computer-vision software and big data analytics, researchers are gathering data to quantify drivers' actions, such as how they respond to various driving situations and perform other actions like eating or having conversations behind the wheel. The research is studying the moments when control transfers from the driver to the car and back again, as well as how drivers respond to alarms (lane keeping, forward collision, proximity detectors, etc.) and interact with assistive and safety technologies (e.g., adaptive cruise control, semi-autonomous parking assistance, vehicle infotainment and communications systems, smartphones and more). The effort aims to develop human-centric insights that drive the safety efficacy of automated vehicle technology development and advances the consumer's understanding of appropriate technology usage.

Advanced Human Factors Evaluator for Automotive Demand Consortium (AHEAD)

http://agelab.mit.edu/AHEAD

The Advanced Human Factors Evaluation for Automotive Demand (AHEAD) consortium was founded in 2013 by DENSO, the MIT AgeLab, and Touchstone Evaluations, Inc. with the goal of creating an empirical HMI evaluation system based upon a scientifically valid framework that supports the assessment of demands placed on the driver by multimodal interfaces and other advanced technologies. Members include Jaguar Land Rover, Google, and Aptiv. AHEAD engages organizations across the automotive industry, participants have included leaders such as Honda, Subaru R&D, and Panasonic.

Economics and Policies of a Highly Automated Mobility System

http://agelab.mit.edu/economics-and-policies-highly-automated-mobility-system

Autonomous technologies are poised to revolutionize how we move. Commuting time for example may be lowered, giving driverless car users more time to work, sleep, or engage in leisure activities. Road safety is also expected to improve. This is especially important given over 1.3 million lives are lost each year in traffic accidents. And certain populations like older adults who can longer drive, teenagers, and people with disabilities may enjoy the benefits of greater mobility.

Our research examines how automation will affect the cost of transportation and structure of jobs in the economy.

NORMAN B. LEVENTHAL CENTER FOR ADVANCED URBANISM

http://lcau.mit.edu
Research: http://lcau.mit.edu/projects

The MIT Norman B. Leventhal Center for Advanced Urbanism is committed to fostering a rigorous design culture for the large scale; by focusing our disciplinary conversations about architecture, urban planning, landscape architecture, and systems thinking, not about the problems of yesterday, but of tomorrow. We are motivated by the radical changes in our environment, and the role that design and research can play in addressing these.

Autonomous Urban Mobility Initiative

http://lcau.mit.edu/project/autonomous-urban-mobility-initative

Autonomous driving (AD) and other automation technologies (AT) are rapidly emerging, with more than $80 billion of investment to date. The first-order effects of AD include improved safety, reduced congestion, on-demand mobility, and cheaper and faster transport. The second and third order effects of AD and AT, however, will likely prove to be far more transformative to our ways of living, creating fundamental changes to society and the physical form of cities. These changes include radical new land-supply equilibriums, widespread flattening of the housing cost curve, and increased access to mobility by economically disadvantaged communities, the elderly, and those with reduced physical mobility....

TOYOTA-CSAIL JOINT RESEARCH CENTER

https://toyota.csail.mit.edu/
Research: https://toyota.csail.mit.edu/projects
Publications: https://toyota.csail.mit.edu/publications

The Toyota-CSAIL Joint Research Center is aimed at furthering the development of autonomous vehicle technologies, with the goal of reducing traffic casualties and potentially even developing a vehicle incapable of getting into an accident.

Led by CSAIL director Daniela Rus, the new center will focus on developing advanced decision-making algorithms and systems that allow vehicles to perceive and navigate their surroundings safely, without human input. Researchers will tackle challenges related to everything from computer vision and perception to planning and control.

A Parallel Autonomous Driving System

https://toyota.csail.mit.edu/node/38

This project will develop a parallel autonomy system to create a collision-proof car. We will instrument a Toyota vehicle with a suite of sensors pointed at the environment and at the driver to create situational awareness, both inside and outside the vehicle. We will develop and integrate the perception and decision- making software components to implement the parallel autonomy software core. We will also develop and implement novel algorithms that take control of the vehicle in dangerous situations to prevent accidents. We will evaluate the system both in simulation and in testing on a closed-course near MIT. We will increase the difficulty of our tests over time, moving from lower to higher speeds and from low to high environmental complexity. We will improve the system over time, following a modular design in which we continually update critical system components with improved algorithms for perception, motion planning and control.

Decision Making for Parallel Autonomy in Clutter

https://toyota.csail.mit.edu/node/12

Motion planning is critical for future driver assistance systems and autonomous cars. Algorithms that are able to design high-performance and provably safe motion through cluttered, dynamics environments are required for cars to operate in complex urban environments. In this research effort, we will develop theories to understand motion through cluttered, dynamic environments; we will also develop algorithms that realize natural, safe motion through cluttered environments, with provable completeness and optimality guarantees. We envision these algorithms to:

(i) understand the density of the "clutter," for instance, as the number of other vehicles or pedestrians in the vicinity of the car

(ii) devise a speed with which the car/robot navigate safely (indoors and outdoors), finding natural and safe paths as the clutter around the vehicle evolves

(iii) design provably-safe trajectories that get the vehicle through the clutter in a natural manner, while guaranteeing safety

(iv) develop collision avoidance and trajectory planning solution for high speeds in dense environments

(v) trajectory planning with rules of the road and safety guarantees.

TRANSPORTATION NETWORKS: ANALYSIS, OPTIMIZATION, AND PREDICTION

MOSHE E BEN-AKIVA

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Intelligent Transportation Systems Lab

https://its.mit.edu/
Research: https://its.mit.edu/research-projects
Publications: https://its.mit.edu/publications

The MIT Intelligent Transportation Systems (ITS) Lab was established in 1990 by Professor Moshe Ben-Akiva. Since its inception, the ITS Lab has conducted numerous studies of transportation systems and developed network modeling and simulation tools. The lab's areas of research include discrete choice and demand modeling techniques, activity-based models, freight transport modeling, and data collection methods for behavioral modeling. Today, lab members are located at MIT's Cambridge campus and its first research center outside of Cambridge – the Singapore–MIT Alliance for Research and Technology (SMART) Centre.

Mobility of the Future

https://its.mit.edu/mobility-future

The goal of this project is to develop a viable framework for analyses and predictions of passenger responses to possible future de-carbonization policies at the urban level. This framework will incorporate behavioral preferences with regard to emerging and upcoming vehicle technologies and mobility services. These will be realized via extensions to an existing agent-based simulation model for urban networks. To test its applicability to many different urban scenarios that exist at the global level, we will determine prevailing city attributes and typologies that describe mobility, energy and emissions characteristics world-wide. From these typologies, we will develop prototypical cities based on existing and simulated data. We will then perform scenario analyses to predict outcomes of potential policy options.

SimMobility – Integrated Simulation Platform

https://its.mit.edu/software/simmobility

SimMoblity is the simulation platform of the Future Urban Mobility Research Group at the Singapore-MIT Alliance for Research and Technology (SMART) that aims to serve as the nexus of Future Mobility research evaluations. It integrate various mobility-sensitive behavioral models with state-of-the-art scalable simulators to predict the impact of mobility demands on transportation networks, intelligent transportation services and vehicular emissions. The platform enables the simulation of the effects of a portfolio of technology, policy and investment options under alternative future scenarios. Specifically, SimMobility encompasses the modeling of millions of agents, from pedestrians to drivers, from phones and traffic lights to GPS, from cars to buses and trains, from second-by-second to year-by-year simulations, across entire countries.

Tripod: Sustainable Travel Incentives with Prediction, Optimization and Personalization

https://its.mit.edu/tripod-sustainable-travel-incentives-prediction-optimization-and-personalization

The ITSLab together with the TrancikLab (MIT) and the University of Massachusetts at Amherst (UMass) will develop and test its "Sustainable Travel Incentives with Prediction, Optimization and Personalization" (Tripod), a system that could incentivize travelers to pursue specific routes, modes of travel, departure times, ride sharing, trip making, and driving styles in order to reduce energy use. Tripod relies on an app-based travel incentive tool designed to influence users' travel choices by offering them real-time information and rewards. MIT researchers are using an open-source simulation platform, SimMobility, and an energy model, TripEnergy, to test Tripod. The system model, which simulates the Greater Boston area, will be able to dynamically measure energy use as changes to the network and travelers' behavior occur. The team's system model will be linked with a control architecture that will evaluate energy savings and traveler satisfaction with different incentive structures. The control architecture will present users with personalized options via a smartphone app, and it will include a reward points system to incentivize users to adopt energy-efficient travel options. Reward points, or tokens, could be redeemed for prizes or discounts at participating vendors, or could be transferred amongst users in a social network.

A latent-class adaptive routing choice model in stochastic time-dependent networks

Ding-Mastera, J., Gao, S., Jenelius, E., Rahmani, M., Ben-Akiva, M.
Transportation Research Part B: Methodological, Volume 124, June 2019, Pages 1-17,
https://doi.org/10.1016/j.trb.2019.03.018

Transportation networks are inherently uncertain due to random disruptions; meanwhile, real-time information potentially helps travelers adapt to realized traffic conditions and make better route choices under such disruptions. Modeling adaptive route choice behavior is essential in evaluating real-time traveler information systems and related policies. This research contributes to the state of the art by developing a latent-class routing policy choice model in a stochastic time-dependent network with revealed preference data. A routing policy is defined as a decision rule applied at each link that maps possible realized traffic conditions to decisions on the link to take next. It represents a traveler's ability to look ahead in order to incorporate real-time information not yet available at the time of decision. A case study is conducted in Stockholm, Sweden and data for the stochastic time-dependent network are generated from hired taxi Global Positioning System (GPS) readings. A latent-class Policy Size Logit model is specified, with routing policy users who follow routing policies and path users who follow fixed paths. Two additional layers of latency in the measurement equation are accounted for: 1) the choice of a routing policy is latent and only its realized path on a given day can be observed; and 2) when GPS readings have relatively long gaps, the realized path cannot be uniquely identified, and the likelihood of observing vehicle traces with non-consecutive links is instead maximized. Routing policy choice set generation is based on the generalization of path choice set generation methods. The generated choice sets achieve 95% coverage for 100% overlap threshold after correcting GPS mistakes and breaking up trips with intermediate stops, and further achieve 100% coverage for 90% overlap threshold. Estimation results show that the routing policy user class probability increases with trip length, and the latent-class routing policy choice model fits the data better than a single-class path choice or routing policy choice model. This suggests that travelers are heterogeneous in terms of their ability and/or willingness to plan ahead and utilize real-time information, and an appropriate route choice model for uncertain networks should take into account the underlying stochastic travel times and structured traveler heterogeneity in terms of real-time information utilization.

Dynamic Toll Pricing using Dynamic Traffic Assignment System with Online Calibration

Zhang, Y., Atasoy, B., Akkinepally, A., Ben-Akiva, M.
Transportation Research Record, 2019, Article in Press,
https://doi.org/10.1177/0361198119850135

The paper presents a toll pricing methodology using a dynamic traffic assignment (DTA) system. This methodology relies on the DTA system's capability to understand and predict traffic conditions, thus enhanced online calibration methodologies are applied to the DTA system, featuring a heuristic technique to calibrate supply parameters online. Improved offline calibration techniques are developed to apply toll pricing in a real network consisting of managed lanes and general purpose lanes. The online calibration methodologies are tested using real data from this network, and the results find the DTA system able to estimate and predict traffic flow and speed with satisfactory accuracy under congestion. Toll pricing is formulated as an optimization problem to maximize toll revenue, subject to network conditions and tolling regulations.

Travelers are assumed to make route choice based on offline calibrated discrete choice models. Toll optimization is applied in a closed-loop evaluation framework where a microscopic simulator is used to mimic the real network. Online calibration of the DTA system is enabled to ensure good optimization performance. Toll optimization is tested under multiple experimental scenarios, and the methodology is found able to increase toll revenue compared with the condition when online calibration is not available. It should be noted that the toll rates and revenues presented in this paper are obtained in a simulation environment based on the calibration and optimization algorithms, and as the work is ongoing these results are far from being a recommendation to operators of managed lanes.

System-Level Optimization of Multi-Modal Transportation Networks for Energy Efficiency using Personalized Incentives: Formulation, Implementation, and Performance

Araldo, A., Gao, S., Seshadri, R., Azevedo, C.L., Ghafourian, H., Sui, Y., Ayaz, S., Sukhin, D., Ben-Akiva, M.
Transportation Research Record, 2019, Article in Press,
https://doi.org/10.1177/0361198119864906

The paper presents the system optimization (SO) framework of Tripod, an integrated bi-level transportation management system aimed at maximizing energy savings of the multi-modal transportation system. From the user's perspective, Tripod is a smartphone app, accessed before performing trips. The app proposes a series of alternatives, consisting of a combination of departure time, mode, and route. Each alternative is rewarded with an amount of tokens which the user can later redeem for goods or services. The role of SO is to compute the optimized set of tokens associated with the available alternatives to minimize the system-wide energy consumption under a limited token budget. To do so, the alternatives that guarantee the largest energy reduction must be rewarded with more tokens. SO is multi-modal, in that it considers private cars, public transit, walking, car pooling, and so forth. Moreover, it is dynamic, predictive, and personalized: the same alternative is rewarded differently, depending on the current and the predicted future condition of the network and on the individual profile. The paper presents a method to solve this complex optimization problem and describe the system architecture, the multi-modal simulation-based optimization model, and the heuristic method for the online computation of the optimized token allocation. Finally it showcases the framework with simulation results.

