ECTQG 2025

24th European Colloquium on Theoretical and Quantitative Geography

Edited by
Atkovska, Irena
Jakonen, Olli
Koforowola, Modupe Osunkoya
Mozaffaree Pour, Najmeh
Partanen, Jenni
Salulaid, Juulia

Programme + Book of Abstracts

September 10–14, 2025
Tallinn, Estonia

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Aalto University
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24th European Colloquium on Theoretical and Quantitative Geography

We warmly thank both the Scientific Committee and the Local Scientific Committee for their valuable contributions to the review process of the conference.

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Editorial Foreword

It is a real pleasure to welcome you to the 24th European Colloquium on Theoretical and Quantitative Geography, hosted this year in Tallinn. Since the first meeting in 1978, the colloquium has travelled across Europe, each time creating a space for geographers to meet in an informal yet rigorous setting. Over the years, ECTQG has become known not only for its scientific contributions but also for the vivid conversations and collaborations that continue long after the formal programme has ended.

Tallinn provides a fitting backdrop for this edition. The city stands at the intersection of historical layers and rapid digital transformation, showing how geographical thinking connects places, data, and people. This year we welcome around 90 participants from 18 countries across Europe and beyond. Together, we represent a wide range of career stages and perspectives, which is one of the enduring strengths of this colloquium.

The programme reflects this diversity. Over three days we will hear keynote lectures from Alison Heppenstall, Tuuli Toivonen, and Tiit Tammaru, and take part in 21 sessions with 76 presentations. The abstracts span themes such as cities, networks, scaling, mobility, segregation, modelling, and new spatial data — topics that illustrate both the continuity and renewal of theoretical and quantitative geography. Beyond the academic sessions, the dinner in Tallinn's Old Town and the Sunday excursion to Lahemaa National Park and Sagadi Manor will give us a chance to exchange ideas in a different setting, while also experiencing some of the finest sides of Estonia.

This meeting is the outcome of many people's efforts. We are grateful to the scientific committee for their careful reviews, to the local organizing team and volunteers for bringing the event together, to the steering group for their support, and to Tallinn University of Technology and Aalto University for hosting this edition. We also thank Ülemiste City for their generous contribution as venue sponsor.

We hope the coming days in Tallinn will bring stimulating discussions, constructive debates, and the enjoyment of reconnecting with old colleagues while meeting new ones. May this colloquium continue the tradition of lively exchange that has made ECTQG a special gathering for nearly five decades.

On behalf of the organizing team,
Professor Jenni Partanen

Keynote speakers

Professor Alison Heppenstall

University of Glasgow, United Kingdom

On Thursday 9:30–11:00
Kosmos Lecture Hall

Biography

Alison Heppenstall is a Professor of Geocomputation within the School of Social and Political Sciences at the University of Glasgow. She holds a PhD in Computer Science from the University of Leeds and was a Lecturer and Associate Professor with the School of Geography at the University of Leeds. She is an Alan Turing Fellow. Alison's expertise is in the development of AI and ML approaches to simulating the dynamics and processes within urban areas. She is particularly fond of individual-based approaches such as microsimulation and agent-based modelling. Her other interests are in synthetic population generation, uncertainty quantification and exascale computation. Her work has been funded by numerous UK and international agencies. She is one of the Editors of Computers, Environment and Urban Systems and won the 2023 International Society of Computational Economics prize for "outstanding work in the area of computational economics and general computational statistics".

Learning the City: AI-Driven Approaches to Urban Complexity

Cities are complex, dynamic systems shaped by human behaviour, infrastructure, and policy. As urban areas face mounting challenges—from climate change and congestion to housing and inequality—AI and machine learning offer alternative tools to analyse, simulate, and inform decision-making at scale. This talk explores how emerging methods, including synthetic data generation, geospatial machine learning, and agent-based modelling, are transforming urban analytics. By combining real and synthetic datasets, we can build more robust and accurate models that support smarter urban planning, mobility forecasting, and public service delivery. This talk will use examples from current work to highlight the potential of AI-driven urban intelligence to create more equitable and resilient cities.

Professor Tuuli Toivonen

University of Helsinki, Finland

On Friday 9:30–11:00
Kosmos Lecture Hall

Biography

Tuuli Toivonen is a geographer and professor of geoinformatics at the University of Helsinki, where she leads the interdisciplinary Digital Geography Lab. Her research focuses on understanding the dynamics of people and places—and their interactions—in both urban and natural environments, using accessibility and mobility as key perspectives. An important part of her work involves developing approaches that leverage open and big data, spatial analytics, and machine learning. In addition to applied geoinformatics, her research contributes to urban geography, land-use and transport planning, sustainability science, and conservation geography.

The current state and future directions of mobility/accessibility research in Finland and beyond

In this talk, I will examine how the focus of accessibility and mobility research has evolved in recent years and outline potential future directions.

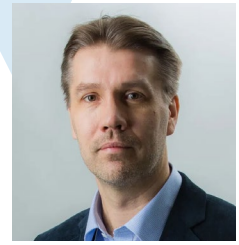
In the European context, the field has been shaped by three interrelated developments: 1) profound shifts in spatio-temporal patterns of human activity driven by the pandemic, geopolitical transformations, environmental crises, and emerging technological solutions; 2) changes in the availability of and access to new forms of data and technologies; and 3) an increasing demand for diverse analytical measures that capture dynamics of people not only for “average” populations but across various social groups, and not only for efficiency but also for experience.

The discussion will draw on the experiences and findings of our research group, the Digital Geography Lab at the University of Helsinki.

Professor Tiit Tammaru

University of Tartu, Estonia

On Saturday 9:30–11:00
Kosmos Lecture Hall



Biography

Tiit Tammaru is Professor of Urban and Population Geography at the University of Tartu, Estonia, where he leads research on socio-spatial inequalities, migration, and segregation. He has played a central role in building Estonia's long-term population data infrastructure, serving as head of the Infotechnological Mobility Observatory (imo.ut.ee), which integrates census and register data with mobility datasets. His research develops new conceptual and empirical approaches to understanding how inequalities are produced and reproduced across the life course and generations, most notably through the vicious circles of segregation framework (segregationcircles.eu). He has published extensively on residential mobility, migration, urban change, and the spatial consequences of digital transition, with work appearing in leading international journals and edited volumes. He is also a member of the global SegregationLab (segregationlab.com), an international network advancing comparative research on segregation. In addition to his academic work, Tammaru engages actively with policy debates on housing, regional development, and urban planning, helping to bridge research, data innovation, and policymaking in Estonia and internationally.

Beyond Home–Activity Space Antagonism: Understanding the Vicious Circles of Segregation

Segregation research has its origins in the study of residential neighbourhoods, from the pioneering maps of Charles Booth in London to the Chicago School of urban sociologists, grounded in census data. With the advent of big data, critics have argued that home locations merely capture the "sleeping population" and are insufficient for understanding social life, calling instead for an activity space approach that shifts attention to schools, workplaces, and leisure time activity places. This keynote aims to transcend this antagonism. It develops the vicious circles of segregation framework, linking how inequalities are produced and reproduced across multiple activity places, centred around the home location. Segregation emerges through sorting into different places and the contextual effects gained within them. Drawing on register data, longitudinal evidence, and mobility-based studies, the talk shows how segregation in one activity place spills into others, generating self-reinforcing feedback loops. These insights are vital for breaking cycles of disadvantage and for rethinking contemporary urban planning paradigms such as the 15-minute city.

Colloquium timetable
10-14 Sept 2025
Öpik Conference Center

	Wed 10th	Thu 11th	Fri 12th	Sat 13th	Sun 14th
8:00 – 9:00		**Registration** *Conference center hallway*			
9:00 – 9:30		**Opening session** *Kosmos*			
9:30 – 11:00		**Keynote:** A. Heppenstall *Kosmos*	**Keynote:** T. Toivonen *Kosmos*	**Keynote**: T. Tammaru *Kosmos*	**Excursion** Lahemaa national park and Sagadi Manor *Bus departs from Sepapaja 1 parking lot next to the "Ülemiste tüdruk" mural*
11:00 – 11:30		**Coffee break** *Conference center hallway*	**Coffee break** *Conference center hallway*	**Coffee break** *Conference center hallway*	
11:30 – 13:00		**Parallel sessions 1** *Session rooms 1-3*	**Parallel sessions 4** *Session rooms 1-3*	**Parallel sessions 7** *Session rooms 1-2*	
13:00 – 14:30		**Lunch** *Restaurant Mona (Valukoja 10)*	**Lunch** *Restaurant Mona (Valukoja 10)*	**Lunch** *Restaurant Mona (Valukoja 10)*	
14:30 – 16:00		**Parallel sessions 2** *Session rooms 1-3*	**Parallel sessions 5** *Session rooms 1-3*	**Parallel sessions 1** *Session rooms 1-2*	
16:00 – 16:30		**Coffee break** *Conference center hallway*	**Coffee break** *Conference center hallway*	**Closing session** *Kosmos*	
16:30 - 18:00		**Parallel sessions 3** *Session rooms 1-3*	**Parallel sessions 6** *Session rooms 1 and 3*		
18:00 – 19:00	**Registration** *Conference center hallway*				
19:00–21:00	**Welcome cocktails** *Öpik Center Rooftop Terrace (Valukoja 8)*		**Conference Dinner** *Restoran Spot (Vene tn 4 in Tallinn Old Town)*		

