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Plenary session 1: Elise Miller-Hooks (USA)

People-centric Models for Roadway Activity Prioritization in Routine and Disrupted Environments

Elise Miller-Hooks*

Professor & Hazel Chair in Infrastructure Engineering, George Mason University

This talk will describe developed mathematical and algorithmic techniques for prioritizing roadway improvement and restoration actions in routine and disrupted environments taking a people-centric approach. This approach puts the system users and community member needs at the core of the optimization. Whether due to a disaster event or more ordinary deterioration processes, roadway improvement activities are necessary. In many locations, they are common and the impacts of even routine maintenence are ever-present. Considering these activities as temporary nuisances that will lead to a future with perfectly performing facilities is idealistic. It is important to consider the effects of these activities on the system users not only in the long run, once they are complete, but also during their execution. Taking a similar, life-in-the-present perspective, post- or peri-disaster restoration actions take time to implement, and the services, such as health care, fueling stations, and food supplies, that our roadways and other infrastructure lifelines support are needed even before restoration is complete. The order in which actions are taken to restore the roadway and other supporting lifelines can affect the availability of these key critical community functions. The developed methods guide these peri- and post-disaster restoration actions by putting critical community functions at the forefront, prioritizing and scheduling activities around their recovery, rather than the recovery of the roadways and other supporting lifelines.

Parallel session 1A:
Activity-Travel behavior in the Covid era

What motivates people to work while travelling and what determines the associated productivity? A case study of the UK rail travellers using a SEM approach

Alessandra Abeille* (1,2), Jacek Pawlak (1,2), Caspar Chorus (3), Aruna Sivakumar (1,2), Eric Molin (3)

1: Imperial college london, United Kingdom; 2: Centre for Transport Studies, Imperial College London; 3: Faculty of Technology, Policy and Management, Delft University of Technology

Limitations in quantifying productive travel time may prevent transport investment from providing appropriate infrastructure or services to commuters. We contribute to these shortcomings by presenting a holistic conceptual model that reflects the stages and determinants of a productive mobile work episode. The model breaks the events leading to a work episode into different moments, thereby allowing to identify each factor's impact on productivity. The model is then operationalised using Structural Equation Models (SEM), which are estimated using data that has been collected among 500 mobile workers on UK trains. Expected results will show how single elements of transport infrastructure or ICT boost or hamper productive mobile work episodes, while taking in account commuters' expectations and their preparation for the journey.

Keywords
Productivity, travel time use, knowledge worker, ICT, travel-based multitasking, Structural Equation Modelling

A Temporal Analysis of Leisure Activity Variety and Social Capital Before and During the COVID-19 Pandemic

Trang Luong*, Michael Maness

University of South Florida, United States of America

The extraordinary disruption caused by the spread of COVID-19 has prompted the need to better understand the changes in people's activity and mobility behavior. Reduced leisure activity space due to public health interventions has changed people's ability to participate in different activities. This paper examines the temporal influence of social capital, mobility, personalities, and demographics on leisure variety using samples collected in 2019 and 2020. Social capital constructs, specifically instrumental support, have substantial and significant effects on increasing leisure activity variety and remain temporally stable. This result supports the robustness and importance of social capital in activity variety, which further provides evidence for the valuable resources offered by one's social network under drastic changes and restrictions. Age, household size, and extraversion are among the factors that exhibit temporal instability. Model inference shows negative impacts of the pandemic on activity variety, especially for people aged 60 or older.

Keywords
Activity diversity modeling, instrumental support, social network, social support, temporal instabilityactivity diversity modeling, temporal instability

The job of public transport, ride-hailing and delivery drivers: conditions during the COVID-19 pandemic and implications for a post-pandemic future

Andres Fielbaum* (1), Felipe Ruiz (2), Giorgio Boccardo (2), Daniela Rubio (3), Alejandro Tirachini (4,5), Jorge Rosales-Salas (6)

1: Department of Cognitive Robotics, TU Delft, The Netherlands.; 2: Departamento de Sociología, Universidad de Chile.; 3: Facultad de Arquitectura y Urbanismo, Universidad de Chile.; 4: Departamento de Ingeniería Civil, Universidad de Chile.; 5: Instituto Sistemas Complejos de Ingeniería (ISCI).; 6: Centro de Economía y Políticas Sociales, Universidad Mayor.

Transport workers were among the most affected by the COVID-19 crisis. In several countries, public transport and delivery drivers were considered essential workers, and the demand changed dramatically. In this paper, we analyse the impact of the pandemic on the daily jobs of public transport, ride-hailing, and delivery app drivers through a survey applied during the first peak of the pandemic in Santiago, Chile. Probit regressions on job satisfaction identify the main COVID-related experiences that explain variations in subjective perceptions. Our results show that the unstable characteristics of app-based jobs sharpened during the pandemic: Public transport drivers have kept their jobs and with a similar income, whereas ride-hailing and delivery app drivers do not as they lack social security. Several ride-hailing drivers lost their jobs without any compensation, while delivery drivers earn less money per hour and are more exhausted.

Keywords
COVID-19, delivery riders, public transport drivers, ride-hailing drivers, sharing economy, transport apps regulation

Will university students return to campus after COVID-19?

Sharifah R. Syed Ihsan, Ioannis Kaparias*

University of Southampton, United Kingdom

The COVID-19 pandemic introduced major challenges to higher education. Many students had to partake in a predominantly virtual educational and social university experience, which inevitably affected travel behaviour around university campuses. The purpose of this study was to explore how student travel behaviour may shape post-COVID-19. Using the University of Southampton as an example, a survey combining stated and revealed preference methods with students was carried out. The responses were analysed using binary logistic regression and the results suggested that students were most inclined to travel to campus for learning and assessment activities, extracurricular activities, individual/group studying and events. A particularly interesting finding was that even if virtual alternatives to several of these activities were offered, they were unlikely to deter students from travelling to campus. This suggests that despite changes in the delivery of higher education activities, university campuses are likely to remain focal points of student life post-COVID-19.

Keywords
travel behaviour, COVID-19, university students

Parallel session 1B: New mobility services

Investigating the Relocation Behavior of Ride-sourcing Drivers

Peyman Ashkrof*, Gonçalo Homem de Almeida Correia, Oded Cats, Bart van Arem

Delft University of Technology, Netherlands

In the business model of ride-sourcing platforms, drivers are individual service suppliers offering door-to-door transport services to riders. Drivers freely adopt their own relocation strategies including waiting, cruising freely, or following the platform recommendations. These decisions can substantially impact the balance between supply and demand, and consequently affect system performance such as match rate, empty mileage, and traffic congestion. To this end, we conducted a stated choice experiment to investigate the searching behavior of ride-sourcing drivers in the current system setting and examine novel policies. A unique dataset of 576 ride-sourcing drivers working in the US was collected and a choice modeling approach was used. The results suggest that ride-sourcing drivers' relocation strategies significantly vary between different groups of drivers depending on their employment status, working experience, daily operations, among others. We discuss the implications of our findings for various platform policies on real-time information sharing and platform repositioning guidance.

Keywords
discrete choice modeling, drivers' behavior, ride-sourcing, shared mobility

The impact of proactive ride-splitting incentives on revenue and service quality

Minru Wang*, Nikolas Geroliminis

Ecole polytechnique fédérale de Lausanne (EPFL), Switzerland

This work studies the role of proactive and targeted ride-splitting incentives on the service level and revenue of a ride-sourcing platform, which is built as a discrete event simulator that incorporates simulated taxi data within a congestible road network. While shared trips offer riders a discount to compensate for any additional travel or waiting time, the success in matching shared trips relies on riders' attitudes towards the trade-off between travel time and cost. Therefore, formulated as a multinomial logit model, alternative-specific coefficients characterize the probability of a random draw among three options: solo ride, shared ride, or a public-transit-like service. A multi-objective analysis shows that for regions where empty vehicle depletion rate is high, by offeringincentives with an additional discount for a shared trip, the platform can proactively rebalance vehicle supply in high-demand regions during peak-hours, and succeed with a small abandonment for trips with high waiting or detour times.

Keywords
pricing incentives, ride-sourcing, shared mobility, simulation, willingness-to-share.

An optimized driver repositioning strategy in ridesplitting with earning estimates: a two-layer dynamic model and control

Caio Vitor Beojone*, Nikolas Geroliminis

Urban Transport Systems Laboratory, École Polytechnique Fédérale de Lausanne, Switzerland

Positioning of ride-sourcing drivers may improve vacant travel times, waiting times and matching opportunities. Herein, we develop a ride-sourcing fare optimizer which, in parallel with a revenue estimator, aids drivers' repositioning decisions to minimize customer abandonments in a system offering ride-hailing (solo) and ridesplitting (shared) rides. A Markov chain estimates near-future individual revenues and forms a second layer in a MFD-based model to predict system conditions. We applied the proposed model in a simulation of the central business district of Shenzhen, China. Our results show that repositioning with fare control can decrease the number of abandonments by 98%. In the other hand, controlling fares decreased travelling speeds in the busiest periods of each area of the system, without entering a hyper-congested regime. These findings expand the literature on fare optimization including ridesplitting operations and providing a tool to estimate near-future earnings.

Keywords
Ride-sourcing, Shared mobility, Repositioning, Model Predictive Control (MPC), Traffic Flow Theory

Emerging Dynamics in Ridesourcing Platforms

Arjan de Ruijter*, Oded Cats, Hans van Lint

Delft University of Technology, Netherlands, The

Ridesourcing businesses operate virtual marketplaces to which free-lancers supply labour and vehicle capacity. A lack of central control over supply may increase the likelihood that socially undesirable levels of supply are attained. Currently, it is largely unknown how co-evolutionary relationships between decentralised supply and demand affect the ridesourcing market equilibrium. To this end, we propose a day-to-day model that accounts for multiple decentralised processes occurring on both sides of the market: (i) initial exposure to information about the platform, (ii) a long-term registration decision, and (iii) daily platform utilisation decisions, subject to day-to-day learning based on within-day matching outcomes. We construct a series of experiments to investigate the effect of different pricing variables and the availability of travellers and workers on ridesourcing system performance. Our results provide indications that regulating the commission fee may be highly beneficial to travellers and drivers, while inducing only a marginal cost for the platform.

Keywords
Emerging dynamics, Gig economy, Pricing, Ridesourcing, Two-sided market

Parallel session 1C: Big Data and travel demand forecasting

Machine learning-based framework for data reviewing of a national household travel survey

Lisa Ecke*, Miriam Magdolen, Sina Jaquart, Peter Vortisch

Karlsruhe Institute of Technology, Germany

Machine learning techniques have mainly been applied to physical measurement data in the past. In this paper, machine learning is applied to survey data of everyday travel behavior provided by the German Mobility Panel (MOP). The presented model framework supports trained staff in checking trips collected in a trip diary. To this aim, four algorithms are applied and tested further. The neural network (NN) shows the most appropriate results. By using the NN for the individual trip checks, the time effort for the trained staff can be reduced by 20.4 %. In addition, it decreases the number of data samples where all reported trips must be checked. Our study shows that machine learning can support the process of data checking in the MOP leading to significant time reduction.

Keywords
Big Data, Data checking, Data quality, German Mobility Panel, Machine learning

Characterizing the Temporal Patterns of Travel Production: A Bird's Eye View of the Urbanization Levels in The Netherlands

zahra Eftekhar*, Adam Pel, Hans van Lint

Delft University of Technology, Netherlands, The

This paper explores the temporal patterns in travel production using a full month of production data from traffic analysis zones (TAZ) in the (entire) Netherlands. This data is a processed aggregated derivative (due to privacy concerns) from GSM traces of a Dutch telecommunication company. This research thus also sheds light on whether such a processed data source is representative of both regular and non-regular patterns in travel production. To this end, the weekly patterns of hour-by-hour travel production of over 1200 TAZs are clustered using inception convolutional neural networks with k-mean methods. A silhoutte score shows that three dominant clusters can be discerned. Each cluster shows different within-day and day-to-day patterns in production. Furthermore, a spatial analysis of these clusters shows that they are related to urbanization levels: Urban, Rural, and mixed group. The findings of this study provide further insights in mobility, relevant for transportation analysis and policies.

Keywords
travel production, spatiotemporal, demand pattern, urbanization, temporal pattern

Exploring Changes in Public Transport Usage during the COVID-19 Pandemic using Smart Card Data: A Case Study from Hiroshima, Japan

Xuan Canh Do* (1,2), Thi Anh Hong Nguyen (1,3), Myo Min Than (1), Akimasa Fujiwara (1), Makoto Chikaraishi (1)

1: Hiroshima University, Japan; 2: University of Transport and Communications, Vietnam; 3: Thuyloi University, Vietnam

There was a sharp decline in public transport (PT) ridership during the pandemic. It would be worth studying the changes in PT mobility during the pandemic to deeply understand PT users' behavior. This study contributes to the growing literature on PT-related studies based on smart card data. As a result, first, we explored the differences in the decrease in PT usage between regular and non-regular public ridership groups. Second, we confirmed a moderately higher reduction in ridership for the non-regular group than for the regular group regarding spatiotemporal dimensions. Third, few active cardholders in the non-regular group and few trips per day per cardholder in the regular group caused the ridership reduction. Finally, higher morning and afternoon traffic peaks are observed in the regular group during workdays.

Keywords
Public Transport, Smart Card Data, COVID-19

Active Learning for transport studies: the case of rare or sparse demand samples

Shen Zhan (1), Guido Cantelmo* (2), Sergio F. A. Batista (3), Mónica Menéndez (3), Constantinos Antoniou (1)

1: Technical University of Munich, Germany; 2: Technical University of Denmark, Denmark; 3: New York University Abu Dhabi

For two decades now, the rapid rise and wide diffusion of new technologies have enabled the generation of a massive amount data – commonly known as Big-Data. Big-Data have been widely adopted in nearly every field of transportation, from behavioural analysis to traffic predictions.
One of the main challenges when dealing with Big-Data is how to sample a representative data-set that can be used for transport analysis. This paper proposes using active learning to address this problem. To that end, we introduce an enhanced active learning algorithm that combines two models. Traditional Active Learning Techniques (such as Gaussian Processes) are used to sample supply-related data. A heuristic model based on the Branch and Bound algorithm is instead used to sample demand-related information. The model is used to sample origin-destination trips for bike-sharing from sparse demand matrices. The case study uses real world data from New York city, showing promising results

Keywords
Active Learning, Big-Data, Data Collection, Mobility Demand, Optimization.

Parallel session 1D: Pricing 1

How different charging prices can contribute to the balancing of ride-hailing services with electric vehicles

Marko Maljkovic* (1), Gustav Nilsson (2), Nikolas Geroliminis (3)

1: École Polytechnique Fédérale de Lausanne, Switzerland; 2: École Polytechnique Fédérale de Lausanne, Switzerland; 3: École Polytechnique Fédérale de Lausanne, Switzerland

Motivated by the growing popularity of both the services offered by the ride-hailing companies and the electric vehicles (EVs), we study a scenario in which a central body e.g., the government, wants to influence how the EVs of different ride-hailing companies spread among different charging stations by offering discounted prices of charging. Because the companies share the charging infrastructure, they inherently compete to minimize their expected total queuing times at the charging stations. From the perspective of Stackelberg and Inverse Stackelberg games we analyze two pricing mechanisms for the government that guarantee existence of a Nash equilibrium of the game played between the ride-hailing companies. We compare their performance in a case study based on taxi data from the city of Shenzhen and also show how the systems behave in terms of robustness

Keywords
Stackelberg game, Inverse Stackelberg game, Electric vehicle charging

Managing Bottleneck Congestion through Incentives on Electric Vehicle Charging and Lane Segmentation

Patrick Stokkink* (1), Carlo Cenedese (2), Nikolas Geroliminis (1), John Lygeros (2)

1: École Polytechnique Fédérale de Lausanne (EPFL), Switzerland; 2: Eidgenössische Technische Hochschule Zürich (ETHZ), Switzerland

An incentive-based traffic demand management policy is proposed to alleviate traffic congestion on a road stretch that creates a bottleneck for the commuters. The incentive targets electric vehicles owners by proposing a discount on the energy price they use to charge their vehicles if they are flexible in their departure time. We propose a dedicated lane for electric vehicles to further reduce traffic congestion and to promote the usage of electric vehicles over fossil-fueled vehicles. We theoretically show the optimal road segmentation and compare this to scenarios with and without incentive-based electric vehicle charging. We support our theoretical findings with numerical simulations that allow us to highlight the power of the proposed methods and to provide practical advice for the design of policies.

Keywords
Bottleneck Congestion, Electric Vehicle Charging, Incentive-Based Traffic Demand Management, Lane Segmentation, Dedicated Lanes

Revenue Maximizing Tariff Zone Planning for Public Transport Companies

Sven Müller* (1), Knut Haase (2), Lorena Silvana Reyes Rubiano (1)

1: Otto-von-guericke-universität magdeburg, Germany; 2: Institute for Transport Economics, University of Hamburg

This paper presents the tariff zone planning problem, which aims to maximize ridership and revenue for public service providers. We propose an optimization approach basis on partitioning the service area into zones and finding a price per zone such that the total expected revenue is maximized. It is assumed that the price per zone takes a discrete set of values. Public transport trips depend on the price system; public transport passengers always choose the time-shortest path. We propose new mixed-integer programming that can optimally solve instances of sizes of more than 120 stops and enforce tariff zones to specific spatial patterns (rings and stripes). The results demonstrate that expected revenue can be maximized without decreasing transit ridership. However, results show enforcing tariff zones to a specific spatial pattern reduces R and CPU time. This paper sheds light on urban public service providers enforcing contiguous tariff zones to maximize expected revenue.

Keywords
Contiguity, districting, mixed integer programming, public transportation, revenue management

Novel metamodel based optimization approach for game theoretical analyses in mobility ecosystem and its demonstration via a case study about toll competition

Gaurav Malik*, Chris Tampère

KU Leuven

First, a concept of novel metamodel-based optimization, in which a transport economics inspired conceptual model acts as a metamodel over an underlying setup of directly interfaced transport models, is discussed. It is hypothesized that this approach can allow to solve transportation problems, at a feasible computational cost, with due consideration to relevant interactions between different stakeholders/(sub)systems. Then, a case study concerning toll competition between a city and its neighboring rural municipalities is developed as a proof of concept. The metamodel in this case study involves the two players optimizing their objectives based on a schematic network and simplified cost & demand functions whereas the underlying setup is a Static Traffic Assignment over the physical network with physical origin-destination demand. Preliminary results suggest that this approach may allow analyzing scenarios involving significant interactions between the stakeholders/(sub)systems and when such interactions are not important, it can be a less accurate but faster alternative to contemporary approaches.

Keywords
Game theoretical interactions in mobility, Pricing and capacity optimization, Transport economics and policy, Metamodel based optimization, Static Traffic

Parallel session 1E: Integrated transport

Evaluation of Cooperation Strategies for Public Transport and Ride-hailing services

Bing Liu* (1,2), Yuxiong Ji (1), Oded Cats (2), Yu Shen (1)

1: Tongji University; 2: Delft University of Technology

Ride-hailing services are continuously gaining popularity in urban cities due to their flexibility and responsiveness. Public transport agencies spot the chance to cooperate with Transportation Network Companies (TNCs) to improve service quality and operational efficiency. While a series of cooperation strategies are proposed and piloted in some cities, little is known regarding how transportation systems respond to these strategies. We proposed three cooperation strategies: no ride-hailing subsidy; providing ride-hailing subsidy and canceling bus; providing ride-hailing subsidy and adjusting bus service frequency. A travelers' choice model for transportation corridors incorporating ride-hailing, public transport, and car is established to analyze the system performance under different strategies. The numerical experiments show that ride-hailing subsidies can reduce the average travel cost and improve public transport ridership in low-demand areas. However, the subsidy strategy can lead to a negative effect on transportation systems in high-demand areas due to limited investment and ride-hailing service supply.