From Traditional to Automated Mobility on Demand: A Comprehensive Framework for Modeling On-Demand Services in SimMobility

Nahmias-Biran, B.-H., Oke, J.B., Kumar, N., Basak, K., Araldo, A., Seshadri, R., Akkinepally, A., Lima Azevedo, C., Ben-Akiva, M.
Transportation Research Record, 2019, Article in Press,
https://doi.org/10.1177/0361198119853553

Mobility on demand (MoD) systems have recently emerged as a promising paradigm for sustainable personal urban mobility in cities. In the context of multi-agent simulation technology, the state-of-the-art lacks a platform that captures the dynamics between decentralized driver decision-making and the centralized coordinated decision-making. This work aims to fill this gap by introducing a comprehensive framework that models various facets of MoD, namely heterogeneous MoD driver decision-making and coordinated fleet management within SimMobility, an agent- and activity-based demand model integrated with a dynamic multi-modal network assignment model. To facilitate such a study, we propose an event-based modeling framework. Behavioral models were estimated to characterize the decision-making of drivers using a GPS dataset from a major MoD fleet operator in Singapore. The proposed framework was designed to accommodate behaviors of multiple on-demand services such as traditional MoD, Lyft-like services, and automated MoD (AMoD) services which interact with traffic simulators and a multi-modal transportation network. We demonstrate the benefits of the proposed framework through a large-scale case study in Singapore comparing the fully decentralized traditional MoD with the future AMoD services in a realistic simulation setting. We found that AMoD results in a more efficient service even with increased demand. Parking strategies and fleet sizes will also have an effect on user satisfaction and network performance.

Future Mobility Sensing: An Intelligent Mobility Data Collection and Visualization Platform

You, L., Zhao, F., Cheah, L., Jeong, K., Zegras, C., Ben-Akiva, M.
IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, Volume 2018-November, 7 December 2018, Article number 8569697, Pages 2653-2658,
https://doi.org/10.1109/ITSC.2018.8569697

A travel data collection and visualization system, Future Mobility Sensing (FMS), has been developed to understand mobility patterns and travel behavior. FMS harnesses multi-source mobility data by collecting, fusing, and visualizing them. It consists of two components: (1) the FMS Data Collection Platform, which makes use of mobile sensing devices, such as smartphones and GPS loggers, and machine learning algorithms assisted with user verification to collect high resolution, multi-day travel data. The second component is (2) the FMS Data Fusion and Visualization Platform, which combines heterogeneous data from multiple sources to be interpreted into knowledge. This paper introduces the architecture of the FMS system and summarizes the various applications, particularly travel surveys, that it can support. Data collected in a recent commercial vehicle study in Singapore is used to demonstrate the capability of the FMS platform.

Automated Mobility-on-Demand vs. Mass Transit: A Multi-Modal Activity-Driven Agent-Based Simulation Approach

Basu, R., Araldo, A., Akkinepally, A.P., Nahmias Biran, B.H., Basak, K., Seshadri, R., Deshmukh, N., Kumar, N., Azevedo, C.L., Ben-Akiva, M.
Transportation Research Record, Volume 2672, Issue 8, 1 December 2018, Pages 608-618,
https://doi.org/10.1177/0361198118758630

Among the new transportation services made possible by the introduction of automated vehicles, automated mobility-on-demand (AMoD) has attracted a lot of attention from both industry and researchers. AMoD provides a service similar to taxi or ride-sharing services, while being driverless. It is expected to attract a huge fraction of travelers currently using mass transit or private vehicles and will have a disruptive effect on urban transportation. While most studies have focused on the operational efficiency of the technology itself, our work aims to investigate its impact on urban mobility. Our contribution is two-fold. First, we present a flexible AMoD modeling and simulation framework developed within a multi-modal agent-based urban simulation platform (SimMobility). The framework allows the detailed simulation and assessment of different AMoD operations together with an activity-based framework that accounts for changes in demand, such as activity participation, trip making, mode, destination, or route choice decisions. Second, we focus our attention on the role of mass transit in a futuristic urban system where AMoD is widely available. Mass transit is already challenged by current ride-sharing services, for example, Uber and Lyft, which provide comparatively better and cheaper services.

This trend will plausibly be exacerbated with the introduction of AMoD, which may indirectly act as a replacement to mass transit. Our simulation results show that mass transit is irreplaceable, despite the high efficiency of AMoD, in order to avoid congestion and maintain a sustainable urban transportation system with acceptable levels of service.

MUNTHER A DAHLEH

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Resilient Control of Transportation Networks by Using Variable Speed Limits

Yazicioğlu, A.Y., Roozbehani, M., Dahleh, M.A., IEEE Transactions on Control of Network Systems, Volume 5, Issue 4, December 2018, Article number 8186244, Pages 2011-2022,
https://doi.org/10.1109/TCNS.2017.2782364

We investigate the use of variable speed limits for resilient operation of transportation networks, which are modeled as dynamical flow networks under local routing decisions. In such systems, some external inflow is injected to the so-called origin nodes of the network. The total inflow arriving at each node is routed to its operational outgoing links based on their current densities of traffic. The density on each link has first-order dynamics driven by the difference of its incoming and outgoing flows. A link fails if it reaches its jam density. Such failures may propagate in the network and cause a systemic failure. We show that larger link capacities, that is, the maximum flows that can be sustained by the links, are not always better for preventing systemic failures under local routing. Accordingly, we propose the use of variable speed limits to operate the links below their capacities, when necessary, to compensate for the lack of global information and coordination in routing decisions. We show that systemic failures under feasible external inflows can always be averted through proper selection of speed limits if the routing decisions are sufficiently responsive to local congestion and the network is initially uncongested. This is an attractive feature as it provides a practical alternative to building more physical capacity or altering routing decisions that are determined by social behavior.

PATRICK JAILLET

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MIT. He holds a joint appointment in the Operation Research and Statistics Group at MIT Sloan. He is also co-Director of the MIT Operations Research Center and the Faculty Director of the MIT-France program.

Dr. Jaillet's research interests include online optimization and learning; machine learning; and decision making under uncertainty. His research is funded by US federal sources such as NSF, ONR, AFOSR, and internationally by Singapore. Professor Jaillet's teaching covers subjects such as machine learning; algorithms; mathematical programming; network science and models; and probability. Dr. Jaillet's consulting activities primarily focus on the development of optimization-based analytic solutions in various industries, including defense, financial, electronic marketplace, and information technology.

Online vehicle routing: The edge of optimization in large-scale applications

Bertsimas, D., Jaillet, P., Martin, S.
Operations Research, Volume 67, Issue 1, January 2019, Pages 143-162,
https://doi.org/10.1287/opre.2018.1763

With the emergence of ride-sharing companies that offer transportation on demand at a large scale and the increasing availability of corresponding demand data sets, new challenges arise to develop routing optimization algorithms that can solve massive problems in real time. In this paper, we develop an optimization framework, coupled with a novel and generalizable backbone algorithm, that allows us to dispatch in real time thousands of taxis serving more than 25,000 customers per hour. We provide evidence from historical simulations using New York City routing network and yellow cab data to show that our algorithms improve upon the performance of existing heuristics in such real-world settings.

Travel time estimation in the age of big data

Bertsimas, D., Delarue, A., Jaillet, P., Martin, S.
Operations Research, Volume 67, Issue 2, 2019, Pages 498-515,
https://doi.org/10.1287/opre.2018.1784

Twenty-first century urban planners have identified the understanding of complex city traffic patterns as a major priority, leading to a sharp increase in the amount and the diversity of traffic data being collected. For instance, taxi companies in an increasing number of major cities have started recording metadata for every individual car ride, such as its origin, destination, and travel time. In this paper, we show that we can leverage network optimization insights to extract accurate travel time estimations from such origin–destination data, using information from a large number of taxi trips to reconstruct the traffic patterns in an entire city. We develop a method that tractably exploits origin–destination data, which, because of its optimization framework, could also take advantage of other sources of traffic information. Using synthetic data, we establish the robustness of our algorithm to high variance data, and the interpretability of its results. We then use hundreds of thousands of taxi travel time observations in Manhattan to show that our algorithm can provide insights about urban traffic patterns on different scales and accurate travel time estimations throughout the network.

Estimation of travel time from taxi GPS data

Lee, K., Prokhorchuk, A., Dauwels, J., Jaillet, P.
2017 IEEE Symposium Series on Computational Intelligence, SSCI 2017 – Proceedings, Volume 2018-January, 2 February 2018, Pages 1-6, https://doi.org/10.1109/SSCI.2017.8280963

Traditionally travel time estimation is performed through data from loop detectors. However, this solution is not truly scalable because of the high cost associated with the installation and maintenance of loop detectors in large transportation networks. As GPS-equipped devices become increasingly common, it proves to be a more viable alternative data source for travel time estimation. Previous studies have successfully estimated travel time with good accuracy either from loop detectors data or GPS data. In this paper, we present a nearest-neighbor method for estimating travel time with partial information, using a distance measure derived from analytical models of the relationship between travel time and trip features. Our method is compared to a baseline nearest-neighbor method using generic Euclidean distance as its distance metric. We tested both methods on 1 million taxi trips and found that our method has successfully reduced the mean absolute percentage error (MAPE) value to 22.29% which is a 16% improvement over the baseline method.

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Professor Osorio's research interests are in applied probability theory, simulation and simulation-based optimization for transportation problems, including macroscopic traffic modeling, large-scale traffic management and transportation systems analysis. She pursues research in simulation-based mobility management, and has developed a simulation-based urban traffic control framework that achieves tractability by coupling simulation-based and analytical urban traffic models. She also develops operations research methods such as analytical models, simulation-based models and optimization methods to mitigate network congestion for health care systems and biological networks.

Analytical Probabilistic Traffic Models for Large-Scale Network Optimization

Principal Investigator: Carolina Osorio
Project Dates: June 1, 2016 – May 31, 2019
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1562912

Major transportation agencies in the U.S. and Europe have recognized the importance of measuring and optimizing the reliability and robustness of our networks. Evaluating reliability and robustness metrics involves the use of probabilistic network models. This project formulates, validates and uses probabilistic network models. Case studies based on actual metropolitan areas will illustrate the importance of accounting for uncertainty in large-scale transportation network analysis. The use of these methods can inform the design and operations of the considered networks, helping to mitigate congestion along with its economic, environmental and health impacts. These case studies on complex regional networks will illustrate the contributions to transportation practice of the methodologies. The findings of this project will be shared through various activities with transportation researchers, transportation stakeholders, the general public and with young engineers interested in learning about and contributing to the transportation challenges of the future. This project formulates an analytical stochastic kinematic wave model for general network topologies. It formulates a model that is suitable to address large-scale network optimization problems. First, the project formulates stochastic link models that are consistent with the kinematic wave model. Two types of models are formulated: (i) models with a complexity that is linear in the link?s space capacity, (ii) models with a complexity that is independent of the link?s space capacity. This is achieved through a combination of ideas from the fields of traffic flow theory, queueing network theory, transient queueing theory, and more generally operations research. Second, the project formulates a network decomposition approach that enables the link models to be used for large-scale network analysis. Third, this project plans a technique to approximate the joint network distribution of a given performance measure based on lower-dimensional subnetwork distributions. The case studies of this project contribute to the modeling of between-link dependency structures, as well as to their use to mitigate congestion for large-scale networks.

Simulation-Based Optimization Techniques for Urban Transportation Problems

Principal Investigator: Carolina Osorio
Project Dates: September 1, 2014 – August 31, 2019
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1351512

The objective of this Faculty Early Career Development (CAREER) Program award is the development of computationally efficient simulation-based optimization techniques for three types of urban transportation problems: (i) dynamic, (ii) large-scale, and (iii) reliable. The techniques enable state-of-the-art urban traffic simulators to address a variety of continuous, nonlinear, constrained and high-dimensional optimization problems. They combine ideas from the fields of metamodel simulation-based optimization, transient finite capacity queueing theory and traffic flow theory. Their performance is evaluated by considering urban traffic management problems for three road networks in the United States, Europe and Asia.

This project will be carried out in collaboration with a transportation agency in the United States. The techniques will support their ongoing planning and operational efforts. Numerous transportation agencies and consultants around the world use these traffic simulation tools to inform their planning and operations decisions. The techniques will enable practitioners to identify transportation strategies that provide both local and network-wide improvements. If successful, these techniques contribute to improve the management of transportation systems, mitigate peak-hour congestion, and thereby reduce its economic and environmental impacts. They also contribute to providing an improved urban mobility experience by identifying traffic management strategies that lead to more reliable transportation services. Enabling the use of microscopic simulators to efficiently identify network design improvements may also lead to substantial savings for infrastructure projects. The ideas and results of this project will be discussed with the main simulation software developers. Through various educational activities, this project will involve, encourage and train underrepresented students in conducting engineering research and problem solving.

High-dimensional offline origin-destination (OD) demand calibration for stochastic traffic simulators of large-scale road networks

Osorio, C.
Transportation Research Part B: Methodological, Volume 124, June 2019, Pages 18-43,
https://doi.org/10.1016/j.trb.2019.01.005

This paper considers high-dimensional offline calibration problems for large-scale simulation-based network models. We propose a metamodel simulation-based optimization (SO) approach. The proposed method is formulated and validated on a simple synthetic toy network. It is then applied to a high-dimensional case study of a large-scale Singapore network. Compared to two benchmark methods, a derivative-free pattern search method and the SPSA method, the proposed method improves the objective function estimates by two orders of magnitude. Moreover, this improvement is achieved after only 2 simulation runs. Hence, the proposed method is computationally efficient. The main idea of the proposed approach is to embed, within the SO algorithm, information from an analytical (i.e., lower-resolution) yet differentiable and tractable network model. It is this analytical structural information that enables the SO algorithm to become both suitable for high-dimensional problems and computationally efficient. For a network with n links, the analytical network model is implemented as a system of n nonlinear equations. Hence, it scales linearly with the number of links in the network and independently of link attributes (such as link length) and of the dimension of the route choice set.

Simulation-based travel time reliable signal control

Chen, X., Osorio, C., Santos, B.F.
Transportation Science, Volume 53, Issue 2, March 2019, Page 523–544,
https://doi.org/10.1287/trsc.2017.0812

This paper addresses a travel time reliable signal control problem. Travel time distributional estimates are obtained from a stochastic microscopic traffic simulator. The estimates are embedded within a simulation-based optimization algorithm. Analytical approximations of the simulated metrics are combined with the simulated data in order to enhance the computational efficiency of the algorithm. The signal control problems are formulated based on the expectation and the standard deviation of travel time metrics. The proposed approach goes beyond the traditional use of first-order simulated information, it addresses a problem that embeds higher-order distributional information. It is used to solve a large-scale signal control problem. The approach addresses these challenging simulation-based optimization problems in a computationally efficient manner. Its performance is compared to that of a traditional simulation-based optimization approach. The proposed method systematically outperforms the traditional approach. Such an approach can be used to informthe design and operations of transportation systems by, for instance, addressing reliable and/or robust formulations of traditional transportation problems.