Parallel session timetable

Sessions take place on
Thursday Sept 11, Friday Sept 12.
and Saturday Sept 13

Thursday Sept 11	
Parallel sessions 1	
[ROOM1] ANDROMEDA 11:30 - 13:00	
Theoretical Geography and History of Geography 1 *Chairs: Cyrille Genre-Grandpierre, Rémi Lemoy, Denise Pumain, Juste Raimbault, Nicolas Szende*	
Cyrille Genre-Grandpierre	Reflexions on the transversal "knowledge objects" of contemporary geography
Juste Raimbault	Mapping the integration between Knowledge Domains in Theoretical and Quantitative Geography
Denise Pumain	Evolutionary theory of urban systems and prediction: the case of Chinese cities

[ROOM2] UNIVERSUM 11:30 - 13:00	
Environmental Health Studies 1 *Chair: Sandra Pérez*	
Sandra Pérez	Towards a theory of pathogenic geographical spaces
Haokun Liu and Céline Rozenblat	Decoding the Urban Exposure: Integrating Network Analysis and GeoAI to Illuminate Environment Health at Lausanne
Malcolm Campbell, Vanessa Bastos, Lukas Marek and **Phoebe Eggleton**	mGeoHealth: using mobile phone location data to better understand population health
Samuel Benkimoun, Malika Madelln and Vincent Dupuis	Crowdsourced Weather Data and Environmental Health: High-Resolution Mapping and Modeling of Urban Heat Exposure in the Paris Metropolitan Region

[ROOM3] GALAKTIKA 11:30 - 13:00	
Models 1 *Chairs: Geoffrey Caruso, Lucas Magalhães*	
Alex Hagen-Zanker	Node-to-node shortest path approximation for large scale agent based urban modelling: a new algorithm using dynamically narrowing destinations
Guangsheng Dong, Tao Cheng, Rui Li and Huayi Wu	Spatiotemporal-Semantic Fusion for User classification based on Virtual Trajectories on Public Map Service Platforms
Lucas Magalhães and **Geoffrey Caruso**	Simulating retail location in the digital era: a spatially-explicit theoretical agent-based monocentric city model
Kelly Oliveira and Eusébio Reis	Recent Climate Evolution in the Sado River Basin, Portugal: Empirical Challenges and Contributions to Spatial Model Validation

Parallel sessions 2	
[ROOM1] ANDROMEDA 14:30 - 16:00	
Theoretical Geography and History of Geography 2 *Chairs: Cyrille Genre-Grandpierre, Rémi Lemoy, Denise Pumain, Juste Raimbault, Nicolas Szende*	
Olivier Orain and Nicolas Szende	Quantitative geography and its intellectual backdrop: socio-historical insights from Britain and France
Richard Harris	36 years later: Some personal reflections on Peter Haggett's 'Revolutions and Quantitative Geography'
Mikhail Rogov and Céline Rozenblat	Cities as boundary objects: can this concept improve the transfer of urban models?

[ROOM2] UNIVERSUM 14:30 - 16:00	
Environmental Health Studies 2 *Chair: Sandra Pérez*	
Marina Toger, Nir Fulman, Yulia Grinblat, Emily Charlotte Wilke, Alexander Zipf, Armagan Teke Lloyd, Umut Türk, Johannes Huber, Sebastián Block and Kirsten Von Elverfeldt	The suitability of volunteered geographic information to support walkability studies in older adults
Phoebe Eggleton, Joseph Boden, Anne Harvet, Bingyu Deng, Geraldine McLeod, Malcolm Campbell and Matthew Hobbs	Investigating the long-term impact of experiencing a major disaster in mid-adulthood on body mass index and waist circumference: A prospective birth cohort study
Els Verachtert, Lien Poelmans and Karen Gabriels	High-resolution spatial greenness metrics supporting environmental health research

[ROOM3] GALAKTIKA 14:30 - 16:00	
Computation, Analyses & Data 1: Emerging Data Practices *Chair: Najmeh Mozaffaree Pour*	
Madeleine Guyot	From geodata abundance to meaningful insights: assessing the limits and potential of diverse geodatasets in urban research
Nikita Sinitsyn and **Andrey Konnov**	Radio call signs of consumer electronics as a data source in human geography
Iuria Betco and Jorge Rocha	Analyzing Street View and Social Media Data to Evaluate the Urban Environment in Lisbon
Bernhard Nöbauer, Alexandre Banquet, Claudia Baranzelli, Michelle Marshalian, **Ana Moreno Monroy** and Felix Winkelmayer	Comparing rural daily systems

Parallel sessions 3
[ROOM1] ANDROMEDA 16:30 – 18:00
Urban Scaling: Global Patterns of Cities *Chair: Itzhak Benenson*

Victor Vignolles and **Rémi Lemoy**	Removing Population Size, World Cities Leave on Land a Footprint of Wealth
Geoffrey Caruso, Kerry Schiel and **Rémi Lemoy**	Comparing and visualizing the radial profiles of urbanized land across a worldwide sample of cities
Thibaud Rivet, **Rémi Lemoy**, Axel Pecheric and Gaëtan Laziou	Radial scaling of land use change in 1800+ world cities since 1975
Paul Kilgarriff, **Geoffrey Caruso** and **Rémi Lemoy**	Recursive City Definition

[ROOM2] UNIVERSUM 16:30 - 18:00	
Food and Nature-Based Systems *Chair: Nasim Eslamirad*	
Frederik Priem, Nikola Obrenović, Maksim Lalić, Hedda Ørbæk, Markus Sydenham and **Els Verachtert**	Maximising sunflower crop yield, pollinator diversity and carbon sequestration in the Vojvodina region (Serbia) through spatial optimisation of Nature-based Solutions
Michal Iliev, James Cheshire and Stephen Law	Access to the night-time city: temporal variability in food accessibility for night workers in London
Irena Atkovska, Todor Stojanovski, Najmeh Mozaffaree Pour and Jenni Vilhelmiina Partanen	Morphological analysis and Geographical Information System (GIS) tools in exploration of green cities, food production and distribution within the urban environment
Nasim Eslamirad, Payam Sajadi and Salman Khan	Mapping the Human Dimension of Urban Flood Risk: A Qualitative Framework for Citizen Engagement in Nature-Based Solutions

[ROOM3] GALAKTIKA 16:30 – 18:00	
Computation, Analyses & Data 2: Applied Spatial Analysis *Chair: Petra Staufer-Steinnocher*	
Kazuhiko Kakamu, Shinichi Kamiya, **Petra Staufer-Steinnocher**, Takashi Yamasaki and Noriyoshi Yanase	Context Comes to Mind: Evidence and Implications for Protection against Catastrophes
Olli Jakonen, Najmeh Mozaffaree Pour and Jenni Partanen	Intraurban Spatial Evolution and Clustering Trends in the Software Industry

Emile Duflot	Residential Mobility and the Contribution of Population Flows to Micro-Local Socio-Economic Dynamics

Friday Sept 12	
Parallel sessions 4	
[ROOM1] ANDROMEDA 11:30 - 13:00	
Novel Spatial Data and Indicators for Assessing the Reality of 15-Minute Cities 1 *Chair: Eric Koomen, Chen Zhong, Joana Barros*	
Jules Grandvillemin, Florian Masse, Vincent Kaufmann and Samuel Carpentier-Postel	Mobility potential: towards an accessibility indicator accounting for the individual ability to move through motility
Xiuning Zhang, Alexei Poliakov and Elsa Arcaute	Recurrent visitations expose the paradox of human mobility in the 15-Minute City vision
Chris Jacobs-Crisioni and Ana Isabel Moreno-Monroy	Service provision in a regional perspective: a trilemma of densities, accessibility and cost-efficiency.

[ROOM 2] UNIVERSUM 11:30 – 13:00	
Mobility 1: Large-Scale Systems, Patterns and Datasets *Chair: Samuel Benkimoun*	
Samuel Benkimoun, Eric Denis and Olivier Telle	Comparative Inference of Urban Functional Systems Through Large Movements Datasets and Network Analysis in Delhi, Cairo, and Bangkok.
Ate Poorthuis, Olle Järv and Anirudh Govind	Open-source, continent-scale human mobility datasets derived from geotagged social media
Fangzhou Zhou, Tao Cheng and Mark Tewdwr-Jones	Tracking Migration Shifts During Covid-19: A Time-Series Clustering Study of English Local Authorities (2017–2022)
Louisette Garcin	Toward a systemic understanding of mobility patterns: modular modeling and cross-territorial validation

[ROOM3] GALAKTIKA 11:30 – 13:00	
Models 2: Validation of Spatial Simulation Models *Chair: Juste Raimbault, Denise Pumain*	
Eduardo Gomes, Cláudia Viana and Jorge Rocha	Participatory validation of land-use simulation models for Cultural Ecosystem Services
Jorge Salgado and Céline Rozenblat	Modelling cities transitioning to a green economy: a multilevel complex approach
Meixia Lin and Tao Lin	Dynamic Construction and Optimization of Ecological Networks in Coastal Regions Under Multi-Objective Scenarios: A Case Study of Gulei Port Economic Development Zone, China
Juste Raimbault and Denise Pumain	Projecting possible future trajectories for systems of cities

Parallel sessions 5	
[ROOM1] ANDROMEDA 14:30 - 16:00	
Novel Spatial Data and Indicators for Assessing the Reality of 15-Minute Cities 2 *Chair: Eric Koomen, Chen Zhong, Joana Barros*	
Jiakun Liu, Eric Koomen and Erik Verhoef	Is the 15-minute city feasible? Assessing the role of the built environment through actual travel behaviour in Alkmaar, the Netherlands
Najmeh Mozaffaree Pour and Jenni Partanen	Spatial Justice and Urban Accessibility: Evaluating the 15-Minute City Metrics for Vulnerable Groups in Tallinn, Estonia
Cate Heine and Chen Zhong	Friendship in the 15-minute city: Social interaction as a key urban resource