Keywords
Ride-hailing, public transport, subsidy, cooperation strategy, mode choice

Pooling from First and Last Mile: Integrating Carpooling and Transit

Andrea Araldo* (2), André de Palma (1), Souhila Arib (1), Vincent Gauthier (2), Romain Sere (1), Youssef Chaabouni (1), Oussama Kharouaa (1), Ado Amadou Abba Ari (2)

1: CY-Tech; 2: Télécom SudParis

While carpooling is widely adopted for long travels, it is by construction inefficient for daily commuting, where it is difficult to match drivers and riders, sharingsimilar origin, destination and time.To overcome this limitation, we present an Integrated system, which integratescarpooling into transit, under the philosophy of Mobility as a Service. Carpoolingact as feeder to transit and stations act as consolidation points, where trips of ridersand drivers meet, increasing potential matching.We present algorithms to construct multimodal rider trips, including transit andcarpooling legs, and driver detours. Simulation shows that our Integrated system in-creases transit ridership and reduces auto-dependency, with respect to current cities,in which carpooling and transit are operated separately. Indeed, the Integrated systemdecreases the number of riders who are left with no feasible travel option and wouldthus be forced to use private cars.

Keywords
Carpooling, Mobility as a Service, Transit, Simulation, Multimodal Transportation

Ride-Parcel-Pooling: Insights to Integrated Passenger and Freight Transportation through a Customer Survey

Fabian Fehn, Lisa Sophie Hamm, Roman Engelhardt*, Klaus Bogenberger

Technical University of Munich, Germany

This paper deals with the idea of ride parcel pooling (RPP); an on-demand service, where passengers, as well as parcels, share – if possible - trips within the same vehicle. Potential users are surveyed to find criteria that are crucial for the success of an on-demand service. The survey looks at socio-demographic aspects and tries to assess the participants' attitudes towards ride pooling services. Subsequently, user preferences for the operation of a future RPP service and possible service scenario parameters are assessed. Finally, we examine the reasons for the pros and cons of ride pooling services and the participants' opinions on different types of vehicles.

Keywords
shared mobility, customer survey, ride pooling, combined transportation, passenger and freight, mobility on demand

Strategic Integration of Flexible Services of Shared Automated Vehicles with Conventional Fixed Public Transit

Charalampos Sipetas*, Claudio Roncoli

Aalto University, Finland

This study focuses on integrating fixed with flexible transit services, aiming to enhance public transit accessibility. Flexible services are offered by shared automated vehicles. The objective is to determine the strategic number of users served by flexible services for designing the integrated system. Analytical modeling is utilized to derive a new formula for the optimal number of flexible services' users that minimizes the total generalized costs. User acceptance towards automation and the competition between transit and private vehicles are also considered. Numerical analysis shows that the user acceptance towards automated vehicles is a binding constraint for the first years after their introduction. Integrated services' competitiveness against private vehicles increases as network's road spacing increases. This study is expected to offer insights and guidance to assist decision-making for a strategic incorporation of flexible services in transit systems.

Keywords
shared mobility, automated vehicles, flexible services, multi-modal transport, public transit

Parallel session 2A: Traffic Assignment

dyntapy: dynamic traffic assignment in python

Paul Ortmann*, Chris Tampère

KU Leuven, Belgium

We introduce dyntapy, a macroscopic vehicular traffic modelling toolkit that brings together both static and dynamic modelling approaches into a combined framework. It provides (i) unified supply and demand definitions for both paradigms, (ii) the ability to extract networks from OpenStreetMap at differing granularity, (iii) a set of static and dynamic traffic assignment algorithms and (iv) visualization utilities, including selected link analysis. Dyntapy is designed to support assignment researchers by removing the need to implement auxiliary functionalities that handle the network parsing and visualization. It is straightforward to add new methods for both static and dynamic assignment since there is a common interface for demand, supply and the visualization of the assignment results. It also caters to model consumers that are interested in analysing assignment results.

Keywords
Dynamic Traffic Assignment, Static Traffic Assignment, Scientific Computing, Transportation Network Modelling, Data Visualization

Stochastic departure time user equilibrium with heterogeneous trip profile

Jean-Patrick Lebacque (1), Mostafa Ameli* (1), Ludovic Leclercq (2)

1: Université Gustave Eiffel, COSYS-GRETTIA, Paris, France; 2: Université Gustave Eiffel, Univ. Lyon, ENTPE, LICIT, Lyon, France

Recently, the generalized bathtub model extended the classic bathtub model to capture various distributions of the trip length by introducing a new state variable: the number of active trips with remaining distances greater than or equal to a threshold. The traffic dynamics are reformulated by four partial differential equations that track the distribution of the remaining trip lengths. This study aims to formulate and solve stochastic user equilibrium for the dynamic departure time choice model based on the generalized bathtub model with heterogeneous trip attributes. In particular, the proposed framework is able to address any distribution for desired arrival time and trip length. We first formulate the problem in continuous form as a fixed-point problem. Then we apply a discretization method to address the trip-based setting. The proposed framework is applied to the real demand profile of the large-scale network of Lyon North for the morning peak hour.

Keywords
traffic congestion, peak-hour traffic dynamics, macroscopic model, stochastic user equilibrium, generalized bathtub model

Algorithms for Non-Separability Problems: The Departure Time Choice

Jeroen Verstraete*, Chris M.J. Tampère

Ku Leuven, Belgium

Many algorithms for choice predictions for dynamic traffic assignment (DTA), e.g. route choice or departure time choice, shift travelers from an expensive alternative to a cheaper alternative in order to find the equilibrium. These algorithms work well if the cost for the alternative is mainly dependent on the alternative itself, meaning that when adding/removing travelers to the alternative, the cost increases/decreases respectively. When this is not the case, these algorithms do not converge smoothly (Dafermos, 1980). In this abstract, some examples are given where these non-separability problems occur in DTA. A generic algorithm on how to solve this kind of problem more efficiently is sketched. We demonstrate the convergence of our approach on a simple bottleneck with departure time choice.

Keywords
Algorithms, Convergence, Departure Time Choice, Dynamic Traffic Assignment, Route Choice

Parallel session 2B: Intelligent traffic management

Modeling Adaptive Platoon and Reservation Based Autonomous Intersection Control: A Deep Reinforcement Learning Approach

Duowei Li* (1,2), Jianping Wu (1), Feng Zhu (2), Tianyi Chen (2), Yiik Diew Wong (2)

1: Tsinghua University, China; 2: Nanyang Technological University, Singapore

As a strategy to reduce travel delay and enhance energy efficiency, platooning of connected and autonomous vehicles (CAVs) at non-signalized intersections has become increasingly popular in academia. However, few studies have attempted to model the relation between the optimal platoon size and the traffic conditions around the intersection. To this end, this study proposes an adaptive platoon based autonomous intersection control model powered by deep reinforcement learning (DRL) technique. The model framework has following two levels: the first level adopts a First Come First Serve (FCFS) reservation based policy integrated with a nonconflicting lane selection mechanism to determine vehicles' passing priority; and the second level applies a deep Q-network algorithm to identify the optimal platoon size based on the real-time traffic condition of an intersection. When being tested on a traffic micro-simulator, our proposed model exhibits superior performances on travel efficiency and fuel conservation as compared to the state-of-the-art methods.

Keywords
Connected and autonomous vehicle, Adaptive platoon, Intersection control, Deep reinforcement learning

Max-Pressure Traffic Signal Control for Mixed Traffic Flow based on Capacity Estimation

Yu Du* (1,2), Anastasios Kouvelas (2)

1: Beijing Jiaotong University, China, People's Republic of; 2: Traffic Engineering Group, Institute for Transport Planning and Systems, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland

Intersection control plays a vital role in addressing the issue of transportation efficiency in urban areas. Connected and Automated Vehicle (CAV) technology emerges as a promising way to save vehicle travelling time and improve intersection capacity. Meanwhile, the mixed traffic environment composed of traffic participants with differing intelligent levels will become a long term important stage of the intelligent transportation system. Considering the changes in the mixed traffic environment, this paper proposed a modified max-pressure traffic signal control method for mixed traffic environment to improve traffic efficiency. The real time traffic penetration rate is considered in the calculation of the saturation flow rate. And the pressure in the max-pressure also depends on the traffic penetration rate. By comparing the proposed MPMF method with the classic max-pressure control and exiting fixed time control method, the proposed MPMF can effectively improve the performance of intersections and be suitable for multi-intersections road network.

Keywords
connected and automated vehicle, mixed traffic flow, max-pressure controller, traffic signal control

Critical node selection method for efficient Max-Pressure traffic signal control in large-scale congested networks

Dimitrios Tsitsokas* (1), Anastasios Kouvelas (2), Nikolas Geroliminis (1)

1: Ecole Polytechnique Fédérale de Lausanne; 2: ETH Zurich

Decentralized signal control of congested traffic networks based on the Max-Pressure (MP) controller is theoretically proven to maximize throughput, stabilize the system and balance queues for single intersections under specific conditions. Increased implementation cost related to queue monitoring reduces MP applicability. We propose a strategy for identifying the most critical network intersections for MP control, with the aim of reaching high efficiency without a full-network implementation. The strategy is based on node congestion and queue variance data. A modified version of Store-and-Forward model is used to emulate spatio-temporal traffic evolution in a large-scale network with more than 500 intersections and evaluate system performance for different MP node layouts. Results show that more than 90 % of the maximum observed improvement can be achieved by controlling only 20 % of nodes, selected via the proposed strategy, thus significantly reducing implementation cost. The impact of MP in network traffic characteristics is demonstrated.

Keywords
adaptive traffic signal control, decentralized control, Max-Pressure; critical node selection; Store-and-Forward

Parallel session 2C: Policy

Efficient growth strategies for bicycle network expansions

Mads Paulsen, Jeppe Rich*

Technical University of Denmark, Denmark

It is common practice to investigate the societal welfare performance of infrastructure projects through cost-benefit analysis. In this paper, we introduce a novel reverse geographical mapping approach where the monetary benefits are mapped back to the network. The mapping allows a more detailed geographical planning breakdown and makes it possible to apply a more stringent optimisation approach regarding the timing and prioritising of network expansions. Based on a Greedy-type optimisation heuristic we consider the case of growing a bicycle network in the Copenhagen region over a time horizon of 50 years. Although only considering travel time benefits in this study, the optimisation heuristic renders a net present value that is approximately 2 Billion DKK higher than other strategies, underlining the importance of efficient growth of networks.

Keywords
Bicycle infrastructure, cycle superhighways, geographical mapping of benefit-cost, infrastructure investment prioritisation

The uptake of electrification and its transport and land use impacts; The case of Southampton (UK)

Victoria Gouge (1), Paraskevi Sarri* (2), Ioannis Kaparias (2)

1: WSP, Southampton, UK; 2: University of Southampton, Transportation Research Group, Southampton, UK

Electric vehicles (EVs) are heralded as a promising green alternative to conventional fossil-fuel-powered vehicles. The introduction of EVs is likely to impact the urban structure, but the magnitude of these impacts remains largely unexplored. The aim of this study is, hence, to shed light on this aspect by utilising the TRANUS Land-Use and Transportation Interaction (LUTI) model and by formulating a methodological framework to model electrification. Southampton (UK) is used as a case study and varying uptakes of EVs are modelled for a set of future scenarios. Based on census data and government projections, the model provides a quantitative outcome of the potential effects. The results indicate that employment might grow substantially in suburban areas. These changes are related to transport changes associated with private car use, such as growth in trips, distance travelled and journey times. Therefore, congestion increases and more interventions need to be implemented alongside electrification.

Keywords
LUTI, Electrification, Southampton

Assortment Optimization for Boundedly Rational Customers

Mahsa Farhani*, Caspar Chorus, Yousef Maknoon

Delft University of Technology

This paper presents an assortment optimization model for boundedly rational customers. The problem has application in designing the travel menu for on-demand mobility services. We present the customer behavior using the Random Regret Minimization choice model, considering the reference-dependency and choice-set dependency of preferences as strong violations of perfect rationality premises. We propose an efficient algorithm to find the optimal assortment when customers' behavior follows RRM. We have tested our algorithm for micromobility services. The results show that our proposed algorithm can find the optimal solution for all studied instances. Moreover, we compare our approach against the widely used multinomial logit model to examine the effects of reference-dependency and choice set-dependency on the assortment decisions. Our results indicate that these behavioral phenomena have significant impacts on the optimal choice set, so they need to be taken into account by those who want to offer a choice set to their customers.

Keywords
Assortment optimization, bounded rationality, mobility on-demand services

Parallel session 2D: Pricing 2

Managing Congestion and Infection Externalities in a Road and Rail Network: Pricing versus Permits

Kexin Geng* (1,2), Zhiyuan Liang (1), Erik T. Verhoef (2), Yacan Wang (1)

1: Departments of Economics, Beijing Jiaotong University, China; 2: Department of Spatial Economics, Vrije Universiteit Amsterdam, the Netherlands

Peak-hour crowding of mass transit not only leads to uncomfortable passenger experiences but may also give rise to severe health risks. This paper analyzes the allocative efficiency of prices and permits before and after COVID-19 based on a crowding road and rail network where the two modes are imperfect substitutes, and mainly focuses on comparative results for uncertainty on social (outside the train system) and private (in the train system) infection cost parameters. By considering the uncertainty during COVID-19, we find that uncertainty of the private infection cost parameter will change the relative efficiency and welfare effect of these two instruments, but not uncertainty on social infection costs. Moreover, the numerical results indicate that pricing regulation performs better than the tradable permit scheme when private infection cost is uncertain. The results provide theoretical support for policymakers to choose the optimal instruments to internalize the multiple external costs when uncertainties exist.

Keywords
COVID-19, crowding costs, infection costs, multiple externalities, uncertainty

The effects of pricing and service configurations on a ride-pooling service with pick-up and drop-off points

Marko Maricic*, Rafal Kucharski, Oded Cats

TU Delft, Netherlands, The

We investigate how the pricing of ride-pooling with pick-up and drop-off (PUDO) locations affects its level of service and operating costs when comparing to its competition such as private ride-hailing and door-to-door ride-pooling. We also examine how demand levels and the service settings affect these performance indicators. To this end, we extend an exact matching algorithm to the case of ride-pooling with PUDO and conduct experiments for the case of Amsterdam, the Netherlands. We find that total traveller utility can be further improved by 2.0% while reducing total vehicle hours by 2.2% when the discount offered for ride-pooling with PUDO is significantly larger than for door-to-door ride-pooling.

Keywords
ride-pooling, ride-hailing, ride-sharing, pick-up and drop-off points, walking

Investigating the acceptance and willingness-to-pay of an urban pricing scheme: The case of Athens

Christina Gasparinatou, Eleni Mantouka*, Eleni Vlahogianni, John Golias

National Technical University of Athens, Greece

Urban pricing strategies have been widely implemented in order to reduce externalities generated by traffic. These strategies have been considered effective schemes that not only it is possible to relieve congestion from metropolitan areas that have heavy traffic, but can also reduce emissions from cars and promote public transport usage. The scope of this paper is to investigate the users' perceptions towards the measure of urban tolls in the center of Athens. Applying discrete choice models to data from a stated preference survey, it was resulted that the majority of respondents would not accept such measure. Furthermore, it was found that drivers are willing to pay an extra 8-euro cents in order to save 1 minute on the travel time of their trip.

Keywords
MNL Models, Road Pricing, Stated Preference Survey, Urban tolls.

Parallel session 2E: Big data analytics in transport

Mode choice estimation on mobile network data: challenges and solutions

Angelica Andersson* (1,2), Maria Börjesson (1,2), Nils Breyer (2), Andrew Daly (3), Leonid Engelson (2), Ida Kristoffersson (1)

1: VTI (Swedish National Road and Transport Research Institute); 2: Linköping University; 3: University of Leeds

The declining response rates of national travel surveys present a major problem in obtaining the data needed to develop transportation demand models and forecasts. In this work two challenges related to the estimation of travel mode choice models based on mobile network data are addressed and proposed solutions to these challenges are evaluated. The first challenge is that bus trips are not distinguished from car trips in the original dataset. This is solved by introducing a composite choice in the logit formulation. The second challenge is how to incorporate trip purpose (private or business) in the model. This is handled by means of a segmented model based on a business indicator. The second challenge is of particular interest for forecasting and appraisal, as business travellers may have different valuations of aspects of travel time than private travellers.

Keywords
Demand model, discrete choice modelling, long-distance travel, mobile phone network data, mode choice, travel behaviour

Estimating Public Transport Demand Information Using Crowdsourced Data

Piergiorgio Vitello*, Richard D. Connors, Francesco Viti

University of Luxembourg, Luxembourg

The analysis of transit demand and its complex dynamics has typically relied on survey-based data that captures only a small fraction of the total demand. Recently, emerging data-driven approaches have been applied to transportation issues and these typically rely on sensing data gathered by mobile devices under the so-called mobile crowdsensing (MCS) paradigm. This type of data can be a powerful source of information especially in areas where transit data is not available. This work aims to investigate the possibility of using Google Popular Times (GPT), a widely available crowdsensed data, to estimate the passenger flows of individual subway stations. Our results show that we can estimate precisely both entrances and exits profiles, which is particularly challenging because GPT only provide popularity trends. Our analysis is carried out on more than 105 subway stations of Manhattan and it is validated using turnstile count data from the stations.

Keywords
Crowdsourced Data, Public Transport Demand, Google Popular Times, Big data analytics

The Potential of Wi-Fi Data to Estimate Bus Passenger Mobility

Léa Fabre* (1,2,3), Caroline Bayart (2), Patrick Bonnel (1), Nicolas Mony (3)

1: LAET - ENTPE - Université Lumière Lyon 2, France; 2: LSAF - Université Claude Bernard Lyon 1, France; 3: Explain, France

Last decades have been marked by several socio-economic transformations, such as demographic growth, population ageing, urbanization… These changes have a strong impact on individual mobility behaviors. Using technologies such as Wi-Fi and Bluetooth allows to gather passive mobility data, useful for ensuring the sustainable development of transport infrastructures. However, some work still needs to be done to address the limits of Wi-Fi sensors. Our research presents interesting solutions for sorting the transmitted signals and estimating Origin-Destination matrices. With a partitioning algorithm, it is possible to automatically distinguish passengers to get transit ridership flow and O-D matrices. The originality of the paper consists in comparing the results with those of other data sources, and in proposing a methodology that can be reproduced. The findings show that the algorithm is efficient and transferable. They provide concrete and replicable solutions to transport operators for understanding travel demand and managing the quality of service.

