

CT 2016  
CS 16

CTCS – Cities as Complex Systems  
structure, scaling, and economics

Herrenhausen Palace, Hanover  
13.-15.7.2016

# Cities as Complex Systems – Structure, Scaling, and Economics (CTCS2016)

Herrenhausen Palace, Hanover  
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Symposium Brochure

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# 1 Preface

For more than a century, quantitative approaches have been used to investigate cities. Recently, urban allometry – in the form of a super- or sub-linear dependence of an urban indicator on the population size – has been reported, causing a ripple in the general interested scientific community, since for some interpretations, large cities are considered more efficient e.g. in terms of patents or gross domestic product. The question whether small or large cities are more efficient is very relevant as illustrated by the CO<sub>2</sub> emissions attributed to them. However, most recent studies question the universality of urban allometry. One key problem is how the definition of cities influences the scaling exponents. In particular, a simple coherent theory of urban allometry is missing, which then would be consistent with the economics of cities, their diversity, and their geography, i.e. taking space into account.

Therefore, the symposium “Cities as Complex Systems (CTCS) – Structure, Scaling, and Economics” aims at a critical inspection and a constructive discussion, with the promise of new research ideas and innovative science. The three overarching topics of the symposium – which is generously funded by VolkswagenFoundation – are urban allometry, urban economics, and urban morphology – unifying the three would represent a breakthrough in the science of cities. We are glad that we could form a group of 45 researchers from such diverse fields like physics, economics, or geography to discuss and investigate cities as complex systems.

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## **3 Programme**



| <b>Day 1: 13<sup>th</sup> July 2016 (Wednesday)</b> |              |                             |   |
|---|--------------|-----------------------------|---|
| <b>Session</b>                                      | <b>Begin</b> | <b>Name</b>                 | <b>Title</b>  |
| <b>Registration</b>                                 | 8:00         |                             |   |
| <b>Opening</b>                                      | 9:00         | Diego Rybski                | Welcome notes   |
|   | 9:10         | Jürgen P. Kropp             | Introductory Remarks: The future of city research   |
|   | 9:30         | Mike Batty                  | A Science of Cities: Historical Precedents, Contemporary Challenges, Open Questions: Framing the Debate and the Meeting |
| <b>Networks, Flows and Transport</b>                | 10:00        | José J. Ramasco             | Digital imprints reveal integration of migrant communities in world cities  |
|   | 10:20        | Yuri Mansury                | City Size, Scaling, and Connectivity in Spatial Systems with Interregional and Local Network Interactions               |
|   | 10:40        | Vsevolod Salnikov           | Mining open datasets for transparency in taxi transport in metropolitan environments                                    |
|   | 11:00        |                             | Quick Discussion, Urgent Questions  |
| <b>Tee/Coffee</b>                                   | 11:20        |                             |   |
| <b>Urban Morphologies</b>                           | 11:40        | Efrat Blumenfeld-Lieberthal | Exploring the effect of morphological and topological features on spatial perception in virtual urban environments      |
|   | 12:00        | Michael T. Gastner          | Density-equalizing map projections – the past, the present and the future   |
|   | 12:20        | Bin Zhou                    | About city size, fractality, and anisometry – correlations with urban heat island intensity                             |
|   | 12:40        | Ramana Gudipudi             | City Density and CO2 Efficiency   |
|   | 13:00        |                             | Quick Discussion, Urgent Questions  |
| <b>Lunch</b>  | 13:20        |                             |   |
| <b>Urban Allometry</b>                              | 14:20        | Somwrita Sarkar             | Do income distributions scale with city size?   |
|   | 14:40        | Haroldo V. Ribeiro          | Rural to urban population density scaling of crime and property transactions  |
|   | 15:00        | Julian Laabs                | Scaling Archaeology? A glimpse on prehistoric settlement research in Neolithic alpine lake shore villages.              |
|   | 15:20        | Nina Schwarz                | Explaining urban allometry – factoring in the countryside   |
|   | 15:40        |                             | Quick Discussion, Urgent Questions  |
| <b>Tee/Coffee</b>                                   | 16:00        |                             |   |
| <b>Urban Spatial Structure</b>                      | 16:20        | Angelika Krehl              | Quantitative assessment of urban spatial structure – a contribution to the discussion.                                  |
|   | 16:40        | Thomas Louail               | Crowdsourcing the Robin-Hood effect in cities   |
|   | 17:00        | Robert Hecht                | Identification of residential building types in topographic databases and maps using machine learning techniques        |
|   | 17:20        | Sven Müller                 | Spatio-temporal variation rooftop photovoltaics in Germany  |
|   | 17:40        |                             | Quick Discussion, Urgent Questions  |
|   | 18:00        | Marc Barthelemy             | Revisiting urban economics in light of data   |
|   | 18:40        |                             | Discussion  |
| <b>Dinner</b>                                       | 19:00        |                             |   |

| Day 2: 14 <sup>th</sup> July 2016 (Thursday) |       |                      |   |
|--|-------|----------------------|---|
| Session                                      | Begin | Name                 | Title   |
|  | 9:00  | Gilles Duranton      | Urban form and driving: Evidence from US cities   |
| <b>Economic Approaches I</b>                 | 9:40  | Clémentine Cottineau | Agglomeration Economies or Urban Inequalities?  |
|  | 10:00 | Giulia Carra         | Modeling the relation between income and commuting distance                                   |
|  | 10:20 | Cheng Guo            | Linking income with segregation and urban sprawl – findings from a stylized agent-based model |
|  | 10:40 | Olivier Finance      | Scaling laws and transnational investment in French cities (2003-2015)                        |
|  | 11:00 |                      | Quick Discussion, Urgent Questions  |
| <b>Tee/Coffee</b>                            | 11:20 |                      |   |
| <b>Economic Approaches II</b>                | 11:40 | Christoph Hedtrich   | Technological Change and Urban Inequality   |
|  | 12:00 | Céline Rozenblat     | Multi-level scaling laws of cities in multinational firms' networks                           |
|  | 12:20 | Max Nathan           | Cities, clustering and innovation in UK technology firms: what can big data tell us?          |
|  | 12:40 |                      | Quick Discussion, Urgent Questions  |
| <b>Lunch</b>                                 | 13:00 |                      |   |
| <b>Scaling and Allometry</b>                 | 14:00 | Andri Brenner        | Romerian Power Laws and Urban Growth: An Approach to Enter the Black Box of Urban Allometry   |
|  | 14:20 | Hyejin Youn          | Scaling and universality in urban economic diversification                                    |
|  | 14:40 | Jens Suedekum        | The pan-European population distribution across consistently defined functional urban areas   |
|  | 15:00 | Deborah Strumsky     | Consequences of Day-time and Night-time Activity Across Spatial Levels for Urban Scaling      |
|  | 15:20 |                      | Quick Discussion, Urgent Questions  |
| <b>Tee/Coffee</b>                            | 15:40 |                      |   |
|  | 16:00 | Denise Pumain        | Interpreting urban scaling laws in a variety of territorial and disciplinary contexts         |
|  | 16:40 |                      | Quick Discussion, Urgent Questions  |
|  | 17:00 |                      | Panel-Discussion & Focus Groups   |
| <b>Dinner</b>                                | 19:00 |                      |   |

| Parallel Session |       |          |      |              |
|------------------|-------|----------|------|--------------|
| Session          | Begin | Duration | Name | Title        |
| <b>Tutorials</b> | 11:40 | 0:30     | NN   | Tutorial I   |
|                  | 12:10 | 0:30     | NN   | Tutorial II  |
|                  | 12:40 | 0:20     | NN   | Tutorial III |
| <b>Lunch</b>     | 13:00 |          |      |              |

| <b>Day 3: 15<sup>th</sup> July, 2016 (Friday)</b> |              |                                   |   |
|---|--------------|-----------------------------------|---|
| <b>Session</b>                                    | <b>Begin</b> | <b>Name</b>                       | <b>Title</b>  |
|   | 9:00         | Juval Portugali,<br>Hermann Haken | Information, adaptation and selforganization:<br>Implications to urban allometry  |
| <b>Morphologies<br/>and<br/>Representations</b>   | 9:40         | Tony Hargreaves                   | Converting regional forecasts of average<br>densities into 3D tiles to represent the variability<br>of the housing stock and the potential of<br>decentralised technologies |
|   | 10:00        | Martin Behnisch,<br>Robert Hecht  | From Building Footprint Data to Building<br>Archetypes  |
|   | 10:20        | Felix Creutzig                    | Urban typologies to bridge the gap between<br>idiosyncratic cities and global environmental<br>change   |
|   | 10:40        | Alberto Hernando de<br>Castro     | Orthonormal collective modes in human<br>behaviour: looking for demographic resonances  |
|   | 11:00        |                                   | Quick Discussion, Urgent Questions  |
| <b>Tee/Coffee</b>                                 | 11:20        |                                   |   |
|   | 11:40        |                                   | Group work on special issue   |
| <b>Lunch</b>                                      | 13:00        |                                   |   |
|   | 14:00        |                                   | Group work and presentation   |
| <b>Networks<br/>And<br/>Disruptions</b>           | 15:00        | Laetitia Gauvin                   | User-based representation of time-resolved<br>multimodal public transportation networks   |
|   | 15:20        | Carlos Molinero                   | The angular nature of road networks   |
|   | 15:40        | Aleix Bassolas                    | Collapse of public transport networks under<br>stress   |
|   | 16:00        | Hadrien Salat                     | Measuring inequality through the multifractality<br>of house prices in London and Paris   |
|   | 16:20        |                                   | Quick Discussion, Urgent Questions  |
| <b>Tee/Coffee</b>                                 | 16:40        |                                   |   |
|   | 17:00        | Dagmar Haase                      | Reconceptualizing Cities and The Urban for<br>Sustainability and Transition Discussions   |
|   | 17:40        |                                   | Quick Discussion, Urgent Questions  |
|   | 18:00        |                                   | Closing Session   |
| <b>Snacks</b>                                     | 18:30        |                                   |   |