[ROOM2] UNIVERSUM 14:30 - 16:00	
Mobility 2: From City to Cross-Border System *Chair: Alex Hagen-Zanker*	
Igor Shusterman, Aleksey Ogulenko and **Itzhak Benenson**	The discreet intelligence of transport accessibility maps
Tuomas Väisänen, Milad Malekzadeh, Oula Inkeröinen and Olle Järv	Structural changes in the catchment areas of student mobility in Europe: Case COVID-19
Yuyang Wu and Konstadinos Goulias	Multi-Scale Analysis of Local Labour Market Areas Using Complex Network Methods: Focusing on the Issue of Excess Commuting

[ROOM3] GALAKTIKA 14:30 - 16:00	
Computation, Analyses & Data 3: Theoretical Spatial Analytics *Chair: Roger Bivand*	
Roger Bivand	Categorical independent variables and spatial regression: interpretation and reporting
Felipe Albuquerque, Cyrille Genre-Grandpierre and Rosa Figueiredo	Integrating equity into efficiency: the p-Median problem with territorial coverage constraint.
Christopher Brunsdon	Geographically Context Sensitive Weighted Indicators: Using the Benefit-of-Doubt Approach
Léandre Fabri and Geoffrey Caruso	How the perimeter and the area of urban patches relate across Europe

Parallel sessions 6	
[ROOM1] ANDROMEDA 16:30 - 18:00	
Novel Spatial Data and Indicators for Assessing the Reality of 15-Minute Cities 3 *Chairs: Eric Koomen, Chen Zhong, Joana Barros*	
Tomas Crols, Lien Poelmans and Els Verachtert	The impact of the 15-minute city on the spatial planning policy of a sprawled region
Joan Perez and Giovanni Fusco	Assessing urban scenes for the 15-minute city through SAGAI (Streetscape Analysis with Generative AI).
Ana Moreno Monroy and Bernhard Nöbauer	Enhancing compactness, connectivity, and accessibility in Korea

[ROOM3] GALAKTIKA 16:30 - 18:00	
Computation, Analyses & Data 4: Machine Learning and AI Applications *Chair: Jorge Rocha*	
Adrian Nowacki, Jarosław Jasiewicz and Anna Dmowska	Using interpretative machine learning to analyze spatial distribution of socio-demographic profiles influencing voting patterns in U.S. presidential elections (2008-2024)
Iuria Betco, Cláudia M. Viana, Eduardo Gomes and Jorge Rocha	Unfolding the black box: Modelling Community-Acquired Pneumonia drivers in mainland Portugal with Explainable-AI

Lien Poelmans, Luc De Keersmaeker, Roggemans Pieter, Frederik Priem, Stijn Tallir, Toon Petermans and Jo Van Valckenborg	Assessing 250 years of land use changes in Flanders through GeoAI
Claudia Viana, Jorge Rocha and Eduardo Gomes	Tracing Agricultural System through Geospatial Theory and Historical Sources: Insights from Portugal

Saturday Sept 13	
Parallel sessions 7	
[ROOM1] ANDROMEDA 11:30 - 13:00	
Sensing Functional Systems Through Mobility from Big Data: From Neighbourhoods to Urban Regions and Global Networks *Chairs: Olle Järv, Ate Poorthuis*	
Egor Kotov, Tom Theile, Ole Hexel, Elizabeth Jacobs, Jisu Kim, Daniela Perrotta and Emilio Zagheni	Impact of Temporary Location Visitors on Mobile App Usage in French Cities: Implications for Socio-Economic Segregation Studies
Olle Järv, Håvard Wallin Aagesen, Tuomas Väisänen and Michaela Söderholm	Sensing Cross-Border Integration of Border Regions in Europe from the Mobilities of People: A Mobile Big Data Approach
Kofoworola Modupe Osunkoya, Tuomas Väisänen, Olle Järv and Jenni Partanen	Mapping Vital Urban Areas Through Social Media Activity: A: Case of Tallinn, Estonia
Anirudh Govind, **Ate Poorthuis** and Ben Derudder	Conceptualizing Functional Neighborhood Boundary Intensities

[ROOM2] UNIVERSUM 11:30 - 13:00	
Mobility 3: Equity and Accessibility *Chair: Nuno Pinto*	
Anna Clara Dantas Cabral, Antônio Nélson Rodrigues da Silva and **Nuno Pinto**	Redefining a strategy for assessing urban mobility resilience from an equity perspective
Joana Barros, Agnes Silva de Araujo and Marcus Saraiva	Gender and mobility: Intersectional inequalities of accessibility in São Paulo, Brazil
Jorge Rocha, Luis Encalada, Iuria Betco and Cláudia M. Viana	Modelling Elderly Accessibility to Pharmacies by Integrating Vertical Mobility Constraints into Network-Based Spatial Analysis
Patrizia Sulis and Alessandro Giordano	Investigating a double vulnerability of accessibility poverty in European urban areas

Parallel sessions 8	
[ROOM1] ANDROMEDA 14:30 - 16:00	
Networks and Connectivity *Chair: Céline Rozenblat*	
Céline Rozenblat	The spatial relay roles in ownership linkage network: from individual firms to cities' properties
Nuno Pinto, Mariam Jamilah and Runqi Xiao	Synthetic cities to support the development of advanced urban models
Oleksandr Karasov, Tiina Rinne, Olle Järv and Henrikki Tenkanen	Quality of personal time as a universal metric: a Telegram bot solution for the spatial assessment of cultural ecosystem services in Ukrainian city during the Russian invasion
Claire Lagesse	From understanding road networks patterns to modeling their evolution
Milad Malekzadeh, Tuomas Väisänen, Anastasia Panori and Olle Järv	Mapping Regional Connectivity: Identifying Mobility Hubs Through Multi-Dimensional Movement Networks in Europe (2012–2022)

[ROOM 2] UNIVERSUM 14:30 - 16:00	
Urban Boundaries: Natural and Social Divides *Chair: Anna Dmowska*	
Jaana Vanhatalo	The nature of urban area boundaries: concepts, dichotomic definitions and reality, case Finland

Tu Giang Vu and **Eric Koomen**	Cities divided by rivers; how water bodies steer urban expansion
Anna Dmowska	Examining spatio-racial patterns at various scales in U.S. metropolitan areas using segregation profiles

Book of Abstracts

Reflexions on the transversal "knowledge objects" of contemporary geography

Cyrille Genre-Grandpierre (*UMR ESPACE - Avignon University*)

ABSTRACT

With the democratization of geographic data and the tools for processing them, understanding the spatial dimension of socio-economic and environmental phenomena is no longer the prerogative of geographers In this context, contemporary geography needs to better (re)define its specific contribution to the production of knowledge about spaces and spatialities.

In this contribution, we invite to discuss the question of geography's theoretical positioning from a specific angle, that of identifying the discipline's «objects of knowledge »., i.e. objects that are specific to space and transversal to the variety of themes and study areas addressed by geography.

Keywords

epistemology, social science, interdisciplinarity

Mapping the integration between Knowledge Domains in Theoretical and Quantitative Geography

Juste Raimbault (*LaSTIG, Univ Gustave Eiffel, IGN-ENSG***).**

ABSTRACT

Theoretical and Quantitative Geography (TQG), since its inception in Europe in the 70s as a scientific current [Cuyala, 2015], has always been motivated by a strong integration between quantitative studies (empirical or modeling) and theoretical constructions. [Livet et al., 2010] has conceptualised, for activities implying modelling in social science in general, a strong integration between three Knowledge Domains, namely Theory, Empirical, and Modelling. This Knowledge Framework has been refined by [Raimbault, 2017] with the addition of other domains with a key importance in TQG: Data, Methods, and Tools. To what extent theories in TQG (in the sense of bodies of knowledge) effectively involve a variety of Knowledge Domains, and mobilises them in an integrated way to produce knowledge?

We propose in this contribution to investigate this question for two case studies: Pumain's evolutionary theory for systems of cities [Pumain, 2018] (which has been developed the last 30 years, is an example of a fruitful TQG approach, and is rather well delimited), and studies of Zipf's law for the size of cities [Cottineau, 2017] (with a longer history, and a less delimited context with several disciplines involved from economics to regional science, physics and geography). Starting from an initial corpus for each case (foundational papers for the Evolutionary Theory, and around fifty papers found by [Cottineau, 2017] in a systematic review), we reconstruct backward citation networks up to depth two using the bibilographic tools provided by [Raimbault, 2019]. We use these citation networks as corpuses in which integration between knowledge domains is studied. Given the relatively small size of corpuses (100 and 500 papers), it is much robust to tag papers for knowledge domains by hand. With the annotated data, we can map interactions between knowledge domains within citations networks, and compute various indicators such as diversity of domains, or modularity in the network capturing how domains are integrated. We find less diversity for Zipf and a much stronger clustering into disciplines with their own use of knowledge domains (theoretical models only in economics for example), while the evolutionary theory witnesses an interdependancy between domains. Digging further into this case, we highlight specific papers focused solely on constructing a dataset or presenting a software, on which almost all of the final knowledge depends, confirming this high integration between knowledge domains.

This contribution thus proposes a first approach in quantitative epistemology to investigate howdifferent components of knowledge interact for the construction of integrated theories. We hypothesise that this aspect is typical in TQG, as our archetypal case study for TQG has shown compared to the more generic case study. Further work

would be needed for a broader confirmation of this, with a more systematic mapping of disciplines, without an arbitrary focus on case studies. Sensitivity analysis to the initial definition of corpuses and to the construction of ctation network would also be needed in our case. Finally, an interesting development would be the development of Machine Learning methods to automatically tag papers into knowledge domains, with however a high requirement on classification quality.

