SOE 10: Transport, Regional and Urban Dynamics

Time: Wednesday 13:00–15:40 Location: SOEa

SOE 10.1 Wed 13:00 SOEa

Adaptive Stop-Pooling for Sustainable Shared Mobility? — •Charlotte Lotze, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Ride-sharing – the bundling of simultaneous trips of several people in one vehicle – may help us to reduce the carbon footprint of human mobility [1,2]. Ride-sharing trades reduced total route traveled by vehicles for increased passenger travel times. Yet standard door-to-door ride sharing services come with the burden of many stops and detours to pick up individual passengers. Requiring some passengers to walk to nearby shared stops may reduce detours yet may become inefficient if spatio-temporal demand patterns do not well fit the stop locations. Here, we present a simple model of adaptive, on-demand stop pooling and analyze its influence on the performance of ride-sharing services. We find counteracting effects of stop pooling on the number of and distance between stops, inducing a roughly constant route length despite stop pooling benefits. Intriguingly, however, stop pooling also reduces the average travel time although passengers walk parts of their trip. Stop pooling may thus break the trade-off between route lengths and travel times. We conclude, that dynamic stop pooling could enable higher sustainability and service quality simultaneously, potentially also in real world ride sharing systems. References: [1] Molkenthin et al., Scaling Laws of Collective Ride-Sharing Dynamics, Phys. Rev. Lett. 125:248302 (2020); [2] Storch et al., Incentive-driven discontinuous transition to high ride-sharing adoption, arXiv:2008.11079 (2020).

SOE 10.2 Wed 13:20 SOEa

The future of traffic jams: Forward propagating congestion in electric vehicle charging infrastructure — •Philip Marszal[1], Malte Schröder[1], and Marc Timme[1,2] — [1]Chair for Network Dynamics, Center for Advancing Electronics and Institute for Theoretical Physics, Technical University of Dresden, Dresden, Germany — [2]Lakeside Labs, Klagenfurt, Austria

Individual motorized mobility is becoming increasingly electrified. The unique properties of electric vehicles promise to give rise to new collective traffic flow dynamics, which are largely unexplored as of now. Here we demonstrate a new type of congestion in the utilization of charging infrastructure, emerging solely from correlations in driver's charging dynamics due to queue-avoidance behavior on long range trips. We explain the formation of forward-propagating congestion waves as phase separation of the traffic flow into free and congested phases, occurring already before the system reaches its theoretical capacity limit. While current numbers of electric vehicles compared to available charging stations are far below the onset of congestion, these results reveal collective dynamics that may influence how future infrastructure supporting sustainable modes of mobility will be built.

SOE 10.3 Wed 13:40 SOEa

Towards Optimal Bikeability of Urban Mobility Networks — •Christoph Steinacker, David-Maximilian Storch, Marc Timme, and Malte Schröder — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Individual transport in cities is most commonly enabled by private cars, an unsustainable status quo both ecologically and socially. On typical urban distance scales, bicycling constitutes a more sustainable alternative that is broadly accessible. Yet, insufficient and poorly designed bike path networks often hinder more prevalent bike use. Here, we propose an optimisation scheme for bike path networks that enables smooth and safe bicycle travel in cities. Evaluating bike-sharing data on millions of city trips, we estimate bike travel demand and find greatly bike-friendly network topologies. Interestingly, a reverse percolation process that starts from a complete bike path network covering all streets and systematically lowers the number of bike paths by eliminating least used bicycle paths yields topologies much more suitable than a forward process with optimised iterative addition of paths. Even just a small number of bike paths, if chosen wisely, may result in a bike-friendly network. These results may support the planning of sustainable mobility networks, strongly improving urban bikeability.

SOE 10.4 Wed 14:00 SOEa

Purely fluctuation-induced congestion in street traffic — •Verena Krall[1], Max Burg[2,3], Malte Schröder[1], and Marc Timme[1] — [1]Chair for Network Dynamics, Center for Advancing Electronics Dresden (cfaed) and Institute of Theoretical Physics, Technical University Dresden, Germany — [2]Institute for Theoretical Physics and Centre for Integrative Neuroscience, University of Tübingen, Germany — [3]Bernstein Center for Computational Neuroscience, Tübingen, Germany

Traffic congestions may emerge spontaneously - out of nowhere. Statistical physics studies provide both qualitative and quantitative insights, yet so far they focused on the consequences of external factors such as street bottlenecks or human behavioral imperfections. Here we present a simple model of traffic flow on a street segment in which congestion spontaneously emerges purely due to fluctuations in the number of incoming vehicles [1]. Agent-based simulations and analytical estimates indicate that this instability exists even in regimes where mean field theory predicts stable traffic flow. Our results thus underline the limitations of mean field analysis for predicting the collective nonlinear dynamics of mobility systems.

[1] V. Krall et al., Number Fluctuations Induce Persistent Congestion, Transport Findings, December 2020. https://doi.org/10.32866/001c.18154.