## 4 Abstracts

**4.1 13.7.2016 (Wednesday)**

13.7.2016 (Wednesday)

## **Digital imprints reveal integration of migrant communities in world cities**

**José J. Ramasco**

13.7.2016 (Wednesday), 10:00-10:20

People are constantly moving within cities and countries, facing the fact of the integration in habits and laws of new local cultures. Immigration phenomena have been studied and described so far by census data, which are indeed expensive to take, both in term of cost and time. Here we conduct an extensive analysis of the migration phenomena in 58 cities in the world by means of Twitter users languages and their spatial distribution within urban areas. Results allowed us to characterized cities by their “Power of Integration”, as an attitude of hosting immigrant communities in urban areas, and by the corresponding process of integration of languages into different cultures, which is a quantitative measure of the differences between welcoming and hosting people in urban areas.

## **City Size, Scaling, and Connectivity in Spatial Systems with Interregional and Local Network Interactions**

**Yuri Mansury**

13.7.2016 (Wednesday), 10:20-10:40

Cities have become the main medium of economic and social exchanges in today's increasingly interconnected world. Connections naturally lead to networks, which pervade complex spatial systems. This study presents the empirical evidence showing that the relationship between local interactions and city size exhibits super-linear scaling with the exponent greater than 1, while long-range connections scale linearly with the unit exponent. The power exponents thus suggest that the impact of population size on connectivity is stronger within cities than between cities. The study next develops an agent-based model to generate a realistic settlement distribution and urban networks from the bottom-up in a spatial setting. Agent-based simulation results show the consistency between the power-law distribution of the population and the scale-free connectivity. Finally, coupling the spatial network with a tipping diffusion model introduces new micro-foundations to the agent-based modeling framework. The multi-modal approach allows the analysis of the evolution of network connectivity, city sizes, and social norms within a single unified framework.

13.7.2016 (Wednesday)

## **Mining open datasets for transparency in taxi transport in metropolitan environments**

Vsevolod Salnikov

13.7.2016 (Wednesday), 10:40-11:00

Uber has recently been introducing novel practices in urban taxi transport. Journey prices can change dynamically in almost real time and also vary geographically from one area to another in a city, a strategy known as surge pricing. In this work, we explore the power of the new generation of open datasets towards understanding the impact of the new disruption technologies that emerge in the area of public transport. With our primary goal being a more transparent economic landscape for urban commuters, we provide a direct price comparison between Uber and the Yellow Cab company in New York. We discover that Uber, despite its lower standard pricing rates, effectively charges higher fares on average, especially during short in length, but frequent in occurrence, taxi journeys.

Building on this insight, we develop a smartphone application, OpenStreetCab, that offers a personalized consultation to mobile users on which taxi provider is cheaper for their journey. After a big success in New York with thousands of users the application is already expanded to London and brought to a new level for deeper feedback. The application users journey queries have provided additional insights on the potential savings similar technologies can have for urban commuters, with a highlight being that on average, a user in New York saves 6 U.S. Dollars per taxi journey if they pick the cheapest taxi provider. We run extensive experiments to show how Uber's surge pricing is the driving factor of higher journey prices and therefore higher potential savings for our application's users. Finally, motivated by the observation that Uber's surge pricing is occurring more frequently than intuitively expected, we formulate a prediction task where the aim becomes to predict a geographic area's tendency to surge. Using exogenous to Uber data, in particular Yellow Cab and Foursquare data, we show how it is possible to estimate customer demand within an area, and by extension surge pricing, with high accuracy.



## **Exploring the effect of morphological and topological features on spatial perception in virtual urban environments**

**Efrat Blumenfeld-Lieberthal** and Juval Portugali

13.7.2016 (Wednesday), 11:40-12:00

The core objective of this work is to examine empirically the impact of morphological and topological information on the way urban agents perceive an unfamiliar urban environment. We propose to do so from a conjunction between three theoretical bodies of work: complexity theories of cities (CTC), spatial cognition and information theory. For that, we use an innovative and challenging approach, namely, we develop virtual urban environments that contain and convey different quantities of morphological information and allow virtual movement of urban agents in them.

Every urban element conveys two forms of information: Shannon's information that refers to the quantity of information conveyed by an object to a receiver, and semantic information, referring to the meaning conveyed by this object. Since our aim here is to assess the morphological Shannonian information, we seek to reduce the semantic information to a minimum (ideally we would have liked to completely isolate the Shannonian information, but it is impossible to entirely exorcise the semantic information that is embedded in people's minds). Virtual Reality (VR) technology enables us to build an abstract urban morphology with minimal semantic information. That is, virtual environment that focuses on the shapes of the buildings and the voids between them, and enables movement in this VR in Real Time.

We developed a number of abstract, virtual environments that represent different morphological and topological features of the environments. In these environments we run experiments with participants that will explore the above abstract environments on the VR in a real time system. The above environments will be converted into a dual network (meaning - networks where the streets represent nodes and the intersections/squares represent the links between them) and their topological characteristics will be analyzed based on these networks. Lastly we will present a comparison between the way the participants moved and perceived the different environment and compare these results to the morphological and topological attributes of the environments.

13.7.2016 (Wednesday)

## Density-equalizing map projections – the past, the present and the future

Michael T. Gastner

13.7.2016 (Wednesday), 12:00-12:20

Density-equalizing map projections, also known as cartograms, are projections of geographic space that scale areas (e.g. countries or provinces) in proportion to total population, average income, gross domestic or other numeric data. The earliest cartograms from the beginning of the 20th century were designed on a case-by-case basis. Today computers can automate the generation of cartograms. I will briefly review algorithms that have been proposed since the 1960s. I will explain a diffusion-based technique that I developed a decade ago and that has been popularised by "The Atlas of the Real World". Although this algorithm performs well in terms of shape preservation and speed, I will argue that some changes should lead to further improvements.

**About city size, fractality, and anisometry – correlations with urban heat island intensity**

Bin Zhou, Diego Rybski, and Jürgen P. Kropp

13.7.2016 (Wednesday), 12:20-12:40

In recent decades, cities have gained, increasing attentions, as cities cogently link both (1) natural systems, through e.g. human-induced land cover modification and subsequent biophysical changes in the planetary boundary layer, and (2) socio-economical systems, by providing shielding and jobs, creating enormous wealth but also poverty. Here we study urban morphological and structural indicators, such as city size, fractality, and anisotropy and investigate how they can influence the urban heat island effect, according to which urban areas experience an elevated temperature than their rural surroundings. Our results for the largest 5000 European cities suggest that all the three indicators are correlated among each other and influence the urban heat island intensity: the larger and the more compact a city is, the higher is its urban heat island effect, although compact and high-density cities are supposed to bring about more benefits in public transportation and greenhouse gas reductions. These results could be of great importance in the current debate on urban sustainability, making us rethink how to adapt our cities more resilient, in a warming world.

13.7.2016 (Wednesday)

## City Density and CO2 Efficiency

Ramana Gudipudi

13.7.2016 (Wednesday), 12:40-13:00

Recent literature on urban allometry displayed how certain socioeconomical and environmental parameters scale with urban population size. Although such a scaling of urban parameters gives better insights about our understanding about cities, they fail to capture a major trait in city specific physical characteristics such as population density. In this work, we analyze how CO2 emissions from buildings and on-road transport scale with population density. Previous research done on finding this relationship led to contradictory results owing to urban/rural definition conundrum and the varying methodologies for estimating GHG emissions. This work addresses these ambiguities by employing the City Clustering Algorithm (CCA) and utilizing the gridded CO2 emissions data. Our results, derived from the analysis of all inhabited areas in the US, show a sub-linear relationship between population density and the total emissions (i.e. the sum of on-road and building emissions) on a per capita basis. Accordingly, we find that doubling the population density would entail a reduction in the total CO2 emissions in buildings and on-road sectors typically by at least 42%.