Keywords

Quantitative Epistemology, Knowledge Domains, Theoretical and Quantitative Geography

Evolutionary theory of urban systems and prediction: the case of Chinese cities

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ABSTRACT

The predictive capacity of a geographic theory is too rarely discussed (Raimbault 2017; Cottineau et al 2024). Here is provided an illustration of the power of theory even when applied to supposedly very specific cases in urban geography. The evolutionary theory of urban systems is characterized by a precise geographical ontology and formalizations of statistical regularities in their structures and their dimensional and functional evolutions, which have been observed in many regions of the world (Pumain et al 2015; Cura et al 2017). Validation of the theory is based on harmonized empirical data observed over long periods of time, and on multi-agent multi-scale simulation models that include its main hypotheses and whose validation methods have been recently considerably improved (Schmitt et al 2015). It is also based on plausible interpretations of the main deviations that are observed in its application to particular systems of cities.

Chinese cities pose an interesting challenge to this theory, for several reasons. The first is the singularity of China's historical, political and economic trajectory, and in particular the highly centralized nature of the governance of its urban development (Wu, 2016). These particularities are sometimes assumed to make the Chinese system of cities irreducible to general models. A second reason is the complexity of the definition of cities within the Chinese administration, which reduces the analysis of the urban fact to a too limited number of cities, unsuitable for solid scientific work and international comparisons. Most publications are content to work on the attributes of prefectural cities, i.e. between 283 and 657 urban units, whereas the country's demographic dimension would suggest several thousand, as attested by a database constructed by Elfie Swerts according to the geographical ontology (2017).

The evolutionary theory of urban systems provides predictions for resolving these contradictions. It tends to demonstrate that the hierarchical inequalities and functional diversity of Chinese cities, as well as the spatio-temporal variations in their growth, are not incompatible with the hypotheses derived from observation of other systems of cities around the world. The harmonized methods for defining and delimiting cities that are beginning to be applied by Chinese authors (Zhang et al 2025) confirm our estimates of the number and size of Chinese cities, and will make it possible to propose better observations, for instance when measuring the exponents of scaling laws aimed at determining the relative productivity, social characteristics and potential sustainability of large and small cities (Pumain 2025).

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This abstract is intended for special session number 4 : Theoretical Geography and the History of Geography

Keywords

evolutionary theory, system of cities, China

Towards a theory of pathogenic geographical spaces

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ABSTRACT

Environmental health research faces challenges in generalizing results due to diverse methodologies, populations, and geographical scales, making studies difficult to compare. The field lacks a solid theoretical foundation, partly because it's relatively new and complex. To address this, we propose the eXpace concept—a blend of "exposome" and "space"—to classify geographical areas based on their potential pathogenic impact, or "geopotential." This approach uses AI and models like gravitational potential energy one to assess space as a health indicator. A new methodology is being developed and partly validated, with the goal of develop a comprehensive theory about the pathogenic spaces.

Keywords

Theory, The eXpace concept, Methodology

Decoding the Urban Exposure: Integrating Network Analysis and GeoAI to Illuminate Environment Health at Lausanne

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ABSTRACT

Environmental exposures, encompassing natural, built, social, chemical, and biological factors, occur across diverse spatial and temporal scales (Wild, 2012). These exposures contribute not only to physical conditions, such as cardiovascular disease, but also to a spectrum of mental health outcomes. Drawing on the socio-ecological model (Glanz et al., 2015), it is important to understand how neighborhood exposed environments affect individual behaviors and mental health (Diez Roux, 2001), especially the contextual effect and corresponding population groups effect over the life-course. It is evident that the environment shapes health over the life course through multiple and intertwined pathways, where the magnitude, duration, and context of exposure play pivotal roles (Kwan, 2018).

While substantial research has focused on isolated associations between environmental components and single catalog of health outcomes using traditional statistical approaches like logistic regression and multi-level modeling, such methods often fail to capture the simultaneous and interactive effects of multiple exposures or account for the spatio-temporal heterogeneity inherent in urban contexts (Fong et al., 2025). This gap is particularly salient when illustrating and examining the causal dynamics of multiple health outcomes in well-characterized cohorts, especially mental health, human sleep, and cardiovascular risks (Hall et al., 2018). Recent theoretical perspectives suggest that a holistic and data-driven approach is beneficial to disentangle the complex mechanisms by which kind of environmental exposure, ranging from air pollution to neighborhood accessibility, influences human health (Rutter et al., 2017; van der Wal et al., 2021).

In this perspective, our study aims to elucidate how multiple neighborhood exposures impact these longitudinal health outcomes among participants of the CoLaus|PsyCoLaus study in Lausanne. The CoLaus cohort data follows since 2003 more than 6,000 Lausanne residents aged 35–75 at that time, collecting individual information on geocoded address, socioeconomic status, lifestyle, and measures of health complemented by perception of health. Other complementary information started during the period on psychology (PsycoLaus), Environment (GeoColaus), Physical activity (ActicoLaus), Sound (DecibeLaus), and many other topics. These multi-source datasets, leveraged by GeoAI approaches, allow us to clarify the direct and indirect pathways linking environmental determinants with health risks adopting network perspectives.

Neighborhood exposures, such as expressing daily life facilities' accessibility and segmenting urban landscape, will be quantified by combining spatial analysis and advanced GeoAI techniques. Subsequently, the complex interdependencies among environmental determinants and health outcomes will be revealed using regularized partial correlation networks and gaussian graphical models, with expected influence serving as a key centrality measure. Finally, integrating statistical methods and machine learning approaches, e.g., random forests, will enable us to explore the cumulative effects of environmental exposure by non-linear and non-additive associations over time.

In conclusion, potential findings are expected to illuminate previously unrecognized pathways linking environmental contexts to multiple stages of human health, thereby offering actionable insights for targeted interventions and advancing our understanding of environmental functions of urban health.

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Keywords

Environmental health, Neighborhood effect, Network approach, GeoAI

mGeoHealth: using mobile phone location data to better understand population health

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ABSTRACT

It is well known that there is a connection between the environment and health outcomes and behaviours. Where we live, work, or play, impacts on our health. Detailed spatiotemporal data, such as mobile phone location data (MPLD), allow richer understandings of the influence of the environment, or more broadly of place, on individual health outcomes and behaviours. This is important as often health and medical geography approaches have normally focused on residence-based conceptualisations as an approximation for exposure. This 'static' place or point in time is usually a residential address, perhaps measured once a decade. However, we now can more accurately measure the 'true' exposure, which can be captured 'dynamically'; people moving between many places, second by second, or hour by hour. Using a dynamic conceptualisation of exposure changes the quantum of data involved, the processing required, and the complexity of the challenges when using established statistical and geographical methods. However, being able to more precisely capture the location, and the duration of exposures to aspects of the environment is crucial to more precisely understand the mechanisms through which the environment influences health. Environmental exposures may also be either fixed or spatio-temporally variable, further complicating how to untangle the impact of the environment on health.

We show that by utilising these 'dynamic' data, such as MPLD, or aggregated versions of MPLD, we are afforded an opportunity to apply new(er) approaches, with richer, large, fine-grained spatial data sources. However, these new data sources and accompanying methods bring with them various challenges, biases and opportunities. There are, for example, potential challenges around who is included or excluded from the data that is collected and used.

This presentation will explore ongoing work in the area of mGeoHealth using case studies of ongoing research. We are particularly focused on mobility and movement as a source of exposure to environments, whether physical or social, and how mobility may exacerbate or ameliorate existing inequalities in health.

Keywords

health, mobility, mGeoHealth, inequalities, mobile phone location data, GPS

Crowdsourced Weather Data and Environmental Health: High-Resolution Mapping and Modeling of Urban Heat Exposure in the Paris Metropolitan Region

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ABSTRACT

This communication proposes to address the issue of environmental health, through the particular angle of the urban heat islands (UHI). UHI is known to be a corollary of certain types of urbanization and intensification of built-up density, leading to major alteration in the city's thermal balance (Lemonsu et al., 2015). City dwellers tend to experience higher temperatures compared to the people living in the peripheries of urban areas, especially during the summer nights when clear sky and low-speed winds prevent efficient air mixing. .

Those specific conditions of the 'urban climate' raise significant health concerns, as urban populations may be exposed to increased heat stress (Oke et al., 2017). This impact can also intersect with other forms of vulnerabilities. In certain contexts UHI are for example favoring the local circulation of vector-borne diseases (Araujo et al., 2015, Misslin et al., 2016). We are focusing in this communication on the particular case of the Paris metropolitan region in France, where extreme temperatures are becoming more frequent during summers due to climate change. This is illustrated by heatwaves reaching up to 43°C in July 2019 and 40°C in June 2022, as well as by the steady increase in the number of tropical nights per year, with resulting increased morbidity and mortality among the populations. This was also exemplified by the particularly devastating heatwaves of 2003 (Laaidi et al., 2012).

However, behind those general measurements, it appears crucial to be able to measure and locate the UHI and its local variations with greater accuracy. In Paris, professionally-run weather stations remain sparsely located, within micro-environments that are not always representative of the living conditions of most of the urban population. Notably, one of the reference stations is located in an urban park. Additionally, the outputs of existing meteorological models are typically provided at a coarse spatial resolution.
This communication, part of the ANR project 'H2C: Heat and Health in Cities,' presents the integration of a novel opportunistic data source: a network of over 12,500 Netatmo weather stations owned by individuals in the Paris region — the densest such network among major European cities (Meier et al., 2017). This type of crowdsourced data enables the monitoring of temperature trends on an hourly basis over the period from 2017 to 2024. While these stations are generally less reliable than professionally

installed and maintained equipment, the application of rigorous filtering and critical data analysis makes it possible to extract unique granular information on local air temperatures.