Keywords
Big data, clustering, public transport, trajectory reconstruction, Wi-Fi/Bluetooth sensors

Poster session 1

Ride Acceptance Behaviour Investigation of Ride-sourcing Drivers Through Agent-based Simulation

Farnoud Ghasemi, Rafal Kucharski*

Jagiellonian University, Poland

Ride-sourcing platforms such as Uber, Lyft and Didi provide their drivers with the set of freedoms to ensure flexible and attractive working conditions of a two-sided platform. One of the main decisions of drivers is to accept or reject the incoming trip requests in real-time according to their preferences and strategies. Despite the significant role of the acceptance decision of drivers in the platform performance, there is no clear understanding of this behaviour and its impact on the results of simulation experiments. In this study, we first reproduce the dynamics of two-sided mobility platforms on the road network of Delft in the Netherlands with our MaaSSim agent-based simulator. Later, we implement a ride acceptance decision model: binary logit model derived from a recent stated preference experiment. Our findings reveal that the acceptance model positively affects the platform operation from both traveller's and driver's perspectives.

Keywords
ride-sourcing, transportation network companies, two-sided mobility, agent-based simulation

Changes in Service Elasticity of Travel Demand during Disaster: A New Indicator of Phase Transition

Nur Diana Safitri* (1), Makoto Chikaraishi (2)

1: Hiroshima University, Japan; 2: Hiroshima University, Japan

The disruptions of transportation network can reduce its performance. The demand can also change, i.e., increase (e.g., recovery) or decrease (e.g., trip cancellation) as the response of the transport supply change, where the phase transition often accompanies these temporal changes discussion. In this study, we attempt to explore the changes in the service elasticity as one of the indicators looking at the reaction of the demand when the transport supply change under the disrupted condition and to identify the phase transition. We use the log-log linear model to calculate the service elasticity and utilize the change point detection algorithm to identify the timing of phase transition. Results show that the service elasticity becomes more elastic, indicating that the people may tend to stop doing non-emergency travel in the first phase of the disruption, but after some time, people start to adapt with the disrupted condition (less elastic).

Keywords
Change Point Detection, Disaster, Elasticity, Phase Transition.

Public transport route choice modelling: Identification of bias when using smart card data

Jesper Ingvardson (1), MIkkel Thorhauge (1), Otto Anker Nielsen* (1), Morten Eltved (2)

1: DTU Management, Technical University of Denmark, Denmark; 2: MOE Tetraplan

Using Automated Fare Collection (AFC) data for public transport analyses has received much research interest recently, including for estimation of passenger preferences through route choice models. However, an important problem persists since AFC data only includes information about the trip within the public transport system, i.e. stop-to-stop. Not knowing the full trip might lead to estimation bias, especially when estimating route choice models using only the chosen stops. This paper highlights this problem by estimating route choice models based on traditional travel survey data and replicated AFC data. In addition, we propose an improved method in which pseudo origin (destination) points in close vicinity of the actually chosen origin (destination) stops are randomly generated, thus allowing pseudo access and egress to be incorporated. The method notably improves parameter estimates of the route choice model compared to estimation assuming AFC stop-to-stop data. Finally, further improvements to the model are presented.

Keywords
AFC data, Discrete choice modelling, Estimation bias, Public transport, Route choice modelling, Smart card data.

Parking Regulations to Harmonize Dockless E-scooters: An Empirical Analysis From Paris

Isac Antonio Olave Cruz* (1), Nicolas Coulombel (2), Eric Brousseau (1), Etienne Côme (3)

1: Governance and Regulation Chair, DRM, University Paris-Dauphine|PSL; 2: LVMT, UMR-T 9403, Ecole des Ponts, IFSTTAR, UPEM; 3: COSYS/GRETTIA, Université Gustave-Eiffel

The auto-oriented paradigm that dominated urban transport rose social and environmental concerns. In response, cities welcomed new micro-mobility services aiming to provide alternatives to reduce car-dependency and improve accessibility. However, how to articulate these services into a multimodal system is an open debate in the literature. We contribute providing empirical evidence from the introduction of dockless e-scooters in Paris. This paper seeks to investigate the effects of parking regulations on parking behavior and on the accessibility of e-scooters. The case of Paris is relevant because the city reallocate public spaces to park e-scooters. However, the effects of these parking bays are not evident and is a pending work in the literature. Using an original administrative dataset that geo-locates dockless e-scooters, we found that parking regulations in Paris helped to harmonize this service with the rest of the mobility mix at the expense of diminishing the accessibility of vehicles.

Keywords
Big data analytics, Dockless E-scooters, Micro-mobility management, Parking regulation, Shared-mobility

Impact of Shared Automated Vehicles on the Total Vehicle Kilometres in Public- versus Private-Transport-Oriented Cities: A Theoretical Analysis

Baiba Pudāne*, Andrés Fielbaum Schnitzler

Delft University of Technology, The Netherlands

Predicting how shared automated vehicles (SAVs) will impact the total vehicle kilometres in a city is crucial for assessing SAV sustainability. Although several studies have simulated this impact, they often determine modal shifts exogenously while concentrating on other reasons for changing vehicle kilometres. Studies incorporating mode choice with SAVs have varied outcomes, likely due to their various assumptions and geographical contexts. This paper theoretically analyses how the SAVs could impact the modal split and the resulting total vehicle kilometres in a city, represented by an origin-destination pair. Travellers choose among private cars, public transport and SAVs while considering the extent of sharing and their heterogeneous sharing preferences. Public transport and SAV services are endogenously optimised. We demonstrate how openness to sharing influences the pre-SAV modal split and the shift to SAVs. We conclude that public-transport-oriented cities would experience a higher absolute increase in vehicle kilometres with SAVs than private-transport-oriented cities.

Keywords
shared automated vehicles, vehicle kilometres travelled, modal shifts, sharing preferences, theoretical analysis

A stated preferences experiment to analyze bike sharing as an alternative transport mode

Margarita Gutjar*, Röth Kai, Kowald Matthias

RheinMain University of Applied Sciences, Germany

Currently, parameters for neither mode- nor route choice are available in terms of bike-sharing, resulting in a lack of knowledge to implement bike-sharing systems in transport demand models. Estimating such parameters is the aim of a stated preferences experiment on choices between shared bikes, public transport, and private motorized transport. Preliminary results of a multinomial logit model on a sample of 69 non-users and users of bike-sharing systems are presented. For all modes, travel costs have a negative effect on the associated utility of transport mode. Travel time shows a negative effect for all modes, while for shared bike and public transport access and egress time has a stronger effect than time in the vehicle. For bicycling, street type has no effect, while asphalt is the most preferred type of street surface. The utility of public transport is lower with higher utilized capacity.

Keywords
micro-mobility, bike-sharing, multinomial logit model, stated preferences, mode choice

Two-echelon Multi-trip Vehicle Routing Problem with Satellite Synchronization for An Integrated Water- and Land-based Transportation System

Cigdem Karademir*, Breno A. Beirigo, Rudy R. Negenborn, Bilge Atasoy

Dept. of Maritime & Transport Technology, Faculty 3mE, Delft University of Technology, The Netherlands

This study considers a two-echelon multi-trip vehicle routing problem with time windows, capacitated hubs, and satellite synchronization to solve the waste collection problem in an integrated water- and -land based transportation (IWLT) system. Research on the issue is motivated by the increased heavy street movements that cause damages to quay walls as well as congestion, besides the collection cost. We present a new mathematical model for the problem, based on a two-index formulation, and evaluate it on small-sized instances for 10 waste points and 4 hubs. We compare the proposed synchronized IWLT approach with three benchmarks that can reduce issues associated with heavy loads. It is shown that the proposed system can provide better solutions with less collection cost, reduced street movements and lightweight garbage vehicles.

Keywords
City logistics, Integrated water- and land-based transportation, Multi-trip, Satellite synchronization, Two-echelon vehicle routing problem

Empty Vehicle Repositioning for Autonomous Mobility-on-Demand systems via Coverage Control

Pengbo Zhu* (1), Isik Ilber Sirmatel (2), Giancarlo Ferrari Trecate (3), Nikolas Geroliminis (1)

1: Urban Transport Systems Laboratory, EPFL, Switzerland; 2: Control Section, Department of Electrical and Electronics Engineering, Trakya University, Turkey; 3: Dependable Control and Decision Group, EPFL, Switzerland

Autonomous Mobility-on-Demand (AMoD) system as an emerging urban transportation method shows its potential to improve mobility in city areas with timely and door-to-door service also reduce congestion. Vehicle repositioning, the process to redistribute empty vehicles to high-demand areas, receives more and more attention nowadays. In this paper, this fleet scheduling problem is translated to a coverage control problem. We present a Voronoi-based algorithm to optimize the empty vehicle distribution with historical demand data for Autonomous Mobility-on-Demand systems leveraging local position information of each vehicle. And for low-demand periods, we studied two methods to select subsets of idle vehicles not to relocate, so to reduce empty travel distance caused by rebalancing. Evaluating with real data from Shenzhen, China, we can achieve a higher service rate and shorter waiting time compared to a baseline.

Keywords
Autonomous Mobility-on-Demand system, Vehicle Repositioning, Coverage Control, Fleet Management.

Spatial modeling of bike-sharing trip data: A methodological comparison

Katja Schimohr*, Philipp Doebler, Joachim Scheiner

TU Dortmund University, Germany

Usage data plays a major role in evaluating and planning sharing systems such as bike-sharing. Hence, effective methods are needed to analyze and model this kind of data. In this research, trip data of the bike-sharing system in Cologne, Germany is modeled. We compare two methods that can be applied in the modeling of spatial trip data, facing the requirements of spatial autocorrelation, zero-inflation and count data simultaneously. A generalized additive model (GAM) based on a Tweedie distribution is compared to a machine learning approach using the XGBoost algorithm. While the results of the GAM are easier to interpret and allow for the direct integration of spatial interdependencies in the model estimation, XGBoost leads to the more precise predictions and can potentially be estimated in a shorter amount of time.

Keywords
bike-sharing, generalized additive model, machine learning, spatial data analysis, trip modeling

Particle-based and stochastic simulation-based traffic assignment

Gunnar Flötteröd*

VTI and LiU, Sweden

The particle-based and stochastic traffic assignment problem is considered. The increasing deployment of “agent-based” traffic assignment models in transport planning renders this problem relevant. Lacking a comprehensive mathematical characterization, the computation of an assignment within this model class is bound to heuristics. One of these approaches is the “sorting technique” of Sbayti et al. (2007). The present article offers a derivation of this method from first principles, works out the effect of model stochasticity, and uses these results to propose a suitable simulation noise filtering rule. Experimental results covering a wide range of variations of the method under different congestion levels illustrate its advantageous performance.

Keywords
traffic assignment, network simulation, agent-based modeling

Parallel session 3A: Ridesharing services

Topological properties of ride-pooling shareability graph as a proxy to key performance indicators

Michał Piotr Bujak*, Rafał Kucharski

Jagiellonian University, Poland

Ride-pooling is a promising and actively developing branch of urban mobility. Algorithmic solutions match travellers with feasible rides using a so-called shareability graphs. However, analysis in the field present very little information on the topological structure of such graphs. In the paper, we experiment with varying demand levels and behavioural parameters of travellers sharing rides in Delft, Netherlands, to observe changes in the graph structure and see how properties of the graph correlate with ride-pooling KPIs. We observed strong relations in our experimental study, suggesting that there is potential to use Network Science tools in order to better understand shareability in the ride-pooling problem.

Keywords
Network Science, Ride-pooling, Shareability

What factors drive ridesharing for commuting trips the most? Comparison of three different institutions in one city

Lucie Vávrová*, Hana Brůhová Foltýnová, Eliška Vejchodská

Jan Evangelista Purkyně University in Ústí nad Labem, Czech Republic

This paper presents the results of a survey on the potential of ridesharing for regular trips to work and school. Using data from three different organizations from one Czech city, it analyses main barriers and drivers of ridesharing among institutions and the significant factors most likely to cause an increase in the share of ridesharing for journeys to work/school.
The data were collected using an electronic questionnaire, which was distributed during October 2019. Our findings indicate that ridesharing is influenced by age, education, distance travelled and attitudes and opinions. No effect of gender on the willingness to use ridesharing was identified in our sample. The character of the institution influences the share of ridesharing among their employees substantially. Our study reveals that ridesharing can contribute to more sustainable institutions, especially the university campus, and that younger people are more willing to use ridesharing.

Keywords
Carpooling, choice of transport mode, commuting trips, factors, ridesharing

Accounting for driver-passenger matching decisions in a ridesharing simulation platform

Rui Yao*, Shlomo Bekhor

Technion - Israel Institute of Technology, Israel

This paper presents a new ridesharing simulation platform that accounts for dynamic driver supply and passenger demand, and complex interactions between drivers and passengers. The proposed simulation platform explicitly considers driver and passenger acceptance/rejection on the matching options, and cancellation before/after being matched. New simulation events, procedures and modules have been developed to handle these realistic interactions. The capabilities of the simulation platform are illustrated using numerical experiments. The experiments confirm the importance of considering supply and demand interactions and provide new insights to ridesharing operations. Results show that larger matching window could have negative impacts on overall ridesharing success rate. These results emphasize the importance of a careful planning of a ridesharing system.

Keywords
ridesharing, simulation, driver supply, passenger demand

Parallel session 3B: Safety

Pedestrian 3D Bounding Box Prediction

Saeed Saadatnejad*, Yi Zhou Ju, Alexandre Alahi

EPFL, Switzerland

Safety is still the main issue of autonomous driving and in order to be globally deployed, they need to predict pedestrians motions sufficiently in advance.
While there is many research in coarse-grained prediction (human center prediction) and fine-grained predictions (human body keypoints prediction), we focus on 3D bounding boxes which are good estimates of humans without modeling complex motion details for autonomous vehicles. This gives the flexibility to predict in longer horizons in real-world settings.
To the best of our knowledge, this is the first method studying the 3D bounding box prediction of pedestrians. This simple method follows an encoder-decoder architecture based on recurrent neural networks and our experiments show its effectiveness in both the synthetic (JTA) and real-world (NuScenes) datasets. The learned representation has useful information to enhance the performance of other tasks such as action anticipation.
Our code will be made available online upon publication.

Keywords
3D bounding box prediction, motion prediction, action anticipation, autonomous vehicles

On the Level of Traffic Stress for Pedestrians

Johanna Vogt*, Lisa Kessler, Klaus Bogenberger

Technical University Munich, Germany

Walking is the most basic and sustainable mode of transportation. Nevertheless, fifty percent of pedestrians in Germany feel unsafe in road traffic. Since feelings of low safety are associated with higher stress, fewer people are likely to walk in less comfortable environments. This paper introduces a new rating scheme called "Level of Stress for Pedestrians". This rating scheme defines five different pedestrian stress levels and links them to attributes of road segments such as the sidewalk width or the number of crossing facilities. The rating scheme is not bound to specific locations due to its static nature and can therefore be applied to different cities. With the aid of the pedestrian level of stress, static weak points in the pedestrian network can be identified and eliminated.

Keywords
Pedestrian Traffic, Level of Stress, Walkability, Pedestrian Safety

Cognitive approach to hazard perception on the road: validation in virtual reality environment

Martyna Bogacz*, Yusak Susilo

University of Natural Resources and Life Sciences Vienna, Austria

This paper proposes a theoretical framework of hazard perception, drawing from the key concepts in cognitive sciences. The proposed model is then validated using virtual environment that allows for collection of behavioural and physiological data in a dynamic road scenario. Specifically, this paper sets out to distinguish between bottom-up and top-down processing in subsequent phases of hazard perception process. For this purpose, the root mean square of successive differences between heartbeats (RMSSD) of heart rate variability in time domain is analysed due to its link to mental workload. The results confirmed proposed hypotheses suggesting that the initial phase of hazard perception is associated with bottom-up processing while the latter one with top-down control. These findings are useful not only in the context of automated vehicles but also provide implications for safety of road users where better understanding of underlying cognitive processes allows designing more effective on-board and on-road safety measures.

Keywords
virtual reality, e-scooter, heart rate variability, RMSSD

Parallel session 3C: Connected and Automated Mobility

Deploying Level 4 Shared Automated Vehicle Services on ODD-compliant Subnetworks: a Multimodal Analysis

Lotte Notelaers*, Chris M. J. Tampère

Centre for industrial management, traffic and infrastructure, KU Leuven, Belgium

This abstract reports on a case study in which a station-based shared automated vehicle (SAV) service would be deployed in Leuven, Belgium. The vehicles are assumed to operate on a level 4 of automation and are restricted to drive on a subnetwork compliant with the operational design domain (ODD). The scenario is evaluated using a multimodal equilibrium assignment model in which the SAV market share is assumed dependent on its level-of-service (LOS) and competition with other modes. The model uses a macroscopic modelling approach based on the traditional 4-step transport model. However, it is integrated with a microscopic modelling approach to properly model the SAV service supply. Results suggest that, in the scenario considered, the new service would serve a market share of 21.0% of which most customers are former car users and passengers. Further, vehicle-hours-travelled (VHT) and vehicle-kilometers-travelled (VKT) increase by 23.6% and 1.7%, respectively.

Keywords
autonomous vehicles, mobility on-demand, multi-modal transportation, ODD, SAE level 4, shared mobility

Temporary traffic management implications of reconfiguring existing motorways to accommodate dedicated Connected Autonomous Trucks (CAT) lanes - A travel delay perspective

Hameed Jehanfo* (1), Sheng Hu (2), Ioannis Kaparias (1), John Preston (1), Fujie Zhou (2), Alan Stevens (1)

1: University of Southampton, United Kingdom; 2: Texas A&M Transportation Institute

Connected Autonomous Vehicles (CAVs) will likely share roads with legacy vehicles. There are many options for reconfiguring the existing roads to accommodate CAVs, but one effective model on motorways could be to assign a dedicated nearside lane for Connect Autonomous Trucks (CATs). The precise wheel-path tracking of CATs permits different lane widths, which impacts on the remaining space for legacy vehicles and, hence temporary traffic management (TTM) designs. With most CAVs studies focusing on permanent operations, there is very limited research quantifying TTM implications of CAT lane cross-section alternatives. This study details performance of various alternatives under TTM conditions during rehabilitation works. Lane width-speed models are used to calculate delays during pavement rehabilitation works, and vehicle travel time-cost relationships are applied to determine cost to each scenario. Next, pavement analysis is used to predict the frequency of these rehabilitations. Finally, travel delay costs of each configuration are calculated and compared.

Keywords
Connected autonomous vehicles, connected autonomous trucks, maintenance cost, temporary traffic management, travel time cost

Simulations of different scenarios of the use of autonomous vehicles with a multi-agent model

Mathilde Moliner* (1), Ouassim Manout (2), Nicolas Saunier (1), Francesco Ciari (1)

1: Polytechnique Montreal, Canada; 2: LAET, ENTPE, Lyon, France

With technological advances and real-life trials taking place, the arrival of autonomous vehicles (AVs) seems to be getting closer and closer. This raises many questions about the impacts that such a mode of transportation would have on mobility and its externalities. Using a multi-agent model, MATSim, this paper provides some answers to these questions by proposing three possible scenarios of use for autonomous vehicles that are simulated for the Montreal region:
private autonomous vehicles
robotaxis
shared robotaxis
The main consequences are a strong increase in the distances covered by the vehicles
by the vehicles, generated by trips without passengers. These additional kilometers lead to an increase in greenhouse gases, as well as an increase in congestion. Only one scenario, in which AVs are used as shared robotaxis, makes it possible to limit these effects.