## Do income distributions scale with city size?

Somwrita Sarkar

13.7.2016 (Wednesday), 14:20-14:40

Recent research postulates that income and wealth creation follow increasing returns, scaling superlinearly with city size (Bettencourt et al., 2007). However, it was also shown that different ways of defining what a “city” is can significantly alter this finding (Arcaute et al., 2015). In this work, we put forth a question on the distributive aspects of income and wealth. If we accept the hypothesis of superlinear scaling of wealth and innovation, as reported in (Bettencourt et al., 2007), then the question of distributive justice arises naturally; i.e., if a disproportionate amount of wealth or income is being generated in larger cities, who is earning it? In other words, how is the distribution of this income organized? Secondly, as reported in (Arcaute et al., 2015), it was found that the ways in which a “city” is defined alters the findings on the superlinear scaling of wealth and income. In this light, the second important question that arises naturally is, how does the scaling behaviour of income distributions vary as city definitions are varied, and do we see the emergence of contradictory findings?

To explore these two questions, we study scaling of per capita incomes for separate census defined categories against population size for the whole of Australia across several urban area definitions. We find that lowest incomes grow just linearly or sublinearly, whereas highest incomes grow superlinearly, with total incomes marginally superlinear. These findings empirically show that to a marginal extent, the bigger the city, the richer the city. But we also see an emergent metric of disproportionate distribution of income: the larger the population size and densities of a city, higher incomes grow more quickly than lower, suggesting a disproportionate agglomeration of incomes in the highest income categories in big cities. Because there are many more (absolute number of) people on lower incomes that scale sublinearly, these findings suggest a scaling of economic inequality.

The results, reported in (Sarkar et al., 2016), bring into sharp focus the question of whether larger cities are somehow more advantageous, since it is frequently claimed that the larger the size of an urban system, the larger the production of wealth and innovation, and smaller the per capita investment to sustain the system. However, in this work, we bring into focus the observation that total wealth and the distribution of this wealth are two separate issues. Bigger cities are certainly more wealthy, but do they make all inhabitants proportionately more wealthy too? If they don't, then the normative question on “the optimal size of a city” ceases to be a simple monotonic one.

13.7.2016 (Wednesday)

## Rural to Urban Population Density Scaling of Crime and Property Transactions

Haroldo V. Ribeiro, Quentin S. Hanley, and Dan Lewis

13.7.2016 (Wednesday), 14:40-15:00

Scaling in the evolution and development of cities has been widely studied. This has led to the urban scaling hypothesis which considers that some properties of cities change with size in scale invariant ways. However, these studies have not looked in detail at the full range of human environments which represent a continuum from the most rural to heavily urban. Here we examined monthly police crime reports and property transaction values across all 573 Parliamentary Constituencies in England and Wales, finding that scaling models based on population density provided a far superior framework to traditional population scaling. We found four types of scaling: *i*) non-urban scaling in which a single power law explained the relationship between the metrics and population density from the most rural to heavily urban environments, *ii*) accelerated scaling in which high population density was associated with an increase in the power-law exponent, *iii*) inhibited scaling where the urban environment resulted in a reduction in the power-law exponent but remained positive, and *iv*) collapsed scaling where transition to the high density environment resulted in a negative scaling exponent. Urban scaling transitions, when observed, took place universally between 10 and 70 people per hectare. Thus, for some metrics, urban scaling represents a high density subsection of overall scaling relationships which continue into rural environments; while some metrics undergo specific transitions in urban environments and these transitions can include negative scaling exponents indicative of collapse. We further present preliminary results on how scale adjusted metrics may unveil relationships between crime and property value.

## Scaling Archaeology? A glimpse on prehistoric settlement research in Neolithic alpine lake shore villages

Julian Laabs

13.7.2016 (Wednesday), 15:00-15:20

Within the scope of the project “*Beyond lake villages: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany and Austria*” special attention is drawn to the modeling of the Western Swiss Neolithic (ca. 4500-2200 cal. B.C.) population density, land use and land cover under consideration of changing technological, socioeconomic and climatic influences. The well preserved waterlogged lake shore settlements of the alpine foreland provide us with an extraordinary quality of archaeological data, including chronological precision, architecture, (bio-)archaeological material and the possibility to retrace taphonomic processes. Several studies showed that social as well as economic behavior can be deduced from archaeological remains. The detailed examination of the three case studies of Murten Pantschau (ca. 3430-3415 B.C.), Sutz-Lattringen Riedstation VI (ca. 3393-3388 B.C.) and Arbon Bleiche 3 (ca. 3384-3370 B.C.) will give an insight into the chronological development and intra-site structures of Late Neolithic lake shore villages. In regard of dependencies between quantities and population size, the presented investigation will compare the quantified silex, ceramic and bone inventories from different Neolithic lake shore settlements in regard to available population proxies. The method of scaling material from excavated settlements do contain noise factors, namely excavation techniques, conditions of conservation, the circumstances of settlement abandonment and its chronological development, which are hard to silence.

13.7.2016 (Wednesday)

## **Explaining urban allometry – factoring in the countryside**

**Nina Schwarz**

13.7.2016 (Wednesday), 15:20-15:40

Urban allometry has gained much interest in research recently, and the scaling of various (mostly socio-economic) indicators with city size has been widely documented. The discussion on processes that could cause the emergent phenomena of scaling relationships is focused on social networks and interactions. In this talk, I will argue that investigating scaling would, in addition to networks and interactions, benefit from also explicitly including the surrounding (rural and urban) area into the analysis. Processes that could additionally be taken into account are, for instance, rural-to-urban migration and (for the historical development of city size) the carrying capacity of a region to sustain its urban population. These hypotheses are illustrated with empirical findings and theoretical considerations.



## Quantitative assessment of urban spatial structure – a contribution to the discussion

Angelika Krehl and Stefan Siedentop

13.7.2016 (Wednesday), 16:20-16:40

A debate has been going on for some decades regarding ‘the world is spiky vs. the world is flat’. Unsurprisingly, an enormous amount of studies addressing this (sub-) center issue conclude differently and thus provide evidence for subcenter existence as well as both concentrated and spatially dispersed spatial structures. It is fairly striking against that background that most studies only focus on one or a few aspects of urban morphology such as built environment and land use, the spatial distribution of employees, firms and residents, or transportation and commuting patterns. In the present study, we acknowledge the multi-dimensionality of urban form by simultaneously considering both the socioeconomic and the built dimension.

Our objective is to gain a deeper understanding of the study regions’ urban spatial structure by suggesting a stepwise, comparative analysis procedure. The empirical strategy is oriented towards four research questions referring to hierarchies in urban systems (question 1), relations between predefined centers and their regions (2) and the subcentering phenomenon (3). A relative assessment of these results (4) will be outlined afterwards to discuss the urban spatial structure and its ‘definition-sensitive’ nature. Taking into account that the sample comprises only four city regions, generalizable answers to these questions are not expected. However, the idea is to present and discuss means of doing comparative urban research with special regards to quantitatively analyzing urban spatial structure.

By applying this empirical strategy we expect to distinguish more concentrated from less concentrated city regions taking into account the multi-dimensional nature of urban spatial structure. Whereas easily interpretable results – a degree or another dimensionless measure – would be desirable, the multi-dimensional nature of urban morphology will likely not permit such a measure. Rather, inspecting the results will certainly show that urban spatial structure displays a great variety. Nevertheless, we do not expect to find that the urban spatial structure is too complex to be analyzed in a quantitative-comparative manner. We rather expect to provide evidence for the feasibility of a consolidated assessment based on the proposed strategy. Thus, the analyses should provide a solid base for the discussion of a relative quantitative assessment of urban spatial structure.

13.7.2016 (Wednesday)

## Crowdsourcing the Robin-Hood effect in cities

Thomas Louail, Maxime Lenormand, Juan M. Arias, and José J. Ramasco

13.7.2016 (Wednesday), 16:40-17:00

Geographical footprints passively produced by individuals reveal information which are useful to coordinate their actions, and consequently large groups of people can tackle issues which are distributed and spatial by nature. This is particularly true in the case of individual mobility networks which integrate data in feedback mechanisms: individuals produce data when moving, and their travel decisions are partly guided by the data produced by others (think about GPS navigation with real-time traffic data, local search of new places, or location-based dating apps). So far these mobility data have been essentially used in applications intended to improve individual satisfaction and immediate rewards (time savings, discovery, a date), but they could be used as well to collectively address complex social issues, with distributed and coordinated approaches. In this talk I will develop further this idea by focusing on a hard problem, the reduction of spatial inequality in large cities. Large cities embody strong economic inequalities between their neighborhoods, and an abundant literature has long highlighted the enduring consequences of the neighborhood effect, and its high societal costs. The “Robin-Hood effect” refers to a process through which capital is redistributed to reduce inequality. A spatial, city-scale implementation of the Robin Hood effect would then consist in taking from the rich neighborhoods to give to the poor. In urban areas, shopping and leisure trips account in average for 15% up to 20% of the total daily trips. These travels have the remarkable property to move money from one part of the city to another, and directly contribute to shape the wealth distribution among neighborhoods. Thanks to the complete credit card transactions of hundreds of thousands of individuals living in two large European cities, we were able to estimate the fraction of daily shopping trips that should be redirected in order to evenly distribute business income among neighborhoods, while preserving key and desirable properties of sustainable cities, such as the total distance traveled and the spatial mixing of individuals living in different neighborhoods. Surprisingly, it appeared that redirecting only a very small fraction of the individuals’ daily travels allows to reach a quasi-homogeneous wealth distribution among the city’s neighborhoods. Since the method could be easily implemented in mobile applications that would assist individuals in reshaping their mobility practices, these results have important consequences for policies intended to mitigate inequality.