This presentation raises the question of an effective integration of such data to complement traditional weather sources—such as professional stations, meteorological models or satellite-derived surface temperature measurements—to produce more robust estimates of air temperature fields within urban areas at fine scale, ultimately fostering a better assessment of heat-related health risks.

While a general center/periphery gradient pattern emerges from the data at the metropolitan scale, with an average urban/rural delta of 3°C at nighttime (Madelin & Dupuis, 2020), occasionally exceeding 4°C, heat accumulation is unevenly distributed across space and time. Therefore, targeted health policies could greatly benefit from a better understanding of 1) which spatial components of the urban area are subject to greater heat exposure, 2) the determinants of local variations in UHI intensity, with regards to land use, built-up structure, local vegetation, elevation profiles and other environmental factors.

The presentation will feature a series of high-resolution maps of air temperature fields, illustrating the dynamic nature of the Urban Heat Island (UHI) phenomenon across different spatial scales. It will also raise important theoretical questions regarding spatial interpolation methods and the choice of appropriate spatio-temporal resolutions. Beyond that, a modeling approach, borrowing from multi-criteria spatial regression and machine learning techniques, will also be presented in order to identify some key factors influencing the UHI local intensity.

Finally, a critical reflection will be shared on the reliability of crowdsourced data in the context of urban health and climate change mitigation, as well as on the role of geography in the field of environmental health studies —particularly in comparison with other disciplinary approaches that have been engaged with the same type of data.

To participate in the special session 1: Environmental health studies.

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Keywords

urban health, urban heat island, crowdsourced data, spatial analysis, machine learning

Node-to-node shortest path approximation for large scale agent based urban modelling: a new algorithm using dynamically narrowing destinations

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ABSTRACT

Shortest path analysis is a computational bottleneck in large scale urban models. This is the case for both aggregate urban models and agent based urban models. Of these, agent based urban models have specific demands as shortest path analysis is needed for each modelled agent or individual with their own specific origin and destination that may be any node in the network. Thus, the number of routes needed is equal or proportional to the number of individuals and the potential routes that are available are those connecting any node in the network to any other node in the network. In aggregate models the computational requirements are different, as origins and destinations within a transport analysis zone are dealt with in an aggregate matter.

This article introduces a novel method for efficient approximate shortest path analysis that is applicable to both agent based and aggregate models. The rationale of the method is that the route from node A to node B is not precisely determined in the first instance. Instead, a route is found from (exactly) node A in the general direction of node B. As the route is followed and nodes along the route become nearer to B, the remaining route is recalculated more narrowly in the direction of node B. This is repeated such that ultimately the final stretch of the route is directed at (exactly) node B. The efficiency of the method is achieved through an adaptive zone system and Dijkstra's one-to-many shortest path algorithm. This adaptive zoning system is nested, exhibiting a negative exponential relationship between the size of aggregated zones and their frequency. Furthermore, larger aggregated zones are targeted as destinations for long-distance trips, while smaller zones are used for short distances. By strategically centering Dijkstra's algorithm on the destination end of the computation (the aggregated zone containing node B), the algorithm effectively leverages this hierarchical structure to dramatically reduce the need to compute far-reaching shortest path trees.

The algorithm is implemented in an open-source Python library and its efficiency is demonstrated by individual assigning and determining routes of 21M individual commuting routes in England and Wales (3.7M edges, 3.1M nodes). The error involved in the approximation is evaluated using goodness-of-fit measures and visualised by comparing exemplar routes. Compared to earlier applications of adaptive zoning to transport network shortest paths, the new method has the advantage that it produces consistent and continuous routes, and computes node-to-node routes rather than centroid-to-centroid routes. Alternative methods for efficient shortest path analysis include Contraction Hierarchies which is based on a hierarchical representation of the

transport network. The proposed method is based on a hierarchical representation of the destination nodes. Future applications seek to exploit both approaches simultaneously.

Keywords

Urban modelling, Transport, Algorithm

Spatiotemporal-Semantic Fusion for User classification based on Virtual Trajectories on Public Map Service Platforms

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ABSTRACT

1. Introduction

Public Map Service Platforms (PMSPs), such as Google Maps, Tianditu, and Amap, aggregate and share spatial information across various domains, including health, environment, agriculture, rivers, and oceans. The widespread use of PMSPs has given rise to diverse and personalized user demands, reflected in the virtual trajectories formed through user interactions with these platforms. However, existing PMSPs lack effective user classification methods, limiting their ability to provide personalized services.

Virtual and physical trajectories represent user interactions in virtual and physical spaces, respectively. Research on physical (especially GPS) trajectory classification has progressed significantly, expanding beyond spatial and temporal dimensions to incorporate semantic and multi-aspect features. These advancements enable more accurate classification by enriching trajectory feature representations. However, significant differences between GPS and virtual trajectories—such as dimensionality (2D vs. 3D), semantic points (stop points vs. browsing targets), and spatial constraints (road networks vs. unrestricted map areas)—render traditional GPS-based methods ineffective for virtual contexts. To address this gap, we propose a novel virtual trajectory classification framework that integrates temporal, spatial, and semantic features.

2. Methodology

Users interact with PMSPs by performing operations such as panning and zooming. These interactions form virtual trajectories, which we represent as sequences of <browsing target, operation> pairs. A browsing target denotes an area of interest, where zooming in typically signals increased user focus. Based on this structure, we extract three types of features.

Temporal Features

The sequence of operations reflects user habits and varies across domains. We use a Variational Autoencoder (VAE) with an encoder-decoder architecture to convert irregular operation sequences into fixed-dimensional vectors, enabling robust temporal feature extraction.

Spatial Features

Each browsing target is matched to map tiles. A color template is applied to the tile to quantify proportions of spatial elements—such as water bodies, forests, and buildings—distinguished by color. This method captures the environmental context surrounding the browsing target.

Semantic Features

Browsing targets are aligned with Points of Interest (POIs). A POI co-occurrence model is developed to embed semantic contexts, based on the principle that certain POIs (e.g., schools and libraries) tend to co-occur. This model captures higher-level semantic patterns relevant to the user's domain.
These three features are concatenated and input into an LSTM-based neural network for classification, enabling the model to learn domain-specific virtual trajectory patterns.

3. Data

The virtual trajectory dataset is sourced from Tianditu, China's national PMSP developed by the National Geomatics Center of China. Tianditu receives over 800 million daily visits, offering a robust dataset for analysis. We use access logs from October 1 to 19, 2020, and focus on five domains with abundant trajectory data: agriculture, navigation, environment, river, and ocean. Domain labels are manually annotated.

4. Results

We evaluated the contribution of each feature type individually and in combination:

Temporal features achieved the highest standalone classification accuracy at 80.67%, indicating strong domain-specific behavioral patterns in user operations. This result challenges the assumption that operation sequences are highly random and personal.

Spatial features and semantic features achieved accuracies of 71.49% and 73.65%, respectively. Their lower performance may stem from overlapping areas accessed by users across domains and the multifunctional nature of spatial elements.

Feature fusion yielded the best performance, achieving 88.13% accuracy. This demonstrates that while individual spatial and semantic features may lack strong discriminative power, their integration with temporal features significantly enhances classification accuracy.

5. Conclusion

This study presents a novel framework for classifying virtual trajectories in PMSPs by integrating temporal, spatial, and semantic features. Our results demonstrate the importance of user operation patterns in trajectory analysis and highlight the value of

multi-dimensional feature fusion. The proposed approach achieved a classification accuracy of 88.13% on real-world Tianditu data. These findings offer a foundation for developing personalized services and recommendation systems within PMSPs. Future work will focus on predicting virtual trajectories to further optimize user experience.

Keywords

virtual trajectory, public map service platform, spatiotemporal-semantic fusion

Simulating retail location in the digital era: a spatially-explicit theoretical agent-based monocentric city model

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ABSTRACT

The retail landscape is undergoing a profound transformation driven by technological advancements, diminishing transportation costs, and shifting consumer behaviours. The proliferation of digital com- merce has introduced new competitive dynamics, challenging traditional brick-and-mortar retailers and reshaping urban spatial structures (Beckers et al., 2021, 2022). Over the past decades, the diffusion of the automobile has induced a suburbanisation of population, due to reduced commuting costs. Given the role retail spaces have as places of vitality in urban centres, offering places of encounter and experiences in addition to the products, understanding the impact of these transformations on location patterns becomes crucial.

To understand why firms locate where they do, we turn first to location-competition literature. Sem- inally, Hotelling (1929) proposed a simple, linear model, in which two firms compete for a homogeneous market distribution by adapting their locations and prices, whose equilibrium location lie at the centre of the market line. Despite being thoroughly explored in further organisational studies and game theory literature, even being applied to non-spatial contexts - e.g., the political spectrum (Feldman et al., 2016), this outcome has also been questioned. d'Aspremont et al. (1979) claim that moving away from linear transportation costs breaks the stable equilibrium proposed by Hotelling (1929). To understand why households locate where they do, we turn to the monocentric-city model literature, as it considers the gradual differentiation of household density when competing for space. Alonso (1964) proposed a simple linear city model with microeconomic foundations that became known as the "monocentric city model". There have also been conciliations between the monocentric city literature and location competition mod- els. Takahashi (2014) explicitly draws from both trends a model joining the same trade-offs of Alonso with retail competition, however still in a linear context. Ushchev et al. (2015) explores location and price competition between central and suburban retailers, approaching a core-periphery setting akin to Krugman (1992). Other studies have enhanced location competition literature, but still restricted to a 2-firm game (Chen and Song, 2021; Dragone and Lambertini, 2020; Heywood et al., 2022; Fleckinger and Lafay, 2010).