SOE 10.5 Wed 14:20 SOEa

On the relation between transversal and longitudinal scaling in cities — •Fabiano L. Ribeiro — Universidade Federal de Lavras, Lavras, Brazil

Empirical evidence has been shown that some urban variables scale non-linearly with the city population size. More specifically, some socio-economic variables, such as the number of patents, wages and GDP, show a super-linear behaviour with the population of the city. On the other hand, infrastructure variables, such as the number of gas stations and length of streets, scale sub-linearly with the city population, generating a scale economy. However, does this scaling properties observed in a system of cities (transversal scaling) also work for individual cities in different stages of their growth process (longitudinal scaling)? The answer to this question has important policy implications, but the lack of suitable data has so far hindered rigorous empirical tests. The work that will be presented was developed looking at the evolution of two urban variables, GDP and water network length, for over 5500 cities in Brazil. It will be shown that longitudinal scaling exponents are city-specific, however they are distributed around an average value that approaches the transversal scaling exponent provided that the data is decomposed to eliminate external factors, and only for cities with a sufficiently high growth rate. This result adds complexity to the idea that the longitudinal dynamics is a micro-scaling version of the transversal dynamics of the entire urban system.

SOE 10.6 Wed 14:40 SOEa

Bimodal Transport: Combining Demand Responsive and Public Transport — •Helge Heuer, Puneet Sharma, Stephan Herminghaus, and Knut M. Heidemann — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Bimodal Transport describes the combination of traditional Public Transport (PT), also called Fixed Route Transport (FRT), and Demand Responsive Transport (DRT). In many of the existing DRT services there is the option to share the rides with other customers to reduce the price and increase the ecological efficiency of the individual rides. Bimodal Transport aims to combine the flexibility of DRT services with the efficiency of classical line services. An advantage of shared mobility in general is the comparably low carbon footprint and less general pollution, resulting from the reduction of active vehicles in comparison to unshared transportation.

Here we study bimodal transport via simulations on a square lattice. We analyze the performance of the system under various parameter settings and identify under which conditions the overall ecological footprint can be minimized while maintaining satisfactory customer service. Simulations are compared to an effective analytical theory.

SOE 10.7 Wed 15:00 SOEa

Policy and Innovation Spreading on the Global City Network — •Niklas Kitzmann[1], Jonathan Donges[1], Xuemei Bai[2], Pawel

Romanczuk[3], and Ricarda Winkelmann[1] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Fenner School of Environment & Society, Australian National University, Australia — [3]Institute for Theoretical Biology, Humboldt University of Berlin, Germany

In the much-needed global sustainability transformation, cities may play an important role. Being among the prime drivers of GHG emissions, as well as of sustainable policy innovation and adoption, cities are known to learn from each other to reduce, prepare for and react to the coming environmental changes. In this way, they can be conceptualized as nodes in a globe-spanning learning network, potentially yielding insights into the social tipping dynamics that are so urgently needed to control the human impacts on the Earth System.

Here, we aim to identify whether network-based contagion effects are dominant in sustainability policy adoption by cities. An attempt is made to approximate the inter-city innovation spreading network using empirical data of the global air traffic network and other city-to-city connections. We analyze the spreading of several municipal policies and innovations related to sustainability, such as the implementation of Bus Rapid Transit public transport systems, as contagion processes on these inter-city networks. Surrogate data methods and a dose-response-contagion approach are used to identify network-spreading-correlations. We then investigate the nature of the spreading process by attempting to reproduce it using generative models.

SOE 10.8 Wed 15:20 SOEa

Indication of correlations between urban scaling and Zipf's exponent — Haroldo V. Ribeiro[1], Milena Oehlers[2], Ana I. Moreno-Monroy[3], Jürgen P. Kropp[2,4], and •Diego Rybski[2,5] — [1]Departamento de Fisica, Universidade Estadual de Maringa, PR 87020-900, Brazil — [2]Potsdam Institute for Climate Impact Research - PIK, Member of Leibniz Association, P.O. Box 601203, 14412 Potsdam, Germany — [3]OECD Centre for Entrepreneurship, SMEs, Regions and Cities, Honorary Associate, Geography and Planning Department, University of Liverpool, 2 rue Andre-Pascal, 75016 Paris, France — [4]Institute for Environmental Science and Geography, University of Potsdam, 14476 Potsdam, Germany — [5]Department of Environmental Science Policy and Management, University of California Berkeley, 130 Mulford Hall #3114, Berkeley, CA 94720, USA

Zipf's law and urban scaling are two fundamental paradigms researched in urban science. They have mostly been investigated independently and are perceived as disassociated matters. Here we present a large scale investigation about the connection between these two laws using population and GDP data from 96 countries. We empirically demonstrate that both laws are tied to each other and derive an expression relating the exponents, capturing the main tendency of the empirical relation. Simulations yield very similar results to the real data after accounting for fluctuations. Our research puts forward the idea that urban scaling of GDP does not solely emerge from intra-city processes.