## Identification of residential building types in topographic databases and maps using machine learning techniques

Robert Hecht

13.7.2016 (Wednesday), 17:00-17:20

The domains of urban and regional planning, land management, urban studies as well as risk assessment require detailed information about the functional, morphological and socio-economic structure of the built environment. Buildings play a key role as they determine the physical structure of a settlement, which in turn is strongly related to the distribution pattern of housing, workplaces, infrastructure or energy consumption. Data, maps and services of the national mapping and cadastral agencies contain the geometric information on buildings, particularly building footprints. Certainly, detailed information about the building function, the housing form, the number of floors, or building age is often not included. Therefore, during the last years various approaches have been developed to classify and describe the urban structure by means of an analysis of remote sensing imagery and topographic data.

In this work a data-driven pattern recognition approach for automatic classification of building footprints is proposed which makes use of machine learning techniques. Using a Random Forest Classifier the suitability of five different data sources (e.g. topographic raster maps, cadastral databases or digital landscape models) is investigated with respect to the achieved accuracies. The results of this study show that building footprints obtained from topographic databases such as digital landscape models, cadastral databases or 3D city models can be classified with an accuracy of 90% to 95%. When classifying building footprints on the basis of topographic maps the accuracy is considerably lower (as of 76% to 88%). The automatic classification of building footprints provides an important contribution to the acquisition of new small-scale indicators on settlement structure such as building density, floor space ratio or dwelling/population densities. In addition to its importance for urban research and planning, the results are also relevant for cartographic disciplines such as map generalization, automated mapping and geo-visualization.

13.7.2016 (Wednesday)

## **Spatio-temporal variation rooftop photovoltaics in Germany**

**Sven Müller**

13.7.2016 (Wednesday), 17:20-17:40

We study spatio-temporal variation of peer effects in rooftop photovoltaic adoption of households. Our investigation employs geocoded data on all potential adopters and on all grid-connected photovoltaic systems set up in Germany through 2010. The detailed locational data allows us to construct an individual measure of peer effects for each potential adopter across Germany. Using a discrete choice model with panel data, we find evidence that the impact of peers on adoption decisions is non-linearly decreasing in distance to a location. The pattern is most pronounced for distances up to 200 meters. We also find that peer effects in photovoltaics adoption decrease over time and that German solar system adopters are of high socio-economic status.

## **Revisiting urban economics in light of data**

**Marc Barthelemy**

13.7.2016 (Wednesday), 18:00-18:40

The recent availability of data about cities and urban systems opens the exciting possibility of a ‘new Science of Cities’. Urban morphogenesis, activity and residence location choice, mobility, urban sprawl and the evolution of urban networks are just a few of the important processes that can be discussed now from a quantitative point of view. In this talk, I will discuss how a data-informed approach can elaborate on urban economics models in order to get predictions in agreement with empirical observations. I will illustrate this approach on (i) the polycentric structure of cities and the number of activity centers, (ii) on the relation between income and commuting distances. I will conclude by highlighting some important challenges and possible research directions.

14.7.2016 (Thursday)

## 4.2 14.7.2016 (Thursday)

**Urban form and driving: Evidence from US cities**

Gilles Duranton and Matthew A. Turner

14.7.2016 (Thursday), 09:00-09:40

We estimate the effect of urban form on driving. We match the best available travel survey for the US to spatially disaggregated national maps that describe population density and demographics, sectoral employment and land cover, among other things. We develop a novel approach to the sorting problem that follows from an intuitive definition of sorting and an assumption of imperfect mobility. We address the endogeneity problem by relying on measures of subterranean geology as sources of quasi-random variation in urban form. The data suggest that increases in density cause small decreases in individual driving. However, because densification policies must generally decrease population in source regions, this means that such policies can be expected to cause only tiny decreases in aggregate driving. This suggests that urban planning is unlikely to be a cost effective policy response to traffic congestion, automobile related carbon emissions, or other automobile related pollution.

14.7.2016 (Thursday)

## **Agglomeration Economies or Urban Inequalities?**

**Clémentine Cottineau**

14.7.2016 (Thursday), 09:40-10:00

Agglomeration economies are a persistent subject of debate among economists and urban planners. Their definition turns on whether or not larger cities and regions are more efficient and more productive than smaller ones. We complement existing discussion on agglomeration economies and the urban wage premium here by providing 1) a sensitivity analysis of estimated coefficients to different delineations of urban agglomeration as well as to different definitions of the economic measure that summarises the urban premium, thus looking at the distribution of wealth at the two levels of the city and the system of cities; and 2) an investigation of the potential for collateral effects of wealth concentration, such as increased economic inequality and increased economic segregation in cities. We argue this point by regressing measures of income and wage over thousands of definitions of cities, based on an algorithmic aggregation of administrative spatial units. This communication therefore seeks to highlight the spatial and economic complexity of cities with respect to discussion about how we measure and value agglomeration economies. It provides a basis for reflection on alternative ways to model the processes which lead to observed variations, and this can provide insights for more comprehensive regional planning.



**Modeling the relation between income and commuting distance****Giulia Carra**

14.7.2016 (Thursday), 10:00-10:20

We discuss the distribution of commuting distances and its relation to income. Using data from Great Britain, US and Denmark, we show that the commuting distance is (i) broadly distributed with a tail decaying as a power law with exponent  $\sim -3$ , and (ii) an average growing slowly as a power law with an exponent less than one that depends on the country considered. The classical theory for job search is based on the idea that workers evaluate potential jobs on the wage as they arrive sequentially through time. Extending this model with space, we obtain predictions that are strongly contradicted by our empirical findings. We then propose an alternative model that is based on the idea that workers evaluate potential jobs based on a quality aspect and that workers search for jobs sequentially across space. We assume that the density of potential jobs depends on the skills of the worker and decreases with the wage. The predicted distribution of commuting distances decays as a power law of exponent  $-3$  and is independent on the distribution of the quality of jobs. We find our alternative model to be in agreement with our data. This type of approach opens new perspectives for the modeling of urban phenomena.

14.7.2016 (Thursday)

## **Linking income with segregation and urban sprawl – findings from a stylized agent-based model**

**Cheng Guo**

14.7.2016 (Thursday), 10:20-10:40

As a complex and heterogeneous system, city faces many problems during the process of development. Urban sprawl is one urban problem associated with physical structure and has many negative impacts. At the same time, economic segregation is a problem related to socioeconomic spatial patterns and indicates inequality in social outcomes. Empirical studies show that income levels and income inequality influence both sprawl and segregation, but the relationship between the two has rarely been investigated. To better understand the mechanism between income patterns and these two urban problems, and more importantly, the relationship between these two urban problems, we developed a stylized agent-based model. In the model, the individual residential choice is based on Alonso's bid-rent theory and sprawl and segregation are the emergent phenomena analyzed. Preliminary results indicate that sprawl and segregation are positively related. The simulation runs to explore the effects of city size into the relationship will be also presented. These results will deeper our understanding of basic settlement patterns and their relations.

**Scaling laws and transnational investment in French cities (2003-2015)****Olivier Finance**

14.7.2016 (Thursday), 10:40-11:00

Usually information about Foreign Direct Investment (FDI) is available at country level only despite the fact that cities are the major recipients of economic activities. However other sources of data can be used for locating FDI location at city level in France. We compare two databases: actual location of employment (at establishment level) in foreign-controlled firms (original database built by combining three main sources [Finance, 2015]) as inward FDI stock in 2008; and geolocalized employment in cross-border investment projects from 2003 to 2015 as FDI inflows.