This research proposes to bridge Alonso's monocentric city model and retail location competition models, while also expanding beyond the linear setting to a spatially ex-

plicit, two-dimensional one. We expand traditional implementations of location-competition models from a limited number of firms to n- firms, endogenous to each setting. We propose a theoretical monocentric city model in which competing retail firms and consuming households interact. In the developed open-city model, households commute to the exogenously-defined Central Business District (CBD), while also travelling to a patronised shop for groceries. We also introduce the relevant topic of online-shopping as an outside option for households: they have always the option to import the uniform product from the outside world incurring in an importing fee. Shops import the same product, benefitting from increasing returns to scale, and resell these to the households patronising them. Households will optimise their utility by choosing a shopping behaviour (online or local) and their location, while shops maximise their profits by choosing a selling-price and, also, their own location. The gains in scale of shops are offset by the extra transportation costs households have when visiting a shop, yielding equilibrium prices and locations.

The main objective of this work is to understand and explore the location patterns achieved by retail firms in equilibrium, sensitive to changes in transportation costs and online-shopping costs, as well as which particular dynamics lead to these equilibria. To account for non-linearities and path-dependencies, we choose to expand beyond an analytical and geometrical approach, towards modelling a spatially-explicit agent-based simulation, in which we test for different parameter configurations. This is done to address three main research questions:

1. Where do retail firms emerge and cluster in an open, agent-based, two-dimensional theoretical urban model?
2. How does altering transportation costs and importing fees affect the equilibrium location of both households and firms?
3. Which location patterns can be found on the way to a price-location equilibrium in this setting?

We show, both theoretically and geometrically, that the expectedly contradictory concepts of minimum- and maximum-differentiation principles, defended respectively by Hotelling (1929) and d'Aspremont et al. (1979), may coexist in a simulation dynamic. Once space and time are discretised, the optimum price for a second firm is the one low enough for it to dominate the consumption decisions of all customers belonging to the incumbent firm, which ends up being the exact same price. Expectedly, however, moving from linear to exponential transportation costs yields optimum location equilibria for firms in out-of-corner solutions, with a range of locations from which households experience the same transportation costs. We conclude then, that both d'Aspremont-like and Hotelling-like local equilibria are possible, which is later confirmed by simulation. However, even with exponential transportation costs, a minimum- differentiation principle can prevail, with new shops choosing optimum locations as adjacent to existing ones. We also highlight a fundamental methodological contribution of adopting agent-based simulations to solve a location-competition problem in which the number of interacting agents exponentially increases the complexity of the calculations.

Keywords

retail geography, agent-based modelling, monocentric city model, location-competition, online shopping

Recent Climate Evolution in the Sado River Basin, Portugal: Empirical Challenges and Contributions to Spatial Model Validation

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Abstract

Understanding the evolution and variability of climate is essential for both scientific research and informed decision-making. In particular, precipitation and temperature are two key variables with far-reaching impacts on natural systems and socioeconomic activities, especially in regions facing increased climatic stress. This study examines the long-term behavior of these variables in the Sado River Basin (SRB), located in the southern part of mainland Portugal—a region that has been identified as particularly vulnerable to climate change and desertification processes. Using daily data on temperature and precipitation covering the period from 1950 to 2019, we applied the non-parametric Mann-Kendall trend test and Sen's slope estimator to detect trends and estimate their magnitude. The dataset includes nine observation points across the basin: temperature data were sourced from the E-OBS gridded dataset, and precipitation data from both E-OBS (two points) and local meteorological stations operated by the SNIRH (Portuguese National Water Resources Information System).

The results reveal consistent trends across most of the basin, with a significant decline in annual precipitation and a marked increase in annual mean temperature for the full period (1950–2019) and the more recent interval (1985–2019). However, while temperature trends exhibit a coherent spatial pattern—suggesting a basin-wide warming signal—the precipitation trends show substantial heterogeneity in their magnitude, depending on the observation point. This lack of spatial coherence poses challenges for the identification of generalized processes and the construction of robust predictive models.

From a methodological and theoretical perspective, this empirical study offers valuable insights for the development, calibration, and validation of spatial simulation models in climate and hydrological sciences. The spatial variability of observed trends exemplifies one of the major obstacles in model validation: the tension between localized climatic contingencies and the need to capture broader, generalizable dynamics. This issue aligns directly with ongoing debates in Theoretical and Quantitative Geography about how to validate geosimulation models when confronted with complex spatio-temporal phenomena. Our findings emphasize the importance of spatial sensitivity analysis and localized calibration techniques to better account for the inherent geographical heterogeneity of climate systems.

Moreover, the SRB represents a real-world testbed for exploring the validation of geosimulation approaches in settings where climate impacts have direct and urgent consequences for land use and water management—particularly in agriculture, which is highly dependent on precipitation variability and water availability. The decline in rainfall and the increasing temperature trends observed here already affect the hydrological balance of the basin, with implications for irrigation, ecosystem health, and regional development strategies. This underscores the potential for combining empirical data such as ours with scenario-based geosimulations to inform sustainable territorial planning.

Finally, our study provides a solid empirical basis for integrating recent methodological advances—such as machine learning-based model surrogates, spatially explicit companion modelling, or hybrid simulation-validation frameworks—into climate-oriented geosimulations. These approaches may help reconcile fine-scale environmental variation with macro-level planning and decision-support needs.

In summary, this research contributes not only to the understanding of climate change dynamics in a vulnerable region of Southern Europe but also to the broader discourse on model validation in spatial simulation. It demonstrates how long-term, spatially distributed empirical observations can both inform and challenge simulation-based approaches, highlighting the need for interdisciplinary dialogue between climatologists, geographers, modelers, and policymakers.

Keywords

climate trends, precipitation, temperature, spatial variability, model validation, geosimulation

36 years later: Some personal reflections on Peter Haggett's 'Revolutions and Quantitative Geography'

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ABSTRACT

In February 2025, the University of Bristol lost one of its most distinguished scholars, and theoretical and quantitative geography one of its most important 'revolutionaries' – Peter Haggett (CBE, FBA), Professor of Urban and Regional Geography, and member of the 'space cadets' that significantly reshaped the study of geography in British schools and universities, and beyond.

I was amongst the last undergraduate cohorts to be taught by Peter, prior to his purported 'retirement' in 1998. (He actually continued as the first Director of the University's Institute for Advanced Studies, remaining a Senior Research Fellow of the University as of last year). Although the waves of the 'quantitative revolution' had receded, and cultural geography was emerging as its own 'paradigm shift' within human geography, Peter was a hugely respected lecturer – the only one to receive a standing ovation from my year group – who continued to pursue many of the ideas captured in books such as Locational Analysis in Human Geography through his studies of the spatial diffusion of disease. He not only taught the class the principles of Monte Carlo simulation, he also alerted us to a global pandemic of the kind of 'the Spanish Flu' outbreak being, in 1995, overdue. We had to wait another quarter century for that teaching to be confirmed.

Amongst the many papers he wrote, and the many presentations he gave, one was made at the 6th European Colloquium on Theoretical and Quantitative Geography; seemingly after dinner, at 8.30pm on Wednesday September 6th, 1989, in Chantilly, France. It is entitled, Revolutions and Quantitative Geography: some personal reflections on the bicentennial and is playful in its meaning: the two centuries was from the French Revolution, but the reference is also to Daniel Bernoulli's 1760 paper and its mathematical modelling of smallpox – Peter was on his way to work with the World Health Organization –, as well as to "the revolutions that mathematics has brought to some parts of geography".

Some of the paper is dedicated to the two decade or so that underpinned 'the quantitative revolution' in (human) geography and the spatial diffusion of its ideas from 'patient zeros' in the United States, through to geographical exposures in departments such as Cambridge and Bristol. Writing about it, Peter is characteristically modest, "many of our papers stressed technique only and addressed only trivial problems [...] It is also probably true that there was little philosophical depth or critical awareness in the studies", yet the ambition remains: "looking back I would say our mistake in the 1950s and 1960s was not being revolutionary, but not being revolutionary enough."

Respectfully, I disagree. There was no mistake as such. Rather, there was an in-built problem that the 'revolutionaries' could not overcome: geography is reducible neither to a science nor to scientific approaches. It is, by nature (and nurture), faculty-crossing and interdisciplinary; hence it can be placed with the humanities in British secondary schools, but with the social or natural sciences in universities. It is part of the Arts, the Humanities, the Sciences, and of the Social Sciences, too, and its character suffers when boxed into any one. Geography is the study of how and where physical, socio-economic and cultural processes, products, outcomes, formations and so much more come together with other geographically situated (co-) occurrences, and of the spatial consequences that arise. There is no distinct canon of literature or bounded set of methods that delimit what is human geography, let alone geography as a whole. Instead, there is something about the pluralism and diversity that, paradoxically, seems to both stretch the meaning of geography but also give it meaning and identity. Peter's geography, in all its brilliance and scholarly wisdom, might be likened to environmental geography, influenced by Peter's love of geomorphology. As a river for channelling geographic research, it flows strongly but is ultimately too narrow, even within quantitative geography. Yet, it has a hugely impressive depth.

None of what I have written is to disavow the important contributions of theoretical and quantitative geography to scholarly learning, or its enduring application to real-world problems. It is certainly not to diminish the enormous respect I have for Peter and his work, or the lasting influence that both have on my own studies. My point is only this: in a databased world of AI, 'big data', machine learning, and such like, geography should avoid the temptation of a second quantitative revolution. It may, however, benefit from greater willingness to engage with data and data technologies with a purpose that is less about revealing or confirming general laws of socio-spatial organisation, but to instead place focus on spatial variations and the socio-economic inequalities they represent. Here we may learn from revolutions themselves: they typically emerge from a local context but end-up being insufficiently sensitive to difference.