A simulation-based optimization algorithm for dynamic large-scale urban transportation problems

Chong, L., Osorio, C.
Transportation Science, Volume 52, Issue 3, May-June 2018, Pages 637-656,
https://doi.org/10.1287/trsc.2016.0717

This paper addresses large-scale urban transportation optimization problems with time-dependent continuous decision variables, a stochastic simulation-based objective function, and general analytical differentiable constraints. We propose a metamodel approach to address, in a computationally efficient way, these large-scale dynamic simulation-based optimization problems. We formulate an analytical dynamic network model that is used as part of the metamodel. The network model formulation combines ideas from transient queueing theory and traffic flow theory. The model is formulated as a system of equations. The model complexity is linear in the number of road links and is independent of the link space capacities. This makes it a scalable model suitable for the analysis of large-scale problems. The proposed dynamic metamodel approach is used to address a time-dependent large-scale traffic signal control problem for the city of Lausanne. Its performance is compared to that of a stationary metamodel approach. The proposed approach outperforms the stationary approach. This comparison illustrates the added value of providing the algorithm with analytical dynamic problem-specific structural information. The performance of a signal plan derived by the proposed approach is also compared to that of an existing signal plan for the city of Lausanne, and to that of a signal plan derived by a mainstream commercial signal control software. The proposed method can systematically identify signal plans with good performance.

CATHY WU

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Cathy Wu works at the intersection of machine learning, optimization, and large-scale urban systems and other societal systems. Her recent research focuses on mixed autonomy systems in mobility, which studies the complex integration of automation such as self-driving cars into existing urban systems. She is broadly interested in developing principled computational tools to enable reliable and complex decision-making for critical societal systems.

Flow: Deep Reinforcement Learning for Traffic Control with Autonomous Vehicles

http://www.wucathy.com/blog/?page_id=3337

I created and led a team which studies the potential of employing deep Reinforcement Learning (RL) to improve traffic flow by controlling a fraction of vehicles on the road. Whereas a vast majority of autonomous vehicle (AV) research focuses on situations with either 100% AVs or just a single AV navigating the world, we study the long arduous transition of partial adoption of AVs. Through a series of increasingly complex traffic control experiments using RL, we learned that a small fraction of AVs (5-10%) can cause a significant improvement in traffic congestion and travel times (by 40-150%, depending on the situation). Our early work suggests that effects of AVs, whether positive or negative, may be felt by society much sooner than expected.

Stabilizing Traffic with Autonomous Vehicles

Wu, C., Bayen, A.M., Mehta, A.
Proceedings - IEEE International Conference on Robotics and Automation, 10 September 2018, Article number 8460567, Pages 6012-6018, https://doi.org/10.1109/ICRA.2018.8460567

Autonomous vehicles promise safer roads, energy savings, and more efficient use of existing infrastructure, among many other benefits. Although the effect of autonomous vehicles has been studied in the limits (near-zero or full penetration), the transition range requires new formulations, mathematical modeling, and control analysis. In this article, we study the ability of small numbers of autonomous vehicles to stabilize a single-lane system of human-driven vehicles. We formalize the problem in terms of linear string stability, derive optimality conditions from frequency-domain analysis, and pose the resulting nonlinear optimization problem. In particular, we introduce two conditions which simultaneously stabilize traffic while imposing a safety constraint on the autonomous vehicle and limiting degradation of performance. With this optimal linear controller in a system with typical human driver behavior, we can numerically determine that only a 6% uniform penetration of autonomously controlled vehicles (i.e. one per string of up to 16 human-driven vehicles) is necessary to stabilize traffic across all traffic conditions.

Multi-lane reduction: A stochastic single-lane model for lane changing

Wu, C., Vinitsky, E., Kreidieh, A., Bayen, A.
IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, Volume 2018-March, 14 March 2018, Pages 1-8, https://doi.org/10.1109/ITSC.2017.8317733

Lane changes can induce natural large perturbations in traffic flow and are known to impact traffic throughput and energy consumption. Their precise effects are understudied. The primary aim of this article is to present a model for lane changing that is tractable for system-level analysis and yet captures qualities of microscopic vehicle dynamics. We present a stochastic lane changing model, which permits a two-stage reduction: 1) of the (microscopic) multi-lane problem into a stochastic single-lane problem, and 2) of the stochastic single-lane model into a Markov chain macroscopic model which captures system-level lane-changing characteristics. The first reduction contributes the first model of lane changing as a single-lane process, which permits the simplification of theoretical analysis. The Markov chain macroscopic model permits the computation of statistics on the traffic parameters, such as expected velocity and headway, thus permitting the quantification of the effect of lane changes on traffic flow. We validate the proposed model on NGSIM and confirm the accuracy of the Markov chain for computing headway statistics. Finally, counter to a common view of lane changes as perturbations which contribute to shockwave formation, we observe that lane changes reduce the variance of the velocity by 10% on a 230-meter ring road benchmark, which suggests that discretionary lane changes may serve to reduce stop and go waves rather than increase them.

Framework for control and deep reinforcement learning in traffic

Wu, C., Parvate, K., Kheterpal, N., Dickstein, L., Mehta, A., Vinitsky, E., Bayen, A.M.
IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, Volume 2018-March, 14 March 2018, Pages 1-8, https://doi.org/10.1109/ITSC.2017.8317694

Recent advances in deep reinforcement learning (RL) offer an opportunity to revisit complex traffic control problems at the level of vehicle dynamics, with the aim of learning locally optimal policies (with respect to the policy parameterization) for a variety of objectives such as matching a target velocity or minimizing fuel consumption. In this article, we present a framework called CISTAR (Customized Interface for SUMO, TraCI, and RLLab) that integrates the widely used traffic simulator SUMO with a standard deep reinforcement learning library RLLab. We create an interface allowing for easy customization of SUMO, allowing users to easily implement new controllers, heterogeneous experiments, and user-defined cost functions that depend on arbitrary state variables. We demonstrate the usage of CISTAR with several benchmark control and RL examples.

FUTURE URBAN MOBILITY

https://fm.smart.mit.edu/
Research: https://fm.smart.mit.edu/research/
Publications: https://fm.smart.mit.edu/publications/

The Future Urban Mobility (FM) Interdisciplinary Research Group (IRG) is 1 of 5 IRGs in the Singapore-MIT Alliance for Research and Technology Centre (SMART). SMART-FM is supported by the National Research Foundation (NRF) Singapore and situated in the Campus for Research Excellence and Technological Enterprise (CREATE).

Research efforts focus the three inter-related research areas:

Modeling, Simulation & Assessment

https://fm.smart.mit.edu/research/modeling-simulation-assessment/

Modeling, Simulation & Assessment will concentrate on the development of models for simulating and assessing the short- and long-term effectiveness of the new concepts and approaches for urban mobility. At the core of this pillar is the development of a uniquely sophisticated and comprehensive simulation suite, called SimMobility, which will serve as a common virtual testbed connecting all efforts in this project.

Control, Optimization & Planning

https://fm.smart.mit.edu/research/control-optimization-planning/

Control, Optimization, Planning will aim at the development of new, scalable, robust, and efficient real-time algorithms long-term policies to improve the operations of transportation systems in a multi-modal, city-wide setting. Efficiency, robustness to disruptions, customer satisfaction will be key drivers in this pillar, as well as sustainability, environmental impact, and flexibility to technological, social, and geopolitical changes.

Devices & Systems

https://fm.smart.mit.edu/research/devices-and-systems/

Devices & Systems will seek to develop novel technologies, including hardware devices, with embedded software, and integrated systems — such as autonomous, self-driving vehicles that would enable dramatically new approaches to urban mobility.

URBAN MOBILITY AND PUBLIC TRANSIT

JOHN P ATTANUCCI

Research Associate, http://transitlab.mit.edu/john-attanucci

John Attanucci is a lecturer, research associate and manager of the MIT Transit Research Program. For 14 years he was president and chief executive officer of Multisystems, Inc., a national public transportation planning and management firm, and he has extensive experience in transportation planning, transit management and operations, and transit information and decision support systems. In addition, he has managed numerous consulting projects including several large transit strategic planning projects, performance audits and management information system installations. At MIT, he specializes in public transport management, fare policy, information technology, and short-term planning and operations, and manages several graduate student research projects sponsored by large public transport and private agencies in London, Chicago and Boston.

Improving High-Frequency Transit Performance through Headway-Based Dispatching: Development and Implementation of a Real-Time Decision-Support System on a Multi-Branch Light Rail Line

Fabian, J.J., Sánchez-Martínez, G.E., Attanucci, J.P.

Transportation Research Record, Volume 2672, Issue 8, 1 December 2018, Pages 363-373,
https://doi.org/10.1177/0361198118794534

Service reliability is a major concern for public transportation agencies. Transit services experience natural variability in operations performance, due to factors such as congestion, changes in demand, and operator behavior. This variability leads to irregular headways, resulting in longer passenger waits and decreased effective capacity as gaps in service form. Real-time control strategies allow controllers to regulate service and improve performance. This research tested the effectiveness of a headway-based dispatching strategy at a terminal on the Massachusetts Bay Transportation Authority (MBTA) Green Line in Boston, a complex, four-branch light rail line. Terminal personnel were provided with tablet computers showing departure times optimized by an even-headway policy. When optimized departure times were adhered to, peak period headway variability was reduced by 40%. The average wait was shortened by 15% (30 sec), and the 90th percentile wait was shortened by 21% (90 sec). The results show that adopting headway-based dispatching at terminals of high-frequency lines promises significant benefits to service and passengers if operational changes are accompanied by improved supervision.

Applying Spatial Aggregation Methods to Identify Opportunities for New Bus Services in London

Viggiano, C., Koutsopoulos, H.N., Wilson, N.H.M., Attanucci, J.
Transportation Research Record, Volume 2672, Issue 8, 1 December 2018, Pages 75-85, https://doi.org/10.1177/0361198118797218

Innovative analyses of origin–destination (OD) data derived from automatic fare collection and automatic vehicle location systems in public transport networks enable planners to gain new insights into how passengers travel in the network and the quality of service provided, and can even inform decisions about network improvements. Particularly in large, complex networks, systematic, data-driven approaches to network evaluation and planning are essential. New methodologies are needed to transform OD data into informative metrics and planning recommendations. This paper proposes a framework for this process and applies it to London's public transport network. Though there are many ways to improve public transport networks, this paper focuses on the addition of new bus routes to reduce circuity. The proposed framework includes three steps that combine OD-level analysis with spatial aggregation methodologies for the identification of corridors for new bus services. First, bus stops and rail stations were clustered into geographic zones. Second, a subset of zonal OD pairs with circuitous service were identified as candidates for improvement through new bus routes, based on performance standards established with user-defined parameters. Third, an algorithm that clusters OD pairs into corridors was applied to identify promising corridors for new bus services. This paper discusses corridors identified for new services in the London case study.

KENT LARSON

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Kent Larson directs the City Science (formerly Changing Places) group at the MIT Media Lab. His research focuses on developing urban interventions that enable more entrepreneurial, livable, high-performance districts in cities. To that end, his projects include advanced simulation and augmented reality for urban design, transformable micro-housing for millennials, mobility-on-demand systems that create alternatives to private automobiles, and Urban Living Lab deployments in Hamburg, Andorra, Taipei, and Boston.

City Science

https://www.media.mit.edu/groups/city-science/overview/
Projects: https://www.media.mit.edu/groups/city-science/projects/
Publications: https://www.media.mit.edu/groups/city-science/publications/

The City Science research group proposes that new strategies must be found for creating the places where people live and work, and the mobility systems that connect them, in order to meet the profound challenges of the future.

Income, Race, Bikes

https://www.media.mit.edu/projects/income-race-bikes/overview/

Is the placement of bike-share docks equitable?
This interactive map explores the question visually.

The map shows the addition of bike-share docks, as well as the changes in income and race throughout the years the bike-share program has been in service. You can toggle the display to see only income, or race, or bikes data, or any of their combinations.

https://aberke.github.io/income-race-bikes

The project currently includes the New York and Boston areas, with more cities coming soon.

3D Mobility

https://www.media.mit.edu/projects/3d-mobility/overview/

...Today, more than ever, the scale and rate of urban expansion is making mobility solutions a key concern, which will impact large segments of the global population since it is estimated that by 2050, more that two thirds of the global population will be living in cities. We propose a new experience and mobility around cities, unfolding the city networks and using its third dimensions, different mobility, speed modes (static, mass transportation, internal transportation), public areas appearing in rooftops, and mix-use spaces in intersticial parts of buildings. Through simulation as a tool, we can understand the impact of this new disrupting mobility system, avoiding to repeat mistakes like those made in the past.

The Impact of New Mobility Modes on a City: A Generic Approach Using ABM

Grignard, A., Alonso, L., Taillandier, P., Gaudou, B., Nguyen-Huu, T., Gruel, W., Larson, K.
Springer Proceedings in Complexity, 2018, Pages 272-280, https://doi.org/10.1007/978-3-319-96661-8_29

Mobility is a key issue for city planners. Being able to evaluate the impact of its evolution is complex and involves many factors including new technologies like electric cars, autonomous vehicles and also new social habits like vehicle sharing. We need a better understanding of different scenarios to improve the quality of long-term decisions. Computer simulations can be a tool to better understand this evolution, to discuss different solutions and to communicate the implications of different decisions. In this paper, we propose a new generic model that creates an artificial micro-world which allows the modeler to create and modify new mobility scenarios in a quick and easy way. This not only helps to better understand the impact of new mobility modes on a city, but also fosters a better-informed discussion of different futures. Our model is based on the agent-based paradigm using the GAMA Platform. It takes into account different mobility modes, people profiles, congestion and traffic patterns. In this paper, we review an application of the model of the city of Cambridge.