Keywords
Autonomous and connected vehicles, Agent-based modeling, private autonomous vehicles, shared autonomous vehicles, Shared mobility

Parallel session 3D: Transport Economics

A multi-sided monopoly platform in presence of same-side effects, information asymmetry and outside-of-the-platform externalities: application to short-distance carpooling platform

Guillaume Monchambert*

Université Lyon 2, France

We model a multi-sided monopoly platform that captures the main features of daily short-distance carpooling platforms: interactions between carpool drivers and passengers create cross- and same-side effects, the platform does not have complete information as it cannot know what mode the agents would have used in the absence of carpooling, and the creation or reduction of traffic has effects beyond the carpoolers. We compare prices set by a profit- and a welfare-maximizing platform, and find non-negligible differences, somewhat reinforced with information asymmetry. We apply the model to short distance carpooling with and without HOV lane, and show that the profit-maximizing platform does not subsidize the “good” side of the market, leading to very little traffic reduction. These results call for the regulation of short-distance carpooling platforms, and for an in-depth discussion on their desirability and financing.

Keywords
economics, platform, pricing, regulation

Tradable Permits versus Congestion Charge on Managing Morning Peak Travel Behavior: A Field Experiment in Beijing

Kexin Geng* (1,2), Yacan Wang (1), Erik T. Verhoef (2), Duan Su (1), Yu Wang (1)

1: Departments of Economics, Beijing Jiaotong University, China; 2: Department of Spatial Economics, Vrije Universiteit Amsterdam, the Netherlands

The efficiency of tradable permits on managing morning peak travel and its comparison with congestion charge have been discussed theoretically but not practically. This study contributes to providing the first practical evidence of both tradable permits and congestion charge to manage actual scheduling decisions in the morning peak using real car drivers. By conducting a two-month field experiment among 532 car drivers in Beijing, we investigate the effectiveness and drivers' attitudes of these two policies. We designed a step-size tradable permits scheme and a similar congestion charge scheme based on Beijing real traffic conditions. The OBD box and phone App have been used to record real-time travel information and online trading. Preliminary results show that both treatments reduce the rush-hour departures. Compared to congestion charge, tradable permits scheme is more acceptable for car drivers.

Keywords
Tradable permits, Congestion charge, Field experiment, Departure time choice

Quantifying the Causal Impact of Airport Capacity Expansion on Delay

Kailin Chen* (1), Daniel J. Graham (1), Anupriya Anupriya (1), Richard J. Anderson (1), Prateek Bansal (2)

1: Imperial College London; 2: National University of Singapore

This paper quantifies the causal impacts of improved gate and runway capacity on airport delay. To estimate the causal effects, it applies a synthetic control method to data on Miami International Airport (MIA) and Fort Lauderdale–Hollywood International Airport (FLL). The results show that the gate capacity expansion in MIA airport substantially relieves departure delay, arrival delay, and taxi-in delay, however, it has no effect on taxi-out delay. The runway capacity expansion of FLL airport results in more than 10-15% decline in departure and arrival delay during peak months and a 30-50% decrease in taxi-out delay, while increasing taxi-in delay. Given the considerable cost of airport delay and new airport infrastructural investments, these results are of high importance for airport operators and government decision-makers to plan such investments.

Keywords
airport capacity, airport delay, causal analysis, synthetic control method

Parallel session 3E: Advanced public transport management

A Combined Bus Splitting And Holding Strategy to Prevent Bus Bunching Using Autonomous Modular Buses

Zaid Saeed Khan*, Monica Menendez

New York University Abu Dhabi, United Arab Emirates

Autonomous modular buses (AMBs) with en-route coupling and decoupling capability can be more effective in preventing bus bunching than strategies available with traditional buses, such as bus-holding and stop-skipping, which suffer from shortcomings. Our previous work introduced bus-splitting, a novel alternative to stop-skipping that directs a modular bus to decouple into individual units when it experiences a longer than normal headway. Despite outperforming stop-skipping, bus-splitting alone cannot eliminate bunching completely since it cannot increase short headways. In this work, we propose combining bus-splitting with bus-holding so that headways that are either shorter or longer than required can both be corrected. We use a macroscopic simulation to compare our combined strategy with the original bus-splitting strategy as well as stop-skipping (both standalone and combined with bus-holding). We find that the combined strategy outperforms all the others by reducing passengers' average travel cost and its variation, especially for busy bus lines.

Keywords
Autonomous modular buses, Bus bunching, Bus holding, Bus splitting, Stop skipping

On the utilisation of dedicated bus lanes for ride-splitting services

Lynn Fayed*, Gustav Nilsson, Nikolas Geroliminis

EPFL, Switzerland

The available capacity in transportation networks is distributed among multiple modes, with some benefiting from an exclusive usage while others competing over the same space. Because the average occupancy of buses is the highest, they are usually allocated dedicated lanes where the speed is larger than in the rest of the network. Private vehicles and ride-hailing drivers use the remaining portion of space which is highly subject to congestion. In this study, we propose to mitigate traffic congestion in the main network by allowing only pooled ride-hailing drivers to use the underutilized capacity in bus lanes. By modeling the accumulation in the system under steady-state using a Macroscopic Fundamental Diagram theory, we show that the optimal strategy that minimizes delays for multi-modal users occurs when a fraction of the pooling vehicles uses the bus network. An adequate pricing discount for pooled trips drives the network towards this system optimum.

Keywords
Multi-modal networks, network delays, public transportation, regulations, ride-splitting services, space allocation

The More the Merrier? On how many passengers should follow real-time crowding information (RTCI) during bus service disturbances

Arkadiusz Drabicki* (1), Oded Cats (2), Rafał Kucharski (3)

1: Cracow University of Technology, Poland; 2: Delft University of Technology, The Netherlands; 3: Jagiellonian University, Poland

Regularity of public transport services can be substantially impeded by feedback loops between supply operations and demand flows. Amongst potential countermeasures, an interesting (yet unexplored) pertains to informing passengers in real-time about estimated travel times and on-board crowding levels of bus arrivals at the stops. In this study, we analyse whether providing such real-time crowding information (RTCI) can restore regular public transport performance, depending on passengers' voluntary responsiveness to the RTCI. We apply the simulation-based assignment model BusMezzo to the real-world model of a busy bus corridor in Warsaw (Poland). Findings from sensitivity analysis reveal that RTCI can bring the most tangible benefits in passengers' journey experience with the 50 – 75% RTCI penetration rate, while also contributing towards greater service regularity. Ubiquitous (100%) response to the RTCI seems also advantageous for the PT supply and demand performance, although with a certain risk of rebound in overcrowding effects.

Keywords
public transport, overcrowding, bus bunching, real-time crowding information, RTCI

Plenary session 2: Michel Bierlaire (CH)

Activity-based models: an optimization approach

Michel Bierlaire*

Swiss Federal Institute of Technology in Lausanne

Modern mobility systems require a detailed representation of travel demand. Activity-based models provide a powerful tool to derive travel demand from daily activity patterns. In this lecture, we propose a modeling approach built on first principles: we assume that a traveler is scheduling her day in order to maximize her utility. Therefore, she has to solve a mixed integer optimization problem. Some decision variables are discrete, such as binary variables capturing the participation in activities (or not), and some are continuous, such as the duration of activities. We propose a detailed specification of the optimization problem, and illustrate it on concrete examples.

Parallel session 4A: Routing

Analysis of Key Route Attributes for Route Choice Model Estimation Based on GPS Data

Anna Danielsson*, David Gundlegård, Clas Rydergren

Linköping University, Sweden

Efficient traffic control requires an understanding of vehicle flows in the road network, where two important components are demand and route choice. The aim of this study is to use GPS data to identify key attributes explaining the route choice observed in data. The data set consisted of about 150,000 trips and was divided into a training dataset and a test dataset. The two datasets were compared and experiments show that the routes used are similar. Discrete route choice models were estimated with a route set of observed routes in the training data. The best model showed a result of 73 % correct predictions and a route choice distribution error of 19 %. Furthermore, the result indicated that simplicity of the route is more important than the travel time.

Keywords
Discrete choice, GPS data, Route attributes, Route choice

Investigating Drivers' Behaviour and Time Sacrifice under Social Routing Advices

Shaghayegh Vosough*, Claudio Roncoli

Aalto University, Finland

Trip information and navigation systems are expected to become key components of future traffic management strategies, contributing to mitigate car usage externalities. In this study, we investigate social routing advices, which could be associated with nudges and delivered via a navigation app, aiming at promoting sustainable routing behaviour, where some drivers are asked to take longer routes and make time sacrifices instead of minimizing personal travel time. To investigate the impacts of various types of information strategies and social goals on drivers' social routing behaviour, we present a stated choice experiment performed in two European cities, Amsterdam and Helsinki, and applied an ordered logit model. The results show that drivers are less inclined to make travel time sacrifices for nudges related to liveability compared with other social goals. Regardless of the goal, 30% of drivers are willing to accept a social route that is 40% longer than the shortest route.

Keywords
Sustainable routing, Traffic management, Transport economics and policy.

Route choice set generation using variational autoencoders

Rui Yao*, Shlomo Bekhor

Technion - Israel Institute of Technology, Israel

Choice set generation is a challenging task, since the consideration set is generally unknown to the modelers, and the full choice set cannot be enumerated in real size networks. The proposed variational autoencoder approach (VAE) is motivated by the idea that the chosen alternatives must belong to the consideration set. The VAE approach explicitly considers maximizing the likelihood of including the chosen alternatives in the choice set, and infers the underlying generation process. The VAE approach for route choice set generation is exemplified using a real dataset. VAE-CNL model has the best performance in terms of goodness-of-fit and prediction performance, compared to models estimated with conventionally generated choice sets.

Keywords
choice set generation, machine learning, variational autoencoder, generative model

A link-based bicycle perturbed utility route choice model for Copenhagen

Mads Paulsen (1), Miroslawa Lukawska* (1), Thomas Kjær Rasmussen (1), Mogens Fosgerau (2)

1: Technical University of Denmark, Denmark; 2: University of Copenhagen

This paper estimates a bicycle perturbed utility route choice model from a large dataset of GPS traces. Results quantify the influence of a range of factors on bicycle route choice. The model allows very fast parameters estimation by ordinary linear regression. In addition, the model uses the complete network – no choice set generation is required.

Keywords
Bicycle traffic, GPS data, Perturbed utility, Route choice

Parallel session 4B: Traffic Flow Theory 1

Investigation of the Relationship between Traffic Hysteresis and String Stability of Vehicle Platoons

Giovanni Albano (1), Konstantinos Mattas* (2), Riccardo Dona (3), Yinglong He (4), Biagio Ciuffo (2)

1: Seidor Italia, Milan, Italy; 2: European Commission – Joint Research Centre, Italy; 3: Uni Systems Italy, Milan, Italy; 4: Department of Mechanical Engineering, University of Birmingham, Birmingham, UK

Traffic oscillations deteriorate traffic safety and efficiency. Relevant to those oscillations, traffic hysteresis and string stability of platoons of vehicles have been extensively studied. However, the relationship between these two remains underexplored, leading to deficits in knowledge about the effect of regulating one on the other. The present paper investigates the correlation between string stability and traffic hysteresis and their possible trade-offs. The two are quantified based on trajectories that are extracted by simulation experiments and by real-world data. A strong correlation between string stability and traffic hysteresis is found. In the case of instability, hysteretic platoons are identified almost every time. It suggests that instability is one of the leading causes of hysteresis, although other factors also play a role since hysteresis loops have also been detected in string stable platoons.

Keywords
String Stability, Traffic Hysteresis, Traffic Flow, Traffic Oscillations.

An automatized signal timing detection at signalized intersections with detailed vehicle trajectory data

Jasso Espadaler Clapés*, Emmanouil Barmpounakis, Nikolas Geroliminis

Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Signalized intersections are a fundamental part of urban networks. Their understanding is crucial to identify congestion patterns, queues, delays, and safety issues in local and network level. In this work, we analyze multimodal vehicle trajectories and propose a methodology to extract the signal timing schedule of an intersection using the pNEUMA dataset. In addition, we combine the available information from OpenStreetMap (OSM) to map match the trajectories to the underlying network and to identify more accurately the location of traffic signals. Then the methodology to extract the signal timing schedule of an intersection consists of the following steps: i) critical movements identification, ii) computation of crossing times at the traffic signals, iii) cycle length detection and iv) phase length of each critical movement. Results show that by using the OSM data, the methodology can then be applied to any intersection in the network and provide critical information in macroscopic level.

Keywords
traffic flow theory, traffic signal timing detection, vehicle trajectory data.

Empirical Analysis of Lane Changing Maneuvers in Motorway Weaving Area

Mohammad Ali Arman*, Chris M.J. Tampère

KU Leuven, Belgium

A lane-changing vehicle effectively occupies two neighboring lanes for a few seconds. In complex sections of motorways networks, especially in weaving areas, the rate of these maneuvers is significantly higher. This is the primary source of turbulence in flow, which results in a decrease in speed, density, and flow quality. There is a significant research gap in the empirical analysis of lane-change maneuvers. This paper presents an empirical analysis of lane change maneuvers in a weaving area in a motorway network with a length of about 3.1 km. Differences in traffic characteristics between the source and target lanes, such as flow volume, density, and speed, were shown to incentivize drivers to undertake lane change movements. However, while discretionary maneuvers are usually associated with easier driving conditions, in most cases, the mandatory maneuvers have been towards slower lanes or with higher flow volume and/or density.

Keywords
Traffic empirical analysis, Lane changing maneuvers, Driving behavior, Motorway weaving areas

Introducing the Platoon Fundamental Diagram for Automated Vehicles based on large-scale empirical observations

Michail Makridis*, Anastasios Kouvelas

ETH Zurich, Switzerland

The interest in understanding the coordinated behavior of car-platoons and their impact on traffic efficiency, safety and energy demand is high. Recently, real-world experiments towards observing car-platoons with ACC-driven vehicles became available. Literature highlights that such car-platoons are string unstable, energy inefficient and potentially safety critical. However, few studies link their behavior at microscopic level to the macroscopic impact on traffic. In this paper, we propose a novel model, namely the Platoon Fundamental Diagram (PFD), that creates explicitly such a link. We validate PFD through worldwide experimental observations and we show that PFD can be reliably used as a means of cross-comparison between platoons with automated vehicles. Furthermore, we present evidence about the invariability of PFD to heterogeneity, i.e. the number of vehicles in the platoon, the order of vehicles, the vehicles' powertrains, the vehicle brands or models within the car-platoon, the particularities of the road infrastructure and the data acquisition methods.

Keywords
Adaptive Cruise Control, Platoon Fundamental Diagram, Traffic Flow, Connected and Automated Vehicles, Intelligent Transportation Systems

Parallel session 4C: Rail management

Energy-efficient timetabling for urban rail transit network considering passenger path choice behaviors

Kang Huang* (1,2), Feixiong Liao (1), Ziyou Gao (2)

1: Eindhoven University of Technology, Netherlands, The; 2: State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing, China

The high energy consumption of urban rail transit (URT) in metropolitan areas becomes a hotspot problem due to the ever-increasing operation mileages and pressing agendas of carbon neutralization. The majority of energy-efficient timetabling studies focus on a single URT line and are insufficient for a URT network with multiple interlinked lines. We propose a general model framework including timetabling and passenger path choice behaviors to optimize energy consumption of a URT network under passenger travel time constraints. A novel dynamic programming and heuristic search method for determining travel time components are incorporated in an iterative solution algorithm to find energy-efficient timetables. The proposed model and solution algorithm are validated with a real-world URT network under various scenarios.

Keywords
urban rail transit, energy-efficient timetabling, travel time, dynamic programming

An analysis of power peaks in stochastic models of railway traffic

Alessio Trivella* (1), Francesco Corman (2)

1: University of Twente, The Netherlands; 2: ETH Zurich, Switzerland

Railway traffic flow can be modeled by a string of consecutive trains, each subject to random speed variations that are described by a stochastic process. Despite analogies with car-follower models, railways include specific features and a safety system that forces vehicles to decelerate towards a fixed lower speed if an absolute safety distance with the vehicle ahead is not respected. By simulating this dynamic system, we compute performance indicators focusing on energy consumption and the power peaks arising when multiple trains accelerate simultaneously. We study how different conditions of the system and assumptions on the stochastic processes, e.g., describing human drivers vs automated train operations (ATO), affect energy consumption and power peaks. Our results show that an ATO controller aware of precise distance and speed information can be effective at reducing energy consumption and smoothing the peaks, which are a major concern of operators.

Keywords
Automated train operations, energy consumption, railway modeling, simulation, stochastic processes, traffic flow theory

Passenger Flow Control at Platforms in Urban Rail Systems

Yotam Yatziv*, Jack Haddad

Technion-Israel Institute of Technology

Flow of passengers is the one of main operational aspects for urban rail systems. Over the recent years, passenger flows vary frequently causing disturbances on trains operation, and unsafe over-crowded environments for passengers. To improve the performance of rail systems, this paper presents a control method to regulate disturbed passenger flows and rail system. A traffic model coupling dynamics between staying times at stations and accumulated passengers at platforms is formulated. The suggested control method applies actions both on the train traffic and stations' facilities, using real time measurements and model predictive control optimization method. Actions at each stage are calculated as a solution of quadratic programming problem with regulation objective, and safety, feasibility, and limited platform capacity constraints. Moreover, the objective function accounts passengers at platforms to reach effective flows during the controlled period. Numerical examples are given to demonstrate the rail system performances under the proposed control method.

Keywords
Train regulation, Passengers flow control, Urban rail systems.

The Wagon Assignment Policy problem: Policy Comparison on the Wagon Fleet optimization.

Federico Bigi* (1), Tommaso Bosi (2), Juan Pineda Jaramillo (1), Francesco Viti (1), Andrea d'Ariano (2)

1: University of Luxembourg, Luxembourg; 2: University of Roma Tre

By 2050, Europe hopes to nearly double the freight traffic train in order to achieve carbon neutrality. One of the challenges that multimodal freight transport will face is related to optimizing the high costs associated with the management of rolling stock.
In this context, we study an integration of the maintenance constraint for the Rolling Stock Problem, defined as the Wagon Assignment Policy problem, focusing on how to optimize the wagon fleet management with a particular focus on the shunting operations. For this reason, an event-based simulation approach has been developed in order to understand the long-term impact of multiple policies. Results show that the criteria for choosing which wagons to assign to a departing train greatly impacts the KPIs regarding fleet management. We show that different criteria for the Wagon Assignment Policy can reduce the number of rolling stock needed for the fulfillment of the freight services.

Keywords
Freight trains operation, Mileage-based maintenance, Shunting operations, Rolling stock problem, Wagon maintenance

Parallel session 4D: Travel behavior

Exploring the role of perception in the association between the built environment and travel behavior: Evidence from dual-earners in Ganyu

Yang Hu*, Dick Ettema

Utrecht university, Netherlands,

The perceived built environment, reflecting how individuals evaluate their surrounding environment, influences their behavior. However, how such perception among different household members is related to the objective built environment, attitudes, and travel behavior has not been thoroughly analyzed. Using data collected in Ganyu (a small Chinese city), this research investigates how attitudes indirectly impact travel behavior via the perceived and objective built environment for females and males within a dual-earner household. Structure equation modeling results show that attitudes could influence walking behavior indirectly by way of both perceived and objective built environments for both females and males. Besides, car use is less affected by either perceived or objective built environment for males, due to household car allocation and travel conditions in local areas.