We compare inward FDI stocks and FDI inflows to measure the long-term and short-term attractiveness of French cities. Scaling laws are the instrument for revealing the possible concentration of both kinds of investments in the biggest or smallest cities. As the FDI operated by transnational firms abroad from their countries of origin started to grow exponentially since about the 1980s, reaching unprecedented level (global FDI inflows of several hundred billion US dollars annually since then) we suggest that we can consider it as an innovation. Scaling laws are therefore used by analogy to the proposal of an evolutionary theory as traces of linkages between urban activity, city size and innovation cycles [Pumainetal., 2006]. Indeed while inward FDI stocks show a clear supra-linear scaling parameter, sign of a concentration in the largest French cities, FDI inflows would indicate at first sight rather a linear distribution, according to the size of the cities. But a closer investigation leading to eliminating statistical bias reveals that FDI inflows are in reality more concentrated in large cities than the formerly accumulated stocks. Instead of meaning a diffusion stage, these results underline a continuation of the concentration process linked with the globalization of the economy. This is a new example of the limits of purely quantitative approach of scaling measurements that are in fact very sensitive not only to urban delineations but to the qualitative definition of the sample of cities potentially receptive to the innovation process. This implies to maintain a sound understanding of the complexity of urban systems. References

14.7.2016 (Thursday)

## Technological Change and Urban Inequality

Jan Eeckhout, **Christoph Hedtrich**, Kurt Schmidheiny, and Roberto Pinheiro

14.7.2016 (Thursday), 11:40-12:00

Wage inequality increased substantially during the last decades in the United States. We argue that urbanization plays a role in explaining changes in inequality and show that increases in wage inequality are more pronounced in large cities. This increase in inequality in big cities was driven by both the lower and upper tail of the wage distribution. In order to account for increasing shares of both low and high wage workers, we argue that large cities feature a stronger complementarity between low and high skilled workers and that this differential complementarity grew over time. In a spatial equilibrium model we give a concrete example of this mechanism by considering the implications of different complementarities in the workforce and their returns to size. Furthermore, we structurally estimate the complementarity structure in the workforce using repeated cross-sections of wages and rent prices from US Census Data. Using the structural parameters we can decompose changes in inequality across locations into differences due to (1) skill-biased technological change (a steeper skills-returns schedule), (2) the productivity dispersion between locations, (3) population mobility and (4) increased complementarity between differently skilled workers.

**Multi-level scaling laws of cities in multinational firms' networks****Céline Rozenblat**

14.7.2016 (Thursday), 12:00-12:20

Cities are recognized as fostering the maximization of networks and many of socio-economic networks (micro-level) develop simultaneously inside cities (meso level) and between cities (macro level). This classification of micro/meso/macro allows considering the complexity of such networks at different geographical levels. One can wonder how the macro-position of cities interacts with their propensity to develop networks at the meso-level, underlying theoretical common foundations between macro-level (inter-urban networks) and meso-level (intra-urban ones) considering networks of exactly the same nature (Pumain et al, 2006; Bettencourt, 2013; Arcaute et al., 2015).

An empirical analysis was conducted at the world scale on the network of the 3,000 first multinational firms and their 800,000 direct and indirect subsidiaries linked by 1.2 million ownership linkages between 1,500 Large urban areas (LUA) delineated in similar way (ORBIS-IGD, 2010-2013-2016). First results outline that linkages developed at the meso-level (intra urban regions) represent nearly 40% of the total linkages. Moreover, the number of linkages inside large urban regions (meso-level) is strongly correlated to the number of inter-urban linkages of cities (macro-level) (with a LOG-LOG relation:  $R^2=0.8$ ) (Rozenblat, 2015). Scaling laws using the population size of city-regions and applied at different dates 2010, 2013, 2016 on these 2 levels and for different activities, can lead to better understand the complexity of this two levels cities' system.

14.7.2016 (Thursday)

## **Cities, clustering and innovation in UK technology firms: what can big data tell us?**

**Max Nathan** and Anna Rosso

14.7.2016 (Thursday), 12:20-12:40

This paper looks at patterns of location and innovation in UK technology companies, using a unique combination of rich administrative microdata and big data. Substantively expanding on previous analysis (Nathan and Rosso, 2015), we develop a very large enterprise-level panel, 1997-2015, from BSD administrative microdata, Companies House filings, and bespoke modelled variables developed by the data science firm Growth Intelligence using machine learning techniques. This provides us with unique insights into firm characteristics, enterprise and plant location and business performance, with the big data components providing useful information on hitherto hidden elements. Further, the administrative data provides a natural setting for validating the modelled data, helping us deal with some common challenges in working with less structured “frontier” datasets (Feldman et al., 2015).

We first perform some descriptive work that exploits a unique product-sector classification, plus standard industry codes, to construct alternative estimates of the counts and postcode-level location patterns of technology businesses across the UK. Next, we run a range of regressions exploring a) patenting activity; b) links from formal IP to product launches; c) predictors of firm productivity and firm high growth status. Among other things, this sheds light on the variety of knowledge production systems and “cluster shapes” (Kerr and Kominers, 2015) across the UK urban system.

## **Romerian Power Laws and Urban Growth – An Approach to Enter the Black Box of Urban Allometry**

**Andri Brenner**

14.7.2016 (Thursday), 14:00-14:20

This work links the physicist's concept of urban allometry to an endogenous economic growth framework and traces a city's power law into production-specific and inhabitant-specific components. This differentiation allows one to spot innovative cities within a nation, which are broadly spread along a nation's size distribution of cities. The presented theory addresses sectoral production shifts, increasing returns, endogenous growth, spatial demand and spatial density.

14.7.2016 (Thursday)

## Scaling and universality in urban economic diversification

Hyejin Youn

14.7.2016 (Thursday), 14:20-14:40

Understanding cities is central to addressing major global challenges from climate change to economic resilience. Although increasingly perceived as fundamental socio-economic units, the detailed fabric of urban economic activities is only recently accessible to comprehensive analyses with the availability of large datasets. Here, we study abundances of business categories across U.S. metropolitan statistical areas, and provide a framework for measuring the intrinsic diversity of economic activities that transcends scales of the classification scheme. A universal structure common to all cities is revealed, manifesting self-similarity in internal economic structure as well as aggregated metrics (GDP, patents, crime). We present a mathematical derivation of the universality, and provide a model, together with its economic implications of open-ended diversity created by urbanization, for understanding the observed empirical distribution. Given the universal distribution, scaling analyses for individual business categories enable us to determine their relative abundances as a function of city size. Finally, we will extend our analysis to labour diversity and skills that are associated with each occupation. These results shed light on processes of economic differentiation with scale, suggesting a general structure for the growth of national economies as integrated urban systems.



**The pan-European population distribution across consistently defined functional urban areas**Kurt Schmidheiny and **Jens Suedekum**

14.7.2016 (Thursday), 14:40-15:00

Beginning with the seminal contributions by Auerbach (1913) and Zipf (1949), there is a long literature on the distribution of population across cities. Virtually all of this research is concerned with cities of the same country. Gabaix (1999) focuses on the United States (US) and shows that population sizes across metropolitan statistical areas (MSAs) closely follow a Pareto distribution with shape parameter close to minus one, also known as Zipf's law. Further studies on the US city size distribution and the underlying urban growth process include Eeckhout (2004), Overman and Ioannides (2003), and Black and Henderson (1999). Focusing on other countries, Eaton and Eckstein (1999), and Giesen and Suedekum (2011) obtain evidence for France, Japan, and Germany, respectively, that is consistent with the US experience. Much less is known about city sizes in a wider context than the nation state, however, even though national borders are steadily losing significance in the ongoing process of economic globalization. The reason is that "cities" are usually not consistently classified; instead, each country adopts its own methods of defining urban areas and delineating their boundaries according to administrative or economic criteria. This is even true in Europe, where official approaches and city definitions differ widely across countries. For this research, we use novel and unexplored data, which allow for a harmonized approach to defining urban areas in 31 European countries and, with the same methodology, in the US. Our goal is to address the pan-European distribution of city sizes, and to compare the European to the American urban system.

14.7.2016 (Thursday)

## Consequences of Day-time and Night-time Activity Across Spatial Levels for Urban Scaling

Deborah Strumsky, José Lobo, and Charlotta Mellander

14.7.2016 (Thursday), 15:00-15:20

Over the last few decades, in disciplines as diverse as economics, geography, archaeology, sociology, and complex systems, a perspective has arisen proposing that many properties of cities are quantitatively regular and predictable due to agglomeration or scaling effects. A specific set of empirical regularities-based on the observation of systematic changes in average socio-economic performance, land-use patterns and infrastructure characteristics of cities as functions of their population size-are generated by the socioeconomic advantages and costs of concentrating human populations in physical space. Such empirical scaling relations are instances of a more general pattern across scientific fields which relate macroscopic properties of a system to its scale (size). For investigations of *urban scaling* in contemporary urban systems the observational units have been in effect *unified labor markets* raising some concerns as to whether some of the reported superlinear effects, whereby measures of socioeconomic output increase as population increases more than proportionally, are artifacts of the chosen spatial units. Availing ourselves of geo-coded micro-level data for Sweden's adult population covering both places of work and residence, we analyze scaling relations for a variety of urban levels. We show that using data for labor markets equivalent to metropolitan areas the expected superlinearity is exhibited. In contrast, for smaller-sized spatial units the difference between using day-time (workplace) population or night-time (residential) population to measure scale has important consequences for the type of urban scaling behavior observed.