CARLO RATTI

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An architect and engineer by training, Professor Carlo Ratti teaches at Massachusetts Institute of Technology, where he directs the Senseable City Lab, and is a founding partner of the international design office Carlo Ratti Associati. He graduated from the Politecnico di Torino and the École Nationale des Ponts et Chaussées in Paris, and later earned his MPhil and PhD at the University of Cambridge, UK.

Senseable City Lab

http://senseable.mit.edu/
Publications: http://senseable.mit.edu/papers/

The real-time city is real! As layers of networks and digital information blanket urban space, new approaches to the study of the built environment are emerging. The way we describe and understand cities is being radically transformed—as are the tools we use to design them. The mission of the Senseable City Laboratory—a research initiative at the Massachusetts Institute of Technology—is to anticipate these changes and study them from a critical point of view.

Not bound by the methodologies of a single field, the Lab is characterized by an omni-disciplinary approach: it speaks the language of designers, planners, engineers, physicists, biologists and social scientists. Senseable is as fluent with industry partners as it is with metropolitan governments, individual citizens and disadvantaged communities. Through design and science, the Lab develops and deploys tools to learn about cities—so that cities can learn about us.

roundAround

http://senseable.mit.edu/roundaround/

Researchers at MIT, in collaboration with the Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute), have developed the concept of roundAround, the world's first dynamic 'bridge' made of autonomous boats, or Roboats. roundAround will connect the waterway between Marineterrein and the City Center in Amsterdam, seamlessly transporting hundreds of people per hour across the water while pushing the boundaries of technology and design. A waterway separates the Amsterdam City Center – and the popular NEMO Science Museum - from Marineterrein Amsterdam, an area in full swing of development. Without a bridge across the canal, it takes more than 10 minutes to walk the almost one kilometer from one side to the other. Roboat and roundAround could reduce this travel time to less than two minutes. As they operate, the system will become increasingly more intelligent and well-equipped to be implemented in other parts of the city and other cities worldwide. Autonomously bridging the waterway between NEMO and Marineterrein Amsterdam illustrates how the intersection of science, technology and design can bring about creative solutions to urban challenges. By involving citizens and visitors of the area, roundAround will provide the research project with valuable feedback loops.

Unparking

http://senseable.mit.edu/unparking/

Private cars sit parked 95% of the time. In fact, a single car usually occupies at least two parking spots: one at home, another at work. Because of this, contemporary cities have roads clogged with traffic, while premium spaces sit empty or occupied by a parked car.

Unparking uses data from Singapore to propose a systematic quantification of parking demand as a function of fluctuating mobility demand. It is based on two scenarios: the current situation with private cars using two parking spots and a scenario where self-driving cars partially alleviate the flow imbalances typical of commuting.

The gradual transition to shared mobility models will bring tangible reductions in parking infrastructure, with a subsequent decrease in traffic, fewer cars on the roads and up to 70% reduction in parking needs while increasing total traveled kilometers less than 5%.

Minimum Fleet

http://senseable.mit.edu/MinimumFleet/

The Minimum Fleet Network model proposes efficient vehicle-trip assignments that reduce the empty time between trips with a passenger onboard. This way, a taxi can serve more passengers in the same time, and overall fleet size is minimized.

Comparing bicycling and pedestrian mobility: Patterns of non-motorized human mobility in Greater Boston

Bongiorno, C., Santucci, D., Kon, F., Santi, P., Ratti, C.

Journal of Transport Geography, Volume 80, October 2019, Article number 102501,
https://doi.org/10.1016/j.jtrangeo.2019.102501

During the past 100 years, many large cities around the world prioritized individual transportation in cars over more sustainable and healthier modes of transportation. As a result, traffic jams, air pollution, and fatal accidents are a daily reality in most metropolis, in both developed and developing countries. On the other hand, walking and bicycling are effective means of transportation for short to medium distances that offer advantages to both the city environment and the health of its citizens. While there is a large body of research in modeling and analysis of urban mobility based on motorized vehicles, there is much less research focusing on non-motorized vehicles, and almost no research on comparing pedestrian and cyclist behavior. In this paper, we present a detailed quantitative analysis of two datasets, for the same period and location, covering pedestrian and bike sharing mobility. We contrast the mobility patterns in the two modes and discuss their implications. We show how pedestrian and bike mobility are affected by temperature, precipitation and time of day. We also analyze the spatial distribution of non-motorized trips in Greater Boston and characterize the associated network of mobility flows with respect to multiple metrics. This work contributes to a better understanding of the characteristics of non-motorized urban mobility with respect to distance, duration, time of day, spatial distribution, as well as sensitivity to the weather.

Estimating savings in parking demand using shared vehicles for home-work commuting

Kondor, D., Zhang, H., Tachet, R., Santi, P., Ratti, C.

IEEE Transactions on Intelligent Transportation Systems, Volume 20, Issue 8, August 2019, Article number 8500344, Pages 2903-2912, https://doi.org/10.1109/TITS.2018.2869085

The increasing availability and adoption of shared vehicles as an alternative to personally owned cars presents ample opportunities for achieving more efficient transportation in cities. With private cars spending on the average over 95% of the time parked, one of the possible benefits of shared mobility is the reduced need for parking space. While widely discussed, a systematic quantification of these benefits as a function of mobility demand and sharing models is still mostly lacking in the literature. As a first step in this direction, this paper focuses on a type of private mobility which, although specific, is a major contributor to traffic congestion and parking needs, namely, home-work commuting. We develop a data-driven methodology for estimating commuter parking needs in different shared mobility models, including a model where self-driving vehicles are used to partially compensate flow imbalance typical of commuting, and further reduce parking infrastructure at the expense of the increased traveled kilometers. We consider the city of Singapore as a case study and produce very encouraging results showing that the gradual transition to shared mobility models will bring tangible reductions in parking infrastructure. In the future-looking, self-driving vehicle scenario, our analysis suggests that up to 50% reduction in parking needs can be achieved at the expense of the increasing total traveled kilometers of less than 2%.

Human mobility and socioeconomic status: Analysis of Singapore and Boston

Xu, Y., Belyi, A., Bojic, I., Ratti, C.

Computers, Environment and Urban Systems, Volume 72, November 2018, Pages 51-67, https://doi.org/10.1016/j.compenvurbsys.2018.04.001

Recently, some studies have shown that human movement patterns are strongly associated with regional socioeconomic indicators such as per capita income and poverty rate. These studies, however, are limited in numbers and they have not reached a consensus on what indicators or how effectively they can possibly be used to reflect the socioeconomic characteristics of the underlying populations. In this study, we propose an analytical framework — by coupling large scale mobile phone and urban socioeconomic datasets — to better understand human mobility patterns and their relationships with travelers' socioeconomic status (SES). Six mobility indicators, which include radius of gyration, number of activity locations, activity entropy, travel diversity, k-radius of gyration, and unicity, are derived to quantify important aspects of mobile phone users' mobility characteristics. A data fusion approach is proposed to approximate, at an aggregate level, the SES of mobile phone users. Using Singapore and Boston as case studies, we compare the statistical properties of the six mobility indicators in the two cities and analyze how they vary across socioeconomic classes. The results provide a multifaceted view of the relationships between mobility and SES. Specifically, it is found that phone user groups that are generally richer tend to travel shorter in Singapore but longer in Boston. One of the potential reasons, as suggested by our analysis, is that the rich neighborhoods in the two cities are respectively central and peripheral. For three other mobility indicators that reflect the diversity of individual travel and activity patterns (i.e., number of activity locations, activity entropy, and travel diversity), we find that for both cities, phone users across different socioeconomic classes exhibit very similar characteristics. This indicates that wealth level, at least in Singapore and Boston, is not a factor that restricts how people travel around in the city. In sum, our comparative analysis suggests that the relationship between mobility and SES could vary among cities, and such relationship is influenced by the spatial arrangement of housing, employment opportunities, and human activities.

FREDERICK P SALVUCCI

Senior Lecturer, http://dusp.mit.edu/faculty/frederick-salvucci

Fred Salvucci is a civil engineer specializing in transportation, with particular interest in infrastructure, urban transportation, public transportation, and institutional development in decision- making. He served as transportation advisor to Boston Mayor Kevin White between 1970 and 1974, and then as Secretary of Transportation of the Commonwealth of Massachusetts under Governor Michael Dukakis between 1975 and 1978 and again from 1983 to 1990. In those roles he participated in much of the transportation planning and policy formulation in the Boston urbanized area and the Commonwealth of Massachusetts of the past 35 years, with particular emphasis on the expansion of the transit system, the development of the financial and political support for the Central Artery/Tunnel Project, and the design of implementation strategies to comply with the Clean Air Act consistent with economic growth. Other efforts include the extension of the Red Line in South Quincy and Alewife, the relocation of the Orange Line in Boston's Southwest Corridor, the acquisition and modernization of the Commuter Rail Network, the restructuring of the MBTA, the formulation of noise rules to halt the increase in aircraft noise at Logan Airport, and the development of strategies to achieve high speed rail service between Boston and New York. Fred teaches graduate courses in Urban Transportation Planning, Institutional and Policy Analysis, and Public Transportation, in the Departments of Civil and Environmental Engineering and Urban Studies and Planning.

Incorporating Product Choice into Transit Fare Policy Scenario Models

Stuntz, A., Attanucci, J., Salvucci, F.P.
Transportation Research Record, 2019, https://doi.org/10.1177/0361198119842118

Customer fare product choices can affect both ridership and revenue, so they are strategically important for transit agencies. Nearly all major agencies offer choices between pay-per-use and pass products, and with each potential fare change, agencies face decisions about whether to modify pass “multiples”—the number of rides needed to “break even” on a pass purchase. However, the simple elasticity spreadsheet models often used to analyze the potential ridership and revenue impacts of fare changes make little or no adjustment for shifts in fare product choices. This paper reviews different options for incorporating product choice into fare policy scenario models, and it presents a ridership and revenue prediction procedure that combines a multinomial logit fare product choice model with the logic of an elasticity spreadsheet model. This combination facilitates evaluation of complex fare changes that are likely to alter fare product market shares while maintaining much of the flexibility and simplicity of a traditional spreadsheet model. Additionally, the proposed model uses only preexisting, revealed-preference automated fare collection data rather than requiring customer surveys. The proposed model is demonstrated using examples at the Chicago Transit Authority (CTA). The CTA experienced a large shift from passes to pay-per-use following a fare change in 2013, illustrating the potential value of accounting for fare product choices in fare scenario evaluation.

PAOLO SANTI

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Paolo Santi is currently leading the MIT/Fraunhofer Ambient Mobility initiative at the MIT Senseable City Lab, and is also Senior researcher at the Institute of Informatics and Telematics

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Ambient Mobility

http://www.ambientmobility.org/

Ambient Mobility is an exploration of future-facing innovations in mobility. The joint initiative between the Senseable City Lab at Massachusetts Institute of Technology (MIT) and the Mobility Innovation Lab at the Fraunhofer Institute for Industrial Engineering IAO aims to create a synergy between the interdisciplinary research model exercised at MIT, and Fraunhofer IAO's strength in transforming concepts into products. The mission of the Ambient Mobility Lab is to become a global frontrunner as a pioneering institution for 'smart mobility' research to analyze, design, develop and test senseable and sustainable mobility systems in interaction with other future urban systems.

ANDRES SEVTSUK

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Lab: http://cityform.mit.edu
Publications: http://cityform.mit.edu/papers

Andres Sevtsuk is a Charles and Ann Spaulding Career Development Associate Professor of Urban Science and Planning at the Department of Urban Studies and Planning, where he also leads the City Form Lab. His work bridges urban design with spatial analysis and urban technology. Andres is the author of the Urban Network Analysis toolbox, used by researchers and practitioners around the world to model pedestrian flows along city streets and to study coordinated land use and transportation development along networks. Applications of this work have led him to study business location choices in cities, particularly in the retail, food and service sector. He is currently publishing a book entitled "Street Commerce: The Hidden Structure of Retail Location Patterns and Vibrant Sidewalks" with Penn Press. Andres is also leading the Future of Streets research initiative, which investigates how cities could adapt their streets and mobility infrastructure to newly emerging transportation technologies in ways that maximize multi-modal, socially inclusive, and environmentally sustainable outcomes.

Cityform

http://cityform.mit.edu/en
Projects: http://cityform.mit.edu/projects
Papers: http://cityform.mit.edu/papers

The City Form Lab at MIT focuses on urban design, planning and real-estate research. We develop new software tools for researching city form; use cutting-edge spatial analysis and statistics to investigate how urban form and land-use developments affect urban mobility and business location choices; and develop creative design and policy solutions for contemporary urban challenges. By bringing together multi-disciplinary urban research expertise and excellence in design, we develop context sensitive and timely insight about the role of urban form in affecting the quality of life in 21st century cities. CFL is directed by Andres Sevtsuk, Charles and Ann Spaulding Career Development Associate Professor of Urban Science and Planning and involves inter-disciplinary students interested in urban design, planning, transportation, spatial analysis and decision-making.

LA: Towards an Automated Transitopia

http://cityform.mit.edu/projects/la-towards-an-automated-transitopia

…This exhibit explores an alternative future for LA in 2047—a future, where automated vehicle technology is captured to revolutionize public transit—in particular fixed-route bus service, instead of small passenger vehicles. The exhibit uses a graphic novel as a medium to depict how typical Angeleno families and visitors could experience an automated public transportation system that not only provides a high quality of service, but also overcomes many of the negative externalities of cars, ride-share services and their future automated counterparts. By encouraging AV technology in truly shared buses of various sizes, which complement the rail network of the city, LA would ultimately gain a better built environment—one that wastes significantly less land and energy on transportation, provides better access for all, leads to shorter commute times, creates more encounter between different segments of society, reduces inequality and segregation, and enables Angelenos to be more productive with their time….

