# SOE 6: Mobility, Traffic Dynamics, Urban and Regional Systems

Time: Tuesday 10:45–12:45 Location: GÖR/0226

SOE 6.1 Tue 10:45 GÖR/0226

**Percolation on the "urban influence" field: analyzing Europe's urban fabric** — •Renan Lucas Fagundes[1] and Diego Rybski[1,2] — [1]IOER, Dresden — [2]CSH, Vienna

We investigate the connectivity of urban settlements using the concept of level-set percolation (LSP). Therefore, we introduce a notion of urban influence, quantifying the impact of the presence of urban settlements in their surroundings. To be specific, we define a power-law field over the urban settlements in Europe in 2018. This field can be understood in a similar fashion as 2D Gaussian Random Field but with a power-law. We find a relationship between the level where the second largest cluster reaches a maximum – an indicator of the percolation transition – and the imposed field-exponent. The exponential slope of the relation correlates with the size of the country. We speculate that the critical behavior of the field is being driven by the spatial organization of the urban structure.

SOE 6.2 Tue 11:00 GÖR/0226

**Global settlement percolation: estimating critical distances** — •Diego Rybski — IOER Dresden

Cities and settlements can be understood as percolating systems. We apply spatial clsutering, where any two items belong to the same cluster if their Euclidean distance is smaller than a threshold. Varying this threshold, at a critical distance a transtion occurs where a giant cluster emerges – resembling a percolation transition. We systematically analyze high-resolution data on the global scale and estimate this critical distance for various spatial units. We find that the critical distance is complementary to other geographical indicators. Our estimates can be of use for down-stream research.

SOE 6.3 Tue 11:15 GÖR/0226

**Scaling laws beyond cities** — •Yiwei Yang[1,2], Benedikt Grammer[1], Rafael Prieto-Curiel[3], David Frantz[4], Helmut Haberl[1], and Dominik Wiedenhofer[1] — [1]BOKU University, Vienna, Austria — [2]MPG-DLU, Jena, Germany — [3]CSH, Vienna, Austria — [4]Trier University, Trier, Germany

Urban scaling laws reveal that larger cities tend to be more resource-efficient and innovative, but the standard framework has two well-known limitations: (1) the one-city-one-value approach assumes that the entire urban area is the only meaningful unit of analysis; (2) carefully delineated city boundaries artificially divide what is in fact a continuous human settlement system. These issues motivate examining scaling relationships within cities and across the rural-urban continuum. We hypothesize that fine-scale properties, in particular infrastructure-related attributes tied to fractal urban form, scale with population across the full fabric of human settlements. We test this using high-resolution gridded maps for the contiguous United States, analyzing how built-environment material stocks, service provisioning, and operational greenhouse gas emissions scale with population at the settlement-cell level. Through stepwise empirical tests, we not only demonstrate that scaling is present at fine spatial scales within human settlements, but also identify three important features of intra-settlement scaling. Our findings reframe the view that the city is the sole scale at which scaling laws arise, reveal pronounced intra-settlement heterogeneities, and offer practical implications for the analysis and planning of sustainable settlement development.

**15 min. break**

SOE 6.4 Tue 11:45 GÖR/0226

**Higher-order interactions yield synergistic infrastructure backbones** — •Christoph Steinacker[1], Henrik Wolf[2], Marc Timme[1], and Malte Schröder[1] — [1]Chair of Network Dynamics, Center for Advancing Electronics Dresden (cfaed) and Institute of Theoretical Physics, TUD Dresden University of Technology, 01062 Dresden, Germany — [2]AMOLF, Amsterdam, Netherlands

Infrastructure networks essentially underlie human mobility across all modes of transport. Higher-order interactions among different network elements impact network performance as they generically induce modified usage at every element across the network. Here, we consider such higher-order interactions to reveal and quantify the synergies between different link upgrades in transport networks. While network expansion strategies based on first-order, individual link importance result in scattered, disconnected networks, sets of pairs of mutually synergistic links automatically form connected backbones of infrastructure networks. We illustrate the approach with a perturbed utility route choice model for bicycle traffic on empirical urban street networks. Our results not only provide a novel theory of evaluating complex transport networks beyond individual link importance, they may also help to guide strategic network planning in practice.

SOE 6.5 Tue 12:00 GÖR/0226

**Where2Share–Complex system predictions of ridepooling potential in Germany** — Philip Marszal, Felix Jung, Marc Timme, and •Malte Schröder — Chair of Network Dynamics, Center for Advancing Electronics Dresden (cfaed) and Institute of Theoretical Physics, TUD Dresden University of Technology, 01062 Dresden, Germany

Complex system modeling often provides general insights about similar systems in vastly different settings by identifying the key mechanisms driving their dynamics. Here, we demonstrate how this perspective may help avoid many individual case studies and expensive pilot projects when planning on-demand ridepooling services that promise to reduce the number of cars on the road and cut back emissions by dynamically combining trips of multiple users in the same vehicle. By exploiting the transferability of complex system models of ridepooling based on a small number of cornerstone parameters, we built an open-data framework to estimate the potential reliability and efficiency of these services. We apply our framework to create a map of the ridepooling potential in Germany, quantifying key performance and operating parameters of ridepooling services across more than 400 vastly different service areas. Our framework is easily applicable to other regions and provides valuable insights about the influence of network topology, fleet size, and demand structure on the potential performance of ridepooling services. The results presented here may help focus the planning of ridepooling services by informing decision-making from the earliest point.

SOE 6.6 Tue 12:15 GÖR/0226

**Self-organized co-existence of fixed and flexible pooling routes** — •Nora Molkenthin, Karolin Stiller, and Alexander Schmaus — Potsdam Institute of Climate Impact Research (PIK)

Shared pooled mobility describes a diverse class of nonlinear, nonlocally coupled transport models, which give rise to rich, yet currently not fully understood dynamics. In this system we have observed the spontaneous emergence of periodic trajectories in passenger-optimized as well as fleet-distance optimized ride-pooling simulations at moderate to high request densities. Despite the uniformly distributed origin-destination pairs as driving input, we find partially periodic routes for some parameter and network choices, while at others, all routes remain unstructured. This dynamical symmetry breaking from unstructured to partially periodic trajectories occurs as the request load increases. These findings suggest a new class of chimera-like behaviour in real-world-inspired, spatially embedded, non-oscillatory systems. This finding has a natural interpretation as a regime of emergent co-existence between shared pooled mobility and line-based public transport, even without policy intervention.

SOE 6.7 Tue 12:30 GÖR/0226

**Pulses, waves, and chaos in migration dynamics** — Niraj Kushwaha[1], Woi Sok Oh[2], and •Edward Lee[1] — [1]Complexity Science Hub, Vienna, Austria — [2]University of Waterloo, Waterloo, Canada

Decisions to migrate depend on others' decisions. Dependence can produce both stable long-term trends and sudden transitions, which appear in data but could be the result of either exogenous drivers or of endogenous dynamics. We propose a simple migration model that accounts for social influence and individual heterogeneity in decisions to migrate. The minimal model displays hysteresis, waves, and chaotic-like regimes. This occurs in special locations of parameter space, suggesting that migration response to external conditions could be highly dependent on whether the system is poised near or far away from dynamical instability. Conditioning on this distance would be key to determining "causal drivers" of migration. In the context of displacement, for example, this would be relevant for oft-considered correlates like armed conflict and onset of natural disasters. We show how the model aligns with features of migration statistics including from internal displacement and maritime crossings.