Keywords

Peter Haggett, Quantitative Revolution, Quantitative and Theoretical Geography, History of Geography, Critical Quantitative Geography

Quantitative geography and its intellectual backdrop: socio-historical insights from Britain and France

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ABSTRACT

Among the generally lacunary attempts to provide a retrospective outlook on contemporary geography, the development of the so-called "quantitative geography" seems to have received enviable attention from various commentators and analysts (Unwin, 1978; Berry, 1993; Haggett, 2008; Cuyala, 2016; Johnston et al., 2019; Gyuris, Michel, and Paulus, 2022). However, this already existing historiography is significantly internalist and mainly focused on methodology and its epistemic consequences, while other approaches would be interesting to develop in the study of this domain. For instance, pragmatic and materialist approaches to the history of science can emphasise the concrete conditions in which "quantitative geographers" worked in, and social inquiries could question if this new style of research 'recruited' a typical pattern of social profiles among advanced students. In our proposition, we would like to develop an inquiry focused on the intellectual background mobilised and constructed by "spatial analysts" in their written production – knowing that published academic texts are very specific in terms of intertextuality and broader intellectual references.

This contribution is built at the intersection of two research endeavours: one focusing on the British tradition of "quantitative geography" (Szende, 2024), the other one having tried to construct the history of French "géographie théorique et quantitative" (Orain, 2009; Orain, 2016; Orain, 2022). Crossing our efforts is not straightforward: we have had to to face a difficulty relating to the temporal discrepancy between a British tradition already very active in the 1960s, while its French counterpart was only initiated in the 1970s and partly drew inspiration from its British precedent. This discrepancy isn't taken here as an obstacle but an occasion to show how historical conditions help us to put an emphasis on differences while strictly synchronous situations would facilitate the research of similarities.

Our contribution is founded on a systematic inquiry into the variety of reference corpuses found in the publications we study in our work, from parochial literature to General System Theory and philosophy of science. Our research showcases, on the one hand, a quite surprising increase of references – and in particular references that are external to geography –, when compared to previous geographical productions. On the other hand, our work also delves into the search of a common universe shared by British and French geographers in the development of quantitative geography. We argue that these similarities result from what French geographers took from their British counterparts, but also from the convergences between their social background and the place of quantitative and theoretical approaches in both national geographical

traditions. The final part of our contribution focuses on the main differences between these two traditions at their beginning, that relates to the national culture, language and peculiarities in which they emerged.

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Keywords

quantitative geography, theoretical geography, history of geography, spatial analysis, national traditions, discipline, references

Cities as boundary objects: can this concept improve the transfer of urban models?

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ABSTRACT

For researchers working on cities, a key challenge lies not only in disseminating their findings and models within their own community, but also in enabling their adoption by other scientific fields, stakeholders, and policy makers. Cottineau et al. (2024) stated well some favorable conditions of the "mobility" or transfer of seminal geographic or regional models including models simplicity, the transparency of their hypotheses and their graphic representation, but also "contingent factors such as their creators' biographies, institutional context and the traditional markers of power relations".

However, in the case of urban models, it is particularly difficult to transfer them, as cities can be apprehended through their physical built components, their social and economic networks dynamics or by their symbolic meanings. Cities need classification systems that are both material and symbolic (Star, 2010) to be recognized by all the parties that are involved in it: by decision-makers, by scientists of various domains, by practitioners facing concrete issues and by people and communities in their daily life. This diversity of perspectives raises the question: could cities themselves be seen as boundary objects – entities that bridge different domains and allow partial, yet coherent, understanding across them? As "something so "in between" a thing and an action" (Bowker & Star, 1999), boundary objects operate as intermediaries that translate and align different interests (Latour, 1996, 2005; Nicollini et al., 2012). They are particularly useful when the divergence of visions is a source of tension or conflict, or when a new model struggles to be adopted (Koskinen, 2005). Defined as "objects which are both plastic-enough to adapt to local needs and the constraints of several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989, p. 393), boundary objects could offer an original perspective on cities and their models.

In our presentation we will question how far this concept of boundary object, originating from the sociology of science and technology, could be useful to geography modelers? Could it help to better organize the spatial analysis community to communicate cities' models and to rise their likelihood of transfer? We will discuss different frameworks they propose in different contexts, in particular in relation to power between science and society, to evaluate the effectiveness of this concept to provide new lens to improve the social impact of our discipline.

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Keywords

boundary objects, cities, urban models

The suitability of volunteered geographic information to support walkability studies in older adults

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ABSTRACT

Walking plays a vital role in the health of older adults, helping to manage chronic conditions and support cognitive and emotional well-being. Empirical work highlights multiple determinants of walking in later life, including age-related changes in sensory, motor, and cognitive functions. The built environment can either facilitate or hinder mobility by shaping route selection, trip frequency, and perceptions of safety. However, initiatives like the 15-minute city often focus on proximity to services and devote less attention to the ease and safety with which people can walk to destinations within an area—commonly referred to as walkability. Collecting data on the built environment relevant to walkability is often done through manual auditing methods, which can be resource intensive and geographically limited, while proprietary geographic information sources pose additional barriers related to accessibility, transparency, and cost.

This study explores the use of volunteered geographic information (VGI) to generate walkability indicators relevant to older adults, as part of the ”hiWALK” indicator set development. We begin by developing a locally adapted indicator framework. Our starting point is a set of adaptations of the Neighborhood Environment Walkability Scale (NEWS)—questionnaire-based instruments designed to capture subjective perceptions of the walking environment—tailored to the older adult demographic (Cerin et al. 2010; Starnes et al. 2014; Koller et al. 2024). To identify which elements of these frameworks are most relevant in our local context, we conduct a structured survey with 100 residents aged 65 and older in Mannheim. Participants rate the perceived importance

and relevance of items using a 5-point Likert scale, covering domains such as pedestrian infrastructure and structural attributes, aesthetics and environmental quality, and access to facilities. In addition, open-ended questions invite participants to suggest any missing features they considered critical to walkability. We explore patterns in item responses using descriptive statistics and exploratory factor analysis, which guided the selection of a refined subset of indicators.

Walkability indicator generation combines OpenStreetMap (OSM) with supplementary remote sensing data (Sentinel-2, SRTM), using Mannheim, Germany, as an illustrative case. We leverage Sentinel-2's Normalized Difference Vegetation Index (NDVI) to capture green infrastructure, while SRTM data inform slope analysis. OSM tags guide the classification of pedestrian infrastructure—highlighting paths designated exclusively for pedestrians versus those shared with motorized traffic—and help evaluate path quality through attributes such as smoothness, surface, and track type. To quantify connectivity, we compare walking distances to relevant destinations with their straight-line equivalents. We then test the transferability of these metrics across urban environments differing in socio-economic and infrastructural contexts.

Early results reveal robust insights in areas with comprehensive VGI coverage. However, regions with limited OSM completeness may require additional data sources or locally tailored adjustments to maintain metric consistency and reliability. Finally, we discuss how these findings can inform 15-minute city initiatives by highlighting the need for robust, open data solutions that account for older adults' unique walkability requirements.

This work is part of the Driving Urban Transitions (DUT) 15-minute City Project "Silver Ways," which aims to improve pedestrian friendliness of cities to better cater to the needs of older adults. HiWalk is part of HeiGIT's Climate Action Navigator, showcasing climate action indicators in the realm of active mobility like hiWalk and hiBike.

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Keywords

older adults, walkability, volunteered geographic information (VGI)

Investigating the long-term impact of experiencing a major disaster in mid-adulthood on body mass index and waist circumference: A prospective birth cohort study

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ABSTRACT

Background

Longer-term studies examining the impacts of a major disaster on health are rare. Experiencing a stressful life event is associated with obesity; however, there is scarce evidence relating earthquake exposure to changes in weight-related outcomes. This study investigates the association between earthquake exposure and measured body composition of a prospective birth-cohort study at six-years post-earthquake.

Method and findingss

Data were gathered from the Christchurch Health and Development Study, Christchurch, New Zealand, which was established in 1977. Trained interviewers obtained waist circumference (cm), height (cm), and weight (kg). Height and weight were used to calculate body mass index at age 30 (2007) and 40 (2017) years of age. A composite measure of exposure to the four major Canterbury earthquakes from 2010-2011 included: i) the immediate impacts of the earthquakes; and ii) the consequences of the earthquakes. This was further simplified into a binary measure of exposure. Linear regression models examined associations between earthquake exposure and weight-related outcomes at a six-year follow-up. Findings showed no association between exposure and body mass index at six-year follow-up. However, relative to those not exposed, those exposed had a higher waist circumference (b=2.13 [95% Intervals (CI) 0.38, 3.84]) that increased with severity of exposure (most severe exposure category b=2.49 [95% CI 0.24, 4.86]).

Conclusion

Exposure to a major earthquake was associated with higher waist circumference at six-year follow-up with some evidence of a dose-response by severity of exposure. Future research should continue to monitor the long-term health impacts of exposure

to major disasters.

Keywords

Earthquake, Body Mass Index, Waist Circumference, Cohort Study, Longitudinal, Disaster

High-resolution spatial greenness metrics supporting environmental health research

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ABSTRACT

A growing body of evidence underlines the critical role of green environments in promoting human health and well-being. Within environmental health research, precise and nuanced representations of green space exposure are crucial to understanding the interactions between human living environments and health outcomes.

The Normalized Difference Vegetation Index (NDVI) has traditionally served as a proxy for green exposure due to its computation ease and applicability across large geographic extents. However, NDVI presents several limitations: it may underrepresent ecologically valuable non-vegetated natural areas such as heathlands or water bodies and offers no insight into land use. These shortcomings motivate the development of more context-sensitive, functionally relevant indicators for environmental health analyses.