Future of streets

Sevtsuk, A., Davis, D.E.
Modeling and Simulation in Science, Engineering and Technology, 2019, Pages 537-546,
https://doi.org/10.1007/978-3-030-12381-9_29

Rapidly evolving mobility technologies and the associated behavioral adjustments of travelers are bringing about dramatic changes to the morphology of cities, some of which have already begun to take root. With the seemingly endless amounts of data that technology is producing about life in cities, new mathematical modeling techniques will be required to fully understand the impact these changes will have on society. As a consequence of innovation in personal mobility technologies, a combination of autonomous and electric vehicles is being seen by many as the solution to personalized and inexpensive urban transport. In this chapter, we explore some of the ways in which this version of the future of streets could reverse decades worth of efforts by cities to reduce congestion and contain sprawl unless policy-makers are proactive in responding to these disruptive forces. Without active efforts to prioritize shared, public, and active mobility, the introduction of automated modes for transporting both humans and goods in an already contested public realm could mean a reversion to Modernist practices of privileging speed, efficiency, and function over human-scale interactions and serendipity. Politically contentious decisions will need to be made around questions of social, environmental, economic, and public health priorities to ensure that streets are made livable and accessible, particularly for vulnerable and marginalized groups. Ultimately, recognizing that the interests of pedestrians, bicyclists, public transit users as well as stationary street users should take priority over those of personal vehicles (autonomous ones in particular) is key to guiding changing urban morphologies in a way that places sustainability and human-focused development at the forefront.

SARAH E WILLIAMS

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Director, Civic Data Design Lab, http://civicdatadesignlab.mit.edu/

Sarah Williams is currently an Associate Professor of Technology and Urban Planning. She also is Director of the Civic Data Design Lab at MIT's School of Architecture and Planning. The Civic Data Design Lab works with data, maps, and mobile technologies to develop interactive design and communication strategies that expose urban policy issues to broader audiences.

Civic Data Design Lab

http://civicdatadesignlab.mit.edu/

The Civic Data Design Lab works with data to understand it for public good. We seek to develop alternative practices which can make the work we do with data and images richer, smarter, more relevant, and more responsive to the needs and interests of citizens traditionally on the margins of policy development. In this practice we experiment with and develop data visualization and collection tools that allow us to highlight urban phenomena. Our methods borrow from the traditions of science and design by using spatial analytics to expose patterns and communicating those results, through design, to new audiences.

Urban transportation resource center for Latin American and Caribbean cities

Dan Pomeroy, International Policy Lab, February 19, 2019, https://cis.mit.edu/news-media/news-releases/urban-transportation-resource-center-latin-american-and-caribbean-cities

A new Resource Center for Digital Urban Transport in Latin America & the Caribbean has been founded, with the support of the Inter-American Development Bank and the Mastercard Center for Inclusive Growth. The Resource Center, which will be run through a collaboration between World Resources Institute Mexico (WRI Mexico), Massachusetts Institute of Technology's Civic Data Design Lab, and Columbia University's Earth Institute, will support the development of open digital urban transport data for and with Latin American and Caribbean cities….

NextStop

http://civicdatadesignlab.mit.edu/#projects/COOPER%20HEWITT, https://nextstop.mit.edu/

NextStop is an analog and digital experience developed as a part of "The Road Ahead: Reimagining Mobility," an exhibit at Cooper Hewitt, the Smithsonian Design Museum. From December 2018 through March 2019, visitors can fill out cards that contain one of ten questions aimed at eliciting their perceptions of how future mobility options will impact societal transit equity, access, and utilization. In addition to specific questions, the back of the card provides an open-ended prompt to enable visitors to elaborate on their responses….

Global Network Mapping Transit

http://civicdatadesignlab.mit.edu/#projects/GLOBAL%20NETWORK%20MAPPING%20TRANSIT

…Global Network Mapping Transit is bringing together innovative methodologies for mapping urban transit systems. Our objective is to understand the achievements and challenges faced in each project, using cross-case comparisons to promote knowledge exchange between cities.

Commuting for women in Saudi Arabia: Metro to driving - Options to support women employment

Williams, S., Qiu, W., Al-awwad, Z. Alfayez, A.
Journal of Transport Geography, Volume 77, May 2019, Pages 126-138,
https://doi.org/10.1016/j.jtrangeo.2019.05.002

Saudi Arabian women traditionally have been dependent on male relatives, hired drivers, or private transportation to get to work as they were not permitted to drive until June 2018. Some believe this has created a barrier for those women who wanted to enter the workforce. This research was conducted to determine whether accessibility (cost and time) for different types of transport has a relationship with women's opportunity to work. The unemployment rate for Saudi women in 2016 was nearly six times that of Saudi men. Qualitative evidence suggests the high cost of private transportation is a limiting factor for women working in Riyadh (Bashraheel, 2009; Jiffry, 2012). However, studies have yet to quantify the relationship between the location of employment, the job participation rate, and commute costs. By using a commuter accessibility model based on the financial cost of commuting for four female employment sectors—manufacturing, retail, healthcare, and education—this research sets out to test the relationship between commute costs and employment for Riyadh women. The study, which provides the first comparative commute cost maps for Riyadh, looks at commute costs for driving alone, private drivers, street-hailed and app-based taxi services, and the new Metro system. The results show that when commute costs increase, employment among women decreases. This means that reducing commute costs, perhaps by allowing women to drive themselves to work, increases the opportunity for women to work. The research also showed that manufacturing is the least accessible sector for women and would benefit from new forms of transit such as car-pooling.

3Q: Sarah Williams on mapping urban transport

Digitally mapping informal transportation networks in developing cities can help them reach the United Nations' Sustainable Development Goals.
Michelle English, Center for International Studies, March 19, 2019, http://news.mit.edu/2019/mit-3Q-sarah-williams-mapping-urban-digital-transport-0319

Imagine that you're a city planner who needs to make decisions about where to place public housing, amenities, or critical services, but you don't have a complete picture of how people move throughout the city. You simply don't have the data needed to make these decisions. That is the case for 92 percent of the world's largest low- and middle-income cities faced with transportation data deficits. Add informal transit into the picture — matatus in Nairobi, colectivos in Mexico City, jeepneys in Manila — and the situation gets even more complex since these modes operate outside of formal public transportation and their routes and schedules tend to be irregular. Not every city has the means of creating or collecting data on informal transit to get that full picture of the network. Sarah Williams is combining her skills as a geographer, architect, data scientist, and city planner to address such deficiencies in developing cities. Her goal is to create data for civic change. Her latest project is an open-platform resource center for Latin American and Caribbean cities....

NIGEL H M WILSON

Professor of Civil and Environmental Engineering, Emeritus,
http://cee.mit.edu/people_individual/nigel-h-m-wilson/

Professor Nigel Wilson, director of the MIT Transit Research Program, has more than 30 years experience dealing with operations, management and planning issues associated with transit systems worldwide. His research and teaching focus on urban public transportation, including topics related to the operation, analysis, planning and management of transit systems. Specific research activities he has directed include using automated data systems to improve planning and operations, workforce planning in the transit industry, short-range transit planning methods, the role of private operators in public transportation and the potential for computers and communication systems to improve the performance of transit systems. During two leaves from MIT, he worked directly in three large transit agencies, the Massachusetts Bay Transportation Authority (1985-86), London Transport (1992-93) and Metro Transit (2008-2009) and has also consulted to a number of other North American transit authorities.

Estimation of Denied Boarding in Urban Rail Systems: Alternative Formulations and Comparative Analysis

Ma, Z., Koutsopoulos, H.N., Chen, Y., Wilson, N.H.M.
Transportation Research Record, 2019, https://doi.org/10.1177/0361198119857034

Monitoring rail transit system performance is important for effective operations planning. The number of times passengers are denied boarding is becoming a key measure of the impact of near-capacity operations on customers and is fundamental for calculating other performance metrics, such as expected waiting time for service. This paper reviews existing methods and proposes a denied boarding probability distribution inference method for closed Automated Fare Collection (AFC) urban rail systems. Using AFC (tap-in and tap-out) and Automated Vehicle Location (AVL) data, the method relaxes some of the limitations of existing approaches. The problem is modeled using a mixture distribution framework that incorporates a priori structural information. It is data-driven and requires neither observations of denied boardings, nor assumptions about access/egress time distributions. Also, for comparison purposes, the paper presents an event-based deterministic transit assignment model with explicit capacity constraints. While the network assignment works at the network level and requires train capacity, the mixture model works at the station level, requires no external parameters, and can be easily applied to any station and for any time period. A case study illustrates the application of the proposed methods using actual data and compares the results against existing methods, and also survey data. The results demonstrate the mixture model's robustness and applicability for monitoring denied boarding.

Inferring left behind passengers in congested metro systems from automated data

Zhu, Y., Koutsopoulos, H.N., Wilson, N.H.M.
Transportation Research Part C: Emerging Technologies, Volume 94, September 2018, Pages 323-337, https://doi.org/10.1016/j.trc.2017.10.002

With subway systems around the world experiencing increasing demand, measures such as passengers left behind are becoming increasingly important. This paper proposes a methodology for inferring the probability distribution of the number of times a passenger is left behind at stations in congested metro systems using automated data. Maximum likelihood estimation (MLE) and Bayesian inference methods are used to estimate the left behind probability mass function (LBPMF) for a given station and time period. The model is applied using actual and synthetic data. The results show that the model is able to estimate the probability of being left behind fairly accurately.

Estimation of population origin–interchange–destination flows on multimodal transit networks

Gordon, J.B., Koutsopoulos, H.N., Wilson, N.H.M.
Transportation Research Part C: Emerging Technologies, Volume 90, May 2018, Pages 350-365, https://doi.org/10.1016/j.trc.2018.03.007

Previous research has combined automated fare-collection (AFC) and automated vehicle-location (AVL) data to infer the times and locations of passenger origins, interchanges (transfers), and destinations on multimodal transit networks. The resultant origin–interchange–destination flows (and the origin–destination (OD) matrices that comprise those flows), however, represent only a sample of total ridership, as they contain only those journeys made using the AFC payment method that have been successfully recorded or inferred. This paper presents a method for scaling passenger-journey flows (i.e., linked-trip flows) using additional information from passenger counts at each station gate and bus farebox, thereby estimating the flows of non-AFC passengers and of AFC passengers whose journeys were not successfully inferred. The proposed method is applied to a hypothetical test network and to AFC and AVL data from London's multimodal public transit network. Because London requires AFC transactions upon both entry and exit for rail trips, a rail-only OD matrix is extracted from the estimated multimodal linked-trip flows, and is compared to a rail OD matrix generated using the iterative proportional fitting method.

P CHRISTOPHER ZEGRAS

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Lead, Transportation Systems, (MIT-Portugal Program)
Publications: https://scholar.google.com/citations?user=3OQUG7IAAAAJ&hl=en

Christopher Zegras is Professor of Transportation and Urban Planning in the Dept. of Urban Studies and Planning at MIT, where he teaches integrated land use-transportation planning, transportation finance, and field-based/client-based workshops. He has co-taught urban design and planning studios in Beijing, Boston, Cartagena (Colombia), Guadalajara (Mexico), Mexico City, and Santiago de Chile. He is the Lead Principal Investigator for the Future Urban Mobility research group, sponsored by the Singapore MIT Alliance for Research and Technology, and is MIT Lead of Transportation Systems under the MIT Portugal Program.

"Digitalizing Walkability": Comparing Smartphone-Based and Web-Based Approaches to Measuring Neighborhood Walkability in Singapore

Yun, H.Y., Zegras, C., Palencia Arreola, D.H.
Journal of Urban Technology, Volume 26, Issue 3, 3 July 2019, Pages 3-43,
https://doi.org/10.1080/10630732.2019.1625016

We evaluated two digitally enabled approaches to measuring neighborhood walkability: a smartphone-based, on-site pedestrian environmental audit tool, WalkTracker (WTracker), and remote, Web-based (Web) observations. Specifically, we examined street segments and intersections of a neighborhood in Singapore assessing: (1) the Inter-Rater Reliability (IRR) of each approach; (2) the Inter-Method Reliability (IMR) across the two approaches; and (3) the average observation times of the two approaches. Each approach had high IRR for the land use and traffic-related domains, with the Web performing better than WTracker for land use. In these same two domains, the two tools were relatively consistent (high IMR), although higher agreement was found within the tools than across them (IRR higher than IMR). For subjective or fine-grained features, both approaches had low IRR, with the Web-based approach performing worse than the app-based approach. Performance across the instruments was also worse than the reliability of measurements within each instrument (IMR lower than IRR). Some items were not observable via the Web. In terms of observation time, there was no statistically significant time difference in measurements between the two observation methods, not including the round-trip travel time to the site. A hybrid approach, combining the two approaches, might be most appropriate.

Transit-oriented development and air quality in Chinese cities: A city-level examination

Gu, P., He, D., Chen, Y., Christopher Zegras, P., Jiang, Y.

Transportation Research Part D: Transport and Environment, Volume 68, March 2019, Pages 10-25, https://doi.org/10.1016/j.trd.2018.03.009

In this paper, we aim to see whether transit-oriented development (TOD) in Chinese cities is associated with better air quality. We first identify 37 Chinese cities with existing urban rail transit and/or bus rapid transit (BRT) systems. For each of these cities we generate performance-based TOD indicators – including measures such as urban area coverage, population coverage, street network density and land use mix within station catchment areas – and construct composite TOD indices for each city using those indicators. We also collect daily air quality index (AQI) data from the Ministry of Environmental Protection of China over the entire year 2014 for 152 cities and calculate annual and seasonal average AQIs for each city. Regression models provide some evidence that rail-based TOD is associated with better air quality, after controlling for meteorological, demographic and economic characteristics. BRT-based TOD shows no significant relationship.

Representing Accessibility: Evidence from Vehicle Ownership Choices and Property Valuations in Singapore

He, H., Ponce-Lopez, R., Shaw, J., Le, D.-T., Ferreira, J., Zegras, P.C.