Keywords
Attitudes; Dual-earner households, Objective built environment, Perceived built environment, Small Chinese cities

Estimating rebound effect for passenger cars and its effects on US policy regulations

Cinzia Cirillo, Shihan Lin, Lavan Teja Burra*, Dennis K Rathbun

University of Maryland, College Park, United States of America

Policies regulating the fuel economy of passenger vehicles have been implemented by many nations around the world to mitigate greenhouse gas emissions and improve energy efficiency. Such policies lead to advancements in-vehicle technology and improved fuel efficiency which then reduce per-mile driving costs. This reduction in passenger vehicle driving cost may result in the rise of vehicle miles traveled, which is referred to as the rebound effect. This study aims at estimating the rebound effect and at covering the difference (if any) between the rebound effect and gasoline price elasticity to vehicle miles traveled. The analysis is based on the 2017 National Household Travel Survey. We estimate a rebound effect in the range of 20%-26%, with estimation consistent across Ordinary Least Square (OLS) and Instrumental Variable (IV) approach. Interestingly we observe an absence of rebound effect in vehicles up to three-year-old and a much smaller rebound effect in hybrid vehicles.

Keywords
Rebound effect, SAFE rule, transport policy, vehicle technology, vehicle miles traveled

Didn’t travel or just being lazy? An empirical study of soft-refusal in mobility diaries.

Mathijs de Haas* (1,2), Maarten Kroesen (2), Caspar Chorus (2), Sascha Hoogendoorn-Lanser (2), Serge Hoogendoorn (2)

1: KiM Netherlands Institute for Transport Policy Analysis, The Netherlands; 2: Delft University of Technology, The Netherlands

In mobility panels, respondents may use a strategy of soft refusal to lower their response burden. In this study we assess the presence of soft refusal in mobility panels and its relation with reported immobility. It is shown that speeding and straightlining in a questionnaire is strongly related to reported immobility in a travel diary. Furthermore, using a binary logit model, respondents who are predicted to leave their home but report no trips are identified. Using a latent transition analysis, four behavioral patterns with respect to soft refusal are identified. The smallest class are respondents with a high risk of showing soft refusal. This class shows a higher attrition rate the other, more reliable, classes. Furthermore, the results show that if respondents don’t drop out of the panel, they tend to remain in the same behavioral class over time. Soft refusal therefore seems to be fixed behavior.

Keywords
Data quality, mobility panels, response behavior, soft refusal, travel behavior research

Response Latency reveals Participants' Motivations to Join a Behavioural Change Program

Danique Ton (1,2), Maarten Kroesen* (3), Caspar Chorus (3)

1: Civil Engineering & Geosciences, Delft University of Technology, The Netherlands; 2: NS Stations, The Netherlands; 3: Technology, Policy and Management, Delft University of Technology, The Netherlands

What motivates people to change their travel behaviour? In voluntary behavioural change programs, this question is typically answered by asking participants why they have joined the program. The frequency of a motivation's citation is then considered a proxy for its importance. In this study, we propose an additional 'proxy' criterion to assess the psychological salience of the stated reasons, namely response latency (the time between the start of the advertising of the program and the moment of registration). Considering that the program is marketed to everyone at the same point in time, we argue that response latency can be regarded as an inverse measure of the degree of motivation to change one's behaviour. This allows us to identify stronger and weaker motivators. We use this idea to identify the importance of particular motivations to join a behavioural change program at TU Delft.

Keywords
voluntary behavioural change, motivation, response latency

Parallel session 4E: Agent based modelling

The potential to reduce long-distance travel emissions: A nationwide agent-based transport simulation

Ana Tsui Moreno*, Wei-Chieh Huang, Alona Pukhova, Carlos Llorca, Rolf Moeckel

Technical University of Munich, Germany

To meet the environmental goal of a largely greenhouse gas-neutral transport system, motorized private vehicle trips need to be shifted to more sustainable modes. This study tested for long-distance travel in Germany in 2030 the the traffic and environmental implications of push strategies (implementing toll roads and increasing auto operating costs) and pull strategies (improving access to rail with on-demand services and improving rail and long-distance bus services). A synthetic population for 2030 was generated. The strategies were simulated using the agent-based travel demand model ALTO. Mode choice accounted for access and egress modes and tolls. The indicators for evaluation of various scenarios include modal split, vehicle kilometers travelled, traffic congestion and CO2eq emissions. Some of the strategies effectively reduced CO2eq emissions. Results suggest that only radical scenarios that will be politically difficult to implement can help to curb emissions substantially.

Keywords
agent-based modeling, discrete choice modeling, long-distance travel, multi-modal transportation

Impacts of real-time information levels in public transport: A large-scale case study using an adaptive passenger path choice model

Mads Paulsen*, Thomas Kjær Rasmussen, Otto Anker Nielsen

Technical University of Denmark, Denmark

Public transport services are often uncertain, causing passengers' travel times and routes to vary from day to day. This study uses three months of historical Automatic Vehicle Location (AVL) data to calculate corresponding realised routes and passengers delays in a large-scale, multi-modal public transport network by formulating and implementing an adaptive passenger path choice model, and apply it to an agent-based scenario of Metropolitan Copenhagen with 801,719 daily trips. Five different levels of real-time information are analysed, ranging from no information at all to global real-time information being available everywhere. The results of more than 258 million inferred passenger delays show that variability of passengers' travel time is considerable and much larger than that of the public transport vehicles. Furthermore, obtaining global real-time information at the beginning of the trip reduces passengers delay dramatically, although still being inferior to receiving such along the trip.

Keywords
Agent-based simulation, Automatic vehicle location data, Passenger delays, Passenger path choice model, Public transport, Real-time information

Preparation of agent-based modelling input from aggregate 4-step model

Haris Ballis, Loukas Dimitriou*

University of Cyprus, Cyprus

Agent-based and activity-based modelling are considered as the most suitable means to model the emerging mobility environment (New Mobility Services, Mobility as a Service, ride-hailing, etc.) but the lack of experience on the development of such models as well as their considerable requirements in fine-grained input have hindered their wider adoption. For those reasons, and despite their shortcoming, aggregate 4-step models still constitute the most wide-spread approach in the field of travel demand modelling. This study evaluates the possibility to exploit the outputs of existing 4-step transport models for the preparation of input suitable for agent- and activity-based modelling. In particular, the typical outputs of 4-step models, namely, multi-period Origin-Destination matrices (ODs) and traffic assignment results (i.e. link counts) are transformed into home-based trip-chains (i.e. tours). The framework is evaluated on the 4-step model of Larnaka, Cyprus.

Keywords
OD Matrices, Disaggregation, Large-scale Combinatorial Optimisation

Simulation-based Optimization Framework for Stage-based Evacuation Planning

Hassan Idoudi* (1,2), Mostafa Ameli (1), Cyril nguyen-van-phu (1), Mahdi Zargayouna (1), Abderrezak rachedi (2)

1: COSYS, University Gustave eiffel, France; 2: LIGM, University Gustave eiffel, France

This study proposes a new framework to solve the road network evacuation problem, considering a dynamic allocation of evacuees to shelters. Although many studies have been performed on this problem with static settings, there are few studies in the literature that address this problem in a dynamic context. We couple and solve the dynamic traffic assignment (DTA) and dynamic shelter allocation problem (SAP) using agent-based dynamic simulation. The model for the SAP aims to satisfy system operator interests by determining the best shelters for evacuees, and evacuees tend to reach their shelters as fast as possible. We validate our methodology on the real network of Luxembourg City and evaluate its performance in front of one of the advanced methods in the literature. The results show that calculating dynamic shelter allocation improves mean evacuation time and significantly reduces the network clearance time compared to the methods with fixed shelter allocation plans.

Keywords
Network evacuation, disaster management, dynamic shelter allocation, dynamic traffic assignment

Parallel session 5A: Impact of Automation

Understanding the Impacts of Automated Vehicles on Activity Schedule Rearrangements

Fatima-Zahra Debbaghi* (1), Baiba Pudāne (2), Maarten Kroesen (2), Gerdien de Vries (2)

1: Vrije Universiteit Brussel, Belgium; 2: Delft University of Technology

This study explores the potential impacts of vehicle automation on travel behavior by looking at the expected changes in activity schedules collected previously through an interactive survey. Using latent class clustering, the responses are clustered with respect to on-board and stationary activity duration changes, and travel departure time changes. The clustering uncovered different types of classes: no change, stationary activity change, single activity on-board (work or spare-time), multiple activities on-board. Essential activities like work, meals, and getting ready were more likely to be transferred to the travel episode, while spare time was generally increased in and out of the travel episode. The findings highlight a fundamental difference in the perception of the usefulness of the newly available time in the autonomous vehicle and highlighted the richness of the potential impacts that automated vehicles can have on travel behavior, one that cannot be captured by the frequently used travel time penalty.

Keywords
Activity schedules, Autonomous and connected vehicles, latent class clustering, on-board activities.

Implementing Social Value Orientation in Measuring the Health and Environmental Dilemmas of Autonomous Driving

Yusak Susilo*, Lukas Birgfellner

University of Natural Resources and Life Sciences (BOKU), Vienna

Understanding users' market reaction towards the positive and negative impacts of the technology as well as its trade-offs is essential to anticipate market reaction once the technology is deployed on the ground. Based on data from 1,000 Austrian participants, this study takes a deeper look into different demographic clusters on how different participants' values and behaviours influence their reaction towards the environmental and health impacts of an autonomous transport network. The results indicated that the respondents exhibited individual-oriented reactions regarding environmental impacts while demonstrating more altruistic reactions in the case of health-related impacts. Also, a distinction can be made between age groups, as older generations aged between forty and sixty revealed more altruistic reactions than younger participants. Despite an individualistic tendency towards environmental issues, when the respondents faced a choice between their own health and the common good, they prioritised the latter.

Keywords
social value orientation, trade-off mechanisms, autonomous driving impacts

Performance of Synthetic Road Networks with Dedicated Streets for Altruists

Alonso Espinosa Mireles de Villafranca*, Claudio Roncoli

Aalto University, Finland

We present an empirical study of network ensembles under static traffic assignment with two vehicle classes: an al-truistic vehicle class (AVs) – potentially automated vehicles that are optimally routed – and a selfishly routing class,corresponding to human-driven vehicles (HVs). We assess a management measure that consists on reserving somenetwork links for exclusive use by AVs, to mitigate the detrimental effects of HVs on the per-vehicle cost of AVs. Weformulate a capacitated, multi-class, static traffic assignment problem (STAP). We solve the STAP as a single-objective,convex optimisation problem with additional flow constraints on AV-exclusive links. We find that randomly selectingthe AV-exclusive links can be detrimental at low penetration rates. However, having several sets of links to choose fromand selecting the best performing link-set for the traffic conditions steers the system closer to optimal even for modestpenetration rates (e.g., 30%).

Keywords
Altruistic Routing, Automated Vehicles, Mixed Equilibrium, Network Segregation, Static Traffic Assignment

Parallel session 5B: Transport electrification

Electric Vehicle Adoption in the Context of Household Fleet Choice: the Case of the Netherlands

Linlin Zhang*, Dea van Lierop, Dick Ettema

Utrecht University, the Netherlands

"This study uses data from the 2018, 2019 and 2020 Dutch National Travel Surveys and employs a multinomial logit regression model to examine the relationship between the household characteristic and the adoption of different types of electric vehicles (EVs) in the context of the household car fleet. Our results show that battery electric vehicles (BEVs) have the smallest sub-user groups. Internal combustion engine vehicles (ICEVs) and hybrid electric vehicles (HEVs) are more likely to be owned by one-car households, while plug-in hybrid electric vehicles (PHEVs) and BEVs tend to be leased by two-car households. PHEV and BEV adoption mostly occurs in highly urbanized areas. In particular, higher education and higher income are the main factors for BEV adoption in one-car household, respectively. Moreover, a 2020 COVID-19 effect shows that people were inclined to adopt BEVs and HEVs in that year and that BEVs appeal to a wider user group."

Keywords
Household fleet choice, EV, transition, ownership, leasing, the Netherlands

Environmental performance of carsharing systems: the impacts of vehicle electrification, lifetime turnover and reuse

Yonsorena Nong* (1), Francesco Ciari (1), Ouassim Manout (2)

1: Polytechnique Montreal; 2: LAET-ENTPE-CNRS-University of Lyon

Several research has documented carhsaring's benefits; however, such benefits have been demonstrated looking at it as a static system and therefore not taking into account the quick turnaround of the vehicles and reuse of former carsharing vehicles. In this case, the environmental contirbution of carsharing is unclear. With the trend of electrification, the negligence of vehicle turnover and reuse can pose uncertainty on electric carsharing's contribution. This paper uses an agent-based modelling with life cycle assessment to examine the environmental impact of individual travel behaviour, operator's fleet management, and second life of former carsharing vehicles. Findings suggest that carsharing can reduce greenhouse gas (GHG) emission by 20% at vehicle level. With electric carsharing, it further reduces 55% more. At scenario level, results suggest that carsharing members can reduce GHG emissions collectively by 12% upon joining carsharing. This saving is attributable to vehicle reuse, car ownership reduction, and fuel efficiency improvement.

Keywords
Agent-based modeling, carsharing, electric vehicle, life cycle assessment, environment

Data needs and challenges for planning electric charging infrastructure for road freight

Wasim Shoman*, Frances Sprei, Sonia Yeh

Chalmers University of Technology, Sweden

To reduce the dependency on fossil fuels in the on-road freight sector, adopting vehicles utilizing alternative fuels, including electricity, requires large investments in infrastructure and distribution of fuels for refueling/charging facilities. Unique to the electric vehicles, journey length and charging time impose important constraints in the placement of charging stations. This research reviews the data needs and challenges in modeling infrastructure requirements, and the role of vehicle-based measurements in alleviating these obstacles, with a special focus on electrification of road freight. Our review shows that estimating energy demand using vehicle-based measurements of highly detailed operational conditions of the vehicles is particularly important for modeling electrified freight. We conclude with major research gaps and future data needs in modeling of electric freight transport.

Keywords
Alternative fuel vehicles, freight transport, energy modelling, transport modelling, charging infrastructure.

Parallel session 5C: Forecasting

Extension of the Hyper Run Assignment Model to real-time passengers forecastingin congested transit networks based on count data

Lory Michelle Bresciani Miristice* (1), Guido Gentile (1), Daniele Tiddi (2), Lorenzo Meschini (2)

1: DICEA, University of Rome La Sapienza, Via Eudossiana 18, Rome, Italy; 2: PTV Group SISTeMA, Via Spallanzani 14, Rome, Italy

Recurrent and non-recurrent congestion phenomena increasingly affect densely interconnected transit networks. In particular, the measures adopted to contain the spread of the COVID-19 pandemic significantly affect public transport capacity, increasing congestion. Typical congestion phenomena, together with service disruptions and atypical demand, can lead to low levels of service harming planned schedules. Therefore, transit operators require a tool that can quickly forecast a potential lack of capacity in transit systems, to perform service recovery (e.g., introducing new runs) and inform passengers about crowding (e.g., through real-time information panels or trip planners). This research proposes an innovative congested run-based macroscopic dynamic assignment model that incorporates real-time measurements and events to compute users' elastic route choices under the assumption that passengers are fully informed. The model simulates the effects of congestion events and countermeasures introduced by the operators, allowing them to test several scenarios on large transit networks faster than in real-time.

Keywords
implicit hyperpaths, public transport services, real-time data, schedule-based assignment, short-term forecast, vehicle capacity constraints

Estimating a seat choice model for Dutch suburban train users

Carlos Romero* (1), Oded Cats (2), Sanmay Shelat (2)

1: Universidad Politécnica de Madrid, Spain; 2: Delft University of Technology

Passenger behaviour and preferences on-board buses and trains have become more relevant after the COVID outbreak. Surprisingly, the impact of seat and individual characteristics on passengers' seat choice in public transport vehicles remained unknown. We estimate an en-route seat choice model for Dutch suburban trains, using a mixed logit with error components. Our model accounts for seat attributes (windows/aisle, group-of-4, etc.), crowdedness level, and individual characteristics. Our findings indicate that: (i) passengers clearly favour sitting alone, are influenced by distance to the entry, and show preferences for window/aisle seats, and (ii) level of crowdedness changes some seat preferences (e.g. passengers choose window seats when the train is empty but aisle seats if the train is highly crowded). Personal characteristics have a moderate influence on seat choice and we could not find significant evidence of COVID perception on seat choice preferences.

Keywords
Seat choice, Public transport, Crowding, Travel behaviour, Stated Preferences

Efficient Traffic Demand Forecasting Using A Meaningful Representation With Social Multiplex Networks and Community Detection

Eleftheria Karakitsou, Panagiotis Fafoutellis*, Eleni I. Vlahogianni

National Technical University of Athens, Greece

In this paper, a meaningful representation of the road network using Multiplex Networks, as well as a novel feature selection framework that enhance the predictability of future traffic conditions of an entire network are proposed. Using data of traffic volumes and tickets' validation from the transportation network of Athens, we were able to develop prediction models that achieve very good performance but are also trained efficiently, do not introduce high complexity and, thus, are suitable for real-time operation. More specifically, the network's nodes (loop detectors and subway/metro stations) are organized as a multilayer graph, each layer representing an hour of the day. Nodes with similar structural properties are then classified in communities and are exploited as features to predict the future demand values of nodes belonging to the same community. The results imply the potential of the method to provide reliable and valid predictions.

Keywords
multiplex network, community detection, traffic forecasting, road network representation

Parallel session 5D: Active mobility

Explaining cycling speed variation during a trip

Hong Yan* (1), Kees Maat (2), Bert van Wee (1)

1: Transport and Logistics Group, Faculty Technology, Policy and Management, Delft University of Technology, the Netherlands; 2: Department of Transport & Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, the Netherlands

A comprehensive and detailed understanding of cycling speed variation is lacking. This study collected cycling data with GPS devices in the Netherlands. Three-level models are adopted to analyse cycling speed variation to account for the hierarchical data structure. In addition, cyclist heterogeneity is tested with a random slope model and interaction terms between cyclist preferences and environment variables. The models show that cycling at separated bicycle facilities and natural areas is faster. Turns, intersections, positive slopes and curvatures decrease cycling speed. In addition, cyclists' preference for high speed and avoiding riding red lights cycling speed. Furthermore, the influence of some facilities or environments on cycling speed varies across cyclists with different preferences, showing the existence of cyclist heterogeneity.

Keywords
cycling speed choice, cycling speed modelling, preferences, heterogeneity, interaction effects

Key e-bike-sharing system attributes. A combination of explicit and implicit methods for user satisfaction assessment

Raky Julio Castillo* (1), Andres Monzon (2), Yusak O. Susilo (3)

1: Universidad Politécnica de Madrid, Spain; 2: Universidad Politécnica de Madrid, Spain; 3: University of Natural Resources and Life Sciences, Vienna, Austria

A common strategy to cope with problems of motorized transport in urban environments (congestion, pollution, noise, etc.) is the introduction of bike-sharing systems (BSS). These systems had proved to have positive effects on cities, moreover, many of them had reached a performance peak. This study aims to identify the most influential attributes of the pioneer Madrid electric BSS on user satisfaction, by applying a novel combination of two methods. The direct, explicit, Importance Performance Analysis (IPA), and the nonlinear, implicit Three-Factor Theory (3FT) to generate a three-dimensional scheme that makes easy the analysis of results. The combination of the two methodologies makes possible to differentiate that maintenance is a priority for subscribers and network extension for occasional users, among the 24 attributes evaluated. The application of this combined method provides precise information for targeted interventions to foster user satisfaction, strengthen service loyalty and increase the number of subscribers.

Keywords
Bike-sharing, user satisfaction, attribute importance, importance-performance analysis, three-factor theory.