## Interpreting urban scaling laws in a variety of territorial and disciplinary contexts

Denise Pumain

14.7.2016 (Thursday), 16:00-16:40

Size inequalities among cities have long been identified by specialists of different disciplines. From the very beginning they were alternately interpreted in terms of social processes (for instance Reynaud, 1841) and similarities with physical laws (Kohl, 1841, Lalanne, 1863). Size inequalities also were analyzed with reference to statistical processes, usually stochastic (Gibrat 1931, Lotka, 1941) and sometimes combinatorial (Hart and Prais, 1956). More recently emerged interpretations in terms of complex systems that try to link these three sources of inspiration (Pumain, 2004, Batty, 2013). The challenge comes from the line tending to “naturalize” the social process, either from the mathematical properties of social interaction (Rybski et al., 2009) or by seeking to identify universal laws whose cases studied would be contingent expressions (Bettencourt & West, 2010). In this last approach the variables used empirically were considered as proxies for unobserved and unobservable physical quantities (Bettencourt et al., 2009). In a more recent paper the authors suggest a combinatorial interpretation of scaling parameters measured for firms in the urban economy (Youn et al., 2016). Other scholars have refined the empirical material and statistical testing throwing light on the necessary connection between the quality of data definition and its interpretation (Arcaute et al., 2014, Cottineau et al., 2014, Hanley et al., 2016). We take inspiration from their conclusion for examining scaling variations in connection with urban definitions and the context of territorial development. Variations in scaling coefficients are interpreted as traces of stages in the societal evolutionary processes that organize urban systems. According to that interpretation the heterogeneity within and between urban systems both appears as an indispensable component of their general dynamics and an explanation of their singular developments over historical time and across a variety of territorial societal organization. Despite difficulties in harmonizing data bases we found a wide confirmation of the temporal linkages between urban growth, functional specialization and the propagation of innovation waves in a diversity of urban systems. This contribution is illustrated by different sets of results as part of the ERC GeoDiverCity team work (Pumain et al., 2015).

15.7.2016 (Friday)

#### 4.3 15.7.2016 (Friday)

## Information, adaptation and selforganization: Implications to urban allometry

Juval Portugali and Hermann Haken

15.7.2016 (Friday), 09:00-09:40

Allometry – the study of the relations between size, form, physiology and behavior, is recently attracting a lot of attention in the study of cities as complex systems (Betten-court et al. 2007; Batty, 2013). The basic idea is that similarly to a natural-organic complex system in which “many of its most fundamental and complex phenomena scale with size in a surprisingly simple fashion” (West and Brown 2005), so is the case also with the city. Yet cities are not natural-organic complex systems; rather they are *hybrid complex systems* (Portugali 2016) some of whose elementary parts – the urban agents – are indeed natural-organic entities, while others, such as buildings, roads, etc., are artifacts. In natural complex systems the parts interact and give rise to the global system; in cities the urban agent interact with each other but the artificial parts cannot; their interaction is mediated by the natural parts – the human urban agents. This interaction is based on the property that the artificial parts of the city at their various scales (buildings, neighborhoods and whole cities) convey *information* that urban agents are capable of reading and on the basis of this information they then behave, interact, build, or act on, other artifacts. In several recent studies (Haken and Portugali, 2003, 2015, 2016) we’ve studied three aspects of information and their interrelations: *Shannon information, semantic information and pragmatic information*. In our presentation we make a first step at exploring the implications to urban allometry: the ways city size scales with the various aspects of information, the tension between urban form and function and the implications thereof to urban dynamics and planning.

15.7.2016 (Friday)

## **Converting regional forecasts of average densities into 3D tiles to represent the variability of the housing stock and the potential of decentralised technologies**

**Tony Hargreaves**

15.7.2016 (Friday), 09:40-10:00

Forecasting the variability of dwellings and residential land is important for estimating the future potential of environmental technologies. An innovative method has been developed to convert average residential densities into one-hectare 3D tiles to represent the dwelling stock (Hargreaves 2015). These generic tiles include residential land as well as the dwelling characteristics. The method was based on a detailed analysis of the English House Condition Survey data and density was calculated as the inverse of the plot area per dwelling. This found that when disaggregated by age band, urban morphology and area type, the frequency distribution of plot density per dwelling type can be represented by the gamma distribution. The shape parameter revealed interesting characteristics about the dwelling stock and how this has changed over time. It showed a consistent trend that older dwellings have greater variability in plot density than newer dwellings, and also that apartments and detached dwellings have greater variability in plot density than terraced and semi-detached dwellings. Once calibrated, the shape parameter of the gamma distribution was used to convert the average density per dwelling type into a frequency distribution of plot density. These were then approximated by systematically selecting a set of generic tiles. These tiles are particularly useful as a medium for multidisciplinary research on decentralized environmental technologies. An example will be presented of how the method was used to forecast at regional scale the potential of low carbon technologies, such as ground source heat pumps and district heating (Hargreaves et al., 2016). Previous studies have found it difficult to reliably estimate their future potential because this depends on the available residential space which varies greatly within a city region. The tiles method showed how spatial planning policies would affect the future potential of these technologies. It also substantially improved estimates of the spatial variation in energy consumption compared to building energy models that use standard dwelling typologies.

## From Building Footprint Data to Building Archetypes

Martin Behnisch and Robert Hecht

15.7.2016 (Friday), 10:00-10:20

In recent years, the building stock has become the focus of political debate in the light of challenges of resource efficiency, the impact of climate change and attempts to reduce CO<sub>2</sub> emissions. In its Energy Efficiency Plan, the European Commission points out that the building sector offers the greatest potential for energy savings. Knowledge of the German building stock is largely based on census data and annual construction statistics. Despite the scope of these collections, they are constrained in terms of temporal, thematic and spatial resolution, and hence do not satisfy all requirements of spatial planning and research.

In this contribution, a workflow for the quantification of building stocks is proposed that uses commonly available authoritative spatial data. The workflow consists of the following processing steps: (1) data preprocessing (2) the calculation of building attributes (3) semantic enrichment of the buildings using a classification tree (4) the intersection with spatial units and finally (5) the quantification of the building structure and dynamic. The approach has been developed, tested and demonstrated exemplary for the whole country of Germany for the years 2012, 2013 and 2014. It is based on official building footprint data, georeferenced addresses and data from the German digital landscape model (ATKIS Base-DLM). The workflow delivers a semantically enriched dataset (approximately 48 million building footprints). Each building holds a set of geometrical, morphological and topological characteristics. On this basis, a classification process allows to distinguish between e.g. functional types (e.g. non-residential vs. residential buildings) and different morphological types (e.g. detached, semi-detached and terraced housing).

In order to get a deeper understanding of the building form an Archetypal Analysis, introduced by Adele Cutler and Leo Breiman in 1994, is applied to the pre-processed building data. As a result of the Archetypal Analysis it is possible to distinct characteristic groups of buildings (archetypes).

The results of the presented procedure seem to be promising both in the context of building stock analysis and urban allometry. The proposed workflow has the potential for further applications in other European countries or even outside Europe if comparable input data is available.

15.7.2016 (Friday)

## **Urban typologies to bridge the gap between idiosyncratic cities and global environmental change**

**Felix Creutzig** and Peter Agoston

15.7.2016 (Friday), 10:20-10:40

The aggregate potential for urban mitigation of global climate change is insufficiently understood. Case studies successfully outline mitigation strategies for specific cities, but the scope for generalization remains unclear. Here, I argue that the building of urban typologies can help to bridge the gap between idiosyncratic cities and global environmental change. The core analysis, using a dataset of 274 cities representing all city sizes and regions worldwide, demonstrates that economic activity, transport costs, geographic factors and urban form explain 37% of urban direct energy use and 88% of urban transport energy use. If current trends in urban expansion continue, urban energy use will increase more than threefold, from 240EJ in 2005 to 730EJ in 2050. The model shows that urban planning and transport policies can limit the future increase in urban energy use to 540EJ in 2050 and contribute to mitigating climate change. However, effective policies for reducing urban greenhouse gas emissions differ with city type. In affluent and mature cities, higher gasoline prices combined with compact urban form can result in savings in both residential and transport energy use. In contrast, for developing country cities with emerging or nascent infrastructures, urban form and transport planning can encourage higher population densities and subsequently avoid lock-in of high carbon emission patterns for travel. The results underscore a significant potential urbanization wedge for reducing energy use in rapidly urbanizing Asia, Africa and the Middle East. For the case of England, I present a more detailed typology that points to district-level mitigation strategies.