Transportation Research Record, Volume 2673, Issue 2, 1 February 2019, Pages 724-733, https://doi.org/10.1177/0361198119825831

This paper compares the relative performance of different measures of accessibility in relevant models. Specifically, the authors formulated three measures of accessibility: gravity-based accessibility, an aggregate measure of potential; trip-based accessibility, a disaggregate, utility-based measure of the value of travel alternatives; and activity-based accessibility, a theoretically richer disaggregate, utility-based measure of the value of alternative activities (including travel). These accessibility measures were used as explanatory variables in household vehicle ownership models and real estate market price models, comparing the explanatory power of each accessibility measure in each model as expressed by the confidence in the coefficient estimates and captured by the models' goodness-of-fit statistics. It was found that trip-based accessibility best represents preferences for accessibility in both vehicle ownership decisions and property valuations. This supports the theoretical value of disaggregate, utility-based accessibility measures over aggregate, potential-based measures. The fact that trip-based measures perform better than activity-based accessibility measures underscores several empirical and technical limitations. Finally, the authors noted that accurately representing accessibility preferences requires congruence between the granularity of the accessibility measure and that of the explained behavior. This emphasizes the importance of understanding what accessibility measures actually capture and ensuring that they align with the analysis purpose.

Tangible Tools for Public Transportation Planning: Public Involvement and Learning for Bus Rapid Transit Corridor Design

Stewart, A.F., Zegras, P.C., Tinn, P., Rosenblum, J.L.

Transportation Research Record, Volume 2672, Issue 8, 1 December 2018, Pages 785-795, https://doi.org/10.1177/0361198118797462

Open governance and open data have given rise to new collaborative tools for public involvement in transit planning. The research presented in this paper extends such tools, adding tangible and interactive features in an attempt to foster interaction, dialog, and social learning. Three tools, representing the impacts of bus rapid transit (BRT) projects at the street, neighborhood, and regional scales, were deployed at a series of public workshops in Boston. A pre-/post- survey design reveals substantive learning about BRT, supported by participants' general agreement with statements about social learning. The quality of dialog in the workshops may point to the potential for more in-depth, double-loop learning. Of the tools used in the workshop, participants judged the one representing the street scale to be the easiest to use, whereas they judged the touchscreen regional map to be the most relevant and credible. Further research could test such tools with more representative participants and in other settings.

Activity recognition for a smartphone and web-based human mobility sensing system

Kim, Y., Ghorpade, A., Zhao, F., Pereira, F.C., Zegras, P.C., Ben-Akiva, M.
IEEE Intelligent Systems, Volume 33, Issue 4, July-August 2018, Article number 8497009, Pages 5-23, https://doi.org/10.1109/MIS.2018.043741317

Activity-based models in transport modeling and prediction are built from a large number of observed trips and their purposes. However, data acquired through traditional interview-based travel surveys is often inaccurate and insufficient. Recently, a human mobility sensing system, called Future Mobility Survey (FMS), was developed and used to collect travel data from more than 1,000 participants. FMS combines a smartphone and interactive web interface in order to better infer users activities and patterns. This paper presents a model that infers an activity at a certain location. We propose to generate a set of predictive features based on spatial, temporal, transitional, and environmental contexts with an appropriate quantization. In order to improve the generalization performance of the proposed model, we employ a robust approach with ensemble learning. Empirical results using FMS data demonstrate that the proposed method contributes significantly to providing accurate activity estimates for the user in our travel-sensing application.

JINHUA ZHAO

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Jinhua Zhao is the Edward and Joyce Linde Associate Professor of City and Transportation Planning at the Massachusetts Institute of Technology (MIT). Prof. Zhao brings behavioral science and transportation technology together to shape travel behavior, design mobility system and reform urban policies. He develops methods to sense, predict, nudge and regulate travel behavior and designs multimodal mobility system that integrates autonomous vehicles, shared mobility, and public transport. Prof. Zhao sees transportation as a language to describe a person, characterize a city, and understand an institution, and aims to establish the behavioral foundation for transportation policies.

JTL Urban Mobility Lab at MIT

https://mobility.mit.edu/
Projects: https://mobility.mit.edu/projects
Publications: https://mobility.mit.edu/publications

The JTL Urban Mobility Lab at MIT brings behavioral science and transportation technology together to shape travel behavior, design mobility systems, and improve transportation policies. We apply this framework to managing automobile ownership and usage, optimizing public transit planning and operation, promoting active modes of walking and cycling, governing autonomous vehicles and shared mobility services, and designing multimodal urban transportation systems.

The Automated Mobility Policy (AMP) Project

https://mobility.mit.edu/av

Three independent forces are converging in the transportation field: sharing economy; electrification; and autonomous vehicles (AV)—together they promise to re-draw the transportation landscape as we know it. The trajectory along which they will evolve, however, remains largely uncertain. Through the Automated Mobility Policy (AMP) Project, JTL researchers bring together urban transportation planning, public policy, engineering, and behavioral science to analyze this revolution, by understanding how humans and policies interact with transportation technology: 1. Examining the formation processes of people's preferences for autonomous vehicles; 2. Embedding shared AV services within the public transportation system, through the integration of information, price, operations, and institutions; and 3. Envisioning how municipal governments can devise AV policies to produce more equitable, sustainable, efficient, and livable cities.

Public Transportation Management

https://mobility.mit.edu/transit

A robust public transit network is an integral part of an urban transportation system. Together with the MIT Transit Lab, we merge behavioral science and systems engineering to determine how to improve the flow of passengers on mass transit, better understand demand, and offer policy solutions to transit agencies to help them respond to emerging challenges in this space.

Advanced Mobility Management, Singapore-MIT Alliance for Research and Technology (SMART)

https://mobility.mit.edu/singapore

As part of the Future Urban Mobility (FM) IRG of the Singapore-MIT Alliance for Research and Technology (SMART), the team led by Prof. Jinhua Zhao combines behavioral science and transportation technology to envision a future urban mobility system for Singapore that integrates public transit, walking and bicycling, shared mobility, and autonomous vehicles. The current phase of the project consists of four topics: 1. Examining the formation process of people's preferences for autonomous vehicles (AVs); 2. Monitoring emotional and physiological responses during AV rides; 3. Designing the integration of on-demand AV service with public transport systems; and 4. Social mobility sharing in the interest of joint optimization of network efficiency and preference for human interaction.

Social Mobility Sharing

https://mobility.mit.edu/sharing

Traffic congestion, dominated by single-occupancy vehicles, reflects not only the inefficiency of the transportation system, but also a sociological state of human isolation. Advances in information and communications technology are enabling the growth of real-time ride sharing—whereby passengers are paired up on car trips with similar origins and destinations and proximate time windows—to improve system efficiency by moving more people in fewer cars. Lesser known, however, are the opportunities presented by shared mobility as a tool to foster and strengthen human interactions. In contrast to typical social interactions in public or private space (meeting rooms, streets, public squares, living rooms, etc.) the nature of shared car rides is impromptu, holds passengers "captive" for a considerable duration, and is remarkably more intimate than other sorts of transportation journeys, representing a unique juxtaposition of spontaneity and intensity. In these ways, it is distinct from mass transit modes such as buses and trains, where most passengers refrain from engaging with each other. Funded by the MIT Institute of Data, System and Society, this research examines the bi-directional connections between shared mobility as a transportation technology, and as an emerging mode of human interaction: how the unique temporal-spatial setting of ride sharing may (a) contribute to or preclude its growth in travel mode share, and (b) affect the quality and quantity of meaningful human interactions in the urban environment.

Global Mobility Culture Comparison and China's Mobility Management

https://mobility.mit.edu/culture

Mobility is already changing in response to evolving demographics, consumer preferences, new business models, connectedness, technology, alternative fuels, and policy. Future changes are anticipated but there is great uncertainty about the pace of change and which mobility options will be adopted. This multi-PI, multi-year MIT study, Mobility of the Future, will explore these possibilities and examine how complex interactions between engine technology options, fuel options, refueling infrastructure, consumer choice, public transit options, new transportation modalities, and government policy might shape the future landscape for mobility.

Mobility Sharing as a Preference Matching Problem

Zhang, H., Zhao, J.
IEEE Transactions on Intelligent Transportation Systems, Volume 20, Issue 7, July 2019, Article number 8478802, Pages 2584-2592, https://doi.org/10.1109/TITS.2018.2868366

Traffic congestion, dominated by single-occupancy vehicles, reflects not only transportation system inefficiency and negative externalities but also a sociological state of human isolation. Advances in information and communication technology are enabling the growth of real-time ridesharing to improve system efficiency. While most ridesharing algorithms optimize fellow passenger matching based on efficiency criteria (maximum number of paired trips, minimum total vehicle-time, or vehicle-distance traveled), very few explicitly consider passengers' preference for their peers as the matching objective. The existing literature either considers the bipartite driver-passenger matching problem, which is structurally different from the monopartite passenger-passenger matching, or only considers the passenger-passenger problem in a simplified one-origin-multiple-destination setting. We formulate a general monopartite passenger matching model in a road network and illustrate the model by pairing 301 430 taxi trips in Manhattan in two scenarios: one considering 1000 randomly generated preference orders and the other considering four sets of group-based preference orders. In both scenarios, compared with efficiency-based matching models, preference-based matching improves the average ranking of paired fellow passenger to the near-top position of people's preference orders with only a small efficiency loss at the individual level and a moderate loss at the aggregate level. The near-top-ranking results fall in a narrow range even with the random variance of passenger preference as inputs.

Gaining Acceptance by Informing the People? Public Knowledge, Attitudes, and Acceptance of Transportation Policies

Li, M., Zhao, J.
Journal of Planning Education and Research, Volume 39, Issue 2, 1 June 2019, Pages 166-183,
https://doi.org/10.1177/0739456X17732623

We examine the connection between public knowledge and attitudes in the context of urban transportation policies. We categorize policy knowledge into received, subjective, and reasoned knowledge, and measure them empirically using a survey of Shanghai's residents (n=1,000) on the vehicle license auction policy. We quantify the relationship between the three types of knowledge and public acceptance and its predecessors (perceived effectiveness, affordability, and equity). We find variegated impacts of knowledge on acceptance: reasoned knowledge increases acceptance but subjective knowledge decreases it, while received knowledge has no direct impact. Public information needs to emphasize societal benefits and the underlying policy rationale.

Are Cities Prepared for Autonomous Vehicles?: Planning for Technological Change by U.S. Local Governments

Freemark, Y., Hudson, A., Zhao, J.
Journal of the American Planning Association, Volume 85, Issue 2, 3 April 2019, Pages 133-151,
https://doi.org/10.1080/01944363.2019.1603760

Problem, research strategy, and findings: Local government policies could affect how autonomous vehicle (AV) technology is deployed. In this study we examine how municipalities are planning for AVs, identify local characteristics that are associated with preparation, and describe what effects bureaucrats expect from the vehicles. We review existing plans of the 25 largest U.S. cities and survey transportation and planning officials from 120 cities, representative of all municipalities with populations larger than 100,000. First, we find that few local governments have begun planning for AVs. Second, cities with larger populations and higher population growth are more likely to be prepared. Third, although local officials are optimistic about the technology and its potential to increase safety while reducing congestion, costs, and pollution, more than a third of respondents worried about AVs increasing vehicle miles traveled and sprawl while reducing transit ridership and local revenues. Those concerns are associated with greater willingness to implement AV regulations, but there is variation among responses depending on political ideology, per capita government expenditures, and population density. Takeaway for practice: Municipal governments' future approaches to AV preparation will likely depend on the characteristics of city residents and local resources. Planners can maximize policy advancement if they work with officials in other cities to develop best practices and articulate strategies that overlap with existing priorities, such as reducing pollution and single-occupancy commuting.

Rider-to-rider discriminatory attitudes and ridesharing behavior

Moody, J., Middleton, S., Zhao, J.
Transportation Research Part F: Traffic Psychology and Behaviour, Volume 62, April 2019,
Pages 258-273, https://doi.org/10.1016/j.trf.2019.01.003

Using online survey data from N = 2041 Uber and Lyft users in the United States collected in 2016 and 2018, this paper establishes the validity, reliability, and invariance of a measure of rider-to-rider race and social class discrimination. This measure is then incorporated into three structural models that investigate associations between rider-to-rider discriminatory attitudes and four aspects of ridesharing behavior. We find no significant relationship between rider-to-rider

discriminatory attitudes and whether a TNC user has ever used a ridesharing service (such as uberPOOL or Lyft Line). However, among those who have used ridesharing services before, rider-to-rider discriminatory attitudes are strongly negatively predictive of an individual's level of satisfaction with the sharing option, and marginally negatively predictive of an individual's percentage of shared TNC trips. Furthermore, among those who have not yet used ridesharing services, rider-to-rider discriminatory attitudes are strongly negatively predictive of willingness to consider using uberPOOL or Lyft Line in the future. Together, these findings suggest that rider-to-rider discriminatory attitudes may discourage sustained and frequent use of ridesharing services among TNC users. Further research is required to identify strategies for addressing discriminatory attitudes in the ridesharing context and overcoming reluctance to sharing.

Value of demand information in autonomous mobility-on-demand systems

Wen, J., Nassir, N., Zhao, J.

Transportation Research Part A: Policy and Practice, Volume 121, March 2019, Pages 346-359, https://doi.org/10.1016/j.tra.2019.01.018

Effective management of demand information is a critical factor in the successful operation of autonomous mobility-on-demand (AMoD) systems. This paper classifies, measures and evaluates the demand information for an AMoD system. First, the paper studies demand information at both individual and aggregate levels and measures two critical attributes: dynamism and granularity. We identify the trade-offs between both attributes during the data collection and information inference processes and discuss the compatibility of the AMoD dispatching algorithms with different types of information. Second, the paper assesses the value of demand information through agent-based simulation experiments with the actual road network and travel demand in a major European city, where we assume a single operator monopolizes the AMoD service in the case study area but competes with other transportation modes. The performance of the AMoD system is evaluated from the perspectives of travelers, AMoD operators, and transportation authority in terms of the overall system performance. The paper tests multiple scenarios, combining different information levels, information dynamism, and information granularity, as well as various fleet sizes. Results show that aggregate demand information leads to more served requests, shorter wait time and higher profit through effective rebalancing, especially when supply is high and demand information is spatially granular. Individual demand information from in-advance requests also improves the system performance, the degree of which depends on the spatial disparity of requests and their coupled service priority. By designing hailing policies accordingly, the operator is able to maximize the potential benefits. The paper concludes that the strategic trade-offs of demand information need to be made regarding the information level, information dynamism, and information granularity. It also offers a broader discussion on the benefits and costs of demand information for key stakeholders including the users, the operator, and the society.