Estimating city wide hourly bicycle flow using a hybrid LSTM MDN

Marcus Skyum Myhrmann*, Stefan Eriksen Mabit

Department of Techonology, Management and Economics, DTU, Denmark

This study proposes a novel method to improve the estimation of hourly bicycle flow. The specific model employed is a Long Short-Term Memory Mixture Density Network (LSTMMND). This model presents the additional upside approximates a distribution of cycling flow conditional on the input data and hence addresses potentially unobserved heterogeneity. In a case of city-wide bicycle flow in Copenhagen, the LSTMMDN yielded $\sim75\%$ more accurate bicycle flow estimates than the calibration-based approach currenty used by transport agencies.
The paper further quantifies the improvement of accident analyses brought on by the improved bicycle volume measures.
The LSTMMDN estimates result in an improved model fit in a crash model, compared to other estimates for bicycle exposure, with all other variables unchanged.
Overall, the results strongly indicate that investing in more advanced methods for bicycle volume estimation will benefit the quality of performance measures related to bicycle issues computed by transport agencies.

Keywords
Aggregation Bias, Bicycle crash risk, Bicycle volume estimation, Deep learning, Long Short-Term Memory Mixture Density Network

Parallel session 5E: MaaS 1

Am I willing to give up my car? An analysis about the willingness of Dutch citizens to adopt MaaS and the triggers affecting their choices.

Francisco J. Bahamonde-Birke*, Luuk Frowijn, Coco van Gils, Rutger Helmink, Sophie Henkus, Sanna van der Hoeven, Mathilde Kolkman, Tim van Onzen, Lisette Ronteltap, Dinah E. Wehl, Dick F. Ettema

Universiteit Utrecht, Netherlands, The

Mobility-as-a-Service (MaaS) is a new way to understand mobility, which integrates services such as car-sharing, bike-sharing, public transport, etc. Its goal is that mobility requirements be no longer privately-owned mobility resources, but requested on-demand. In this paper we considered the willingness to adopt MaaS services, choices between different kinds of MaaS subscriptions as well as the choice between MaaS and private vehicle ownership by means of two choice-experiments, address simultaneously on the basis of an HDCM framework.
The results show that the willingness to adopt MaaS is greatly influenced by the socio-demographic characteristics of the individuals, while the WTP for different mobility services within MaaS subscriptions lies below the current prices paid for those services individually. However, the WTP exhibits a large variation across individuals indicating that MaaS may be interesting for specific user groups.

Keywords
mobility-as-a-service, MaaS, car ownership, mobility choices

Bundle Design for Mobility as a Service

Sina Bahrami*

Eindhoven University of Technology, Netherlands

Mobility as a service (MaaS), which offers users access to different transportation modes through an integrating platform by paying a discounted subscription fee, is becoming prevalent worldwide due to its potential in increasing transportation equity and accessibility. The success of the MaaS depends on users shift to subscribing than pay-as-you-go for using different transportation modes, which is highly reliant on bundle assortment, and its subscription fee. This paper investigates the optimal assortment and cost of the MaaS bundle considering the users travel needs, and provides a foundation for designing optimal MaaS bundles. The analysis shows that the number of trips offered in MaaS bundles should be equal to or greater than the travel needs of the users. Moreover, the analysis shows that the market share of the MaaS is at most 50%, and the majority of the users still prefer to pay for their trips as they go.

Keywords
Mobility as a Service, bundle assortment, bundle subscription fee

Comparing MaaS Business Plans Using an Agent Based Modelling Approach

Carolina Cisterna*, Federico Bigi, Francesco Viti

university of Luxembourg, Luxembourg

The Mobility-as-a-service is based on customized bundles in which different mobility services are gathered under one subscription-based-digital platform. Currently, in the literature MaaS packages have been customized and hypothesized through running surveys and pilot projects, underling the lack of a generic model able to capture and compare MaaS demand when different bundles are provided. This study aims to endogenize different MaaS plans in the users' mode choice set using an agent-based model and to capture and compare the MaaS potential demand. Results show that MaaS users who have long daily travel time are indifferent to the type of package provided, while time-limit package members substitute the car by travelling longer using public transport and by employing free floating service. In contrast, the trip-discount bundle members are less willing to substitute the car and they use public transport within a long trip chain but reducing their single trip time.

Keywords
Agent-based model, Business models, MaaS membership

Poster session 2

Contributory Factors Affecting Willingness to Use Shared Autonomous Vehicles in Greece

Eirini Triantafyllidi, Panagiotis Tzouras, Ioanna Spyropoulou*, Konstantinos Kepaptsoglou

National Technical University of Athens, Greece

The aim of this paper is to investigate the factors that affect willingness to use Shared Autonomous Vehicles in Greece. To achieve this goal, an on-line questionnaire survey was designed and distributed via various different channels, with a final sample size of 164 questionnaires. The designed questionnaire explored modal choice through a stated preference experiment, while revealed preferences related travel characteristics, traveler perceptions and attitudes, as well as demographic characteristics were also collected. Statistical analysis was performed through the design of multinomial logit models, with the dependent variable being modal choice. Results indicated several contributory factors including travel cost, travel time, trip purpose, transport mode, preferences and attitudes considering privacy and flexibility, technology familiarisation and traveller age and income. The results of this work can be utilized for the design of targeted policies towards promoting the use of shared autonomous vehicles in the future.

Keywords
shared autonomous vehicles, discrete choice analysis, questionnaire survey, shared mobility, smart urban mobility

Applying Serious Games in Models of Preferences of Shared Automated Vehicles

Shelly Etzioni* (1), Mor Collins (2), Eran Ben-Elia (2), Yoram Shiftan (1)

1: Technion Israel Institute of Technology, Israel; 2: Ben-Gurion University of the Negev

Data obtained from a serious game was used to estimate a game-based model to better understand user preferences regarding shared automated vehicles (SAVs), while modeling how user experience and social interactions can shape decisions over time. Users' choice of three novel, fully automated transportations modes; shared ride, shared car, and automated transit, was studied with ten interacting players engaged in a competitive mode choice game. The players aimed to maximize their overall score, which was affected by their mode choice, their punctuality, and the choices of all the other players. Each game had 50 rounds to allow implicit learning and provide insight on how choices are shaped with experience. Results showed a strong shift to shared rides over shared cars and transit with road users reaching a state of equilibrium in terms of scores. The implications of game-based methods on formation of user preferences and mode choice is discussed.

Keywords
Autonomous and connected vehicles, Game Based Models, Discrete choice modeling.

Changing Strategic Alignments in European Urban Traffic Control - Requirements for Future Developments

Mario Ilic*, Natalie Sautter, Martin Margreiter, Allister Loder, Klaus Bogenberger

Chair of Traffic Engineering and Control, Technical University of Munich, Germany

The objective of this paper is to provide an overview of the changing strategic alignment of European urban traffic control (UTC) and to subsequently derive requirements for future UTC systems. Therefore, data from expert interviews with Central European representatives of UTC authorities were used. Several topics of interest are addressed, with a special focus on multimodality and its resulting challenges for UTC as well as on spatial levels of UTC measures. The results show a changing strategic focus on promoting public transport, cycling and walking and a lack of network-wide control systems for UTC. Subsequently, general requirements for future (network) control systems were synthesized from the interview results, such as multimodal functionalities, improvement of traffic state estimation and prediction, and inclusion of general traffic management tasks. Additionally, transparency of the operating principle of complex traffic control systems is identified as prerequisite for future research and development.

Keywords
multi-modal transportation, urban traffic control strategies, requirements for future urban traffic control systems

Investigating the Relationship between Efficiency and Criticality: Some Experimental Findings

Charis Chalkiadakis*, Eleni Vlahogianni

National Technical University of Athens, Greece

Resilience is a complex term, bearing multiple definitions and resilience-related metrics. Two of the most common metrics are efficiency and criticality. Efficiency examines resilience from a topological aspect and considers the shortest paths between the nodes, whereas criticality considers transportation-related variables such as travel demand. In the present research, the interrelation between efficiency and criticality is examined through a series of simulations on the Athens testbed. For the quantification of efficiency and criticality, an iterative approach is used where, per iteration, one link of the network was removed. The outputs of the experiments are then statistically analyzed. Findings reveal that the relation between efficiency and criticality hinders some complex dynamics that are approached by incorporating traffic flow in the investigation of their relation. As a result, a polynomial relationship between the ratio of criticality and efficiency, and traffic flow of each link per functional class of the links is developed.

Keywords
Criticality, Efficiency, Resilience

The sensitivity of transportation networks criticality to demand variation, level of supply degradation, and network abstraction

Chrysostomos Mylonas* (1), Konstantinos Kepaptsoglou (1), Evangelos Mitsakis (2)

1: National Technical University of Athens, Greece; 2: Centre for Research and Technology Hellas

Criticality assessment constitutes a major step towards the vulnerability analysis of transportation networks, enabling the identification of crucial infrastructure elements the unavailability of which provokes significant impacts. This paper aims to investigate the extent to which criticality in transportation networks is sensitive to several factors, including demand variation, level of capacity degradation, and network abstraction. A case study takes place in Sioux Falls, assuming that road users follow the user equilibrium routing behavior. Results showcase that criticality is sensitive to all mentioned factors, highlighting the need for transportation planning authorities to incorporate these factors in the preparation of adaptation plans to unexpected events and the enhancement of road networks robustness.

Keywords
Criticality, demand variation, capacity degradation, network abstraction

An economic comparison between zero-emission vehicles for urban deliveries from the logistics company perspective

Mario Binetti, Aleksandra Colovic*, Luigi Pio Prencipe, Michele Ottomanelli

Polytechnic University of Bari, Italy

Through the recent years, the sustainable eco-friendly vehicles have been demonstrated as an adequate solution for urban deliveries and restricted areas facing with traffic congestions and traffic zone limitation. Therefore, in this paper, we adopted a mathematical model, formulated as Electric Vehicle Routing Problem with Time Windows and Partial Recharging (EVRPTW-PR), which aims at selecting the best zero-emission vehicle for delivering goods in city logistics through a cost comparison. In this way, we compared two most emerging vehicles, i.e., e-cargo bikes and e-scooters, by minimizing the total costs related to the vehicles' investment salary costs, drivers' salary costs and energy costs. The comparison between these two types of vehicles encourages the adoption of zero-emission strategies for last-mile deliveries and helps the logistics companies to decide the type of vehicle that could fit with the environmental as well as economic aspect.

Keywords
e-cargo bikes, e-scooters, green logistics, electric vehicle routing problem

Benchmarking the Performance of Urban Rail Transit Systems: A Machine Learning Application

Farah A. Awad* (1), Daniel J. Graham (1), Laila AitBihiOuali (2), Ramandeep Singh (1), Alexander Barron (1)

1: Transport Strategy Centre, Centre for Transport Studies, Department of Civil Engineering, Imperial College London, London, United Kingdom; 2: Department of Civil Engineering, University of Southampton, Southampton, United Kingdom

Urban rail transit systems operate in heterogenous environments. Distinguishing between inherent performance and the role of efficiencies due to differing environmental and system-specific characteristics is challenging. This study provides a data-driven benchmarking method which accommodates heterogeneity in operational performance among urban rail systems. Using an international dataset of 36 metros in year 2016, operators are clustered into peer groups through clustering algorithms based on operational characteristics. ANOVA and post-hoc tests are then applied to explore variations between clusters. Finally, efficiency performance benchmarking is conducted through Data Envelopment Analysis. Our clustering results corroborate to the natural geographic grouping of the systems. Moreover, our results show that the use of an aggregated index is inadequate to represent the operator's overall quality-of-service. Finally, results show that clustering operators into groups based on similarities in their operational characteristics would introduce more meaningful benchmarks for best practices as they are more likely to be attainable.

Keywords
benchmarking, cluster analysis, DEA, performance evaluation, urban rail

Multi-class Dynamic Traffic Assignment based on Link Transmission Model and Mathematical Programming

Xiao Lin*, Lorant Tavasszy

Dept. Transport and Planning, Delft University of Technology, The Netherlands

We develop a multi-class dynamic traffic assignment procedure based on the link transmission model. LTM has been used for DTA, but without the consideration with multiple vehicle classes. We extend LTM using the dynamic PCE principle that considers vehicle spacing under both free flow and congested conditions. The multi-class DTA can be formulated as linear programming. A small instance is implemented in Matlab. The results of the instance are illustrated and discussed.

Keywords
Dynamic traffic assignment, link transmission model, multi-class traffic, operations research, linear programming

A MILP Framework to Solve System Optimum with Link MFD Functions

Niloofar Shakoori* (1), Giovanni De Nunzio (1), Ludovic Leclercq (2), Antonio Sciarretta (1)

1: IFP Energies nouvelles, France; 2: Univ. Gustave Eiffel, Univ. Lyon, ENTPE, LICIT

This work aims to calculate the optimal routing strategy minimizing total travel time in a transportation network. We solve a mixed integer linear program (MILP) for the system-optimum dynamic traffic assignment with a link-based Macroscopic Fundamental Diagram (SO-MFD-DTA) and with multiple origins and destinations. Previous studies resort to cell transmission model and triangular fundamental diagram to describe traffic dynamics. Here, each link is associated with a single cell characterized by a more advanced cost-function: the link-MFD better describing the speed variation related to the network loading and traffic control impacts. Link MFDs are approximated by piecewise linear functions and adapted to the MILP framework by employing the convex combination method with special ordered sets of type 2 variables. Vehicle holding (VH) that originates from the linearization of traffic model is also addressed. Finally, on a synthetic network, we present the sensitivity analysis on the parameters of the model.

Keywords
system optimum, dynamic traffic assignment, link macroscopic fundamrntal diagram, routing strategy, mixed integer linear program

Generalization of the Social Force Model for Mixed Traffic Contexts including Personal Mobility Devices

Yeltsin Valero* (1), Christos Gioldasis (2), Zoi Christoforou (1,2)

1: COSYS-GRETTIA. Univ. Gustave Eiffel, IFSTTAR, F-77454 Marne-la-Vallée, France; 2: University of Patras, Department of Civil Engineering, Panepistimioupoli Patron 265 04, Patras, Greece

The emergence of Personal Mobility Devices (PMDs), more specifically e-scooters, has transformed the way people move in large cities. These devices can be used in contexts where they interact with low, medium and high pedestrian flows; on cycle paths; but also on roads where they directly interact with motor vehicles. In particular, their coexistence with other soft mobility modes has not been sufficiently explored but is critical for safety and other reasons. In this paper, we propose a novel modeling approach for the description of the movements and interactions among PMDs, cyclists, and pedestrians extending the Social Force Model and introducing specific vehicle dynamics. The novel model is calibrated and validated using a trajectory database obtained through experimentation in a semi-controlled environment. The results show that the proposed model is able to accurately describe all road user interactions and significantly reduces the error in the estimation of the lateral movements.

Keywords
Social Force Model, vulnerable users, e-scooters, bicycles, pedestrians, PMDs.

Learning Solutions for LWR-type Traffic Flow Models

Bilal Thonnam Thodi* (1,2), Saif Eddin Jabari (1,2)

1: New York University Abu Dhabi, Abu Dhabi, UAE; 2: New York University Tandon School of Engineering, New York, US

First-order macroscopic traffic flow models in the form of partial differential equations are conventionally solved using numerical schemes which are grid-dependent. We propose a kernel-based method for learning solutions of first-order traffic flow models. The solution kernels are approximated by Fourier Neural Operators - a variant of deep neural networks. Unlike the conventional schemes, our method learns solutions to arbitrary initial and boundary conditions. This avoids resolving the problem for every new instance of input conditions, thereby lowering the computational cost. We apply this method for learning traffic density solutions of the Lighthill-Witham-Richards (LWR) traffic flow model. Numerical experiments to show the neural network solution's accuracy, grid-independence, robustness, and computational complexity are included.

Keywords
Deep Learning, Learning Traffic Dynamics, LWR Traffic Flow Model.

Parallel session 6A:

Highway capacity and traffic flow estimation and prediction

Implementing partial least squares regression in high dimensional road capacity calibration

Guang Wei* (1), Joakim Ekström (1), Gunnar Flötteröd (1,2)

1: Department of Science and Technology (ITN), Linköping University, Sweden; 2: Swedish National Road and Transport Research Institute (VTI), Sweden

In this paper, a new calibration method for road capacities in urban networks is presented. The method relies on partial least squares (PLS) regression, which combines calibration and dimensionality reduction capabilities. A sampling strategy is implemented to further improve the calibration efficiency and accuracy. Moreover, influences of different parameters on calibration results are investigated. This method is demonstrated to be feasible and efficient in an urban road network (Stockholm, Sweden).

Keywords
dimensionality reduction, partial least squares regression, road capacity calibration

Probabilistic representation of driver space and its inference from trajectory data

Yiru Jiao* (1), Sander van Cranenburgh (2), Simeon C. Calvert (1), Hans van Lint (1)

1: Department of Transport & Planning, Delft University of Technology, The Netherlands; 2: Department of Engineering Systems and Services, Delft University of Technology, The Netherlands

Driver space describes the vehicle-centred area where other road users cannot intrude without causing discomfort. It is traditionally measured by a deterministic distance to the boundary within which discomfort is caused. However, driver space is better regarded as probabilistic because intrusion into the driver space may cause varying levels of discomfort. In this study, we present a probabilistic representation of driver space, which conceptually captures the proximity resistance of a vehicle to its surrounding vehicle. Specifically, we develop a method to empirically infer driver space and demonstrate the method by applying it to an urban trajectory dataset. Our results show that driver space grows quadratically with the relative speed of a vehicle to its surrounding vehicle. Furthermore, we find that the longitudinal boundaries of driver space are significantly less sharp than the lateral ones. This implies that traditional distance-based approaches are inadequate for the longitudinal measurement of driver space.

Keywords
driver space, probabilistic representation, urban vehicle trajectories, personal space measurement

STATNet: Spatial-temporal attention in the traffic prediction

Seyed Mohamad Moghadas* (1), Amin Gheibi (1), Alexandre Alahi (2)

1: Amirkabir University of Technology (AUT), Iran, Islamic Republic of; 2: Ecole Polytechnique Federale de Lausanne (EPFL)

Recent traffic flow prediction methods are lacking abilities to determine predictive features. Thus, they will propagate the error in the next timestamps. In this paper, first, we assess the role of spatial and temporal features on the traffic speed prediction task. Secondly, we propose an attention-based architecture to effectively leverage both cues. Our model mainly consists of two major building blocks to capture the spatial-temporal features in the data and dynamically calculate the attentive features. More specifically, the first block sequentially applies temporal convolution to produce time-based features and then employs graph convolution to capture spatial features. The second component determines the attention between spatial and temporal features. The combination of the component's output will be calculated to generate the final prediction results. Experiments on two real-world large-scale road network traffic datasets (i.e., METR-LA and PEMS-BAY) demonstrate that the proposed STATNet (spatial-temporal attention traffic network) model outperforms the state-of-the-art baselines such as graph-wavenet and STGCN (spatial-temporal graph convolutional networks).

Keywords
Spatial-temporal Attention, Graph Neural Networks, Traffic speed forecasting

Parallel session 6B: Transport electrification 2

A bi-level optimization model for the EV charging stations location problem using a tripartite graph representation

Nurit Oliker*, Margarida Carvalho

University of Montreal, Canada

We propose a bi-level mixed integer program to model the optimal location and sizing of Electric Vehicle (EV) charging stations deployment in an inter-urban area, aiming to accommodate in-route charging demand. Our key step is a network simplification, allowing to model the charging behavior through a tripartite graph of origins, charging stations, and destinations. We apply a heuristic to find a high-quality solution, where parametric versions of the two levels are independently solved. While the upper level is a linear integer program, the lower level is suitably solved through a user equilibrium model, highly benefiting from the compact network. Our methodology is validated in the Quebec network and shown to achieve a robust solution in a short running time. Charging stations were located between the primary population centers, serving the main share of the demand. Layout alternatives and parameters changes can be easily evaluated due to the model simplicity.