## Orthonormal collective modes in human behaviour: looking for demographic resonances

Alberto Hernando, Ricardo Hernando, Angelo Plastino, Miroslav Šulc, Marius Wehrle, and Eduardo Zambrano

15.7.2016 (Friday), 10:40-11:00

A formidable effort towards an unified *theory of cities*—based on testable principles and endowed with predictive power—is joining the forces of specialists from many different disciplines. Fortunately, exhaustive databases in space and time on demographics is helping us to construct quantitative models for defining the basic principles of this notorious theory. In this direction, Gibrat’s law of proportional effect constituted the paradigm for describing cities’ growth for almost a century. However, it is not able to describe recent findings in cities’ dynamics as distance-dependent correlations or exponentially-decaying memory effects. Here, we show that Gibrat’s law can be extended to a Langevin-like equation that naturally accounts for these two features. This assertion is proved both empirically—with an exhaustive census database of population for more than 8000 Spanish municipalities along more than a century—and numerically with computer simulations. Additionally, we discover the empirical existence of collective modes in urban dynamics—in analogy with physical phenomena as waves in media, resonances in musical instruments, or vibrational states in quantum dynamics—that help us for a deeper characterization and understanding of the demographic forces at play, as the global migration to urban areas that is taking place since the last century. Remarkably enough, only a few of harmonics contributes to the dominant deterministic component of demographic evolution, representing an enormous reduction of the effective degrees of freedom of the dynamics. We finally discuss on how to construct a technology able to stimulate or suppress resonances in the amplitudes of the collective harmonics to actively drive demographics towards a global sustainable growth.

15.7.2016 (Friday)

## User-based representation of time-resolved multimodal public transportation networks

Laura Alessandretti, Márton Kársai, and **Laetitia Gauvin**

15.7.2016 (Friday), 15:00-15:20

Urban transportation systems interweave our everyday life and although their construction is based on conscious design they appear with complex structural and dynamical features. Their most straightforward description is given by networks where stations are identified as nodes and links are the transportation connections between them. Based on this representation considerable research efforts have been dedicated to address their sustainability, to optimise their efficiency and their reliability. These investigations have been accelerated lately by the availability of large open datasets describing complete multimodal transportation systems in cities, regions, countries, and even internationally. Such data also highlights the complexity of public transportation networks: (a) they are all embedded in space, setting constraints in their structural design, (b) networks of different transportation means may coexist in the same space, and (c) they are all inherently temporally-resolved. These characteristics render their study challenging and pushes to investigate the transportation systems by developing methodology able to deal with multimodality, time resolution and spatial embedding. Here, our aim is to provide a novel user-based methodological framework to represent public transportation systems considering the total travel time, its variability across the schedule, and taking into account the number of transfers necessary. This framework is based on the combination of two representations: multi-edge and P-space taking into account the multimodality and the spatial embedding of the system. Computing the shortest-paths with this representation and open data including forecasted schedules (General Transit Feed Specification data) we analysed public transportation systems in several French municipal areas. This framework enables us to quantify the networks overall efficiency as compared to the specific demand and to the car alternative.

**The angular nature of road networks**

**Carlos Molinero**, Roberto Murcio, and Elsa Arcaute

15.7.2016 (Friday), 15:20-15:40

Road networks are characterised by several structural and geometrical properties. The topological structure determines partially the hierarchical arrangement of roads, but since these are networks that are spatially constrained, geometrical properties play a fundamental role in determining the network's behaviour, characterising the influence of each of the street segments on the system. In this work, we apply percolation theory to the UK's road network using the relative angle between street segments as the occupation probability. Using Shannon's entropy, we construct a hierarchical index that serves to classify roads in terms of their importance. The obtained classification is in very good correspondence with the official designations of roads. This methodology hence provides a framework to consistently extract the main skeleton of an urban system.

15.7.2016 (Friday)

## **Collapse of public transport networks under stress**

**Aleix Bassolas**, Maxime Lenormand, Fabio Lamana, and José J. Ramasco

15.7.2016 (Friday), 15:40-16:00

Public transportation system must cope with increased demand in exceptional crowd gathering such as concerts, football matches or other localized events. Here we study the emergence of delays and the collapse of a public transport network under situation of stress. A simplified model to simulate the mobility of users through the public transport system of the metropolitan area of Barcelona. The city is divided in cells represented as nodes in a multilayer network. Each of the layers stands for transport modality interconnected in the nodes and allowing an extra-layer for pedestrian movements. The transport vehicles run through the corresponding layers, while new trips are generated at a given rate producing the demand for transport that matches in origin and destination the empirical data from the city as obtained from surveys. The agents then travel through the network using two different routing protocols: either following the shortest paths, or by an adaptive mechanism that tries to avoid congested areas. We test how the network behaves when a large amount of people are injected in a fixed point of the city as it would occur in a special event. This sudden increase on the demand leads to the appearance of delays and queues in the system with a dependence on the topology of the network and the distance from the injection point. The reaction of the system depends on the part of the city where the agents are generated. While some parts of the city are highly connected and are able to handle huge amount of people, there are others poorly connected that require a lot of time to redistribute the agents. We also test how the system reacts to a strike with less vehicles running, and which is the minimum amount of vehicles to avoid the collapse.

## **Measuring inequality through the multifractality of house prices in London and Paris**

**Hadrien Salat**

15.7.2016 (Friday), 16:00-16:20

Multifractality is used to describe highly irregular measures which locally behave as power laws but for a set of different indices instead of just one. In that case, the pattern formed by points where the measure scales with a similar index is itself a fractal set whose dimension can be extracted. The complete structure is therefore a range of intertwined fractals carrying both global information such as evenness and compactness of the measure's density and local information through the symmetries and spread of fractal dimensions versus a local power law index. Multifractal analysis provides a method to quantify heterogeneity and irregularity in a spatial environment.

This technique has already been used to look at irregularities in urban systems, for example, to study the evolution of agricultural land use (Wang et al., 2010), and to characterize the evolution of land price distributions (Hu et al., 2012, 2013). In this work, we apply the multifractal methodology to the distribution of house prices in London and Paris between 1995 and 2015 to characterize the evolution of inequality in those cities.

15.7.2016 (Friday)

## **Reconceptualizing Cities and The Urban for Sustainability and Transition Discussions**

**Dagmar Haase**

15.7.2016 (Friday), 17:00-17:40

Existing definitions and classifications of 'the urban' are insufficient for an analytical discussion of sustainability, resource use efficiency, low carbon futures and any related transition processes including planning and governance. The delineation of land into discrete categories of land covers/uses ignores the multiple functions and purposes urban land may provide and the movement of people, matter, information, and energy they facilitate. Land used and populated by man is far from being static, and thus new conceptualizations are needed which incorporate an understanding of the processes that shape, take place on, and are facilitated by land area, especially urgent in times of rapid global urbanization, where the structure and function but also mental models of lands may affect one another even at great distances and at near instantaneous speeds, a phenomenon that we call urban land teleconnections (Seto et al., 2012). Teleconnections are amplified by urbanization, with the result that even seemingly remote areas may have 'urban' characteristics. For these reasons, traditional concepts of urban/non-urban have become increasingly less useful in describing the function and structure of land as places of human activity. In my paper I will discuss ideas of land that measures and analyzes urbanity, the urban-ness of places including communication, economic activities and other population characteristics of the land. Urbanity can be defined as how people support themselves through various livelihoods, the material culture and patterns of consumption representing different lifestyles, their spatial connectivity, and how they identify with the places where they reside and upon which they rely. The magnitude and qualities of livelihoods, lifestyles, connectivity, and place create the degree of urban-ness of intertwined human experiences and land configurations (Boone et al., 2014). Realworld examples and applications of the concept are presented as a solid base for a vivid discussion.

# 5 Practical Information

## 5.1 Venue

Herrenhausen Palace  
Herrenhäuser Straße 5,  
D-30419 Hannover  
Phone +49 (0) 511 763744-0

Underground/Tram *station* “*Herrenhäuser Gärten*”

The CTCS Symposium will take place in the **seminar rooms SR4 (main) and SR2.**

## 5.2 Accommodation

We have reserved a room for you at the Grand Palace Hotel in Hanover. The room is booked in your name. The hotel is conveniently located in the center of Hanover near Hanover’s main station.

Grand Palace Hotel, Lavesstraße 77, 30159 Hannover  
Phone: +49 (0)511 543 60-0 / Fax : +49 (0)511 543 60-777  
Email: info@grand-palace-hannover.de

Reservation-/ Banquett Manager  
Jana Lorenscheit, Phone : +49 (0)511 / 543 60-198  
Email: j.lorenscheit@grand-palace-hannover.de

## 5.3 Transportation

### 5.3.1 Transportation airport

From the airport take the S5 S-Bahn (suburban train) from Terminal C in the direction of Paderborn main station or Hameln and get down at Hannover main station and walk approx. 600 m to reach the hotel. Please note, “S-Bahn” is a different type of train than “underground/tram”.

From the city, the S5 S-Bahn (Hannover Airport Line) runs every 30 minutes and takes you straight to Terminal C of the airport. The journey takes around 18 minutes.