A randomized controlled trial in travel demand management

Rosenfield, A., Attanucci, J.P., Zhao, J.

Transportation, 2019, Article in Press, https://doi.org/10.1007/s11116-019-10023-9

This paper presents a trial aimed at reducing parking demand at a large urban employer through an informational campaign and monetary incentives. A 6-week randomized controlled trial was conducted with (N = 2000) employee commuters at the Massachusetts Institute of Technology, all of whom frequently drove to campus. Split into four arms of five hundred each, one group received weekly informational emails highlighting MIT's various new transportation benefits; a second group received monetary rewards for reducing their frequency of parking; a third group received both interventions, while a control group was monitored with no intervention. The paper aims to examine how behavioral incentives, namely targeted information provision and monetary rewards, can be used independently or in combination to encourage alternatives to drive-alone commuting. Success was measured as the extent to which drivers decreased their frequency of parking and increased their use of alternative modes during and after the campaign. While the combined treatment group contained the highest number of top-performing participants, no statistically significant differences-in-differences were observed amongst the treatment arms compared to the control. A post-experiment survey indicated a widespread increase in awareness of employer transportation benefits, and a much larger stated shift from driving towards transit than was supported by passively-collected data. Survey results suggested that while intent to reduce car use existed, complaints of insufficient quality of transit service and relative convenience of driving suppressed modal shifts. Most importantly, the discrepancy between self-reported and actual behavior change highlights important limitations and biases of survey-based travel behavior research.

Home-work carpooling for social mixing

Librino, F., Renda, M.E., Santi, P., Martelli, F., Resta, G., Duarte, F., Ratti, C., Zhao, J.
Transportation, 2019, Article in Press, https://doi.org/10.1007/s11116-019-10038-2

Shared mobility is widely recognized for its contribution in reducing carbon footprint, traffic congestion, parking needs and transportation-related costs in urban and suburban areas. In this context, the use of carpooling in home-work commute is particularly appealing for its potential of lessening the number of cars and kilometers traveled, consequently reducing major causes of traffic in cities. Accordingly, most of the carpooling algorithms are optimized for reducing total travel time, cost, and other transportation-related metrics. In this paper, we analyze carpooling from a new perspective, investigating the question of whether it can be used also as a tool to favor social integration, and to what extent social benefits should be traded off with transportation efficiency. By incorporating traveler's social characteristics into a recently introduced network-based approach to model ride-sharing opportunities, we define two social-related carpooling problems: how to maximize the number of rides shared between people belonging to different social groups, and how to maximize the amount of time people spend together along the ride. For each of the problems, we provide corresponding optimal and computationally efficient solutions. We then demonstrate our approach on two datasets collected in the city of Pisa, Italy, and Cambridge, US, and quantify the potential social benefits of carpooling, and how they can be traded off with traditional transportation-related metrics. When collectively considered, the models, algorithms, and results presented in this paper broaden the perspective from which carpooling problems are typically analyzed to encompass multiple disciplines including urban planning, public policy, and social sciences.

Real time transit demand prediction capturing station interactions and impact of special events

Noursalehi, P., Koutsopoulos, H.N., Zhao, J.
Transportation Research Part C: Emerging Technologies, Volume 97, December 2018, Pages 277-300, https://doi.org/10.1016/j.trc.2018.10.023

Demand for public transportation is highly affected by passengers' experience and the level of service provided. Thus, it is vital for transit agencies to deploy adaptive strategies to respond to changes in demand or supply in a timely manner, and prevent unwanted deterioration in service quality. In this paper, a real time prediction methodology, based on univariate and multivariate state-space models, is developed to predict the short-term passenger arrivals at transit stations. A univariate state-space model is developed at the station level. Through a hierarchical clustering algorithm with correlation distance, stations with similar demand patterns are identified. A dynamic factor model is proposed for each cluster, capturing station interdependencies through a set of common factors. Both approaches can model the effect of exogenous events (such as football games). Ensemble predictions are then obtained by combining the outputs from the two models, based on their respective accuracy. We evaluate these models using data from the 32 stations on the Central line of the London Underground (LU), operated by Transport for London (TfL). The results indicate that the proposed methodology performs well in predicting short-term station arrivals for the set of test days. For most stations, ensemble prediction has the lowest mean error, as well as the smallest range of error, and exhibits more robust performance across the test days.

Impact of Built Environment on First- and Last-Mile Travel Mode Choice

Mo, B., Shen, Y., Zhao, J.

Transportation Research Record, Volume 2672, Issue 6, 1 December 2018, Pages 40-51,
https://doi.org/10.1177/0361198118788423

The paper studies the impacts of built environment (BE) on the first- and last-mile travel modal choice. We select Singapore as a case study. The data used for this work is extracted from the first- and last-mile trips to mass rapid transit (MRT) stations in the Household Interview Travel Survey of Singapore in 2012 with nearly 24,000 samples. The BE indicators are quantified based on four “D” variables: Density, Diversity, Design, and Distance to transit. We also take into account sociodemographic and trip-specific variables. Mixed logit (ML) modeling frameworks are adopted to estimate the impact of BE and the heterogeneity of taste across the sample. Based on the availability of light rail transit (LRT) in different areas, two modeling structures are implemented with binary ML models for non-LRT areas where “walk” and “bus” are the available travel modes, and multinomial ML models for areas where LRT is an additional alternative. The modeling results shed light on the following findings: BE—especially distance to MRT station, transportation infrastructures, land-use mix, and socioeconomic activities—significantly influences the first- and last-mile travel behaviors. Those who live or work close to MRT stations and in an area with high socioeconomic activities and land-use mix may have stronger preferences to walk for the first- and last-mile trips. The impact of physical BE (i.e., distance, infrastructures) is relatively homogeneous among the sample, while the impact of socioeconomic BE factors (i.e., floor space density, entropy) tends to vary across the sample.

Integrating shared autonomous vehicle in public transportation system: A supply-side simulation of the first-mile service in Singapore

Shen, Y., Zhang, H., Zhao, J.

Transportation Research Part A: Policy and Practice, Volume 113, July 2018, Pages 125-136,
https://doi.org/10.1016/j.tra.2018.04.004

This paper proposes and simulates an integrated autonomous vehicle (AV) and public transportation (PT) system. After discussing the attributes of and the interaction among the prospective stakeholders in the system, we identify opportunities for synergy between AVs and the PT system based on Singapore's organizational structure and demand characteristics. Envisioning an integrated system in the context of the first-mile problem during morning peak hours, we propose to preserve high demand bus routes while repurposing low-demand bus routes and using shared AVs as an alternative. An agent-based supply-side simulation is built to assess the performance of the proposed service in fifty-two scenarios with different fleet sizes and ridesharing preferences. Under a set of assumptions on AV operation costs and dispatching algorithms, the results show that the integrated system has the potential of enhancing service quality, occupying fewer road resources, being financially sustainable, and utilizing bus services more efficiently.

MIT TRANSIT LAB

https://transitlab.mit.edu
Research: https://transitlab.mit.edu/research

Research in the MIT Transit Lab focuses on several areas including service and operations planning, management, and control; transit policy, finance and strategy; and transportation modeling. Research is carried out principally by faculty and students in MIT's Master of Science in Transportation program, a multi-disciplinary course of study involving both classroom and field work, supplemented by summer internships in transit agencies.

Service and Operations Planning, Management, and Control

https://transitlab.mit.edu/research

In the area of service and operations planning, the MIT program faculty are led by Nigel Wilson and John Attanucci. As Principal Investigator, Dr. Wilson has a long history of focusing research on techniques to improve both rail and bus operations, many of which are detailed in his intensive week-long summer course designed for transit managers. These efforts begin with a focus on the operations planning and scheduling procedures used on a daily basis by transit practitioners, and then proceed to techniques to ensure reliable field operations through effective management and control "on the street." A wide range of research projects have produced implementable tools and realistic recommendations in such areas as:

- effective scheduling for increasing network connectivity
- planning express and limited-stop bus services
- rail service disruption recovery strategies
- determining appropriate corridor operational characteristics for BRT services
- utilizing AVL (Automated Vehicle Location) data to develop a bus route simulation model

A current focus of the group is on determining the best uses of the new ITS technology which is transforming a once data-starved arena into one of the most data-rich planning environments in any industry.

Transit Policy, Finance and Strategy

https://transitlab.mit.edu/research

The program faculty, led by Frederick Salvucci, former Secretary of Transportation for the Commonwealth of Massachusetts, has extensive policy and finance leadership credentials. The research team has actively participated in the development, design and construction phases of major capital investments such as San Juan's Tren Urbano rail transit system, Chicago's proposed Circle Line and Airport Express projects, and Boston's MBTA Silver Line bus rapid transit project, as well as in numerous transit improvement projects in the Boston area while in previous positions.

A key contribution of the team has been its ability to position an agency's capital program to attract Federal 'New Starts' funding and to maximize the local impact of these Federal funds. The MIT team has undertaken a variety of policy and strategic planning projects including organization studies, contract management analyses, development impacts of transit improvement projects, fare policy reviews, and examination of the appropriate mix of state and local funding sources. An ongoing focus in this area has been to identify innovative funding strategies for the operating budget to relieve the pressure on traditional funding sources.

Transportation Modeling

https://transitlab.mit.edu/research

In the area of transportation modeling, the program faculty is led by Mikel Murga. Models are applied at different scales, depending on the specific research focus. These modeling tasks usually cut across all other areas of work, whether the task at hand is a policy question, an operations problem or even the need to improve the service quality of a given facility.

The program aims to build in-house agency capabilities by encouraging the transition from a GIS description of the system to a full transit network model. This allows a precise description of system accessibility, including behavioral aspects that explain individual choices. The growing availability of realtime operations and demand data enhances our ability to calibrate these models. Examples of recent research projects include a new project which needed a quick and transparent evaluation method to rate a number of options; the estimation of transit transfer parameters describing the user perceptions at a given transfer facility; and a microscopic representation of bus operations in mixed traffic, to analyze the impact of traffic growth and the feasibility of transit priority.

ADDITIONAL FACULTY AND LABS

ERAN BEN-JOSEPH

Professor of Landscape Architecture and Planning
Department Head / Urban Studies and Planning, http://dusp.mit.edu/faculty/eran-ben-joseph, http://web.mit.edu/ebj/www/
Head, Joint Program in City Design and Development (CDD)

Eran Ben-Joseph is a Professor and Head of the Department of Urban Studies and Planning at the Massachusetts Institute of Technology.

His research and teaching areas include urban and physical design, standards and regulations, sustainable site planning technologies and urban retrofitting. He authored and co-authored the books: Streets and the Shaping of Towns and Cities, Regulating Place: Standards and the Shaping of Urban America, The Code of the City, RENEW Town and ReThinking a Lot. Eran worked as a city planner, urban designer and landscape architect in Europe, Asia, the Middle East and the United States on projects including new towns and residential developments, streetscapes, stream restorations, and parks and recreation planning. He has led national and international multi-disciplinary projects in Singapore, Barcelona, Santiago, Tokyo and Washington DC among other places.

Parking governance: Future trends and speculation

Rosenblum, J., Hudson, A.W., Ben-Joseph, E.
Land Use Policy, 2019, Article number 104054, https://doi.org/10.1016/j.landusepol.2019.104054

The explosion of low-cost, on-demand taxi services and the anticipation of an autonomous vehicle future has made transportation the center of debate and discussion for the first time since the massive expansion of the US highway system in the 1950s. Yet the realm of parking boasts innovations and developments far beyond the high-profile issues of TNCs and AVs. Rather, innovation in parking is happening in many cases quietly on a wide variety of fronts, including technology, public policy, and design. This paper serves an overview of emerging trends in parking, primarily within the US context. We identify and outline five developments and the pertinent technologies helping to catalyze change: unbundling parking costs, reducing parking minimums, pricing and allocating curb space dynamically, designing hybrid parking structures, and preparing for the autonomous era and "mobility as a service." This paper presents these trends with illustrative examples highlighting current practices, governance challenges, and possible future scenarios.

BERTHOLD K P HORN

Professor of Computer Science and Engineering, https://www.csail.mit.edu/person/berthold-horn, http://people.csail.mit.edu/bkph/
Publications: http://people.csail.mit.edu/bkph/publications

Professor Horn and his students work on problems in motion vision and computational imaging. Because recovery of information about the world from a single cue such as motion parallax, binocular stereo disparity, or shading in images tends to be unreliable, Professor Horn works on the integration of information from multiple cues at a low level.

Driver-Friendly Bilateral Control for Suppressing Traffic Instabilities

https://toyota.csail.mit.edu/node/26

Traffic flow instabilities (such as stop-and-go traffic and "phantom traffic jams") can be suppressed using "bilateral control". We are studying how best to implement bilateral control and make it acceptable to drivers. We need to determine what fraction of vehicles need to implement bilateral control before significant benefit can be observed. This is so that we can understand the transition to a world where every vehicle implements bilateral control. To better understand the dynamics of traffic under bilateral control, we are building macroscopic models (densities and flow rates) on top of the underlying microscopic interactions (vehicle to vehicle). In order to demonstrate the potential improvement in safety we are also deriving conditions that will guarantee that there will be no collisions.

A Macroscopic Traffic Simulation Model to Mingle Manually Operated and Self-driving Cars

Cao, Z., Liu, Y., Zhou, L., Fang, Y., Horn, B.K.P.
4th IEEE International Conference on Universal Village 2018, UV 2018, 13 February 2019, Article number 8642115, https://doi.org/10.1109/UV.2018.8642115

As the rapid development of AI, computer vision and automatic control technologies, self-driving cars have been well designed and developed. Since self-driving cars should coexist efficiently with human-driving cars, how to make practical strategies for them is increasingly significant. This paper optimizes cellular automaton to do simulation and quantizes the human factors as realistic and comprehensive as possible based on spectral clustering which is very suitable for large-scale simulation and crowd management for future smart cities. Compared with traditional analysis which record trajectories of cars, the new model employs unsupervised learning to augment average speed and reduce collision time by realizing algorithm optimization to reduce complexity and computational cost. This paper not only demonstrates the progress and results of traffic simulation, but also illustrates the concrete strategies for both self-driving cars and human drivers.