Keywords
bi-level, compact network, electric vehicles, facility location, variables relaxation

Examining the effect of infrastructure features on the energy consumption of diesel and electric buses: A microsimulation-based analysis

Sijia Sun* (1,2), Sérgio Batista (1), Mónica Menéndez (1), Yuanqing Wang (2)

1: New York University Abu Dhabi, United Arab Emirates; 2: Chang'an University, China

The transition from fossil fuel-powered buses to battery-powered buses has been a long process. How to deploy such a mixed bus fleet composed of diesel and electric buses to minimize the energy consumption of transit systems is one of the biggest challenges faced by transit agencies. This study takes an important step in addressing this challenge by investigating the impact of different infrastructure features on the energy consumption of diesel buses and electric buses under a variety of traffic conditions. We leverage a simulated-based approach to generate various transit operating scenarios, and adopt two vehicle activity-based energy consumption models for diesel and electric buses. Preliminary results show that bus stop density has a positive linear effect on the energy consumption of both types of buses. Under congested traffic, diesel buses consume less fuel on dedicated bus lanes, while electric buses achieve energy conservation on regular lanes.

Keywords
energy consumption, diesel bus, transit operation, electric mobility

A Random Parameters Latent Class Analysis to Estimate the Value of Free Charging Bundle in Electric Vehicle Purchases

Michael Maness* (1), Divyamitra Mishra (1), Natalia Barbour (3), Zhenhong Lin (2)

1: University of South Florida, United States of America; 2: Oak Ridge National Laboratory, United States of America; 3: TU Delft, Netherlands

Although there has been a sudden surge of interest in the Electric Vehicle (EV) market due to climate change and sustainability concerns, their regular users are still a minority. As policymakers and businesses consider expanding EV infrastructure and updating the pricing structures to increase EV demand, there is limited guidance on the value that consumers place on free charging. Using a representative sample of 250 individuals from the US, the project proposed finding out the potential consumer 'value of free charging' as a function of dollars per charging event, exclusively for public charging infrastructures, by employing an adaptive labelled stated preference (SP) survey and a mixed logit model. This paper finds willingness-to-pay for free charging bundles that range from about $1100/year to $3000/year which is well below the average cost of EV fueling (~$500) and conventional vehicle fueling (~$1200) in the United States.

Keywords
Vehicle Preference, Stated Preference, Choice Experiment, Charging Policy

Parallel session 6C: Demand Responsive services

Departure-expanded network for electric demand responsive feeder bus coordination with timetabled transit

Yumeng Fang*, Tai-Yu Ma

Luxembourg Institute of Socio-Economic Research, Luxembourg

On-demand feeder service using electric vehicles provides user-centered mobility solutions to increase connectivity in the low-demand area and reduce their negative impacts on the environment. However, most studies neglect the synchronization of feeder service and timetabled transit to minimize customers' waiting time at transit stations. Moreover, existing studies on electric vehicle routing problems assume charging stations are uncapacitated. We propose an on-demand first-mile feeder service to coordinate its service with timetabled transit using electric buses/shuttles. The problem is modeled on a departure-expanded graph and formulated as a mixed-integer linear programming problem. Several new contributions are proposed in this study: considering flexible bus stops based on the meeting points of customers' origins, coordinating arrival time at transit stations, and coordinating electric bus charging scheduling to ensure charging station capacity constraints. We provide an illustrative example and conduct numerical studies on a set of instances to validate the proposed methodology.

Keywords
feeder service, demand responsive transport, electric vehicle routing, transit

A variable neighbourhood search algorithm for a demand-responsive bus system with capacitated vehicles

Dilay Aktas* (1), Kenneth Sörensen (2), Pieter Vansteenwegen (1)

1: KU Leuven, Institute for Mobility – CIB, Celestijnenlaan 300, 3001, Leuven, Belgium; 2: ANT/OR - Operations Research Group, Department of Engineering Management, University of Antwerp, 2000 Antwerp, Belgium

In this study, we design a metaheuristic algorithm for a demand-responsive public bus system operating during peak hours with capacitated vehicles. Morning peak hours are considered where the passenger flows towards a city center are typically much larger than the flows in the opposite direction. A single-line system with express services away from the city center is optimized. Based on the expected demand, it is decided whether a bus should visit all the stops ahead or take the express route away from the city center to increase the frequency of the service towards the city center. Due to problem complexity, only small-sized instances can be solved optimally. Therefore, a metaheuristic algorithm is proposed based on Variable Neighborhood Search. The results show that the demand-responsive system can improve the average passenger travel time up to 25% compared to the conventional system especially if limited vehicle capacities need to be considered.

Keywords
demand-responsive bus services, semi-flexible bus services, variable neighbourhood search

Optimizing a demand-responsive feeder system for low-demand areas

Fábio Sartori Vieira* (1), Kenneth Sörensen (2), Pieter Vansteenwegen (1)

1: KU Leuven Institute for Mobility– CIB, Leuven, Belgium; 2: ANT/OR – University of Antwerp Operations Research Group, Antwerp, Belgium

Efficient public transport systems are essential for the dynamism of medium and large cities. With the growth of urban areas around large centers, new neighborhoods emerge in the suburbs and pressure the public transport system. A limited solution is to extend the system with feeder lines. However, in the last decades, demand-responsive systems emerged, complementing traditional systems and providing efficient transportation services for users and operators. We introduce a demand-responsive public bus system that considers shortcuts and detours and modifies the departure times of a feeder system, based on the current demand. This system contains a recognizable backbone, but it is not fixed. The operation is optimized, using a memetic algorithm, for each operation period in order to reduce passenger travel time. The optimized system in our experiments reduces passenger travel time with 18 to 38% compared to a traditional system operating the same network with fixed routes and timetables.

Keywords
demand-responsive transportation, dynamic offline optimization, memetic algorithm, transportation network modeling

Parallel session 6D: Transit data

Measuring Activity-Based Social Segregation using Public Transport Smart Card Data

Lukas Kolkowski* (1), Malvika Dixit (2), Oded Cats (2,4), Trivik Verma (3), Erik Jenelius (4)

1: Graduate student M.Sc. Transport, Infrastructure and Logistics, Delft University of Technology, The Netherlands; 2: Delft University of Technology, Faculty of Civil Engineering and Geosciences, The Netherlands; 3: Delft University of Technology, Faculty of Technology, Policy and Management, The Netherlands; 4: KTH Royal Institute of Technology, Division of Transport Planning, Sweden

~please see extended abstract in the files~
While social segregation is often assessed using static data concerning residential areas, the extent to which people with diverse background travel to the same destinations may offer an additional perspective on the extent of urban segregation. For this study, social segregation is measured using the ordinal information theory index to measure the income group mix at public transport journey destination zones using public transport smart card data of Stockholm County, Sweden. Applying the index on 2017-2020 smart card data sets for a selected week, shows significant differences between income groups' segregation along the radial public transport corridors. This method helps to quantify social segregation, enriching the analysis of urban segregation and can aid in evaluating policies based on the dynamics of social life.

Keywords
Social segregation, Public transport, Ex-post transport appraisal, Smart card data analysis

Evaluating practical approaches for building the consideration set in route choice modeling using smart card data from a large-scale public transport network

Jacqueline Arriagada* (1), Angelo Guevara (1,2), Marcela Munizaga (1,2)

1: Universidad de Chile, Chile; 2: Instituto Sistemas Complejos de Ingeniería (ISCI)

Choice modeling requires the researcher to know the consideration-set, the group of alternatives that the individual bears in mind when making a choice; but that almost never occurs with revealed preference data. Various approaches had been proposed for this but, so far, no comprehensive assessment of them has been possible. This study proposes and applies a methodology to assess feasible approaches to address the consideration-set problem in public transport route choice models, from a theoretical and an empirical perspective. Six out of seven methods are shortest path-based heuristics, and one of them (the Historical/Cohort method) is originally motivated by intuition, but can also be fully justified from a theoretical viewpoint. For the empirical assessment, three weeks of route choices inferred from smart-card data are used for model estimation and a fourth week is used for out-of-sample analysis. The results show that the Historical/Cohort method outperforms all other feasible approaches analyzed.

Keywords
public transport, route choice, consideration set, smart card data

Public transport trip purpose estimation using automated fare collection data: A comparison of methodological approaches

Jesper Ingvardson*, Otto Anker Nielsen, Jeppe Rich

DTU Management, Technical University of Denmark, Denmark

Public transport smart card data hold vast amount of information on passenger behaviour. However, no information on trip purpose is recorded, hence limiting its use in practice. While several studies have developed methods for estimating trip purpose, estimation accuracy is still a challenge. This study proposes a two-fold methodology for trip purpose inference, which incorporates i) cluster analysis of trip purposes, and ii) trip purpose estimation. The grouping of similar trip purposes through cluster analysis reduces the complexity of the subsequent trip purpose estimation, hence ensuring a better performance. Several methods are applied for the trip purpose estimation, including discrete choice models with the utility function being specified using Bayesian relevance determination. Preliminary results solely based on temporal characteristics are promising. Future work will include also relevant land use characteristics as well as estimation based on other relevant methods, including Random Forests.

Keywords
AFC data, Discrete inference, Public transport, Smart card data, Trip purpose estimation

Parallel session 6E: MaaS 2

MobilityCoins – First results on social acceptance, system boundaries and individual budgets in a tradeable credit system in Germany

Lisa S. Hamm*, Klaus Bogenberger

Technical University of Munich, Germany

We propose a holistic, budget-based mobility management system that accounts for negative transport externalities and transport equity. Based on research in tradeable credit schemes, the concept of MobilityCoins incentivizes sustainable mobility by offering the possibility to earn credits with active mobility and by making resource-intense modes more costly. As the allocation of individual mobility budgets might be socially contested and requires tracking of daily trips, we conducted a qualitative analysis through expert interviews to evaluate acceptance and equity issues. Representing different sectors, the experts assessed that i) the system would contribute mostly to traffic efficiency and climate mitigation, ii) data security and user effort would be the most critical issue for social acceptance, iii) a yearly budget allocation cycle and a regional-to-national enrollment would be suitable and iv) mobility impairment and public transport supply should be high-priority parameters when setting up the budget allocation function.

Keywords
traffic management, tradeable credit schemes, sustainability, transport equity, mobility budget

Large-Scale Multimodal Transit Package Optimization: The Case of Hong Kong

Ashraf Uz Zaman Patwary* (1), Sisi Jian (2), Enoch Lee (2), Hong K. Lo (2)

1: Polytechnique Montréal, Canada; 2: Hong Kong University of Science and Technology, China

Mobility-as-a-Service (MaaS) allows travelers to access multiple mobility services through an integrated platform providing a seamless multimodal transport system. In this paper, we evaluate the financial feasibility of mobility packages for the city of Hong Kong. We formulate a revenue and social welfare maximization problem with a specific focus on transit packages. We incorporate demand elasticity in the modeling framework and capture the changes in travel demand, transport system travel time, social welfare, and transit service operators' profitability caused by the implementation of transit package in an activity-based traffic model. A gradient-based optimization framework is developed to solve the proposed optimization problems. Numerical experiments on the multimodal network of Hong Kong Island for both government and commercially owned transit packages indicate that transit package implementation can reduce total system travel time and increase social welfare. Moreover, transit package can induce travelers to reduce auto trips and increase transit trips.

Keywords
Transit package, Iterative Backpropagation, Activity-based modeling, Gradient-based optimization

Creation of a MaaS Readiness Index with local features

Domokos Esztergár-Kiss*, Attila Aba

Budapest University of Technology and Economics, Hungary

In this research smart mobility solutions are examined in the perspective of a Mobility-as-a-Service (MaaS) scheme. The main foundation behind the elaborated MaaS Readiness Indexes (MRI) is that there are specific features on which a MaaS framework could be based. It serves as a local index focusing on the mobility opportunities, the stakeholders, and the environment. The features included in the index can be divided into three areas: technical features, coopeti-tion features, and added value features. To have comparable datasets, local partner and mobili-ty service provider surveys are created. The MRI values are calculated for every pilot region and related to the outcomes of the pilot activities. As a result, the performance of the pilot ac-tivities is quantified. In most cases, the pilots support extensively the development of smart mobility solutions as justified by the positive change of the index values.

Keywords
framework, features, indicators, MaaS Readiness Index, Mobility as a Service, smart mobility

Plenary session 3: Oded Cats (NL)

Symbiotic relations in passenger transport systems – the premise, promise and pitfalls

Oded Cats*

Associate Professor at the Department of Transport & Planning at Delft University of Technology, the Netherlands

Passenger transport systems encompass a range of mobility services that have the potential to facilitate a car-independent lifestyle. Shared fleets and mobility-on-demand pose new challenges for service planning, operations and control as well as for policy makers. In particular, mobility services are not exclusively centrally planned anymore and there is no guarantee as to their synergetic prospects. Recent advancements related to the modelling of two-sided mobility platforms and behavioral findings in the context of mobility-on-demand will be presented.

Parallel session 7A: Activity and Mobility modelling

Heterogeneous Activity Generation for a Synthetic Population: Synthetic Sweden Mobility (SySMo) Model

Çağlar Tozluoğlu* (1), Swapnil Dhamal (1), Sonia Yeh (1), Frances Sprei (1), Yuan Liao (1), Madhav Marathe (2), Christopher Barrett (2), Devdatt Dubhashi (3)

1: Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden; 2: Department of Computer Science, University of Virginia, Charlottesville, United States; 3: Department of Computer Science and Engineering, Chalmers University of Technology, Gothenburg, Sweden

The heterogeneous diversity of activity patterns within population groups has often been disregarded in most literature, resulting an unrealistic representation of travel behavior. We develop a stochastic approach combined with machine learning (ML) to generate heterogeneous activity in a synthetic population. We implement the novel methodology to model the mobility pattern of the synthetic population of Sweden. Comparing the simulated activity schedules with survey data, our results show that the methodology generates realistic mobility pattern of individuals. The proposed model with a realistic representation of activities can make an unique contribution to capture the complexity of travel behaviors, thus better inform policies to improve future transportation systems.

Keywords
Heterogeneous activity generation, Agent-based modeling, Activity-based modeling, Big data analytics, Machine learning

Feeling unpleasant in daily activities – Exploring the effects of travel and non-travel time use in Germany

Bhuvanachithra Chidambaram*, Joachim Scheiner

Technical University Dortmund, Germany

In this study, we examine the association between unpleasant feeling of daily activities (travel, paid and unpaid work) and various diverse factors: personal socio-economic status; travel behavior, travel time use and non-travel time use behavior (primary tasks and multitasking). We used the German National Time Use Survey 2012/13 and adopted multilevel logistic analysis. The results revealed that travel behaviour and travel time use (passive activities, ICT use, socialising, paid and unpaid work during travel) significantly explain the unpleasant feeling of travel activity. For paid work, factors such as socioeconomic attributes, paid work hours and multitasking had a significant positive effect on unpleasant feeling of paid work. For unpaid work, factors such as female gender, travel behavior, unpaid work hours and multitasking positively determine the unpleasant feeling. The interaction between gender and travel /non-travel time use has a significantly larger effect on men's unpleasant feeling on time use activities than women.

Keywords
Keywords: Activity based modeling, Gender interaction, Non-travel time use, Satisfaction Travel behavior, Travel time use, Work-family life

Parallel session 7B: Demand estimation

Efficient Gradient Estimation of Traffic Assignment Models with Iterative Backpropagation

Ashraf Uz Zaman Patwary* (1), Hong K. Lo (2), Francesco Ciari (1)

1: Polytechnique Montréal, Canada; 2: Hong Kong University of Science and Technology, China

Traffic assignment (TA) optimization is at the heart of many transportation planning and operation problems. For a reasonably sized network with high-dimensional decision variables, TA optimization quickly becomes intractable due to high computation time and a large number of function evaluations. Generally, TA models have cyclic dependencies among their components and hence, have no closed-form gradients, which is crucial for high dimensional optimization. This paper proposes an efficient TA gradient estimation technique called Iterative Backpropagation (IB) to solve this problem. IB exploits the iterative TA solution algorithms and generates the TA gradients while the TA model converges. IB neither requires solving any system of equations nor any additional functional evaluations irrespective of the problem dimension. In our experiments, IB gradients match the finite-difference gradients at machine precision. IB gradients are usable with any state-of-the-art gradient-based optimization algorithms and can be extended to a wide range of TA optimization problems.

Keywords
Iterative Backpropagation, TA Optimization, Gradient-based, OD estimation

Estimating travel demand based on OpenStreetMap in the context of urban digital twins

Lotte Notelaers*, Chris M.J. Tampère

Centre for industrial management, traffic and infrastructure, KU Leuven, Belgium

A digital twin of a smart city captures the dynamics of people interacting within the urban environment composed of several interconnected systems. Urban mobility, which is simulated by a traffic model within an urban digital twin, is becoming an increasingly complex component within this ecosystem. Demand modeling is an important part of the set-up of a traffic model for a city. Nevertheless, most cities do not have the data, budget, or experience to estimate the demand in their region. Therefore, this study develops a demand generation method that enables to easily estimate travel demand for any region. It is a trip-based modeling approach based on the freely-available land-use data of OpenStreetMap (OSM). The model is applied to a case study of Antwerp as part of the Flemish DUET pilot. It is shown a crude estimate of travel demand can be generated from widely available open OSM data.

Keywords
Keywords: Demand modeling, OpenStreetMap (OSM), Multi-modal transportation, Big data analytics, Digital Twins

Parallel session 7C: Multimodality

Mode share equilibrium with tradable credit scheme and license plate rationing

Louis Balzer*, Ludovic Leclercq

Université Gustave Eiffel, France

License plate rationing (LPR) is an established measure to decrease car demand and thus decrease exhaust gas emissions. However, it has significant drawbacks: drivers can circumvent this policy by acquiring a second vehicle, and it does not account for the users' necessity to drive their car. The Tradable Credit Scheme (TCS) was introduced about one decade ago as another Demand Management Strategy (DMS). We propose comparing LPR and TCS over a large and realistic simulation test case (morning commute in Lyon), considering several days as a horizon. A trip-based Macroscopic Fundamental Diagram (MFD) represents the congestion dynamics. The modal split between private cars and Public Transportation (PT) is computed at equilibrium. We show the TCS surpasses the LPR in terms of both social costs and carbon emissions.

Keywords
license plate rationing, mode choice, tradable credit scheme, traffic flow theory, transport economics and policy, trip-based MFD

Evaluating Mobility Service Providers' Strategies in an Activity-Based Supernetwork

Claudia Bandiera* (1), Richard D. Connors (1,2), Francesco Viti (1)

1: University of Luxembourg, Luxembourg; 2: University of Leeds, UK

A Mathematical Problem with Equilibrium Constraints (MPEC) is formulated to capture the relationships between multiple Mobility Service Providers (MSPs) and the users of a multimodal transport network. The network supply structure is represented as a supernetwork where users' daily activity chains are represented sequentially and their modal choices to reach different destinations are based on the mobility services active in each connection. At the upper level, a profit maximization formulation is introduced to describe MSPs' behaviour. At the lower level, groups of users choose the routes with the lowest cost, according to Wardrop's first equilibrium principle. Due to non-separable interactions between supernetwork links, the equilibrium conditions defining users travel behaviour are written as Variational Inequality (VI). Finally, a numerical example is presented in order to show the characteristics of the model when car-sharing, bus and private car are available in the network.