### 5.3.2 Transportation Hotel – Venue

Herrenhausen Palace can easily be reached by tram. It takes 5 minutes to walk from the hotel to the underground/tram *station* “*Kröpcke*”. The tram to the conference

## Transportation

venue/hotel runs every three minutes.

Direction to the palace:

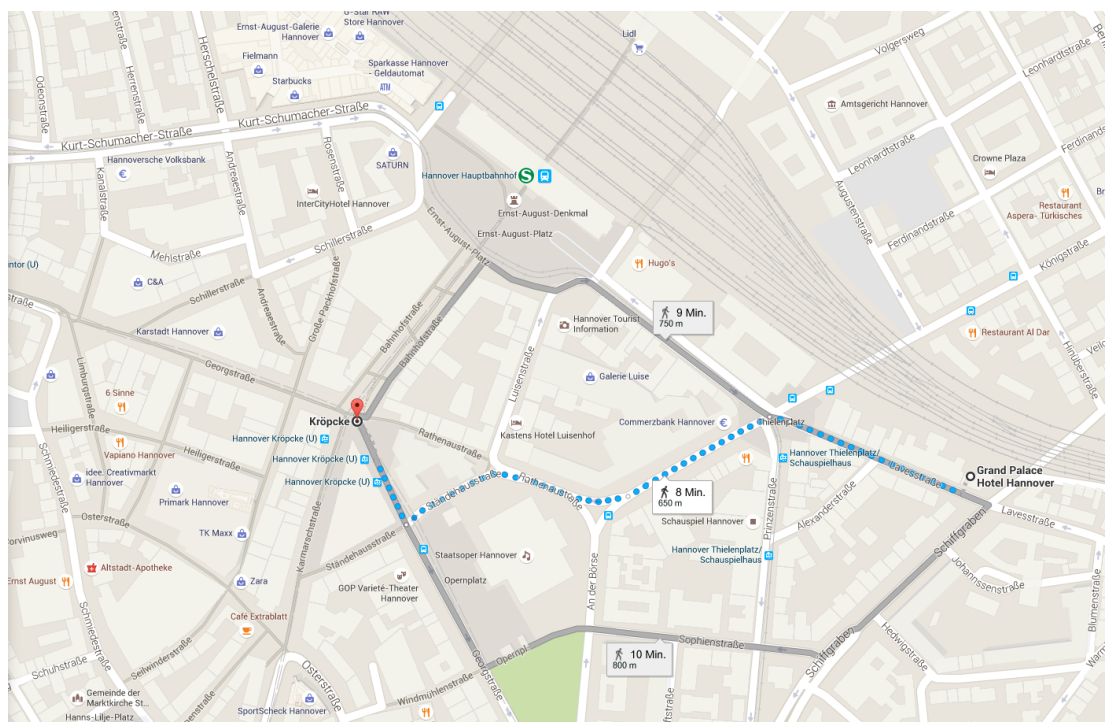
Take Line 4 (to Garbsen) or Line 5 (to Stöcken) and get off at the stop “Herrenhäuser Gärten”.

Return to the hotel:

Take Line 4 (to Roderbruch) or Line 5 (to Anderten) and get off at the stop “Kröpcke”.

### 5.3.3 Congress Card

You will get the so-called “Congress Card” when you check into the hotel. Please ask for it at the reception in case you do not get it automatically. The “Congress Card” is valid throughout the whole period of the symposium (13.-15.7.2016) and serves for public transport in all 3 zones. Otherwise, additional tickets need to be purchased, e.g. for the ride from the airport to the hotel a Zone 2 ticket is necessary (€3.40).



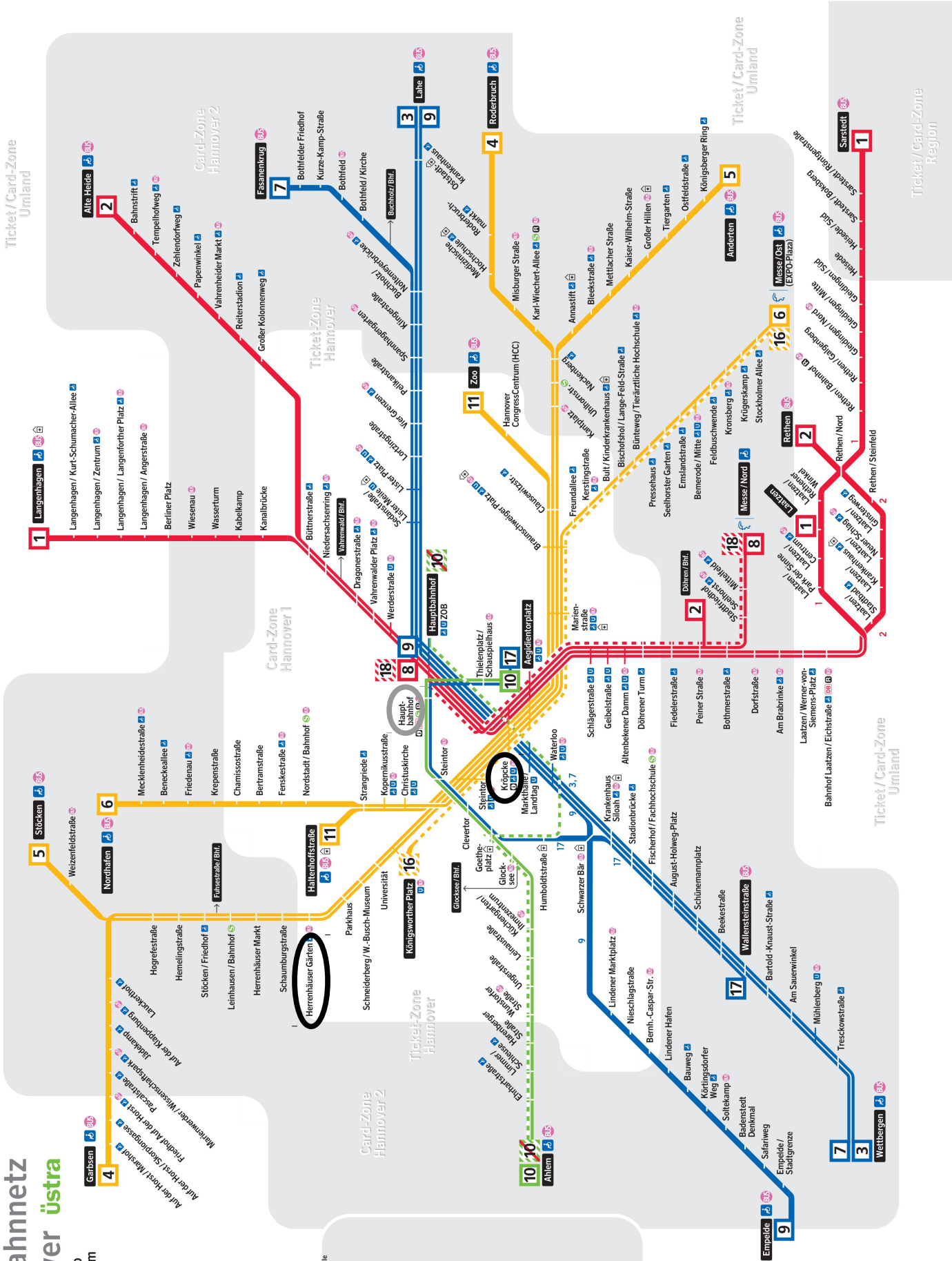


# Stadtbahnnetz Hannover üstra

Tram network map  
Plan du réseau tram

- Stadtbahnlinie mit Haltestelle
- Station
- Information
- S-Bahnlinie
- R-Bahnlinie
- Anschluss an BUS
- Krankenhaus / Klinik
- Stufenloser Zutritt / Zugang
- Besondere Linienführung im Nacht/Sperrverkehr
- Tram line with stop
- Station
- Information
- S-Bahn train
- Local train
- Interchange with bus
- Hospital / clinic
- Step-free access / entry / exit
- Special service
- Night service
- Ligne de tram avec arrêt
- Station
- Information
- RER
- Train de banlieue
- Correspondance bus
- Accès / sortie sans marche
- Service spécial
- Service de nuit

Stand  
December 2004



## **5.4 Meals**

Breakfast is included at the hotel. Lunch and dinner will be served at the venue. On the evening of day3 (Friday) a snack will be served. There is no dinner included on day0 (Tuesday). Lunch and dinner will be buffet-style together with participants of other symposia taking place at the palace.

## 6 Organizing Committee

Organizing Committee:

Dr. Diego Rybski (Potsdam Institute for Climate Impact Research)

Dr. Elsa Arcaute (Centre for Advanced Spatial Analysis)

Prof. Michael Batty (Centre for Advanced Spatial Analysis)

Assistance:

Anke Harwardt-Feye (VolkswagenFoundation)

Ramana V. Gudipudi (Potsdam Institute for Climate Impact Research)

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Web-address: <https://www.pik-potsdam.de/ctcs2016/>



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