Real-time Vehicle Status Perception Without Frame-based Segmentation for Smart Camera Network

Chen, J., Fang, Y., Sheng, H., Masaki, I., Horn, B., Xiong, Z.
4th IEEE International Conference on Universal Village 2018, UV 2018, 13 February 2019, Article number 8642118, https://doi.org/10.1109/UV.2018.8642118

Nowadays camera network plays an important role in the Intelligent Transportation System (ITS), and due to the weak computing ability of smart devices in the camera network, collecting traffic status in real time is one of the critical tasks in this field. A common strategy for traffic status collecting is first to form the trajectories of vehicles and then to measure interested indicators. To address this problem, we present a real-time vehicle status perception approach, which directly extracts vehicle status from our proposed novel video feature, temporal component-weight. Specifically, temporal component-weight is calculated based on a sampling of the whole frame. Also, a hybrid model is proposed to handle crowded situations. We test our approaches in surveillance sequences, and the results show that the proposed approach can effectively collect the vehicle status, including number, relative location, and relative speed.

MIT CENTER FOR ENERGY AND ENVIRONMENTAL POLICY RESEARCH

http://ceepr.mit.edu
Research: http://ceepr.mit.edu/research
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Since 1977, the Center for Energy and Environmental Policy Research (CEEPR) has been a focal point for research on energy and environmental policy at MIT. CEEPR promotes rigorous, objective research for improved decision making in government and the private sector, and secures the relevance of its work through close cooperation with industry partners from around the globe.

CEEPR is jointly sponsored at MIT by the MIT Energy Initiative (MITEI), the Department of Economics, and the Sloan School of Management. Financial support comes from a variety of sources, including state and federal government research funds, foundation grants and contributions from our corporate and government Associates.

Generational Trends in Vehicle Ownership and Use: Are Millennials Any Different?

Christopher R. Knittel and Elizabeth Murphy
http://ceepr.mit.edu/publications/reprints/700

Anecdotes that Millennials fundamentally differ from prior generations are numerous in the popular press. One claim is that Millennials, happy to rely on public transit or ride-hailing, are less likely to own vehicles and travel less in personal vehicles than previous generations. However, in this discussion it is unclear whether these perceived differences are driven by changes in preferences or the impact of forces beyond the control of Millennials, such as the Great Recession. We empirically test whether Millennials' vehicle ownership and use preferences differ from those of previous generations using data from the US National Household Travel Survey, Census, and American Community Survey. We estimate both regression and nearest-neighbor matching models to control for the confounding effect of demographic and macroeconomic variables. We find little difference in preferences for vehicle ownership between Millennials and prior generations once we control for confounding variables. In contrast to the anecdotes, we find higher usage in terms of vehicle miles traveled (VMT) compared to Baby Boomers. Next we test whether Millennials are altering endogenous life choices that may, themselves, affect vehicles ownership and use. We find that Millennials are more likely to live in urban settings and less likely to marry by age 35, but tend to have larger families, controlling for age. On net, these other choices have a small effect on vehicle ownership, reducing the number of vehicles per household by less than one percent.

MIT CENTER FOR TRANSPORTATION AND LOGISTICS

https://ctl.mit.edu/
Research: https://ctl.mit.edu/research
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MIT CTL is based in the MIT School of Engineering in Cambridge, USA. We maintain extensive ties with other MIT schools. To grow insight on global supply chains we founded a network of affiliated research centers in Asia, Europe, and South America. The MIT Global Supply Chain and Logistics Excellence (SCALE) Network strives to develop and disseminate supply chain expertise around the world.

SCALE

https://ctl.mit.edu/scale

The MIT Global SCALE Network is an international alliance of leading research and education centers dedicated to supply chain and logistics excellence through innovation. The Network consists of students, researchers, and faculty at six centers spanning four continents. Most offer a masters degree programs in Supply Chain Management, and one offers a six-week graduate certificate course.

INTERDEPARTMENTAL PROGRAM IN TRANSPORTATION (SM AND PHD)

http://cee.mit.edu/graduate/graduate-degree/
http://catalog.mit.edu/interdisciplinary/graduate-programs/transportation/
http://catalog.mit.edu/degree-charts/master-transportation/

The interdepartmental Master of Science in Transportation (MST) degree program emphasizes the complexity of transportation and its dependence on the interaction of technology, operations, planning, management and policy-making. For this reason, the Master of Science in Transportation program is interdepartmental. Faculty members and research staff from several centers, departments and divisions within MIT are affiliated with the program and serve as research advisors and mentors to MST students.

MIT ENERGY INITIATIVE (MITEI): MOBILITY OF THE FUTURE

http://energy.mit.edu/
http://energy.mit.edu/research/mobilityofthefuture/

The MIT Energy Initiative is MIT's hub for energy research, education, and outreach—connecting faculty, students, and staff to develop the technologies and solutions that will deliver clean, affordable, and plentiful sources of energy.

The three-year Mobility of the Future study explores the major factors that will affect the evolution of personal mobility leading up to 2050 and beyond. Using a scenario-based approach, the diverse study team of MIT faculty, researchers, and students have examined how different factors will play a role in shaping the future of personal mobility at different scales, from global and national markets to policy and mobility choices at the city and individual levels. The resulting report, Insights into Future Mobility, will be released in November 2019. The report will present results and findings to help stakeholders and policymakers anticipate and navigate the disruptions and changes that lie ahead....

The study is organized into five main areas of inquiry, each of which focuses on a particular aspect or set of influences on the future landscape for personal mobility:

- The potential impact of climate change policies on global fleet composition, fuel consumption, fuel prices, and economic output
- The outlook for vehicle ownership and travel, with a focus on the world's two largest light-duty vehicle markets—the U.S. and China
- Characteristics of alternative vehicle powertrains and fuels that could affect their future market share
- Infrastructure considerations for charging and fueling, particularly as they affect future demand for electric and hydrogen fuel cell vehicles
- The future of personal mobility in urban areas, with a focus on the potentially disruptive role of autonomous vehicles and ride-hailing services

NEW ENGLAND UNIVERSITY TRANSPORTATION CENTER

http://utc.mit.edu/
Research: http://utc.mit.edu/research/research-themes

The nationwide University Transportation Centers program was created in 1987 by the US Department of Transportation to attract the nation's best talent to the study of transportation. It established ten university transportation centers, one each in the ten standard Federal regions, to provide a national resource for research and education in both freight and passenger transportation.

The New England Center focuses its research investments on safety and livable communities. With an emphasis on highways and transit, three integrated technology research categories are addressed by the Center's research, education and technology transfer activities: ubiquitous intelligence, big data and user performance across the lifespan.

MIT is the lead university in Region One, where the UTC program is administered through the New England University Transportation Center. The other schools in the New England Center consortium are: the University of Connecticut, the University of Maine, the University of Massachusetts, Amherst, and Harvard University. For UTC contact information at each of these member schools, see the Policy Committee link under Key Personnel.

MIT-RELATED STARTUPS

MIT STARTUP EXCHANGE

https://startupexchange.mit.edu/

MIT Startup Exchange is a web community for the MIT innovation ecosystem, particularly MIT ILP's members, MIT-connected startups and all MIT employees or alumni who have active startup engagements.

BONZER INC.

MIT Relationship: Ivan Li Huang (Founder, MIT Alumnus)
Cambridge, MA, http://www.bonzer.rocks/

There are many blind spots in a city where people cannot reach easily through public transportation. Going by bicycle would be too far and by taxi would be too expensive. BONZER is a one-way trip car sharing program. As a one-way trip solution, based on modern and small electric cars spread in charging/parking stations throughout the area, BONZER aims to help, to facilitate and to provide one more alternative to transportation within the limits of the metropolis.

DATADRIVEN

MIT Relationship: Josh Siegel (alum/founder)
Boston, MA, http://www.mit.edu/~j_siegel/datadriven/

DataDriven is an MIT spin-out company focused on developing applications of pervasive sensing within the auto industry. The algorithms turn mobile devices into machine-learning mechanics. Using smartphone audio and vibration data, we make automotive diagnostics and maintenance proactive -- all without using OBD. To date, DataDriven has demonstrated successes in passively identifying engine faults, suspension faults, and maintenance needs. Our accuracy exceeds the state of the art in industry, and runs on any web-enabled mobile device.

EV TRANSPORTATION SERVICES, INC

MIT Relationship: David Solomont (Founder & Chairman, MIT Alumnus)
Brookline, MA, http://evtaas.com

evTS offer all-electric light weight commercial utility vehicles for the Essential Services Transportation Market. Its focus is on the FireFly ESV. evTS is deploying vehicles through its innovative "Transportation as a Service" Program. This is an all-in-one leasing program which includes the vehicle, battery, repairs and maintenance, charging station and installation, electricity and real-time in-vehicle data communications for vehicle tracking and fleet management.

GOWITH

MIT Relationship: Marc-Philippe Rudel (Founder, Fmr. MIT Staff)
Jerusalem, Israel, https://www.gowith.io/

Our three lines of business, Flow, FlyWith and RideWith, all share the same goal: help transportation companies and operators (airports, airlines, railway companies) enhance the passenger experience. By providing their customers with Flow's door-to-gate time estimates, airports end up reducing the stress level of passengers and thus increase non-aeronautical revenues; airlines on their part can minimize both passenger delays and the financial losses they result in. By incorporating FlyWith's or RideWith's seatmate arrangement features into their reservation systems, airlines and railway companies can give the level of hyper-personalization that today's customers expect.

POWERHYDRANT

MIT Relationship: Kevin Leary (Founder, CEO, MIT Alum)
Boston, MA, https://powerhydrant.com/

PowerHydrant is a computer-vision directed robotic charger. It has been designed to perform in any charging or charge-sharing scenario where it is not practical to have a human operate the charger. PowerHydrant can automatically and sequentially charge a robot or vehicle without human intervention reliably and efficiently.

The case for EVs is compelling. The case for mainstream adoption of EVs may not be. Users will face state-of-charge anxiety, finding a charging station, plugging-in several times a day, forgetting to connect. Plug-in vehicles will be hard to justify for the less tech-savvy, older, or disabled. As the EV fleet grows there will be a need for charging infrastructure. PowerHydrant provides a care-free, robotic, automated conductive charging system for residential & public spaces. Park & Forget.

REMIX

MIT Relationship: Tiffany Chu (Co-Founder, COO, MIT Alumna)
San Francisco, CA, https://www.remix.com

Remix helps you plan great transit. Design routes in any city and immediately understand the cost and demographic impact of a proposed change. Automatically pull in your region's existing transit networks to quickly evaluate different alternatives. When you're done, export to Excel, shapefile, KML, or GTFS. Everything runs in your browser, and integrates with the tools you already have.

Transit trade-offs are often invisible and hard to explain. Remix empowers your planning team to visualize ideas in a way that anyone can understand and support. See who is affected by a change and ensure service equity by overlaying demographic data. Show how far riders can travel on your network using isochrones. Engage your community with our built-in public feedback platform.

SMACK INNOVATIONS

MIT Relationship: Gregor Hanuschak (Founder, Sloan MBA)
Delaware, https://smackinnovations.com/

Smack Innovations wants to reduce the number of accidents and deaths due to distracted driving. Specifically, we've developed a way to safely control your smart phone while driving any motor vehicle. SafeConnect is an aftermarket product that a driver can clamp onto any size steering wheel in seconds. Using SafeConnect, a driver can safely control apps and features of his iPhone or Android phone. While always keeping hands on the wheel, eyes focused on the road, and phone in his pocket, the driver can push buttons on SafeConnect to dictate text messages, make phone calls, check the local weather, check sports scores, play music, find the cheapest gas station nearby, get directions that avoid traffic, and much more. Any app on the user's phone is potentially compatible.

SUPERPEDESTRIAN INC.

MIT Relationships: Assaf Biderman (Founder, MIT Staff), Carlo Ratti (Strategic Advisor, MIT Faculty)
Cambridge, MA, https://www.superpedestrian.com

Superpedestrian is a transportation robotics company located in Cambridge, Mass. Founded out of MIT and beginning operations in 2013, Superpedestrian develops core technologies for micro-mobility. The company invested 3.5 years in research and development to produce its Vehicle Intelligence technology, which it introduced into the market in 2017 with its award-winning Copenhagen Wheel. Having set a new standard in electric bike drive systems, the company now brings its Vehicle Intelligence technology to shared fleets of electric bikes and scooters.

Our first product, the Copenhagen Wheel, is the first human-enhancing transportation technology available to the mass market. Almost any bike can be equipped with the Copenhagen Wheel, which senses the rider's motions and amplifies their pedaling power by up to 10 times using the drive system embedded within the sleek red hub.

With the explosion of micromobility demand we have developed a transformative set of electric vehicles for large shared fleets. Combining rigorous vehicle design with self-sustaining capabilities and minimal battery charging needs, the new scooters are safer, sturdier, and cost a fraction to maintain. Superpedestrian's solution addresses the most pressing problems faced today by operators, which experience significant barriers to scale due to low reliability and high operational costs of fleets.

TIER MOBILITY

MIT Relationship: Marton Sarkadi Nagy (Founder, MIT Alumnus)
Berlin, Germany, https://www.tier.app/

TIER Mobility provides you with a fleet of electric scooters to get you through the city taking a faster, more fun way from A to B. TIER is here to change mobility for good. We believe it's time to make space for the actual inhabitants of cities: You! Take back your city and rediscover a long-gone feeling: the joy of movement. Just follow your instincts, get moving and see all the city has to offer: Inspiration, diversity, and opportunities.

TRANSIT X

MIT Relationship: Mike Stanley (Founder, MIT Alumnus)
Boston, MA, http://transitx.com/

Transit X is privately-funded public transit that can transform cities and metropolitan areas to be green and car-free. Transit X is microrail with the convenience, capacity, and cost to replace cars, buses, trains, trucks, ferries, and short flights.