Keywords
Multi-modal transportation, Network Design Problem, Profit Maximization, Supernetwork, Variational Inequality

Parallel session 7D: Activity-based modelling

Modelling electric vehicles usage in a carsharing fleet using MATSim

Idriss El Megzari* (1), Ouassim Manout (2), Francesco Ciari (1)

1: Polytechnique Montreal, Canada; 2: ENTPE, Transport Urban Planning Economics Laboratory, Lyon, France

In many countries, urban transportation systems strive to serve travel demand. With increasing mobility needs and climate change concerns, carsharing, among other solutions, can be a serious alternative to private car. With current environmental concerns, carsharing operators have started to introduce electric vehicles into their fleet. The electrification of carsharing is challenging, for operators and users. In this paper, we examine the impact of weather conditions (temperature) and range anxiety on the adoption and use of electric shared cars in comparison with conventional cars.
The adoption of electric vehicles in the context of carsharing is simulated using the multi-agent system MATSim. Results show that, in the case of Montreal, the potential negative impact of temperature and range anxiety on carsharing demand and use is very limited. Findings of this research can be of interest to carsharing operators.

Keywords
Carsharing, Electric vehicles, Agent-based modelling, Range anxiety, Temperature, Battery

Integrated in- and out-of-home scheduling framework: A utility optimization-based approach

Negar Rezvany* (1), Tim Hillel (1,2), Michel Bierlaire (1)

1: EPFL, Switzerland; 2: University College London (UCL), United Kingdom

Existing activity-based modeling predominantly focus on out-of-home activities in order to understand transport demand. In this research, we extend the state of practice in activity-based modelling by determining both in- and out-of-home activities in a single scheduling framework. This approach has two main benefits: Firstly, it can capture the trade-offs between in-home and out-of-home activities. Secondly, in-home time-use patterns can be used to model high resolution energy demand.
Our work builds on an existing optimisation framework, which treats individuals as maximising their total utility from completed activities and incorporates multiple scheduling decisions simultaneously. The approach is tested on a set of detailed daily schedules extracted from the the 2016-2020 UK Time Use Survey data.
The results show that the model is able to generate peoples' daily activity schedules based on their individual preferences and constraints

Keywords
Activity-based modeling, Daily scheduling behavior, Discrete choice modelling, Mixed-integer optimization; Simulation, Time use survey data

Parallel session 7E: Traffic Flow Theory 2

High-occupancy vehicle lanes: modeling the upstream interface capacity

Mathis Boukhellouf* (1), Nicolas Chiabaut (2), Christine Buisson (3)

1: École nationale des travaux publics de l'État, Laboratoire d'Ingénierie Circulation et Transports, France; 2: Citec Ingénieurs Conseils SAS, France; 3: Université Gustave Eiffel, Laboratoire d'Ingénierie Circulation et Transports, France

This work contributes to the understanding of the behavior of the upstream end of a high-occupancy vehicle (HOV) lane. Indeed, just upstream of this lane, vehicles may change lanes to be sure they are allowed to use the downstream lane (either HOV or general-purpose lane(s)). This upstream end is therefore the place of lane changes that may reduce the capacity. To estimate this drop, we adapt an existing weaving section analytical model to this upstream interface. We assess this model by comparison with the maximal theoretical supply and with simulation results. Our model adaptation indeed reproduces a capacity drop. Although with a less important drop, simulation results are coherent, except for cases with 0 or 100% of the vehicles being highly occupied. Further work should focus on treating the successive lane changes when considering more than two upstream lanes, and on comparing the results with the ones of other simulators.

Keywords
capacity drop, high-occupancy vehicle lanes, microscopic traffic simulation, shared mobility, traffic flow theory, weaving section

Macroscopic Fundamental Diagrams for Low-Altitude Air City Transport

Yazan Safadi* (1), Rao Fu (2), Quan Quan (2), Jack Haddad (1)

1: Technion--Israel Institute of Technology; 2: Beihang University

Low-altitude aircraft is being developed as a new mode of urban transport; consequently, the penetration of low-altitude passenger and delivery aircraft into the urban airspace is inevitable soon. This will give rise to new urban air transport systems, called low-altitude air city transport (LAAT) systems.

Inspired by urban road networks, this paper investigates the collective and aggregate aircraft traffic flow diagrams, i.e. Macroscopic Fundamental Diagrams (MFDs) for LAAT systems. Firstly, aircraft collision-avoidance models with cooperative distributed control algorithms from the literature are implemented to describe the low-altitude aircraft interactions, implying the microscopic traffic behavior. Afterwards, using the generalized definitions of Edie, the MFD is constructed for LAAT networks, by linking flow, density, and speed. Different case study examples are simulated to analyze the MFD shapes for LAAT systems, considering different microscopic collision avoidance approaches and the effects of aircraft and airspace settings.

Keywords

Traffic Flow Theory, Macroscopic Fundamental Diagram, Low-Altitude Air City Transport System

Parallel session 8A: Parking management

Searching for parking: The case of Zurich

Christopher Tchervenkov*, Kay W. Axhausen

ETH Zurich, Switzerland

This study analyzes the extent of parking search behaviour in Zurich, Switzerland using segmented and labelled GPS data collected from a smartphone-based GPS tracking app. The GPS data corresponding to over 1,000 car trips ending within the city of Zurich are map-matched to the underlying OSM road network, and the least-cost path between the trip start and end points are then computed on the same network, with the difference in path length assumed to be attributed to parking search behaviour. This excess travel distance is found to be marginal across all trips and equal to 100\thinspace m. However, it depends on both trip purpose and parking availability. Work trips exhibit the shortest excess distance (76 m), whereas leisure trips the longest (128 m). The availability of parking at home and type of parking at work also play a strong role, with on-street parking leading to longer excess travel.

Keywords
GPS tracking, map-matching, parking search

Urban parking lot occupancy monitoring with drone flights

Sohyeong Kim*, Yura Tak, Emmanouil Barmpounakis, Nikolas Geroliminis

Urban Transport Systems Laboratory (LUTS), EPFL, Switzerland

Monitoring open space urban parking remains a challenging question due to the high cost of sensing. With the advancement of Unmanned Aerial Systems, also known as drones, which come with strong visual sensors, it becomes possible to observe the traffic stream from the unique drones' point-of-view. In this study, we aim to monitor the utilization level of open public parking lots by utilizing drones. Specifically, we deployed drones multiple times for two days over four main parking lots in the city of Pully, Switzerland. Once the parking spaces were located in the collected videos, they were classified as either free or busy using a trained neural network model. Finally, the occupancy rate over time and days was analyzed. Compared to other existing methods of monitoring parking lot occupancy, using drones is more efficient with competitive advantages in reducing times and cost while providing accurate measurements in a privacy-friendly way.

Keywords
Big data, Drone, Image Processing, Public parking space monitoring

Costs and benefits of parking charges in residential suburbs

Jonas Eliasson* (1), Maria Börjesson (2)

1: Linköping University, Sweden; 2: VTI, Sweden

We present a model for evaluating social costs and benefits of street parking charges, and apply it to parking charges recently introduced in suburban residential areas in Stockholm. We also report the charges' effects on parking demand and occupancy rates. The analysis shows that the direct effect of the charges was a substantial welfare loss. The model can also be used to calculate optimal parking charges and occupancy levels. Using parameters and demand functions estimated from the case study, we calculate optimal parking charges and occupancy levels, and show that the optimal charges are considerably lower than the introduced ones.

Keywords
parking charges, parking regulation, suburban streets, cost-benefit analysis

Parallel session 8B: Accessibility and equity

Space-time accessibility and equity in multimodal supernetwork: a case study in Rotterdam-The Hauge- metropolitan area

Jing Qin*, Feixiong Liao

Eindhoven university of technology, Netherlands, The

Space-time prism (STP) is an essential concept in time geography and has been predominately constructed in unimodal transport networks. Because of the vast trip chaining options by private vehicles and public transportation, it was challenging to construct STP over multimodal transportation networks. An efficient method has been put forward to narrow down the action space for trip chaining and construct STP efficiently in a multimodal supernetwork. This study applies the multimodal STP modeling for space-time accessibility and equity analysis with two accessibility indicators and two equity metrics to examine for a common activity in the Rotterdam-The Hague metropolitan area, the Netherlands. We found that multimodal trip chaining improves accessibility, especially for those without a car. Based on the accessibility indicators, Gini coefficients and the 20:20 ratios of the 20% richest people and 20% poorest people show that the study area has low inequity, and multimodal trip chaining can improve equity.

Keywords
accessibility, equity, multimodal supernetwork, space-time prism

A Statistical Assessment of Work-from-home Participation During Different Stages of the COVID-19 Pandemic

Natalia Barbour* (1), Nikhil Menon (2), Fred Mannering (3)

1: Delft University of Technology; 2: Penn State Harrisburg; 3: University of South Florida

Responses to the COVID-19 pandemic have dramatically transformed industry, healthcare, mobility, and education. Many workers have been forced to shift to work-from-home, adjust their commute patterns, and/or adopt new behaviors. This paper focuses on two major shifts along different stages of the pandemic. First, it investigates switching to work-from-home during the pandemic, followed by assessing the likelihood of continuing to work-from-home as opposed to returning to the workplace. Using a survey collected in July and August of 2020 in the U.S., it is found that nearly 50 percent of the respondents who did not work-from-home before but started to work-from-home during the COVID-19 pandemic, indicated the willingness to continue work-from-home. The methodological approach used to study work-from-home probabilities in this paper captures the complexities of human behavior by estimating two random parameters logit models with heterogeneity in the means and variances of random parameters.

Keywords
travel behavior and COVID-19, telecommute, random parameters model with heterogeneity in the means, work-from-home

Assessing transportation accessibility equity via open data

Amirhesam Badeanlou* (1), Andrea Araldo (2), Marco Diana (1)

1: Politecnico di Torino; 2: Institut Polytechnique de Paris - Télécom SudParis, France

We propose a methodology to assess transportation accessibility inequity in metropolitan areas. The methodology is based on the classic analysis tools of Lorenz curves and Gini indices, but the novelty resides in the fact that it can be easily applied in an automated way to several cities around the World, with no need for customized data treatment. Indeed, our equity metrics can be computed solely relying on open data, publicly available in standardized form. We showcase our method and study transportation equity of four cities, comparing our findings with a recently proposed approach.

Keywords
Transportation accessibility, Transportation equity, Open Data.

Parallel session 8C: Macroscopic modeling

On the overlap between regional paths in multi-region macroscopic fundamental diagram traffic equilibrium models

Lawrence Christopher Duncan*, Thomas Kjær Rasmussen

Technical University of Denmark, Denmark

Multi-region Macroscopic Fundamental Diagram (MFD) traffic equilibrium models have been developed as a computationally efficient alternative to classical route choice traffic assignment models. There remains a gap in the research, however, for adapting and extending existing state-of-the-art route choice models to formulate analogous (but context specific) regional path choice models. In this study, we focus on adapting/extending the most commonly used Path Size Logit (PSL) route choice model. A key difference between route choice and regional path choice is that for the latter the travel time experienced traversing through a region depends on the regional path being taken. Therefore, the degree to which two regional paths overlap depends not only on the regions that are shared but also the travel time that is shared within those shared regions. Accounting for this, we formulate a new Intersectional PSL regional path choice model and discuss/demonstrate its theoretical properties compared to standard PSL.

Keywords
discrete choice modelling, macroscopic fundamental diagram, multi-region system, regional path choice, regional path correlation, transport network modelling

An Empirical Macroscopic Bottleneck Model for the Randstad Area

Erik Teodoor Verhoef* (1), Bas Turpijn (2), Maarten Teun Verhoef (1)

1: VU Amsterdam, Netherlands, The; 2: Rijkswaterstaat, Netherlands, The

We propose an area-wide Macroscopic Bottleneck Model for the Dutch Randstad area and use it to estimate a relation between dynamic aggregate inflow patterns and travel delays on highways. We find plausible parameter estimates, and a strong time variation of marginal external congestion costs, which are €9.68 in the busiest 30 minutes and only €2.08 for the other 60 minutes in the busiest 90 minutes.

Keywords
Traffic congestion, Congestion modelling, Bottleneck model, Macroscopic Fundamental Diagram, Traffic Flow Theory

Exploring accelerated evolutionary parameter search for iterative large-scale transport simulations in a new calibration testbed

Sebastian Hörl*

IRT SystemX, France

Large-scale agent-based transport models of whole territories have become an important tool in research and planning of new services and policies. Yet, studies based on those tools are rarely reproducible due to the complexity of data sources and modeling processes. One important element towards fully replicable simulations is automatic calibration of behavioral and infrastructural model parameters. The present paper contributes to standardizing the calibration process by describing a consistent framework for benchmarking calibration objectives and optimization algorithms. Furthermore, the paper advances the current state of the art by exploring the integration of a search acceleration method for iterative simulators (opdyts) with sample-based evolutionary search algorithms. In a use case for Paris and the MATSim simulator, we demonstrate the applicability of the framework. We show that opdyts accelerates the parameter search process, although its comparative runtime benefits decrease with higher availability of computational resources.

Keywords
transport simulation, calibration, parameter search, acceleration, mode share, MATSim

Parallel session 8D: Advanced discrete choice modeling

Enriching discrete choice models with computer vision for understanding choice behaviour in the presence of visual stimuli

Sander Van Cranenburgh*

Delft University of Technology, Netherlands, The

Discrete Choice Models (DCMs) are a key methodology in the transportation. However, current DCMs literally suffer from a blind spot: they cannot handle visual information. This blind spot hampers (1) a deeper understanding of human choice behaviour in the presence of visual stimuli and (2) using DCMs to deduce economic outputs for policies that involve changes to the visual environment. This study aims to bring visual information, in the form of images, to the realm of choice modelling. Specifically, it develops a series of discrete choice models –with computer vision parts embedded in different ways– to model the behaviour of decision makers when confronted with alternatives comprising both visual stimuli and conventional numeric attributes.

Keywords
Computer vision, Discrete choice modelling, Machine Learning

A Benders decomposition for maximum simulated likelihood estimation of advanced discrete choice models

Tom Haering*, Claudia Bongiovanni, Michel Bierlaire

Swiss Federal Institute of Technology Lausanne (École Polytechnique Fédérale de Lausanne), Switzerland

In this paper, we formulate a mixed integer linear program (MILP) for the simulated maximum likelihood estimation (MLSE) problem and devise a Benders decomposition approach to speed up the solution process. This framework can be applied to any advanced discrete choice model and exploits total unimodularity to keep the master problem linear in the decomposition. The proposed decomposition approach is benchmarked against the original MILP formulation and PandasBiogeme. Computational experiments are performed on a binary logit mode choice model with up to 200 respondents. Results show that the Benders decomposition approach solves instances on average 35 and up to 100 times faster than the MILP while maintaining high quality solutions.

Keywords
benders decomposition, discrete choice, maximum likelihood estimation, mixed integer linear programming, simulation

Forecasting with Strategic Transport Models Corrected for Endogeneity

Thomas E Guerrero B* (1), C. Angelo Guevara (2), Elisabetta Cherchi (3), Juan de Dios Ortúzar (4)

1: Universidad Francisco de Paula Santander Ocaña, Colombia; 2: Universidad de Chile, Chile; 3: Newcastle University, UK; 4: Pontificia Universidad Católica de Chile, Chile

We propose a variation of the classical Control Function (CF) method, called Control Function Updated (CFU), which considers updating the endogeneity correction using information from the future equilibria. The proposed method is assessed using Monte Carlo simulation for a strategic transport model affected by three endogeneity sources, examining the equilibrium results for various future scenarios. We compare the CFU method by doing nothing and with the classical CF approach. The forecasts are evaluated in terms of recovering the true (simulated) travel times and two indices of fit. Results show that the endogenous (do nothing) model produces large biases in simulated travel times and poor goodness-of-fit measures that steeply worsen with time in future scenarios. The corrected models perform much better and, in particular, the new CFU approach shows statistically significant improvements over the classical approach in all scenarios tested.

Keywords
Endogeneity, discrete choice models, forecasting, control function, strategic transport models.

Parallel session 8E: Traffic Flow Theory 3

Penalized denoising of vehicle trajectories collected by a swarm of drones

Georg Anagnostopoulos*, Emmanouil Barmpounakis, Nikolas Geroliminis

Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland

Vehicle trajectory datasets collected in urban traffic environments with drones pose unique challenges in terms of denoising due to extensive visual restrictions, perspective distortions and human-induced errors. This article taps into the unexplored potential of penalties in the context of vehicle trajectory reconstruction with the example of the massive pNEUMA dataset. We contribute to the literature by shifting the focus of denoising from smoothing to anomaly detection. Specifically, we distinguish between stationary and non-stationary errors and argue that the latter accounts for the largest part of the noise. We propose a re-purposing of the Butterworth filter for the detection of anomalous events and enforce spatial autocorrelation constraints on the errors with functional data analysis. The calibration of our reconstruction makes further use of penalties and is inspired by the theory of human-machine interaction. Our method can be used for quantifying autocorrelated errors or for identifying network segments that are devoid of errors.

Keywords
anomaly detection, Butterworth filter, functional data analysis, penalized denoising

Two-level resolution neural network for freeway traffic prediction

Semin Kwak*, Danya Li, Nikolas Geroliminis

Urban Transport Systems Laboratory (LUTS), EPFL, Switzerland

As deep learning has achieved great success in different fields, introducing proper prior domain knowledge is proven to be an efficient way of improving neural networks' performance, which can also be applied in the transportation domain. Traffic forecasting is one of the most challenging problems heavily tackled by deep learning because it requires learning highly complex Spatio-temporal correlations of traffic states. In this paper, we suggest a two-level resolution deep neural network architecture, arguing that existing methods extract the correlations in a flat manner. The two-level resolution blocks promote decomposition of the Spatio-temporal correlations into low and high-resolution ones, which explain general changes and details of traffic speed. Therefore, each block learns a representative regional traffic fluctuating behavior and detailed local changes separately. We successfully apply this two-level resolution structure to two existing neural network models and obtain improved performance.

Keywords
Traffic speed prediction, Freeway sensor network, Two-level resolution block, Deep neural network

A macroscopic first-order lane-group-based signalized node model

Raheleh Yahyamozdarani*, Chris M.J. Tampère

KU Leuven, Belgium

In macroscopic dynamic network loading algorithms, node models that find the possible transfer flow at signalized intersections often disregard the role of turning lanes. This may result in finding wrong solutions when different turning lanes have different green times. This paper extends the recently presented node model of (Yahyamozdarani, Himpe, & Tampère, 2021) to a lane-group-based signalized node model. The presented node model can consider different green times for different turns coming from the same link while it does not impose any extra requirements on the link model. In fact, the link model remains ignorant of the lane compositions. Consequently, the signalized node model would be more accurate regarding the exact green time of each turn while the computational burden is kept limited and the compatibility with the connecting link model is unchanged.

Keywords
dynamic traffic assignment, first-order signalized node model, lane-based macroscopic signalized node model, macroscopic dynamic network loading, macroscopic signalized node model, traffic flow theory