Recently, we developed a suite of spatially-explicit greenness indicators for Flanders (northern part of Belgium) aimed at supporting such studies by accurately characterizing the green environment surrounding individuals' residences or workplaces. To structure our overview, we adopted the 3-30-300 framework (Konijnendijk, 2021) for green neighbourhoods, which recommends that every person should be able to see three trees from their home, have 30% tree cover in their surroundings, and have access to a green space within 300 metres. Our work provides spatial operationalizations of each component of this rule, adapted for high-resolution and large-scale applications.

Visual Access to Greenery: The "3" Component

To address the visibility component, we developed a Viewshed Greenness Visibility Index (VGVI) for the entire region of Flanders, based on viewshed analysis using high-resolution digital surface models (5 m grid). Our method builds upon previous work by Labib et al. (2021) and incorporates technical refinements that enhance computational performance, allowing for application at a national scale (Vervoort et al. 2024). This indicator quantifies the proportion of visible green elements from any given point, capturing the visual experience of greenery from residential locations. This indicator has already been applied in regional epidemiological studies, including one showing a significant negative association between low VGVI and mental illness prevalence, highlighting the importance of visual green exposure for psychological health.

Tree Cover Percentages: The "30" Component

The second pillar of the 3-30-300 rule is the 30% tree cover recommendation. We estimated green and tree cover from satellite imagery (Copernicus Tree Cover Density) and local high resolution aerial flight campaigns, processed to classify detailed land cover and vegetation structure across Flanders. To reflect the spatial influence of greenness, we calculated total green cover and tree cover percentages within different distance bands: immediate surroundings/garden (0–50 m), the neighbourhood (up to 500 m), and the wider living surroundings (up to 2000 m). These gradations enable differentiated analyses of green exposure and help evaluate whether environments meet ecological and health-related thresholds. For example, immediate tall vegetation has been linked to cooling effects and slower biological aging (telomere length), while green areas at 1000–2000 m distances have been associated with lower diastolic blood pressure and fewer respiratory infections (Department of Environment, 2021).

Accessible Green Clusters: The "300" Component

To assess access to larger green spaces, we developed a spatially-explicit approach to create green cluster indicators based on land cover and use, including natural areas and urban parks, within different walking distances. Clusters were defined using spatial connectivity rules that account for size, allowing minor gaps (e.g. roads, water bodies, agriculture) to be bridged in larger green zones and accessible. We identify, among others, access to 'neighbourhood green' as clusters at least 0.2 ha within 400 m and 'district green' at least 10 hectares within 800 m. One health study (Verheyen et al., 2021) found a statistically significant relationship between access to district green and lower cortisol concentrations in the hair of pregnant women, suggesting potential stress-buffering effects.

Conclusion

By integrating multi-scale, multi-source geospatial data and tailoring indicators to reflect human experiences of green space, our greenness metrics offer strong support for environmental health research. They enable more precise quantification of residential environmental exposure and have already demonstrated relevance in epidemiological studies. They also provide actionable insights for urban planning, environmental justice, and public health policy by identifying green space disparities across socio-demographic groups.

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Special session Environmental Health Studies (optional)

Keywords

health geography, neighbourhood greenness, visible green

From geodata abundance to meaningful insights: assessing the limits and potential of diverse geodatasets in urban research

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ABSTRACT

Over the past decade, spatial data sources have multiplied—from institutional surveys and satellite-based environmental models to citizen-generated platforms. These developments have ushered in what Goodchild (2018) describes as an era of Big Geodata, defined by its volume, velocity, and variety. Urban researchers now have easier access to micro-scale and individual-level information, offering the promise of unprecedented precision in diagnosing socio-environmental disparities. This proliferation of spatial data has triggered renewed debates about the epistemological foundations of geographic research and the need to critically assess the assumptions embedded in big data infrastructures (Ferreira, Vale, 2024; Kitchin, 2013). What exactly are these datasets capturing? How can we meaningfully integrate such heterogeneous sources to understand spatial inequalities? And what are the risks of reproducing biases and blind spots through the data infrastructures we rely on?

This presentation draws on empirical work conducted in the Brussels-Capital Region to examine these tensions. It focuses on three case studies that reflect the diversity of geodata sources and their potential, as well as their limits: (i) FixMyStreet citizen reports were used to model the urban determinants of illegal dumping across the city, revealing both the usefulness of crowdsourced reporting and its strong dependence on the context (Guyot, Thomas, Vanwambeke, 2025). (ii) High-resolution urban morphology data (Guyot, Araldi, Fusco, Thomas, 2021) were integrated with individual-level socio-economic microdata from Statbel to explore how neighbourhood typologies intersect with socio-economic vulnerabilities. (iii) A third study combined survey-based health data with environmental indicators to analyse associations between mental health status and access to urban amenities, underscoring the importance of accounting for non-response bias even in robust survey designs (Guyot, Pelgrims, et al., 2021; Pelgrims et al., 2021).

These examples illustrate the practical and epistemological challenges of working across datasets that are collected through different means (institutional, modelled, volunteered), at different spatial and temporal resolutions, and for different original purposes. While Big Geodata allows for analysis at fine scales—streets, buildings, individuals—such granularity does not automatically equate to meaningful insight. Most of these data were not originally produced for scientific research, and often serve as imperfect proxies when repurposed. Analytical strategies therefore require careful design to mitigate spatial biases (e.g. in data coverage or reporting patterns), semantic mismatches (e.g. between administrative units and lived space), and structural limitations (e.g. restricted access to sensitive data). Rather than embracing data-driven sci

ence uncritically, our work calls for a return to place-based analysis—grounded in local context and sensitive to spatial heterogeneity. We advocate for a critical and pluralistic use of geospatial data, arguing that only by aligning the scale, scope, and epistemic status of different data types can we generate insights that are both scientifically robust and relevant for urban policy.

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Keywords

geodata, urban research, critical GIS

Radio call signs of consumer electronics as a data source in human geography

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ABSTRACT

Consumer electronics often interact with other devices by radio signals. The call signs of Bluetooth and Wi-Fi devices are open and unencrypted. They can be received by cell phone or laptop, but special apps are required (Wiggle for Android or BLE-scout for Windows). Every device has a unique identifier, called a MAC address, which is included in the call sign. The radio monitoring app also records time and geographical coordinates of every received signal.

Radio monitoring data is a good source of information for interesting analytical insights. It's important because many existing studies are more about technical details and descriptive visualizations, rather than complex interpretation in terms of human geography.

Two studies were conducted – reconstruction of pedestrian flows in the city and monitoring of population in the country.

The map of pedestrian flows was created for the territory of the Lomonosov Moscow State University. The measurements of radio signals were conducted on Monday, October 21, 2024, from 14:30 to 17:30. The volume of pedestrian flow between two points is equal to the number of devices that were detected at both points. The points were educational buildings, dormitories, a subway station, tram station.

There are 2 educational clusters in the network of pedestrian flows, where educational buildings are strongly connected: the science cluster and the cluster of humanities (Fig. 1).

There are two subway stations on the territory of the university. The hinterland of "Universitet" is bigger, because:
- there are more faculties near this station (it was opened in 1959, "Lomonosovskiy prospekt" was opened in 2017)
- "Universitet" is situated at the same level as many university buildings, but "Lomonosovskiy prospect" is much lower, so people have to go uphill, it is not comfortable.

The intermediate zone is between the hinterlands of distinct stations.

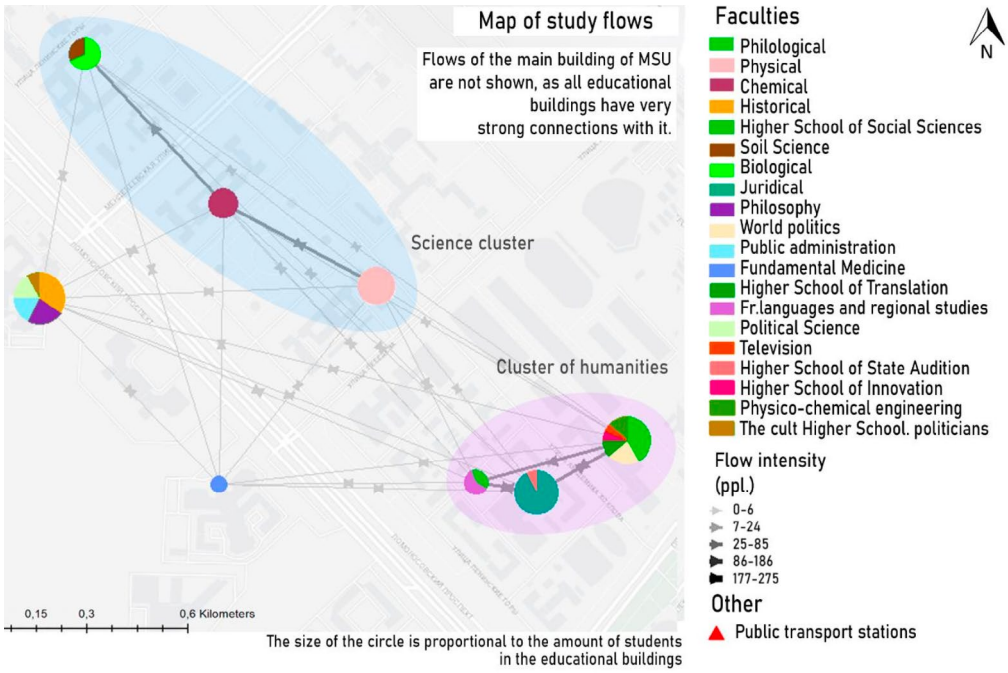

Figure 1. *The map of pedestrian flows between educational buildings*

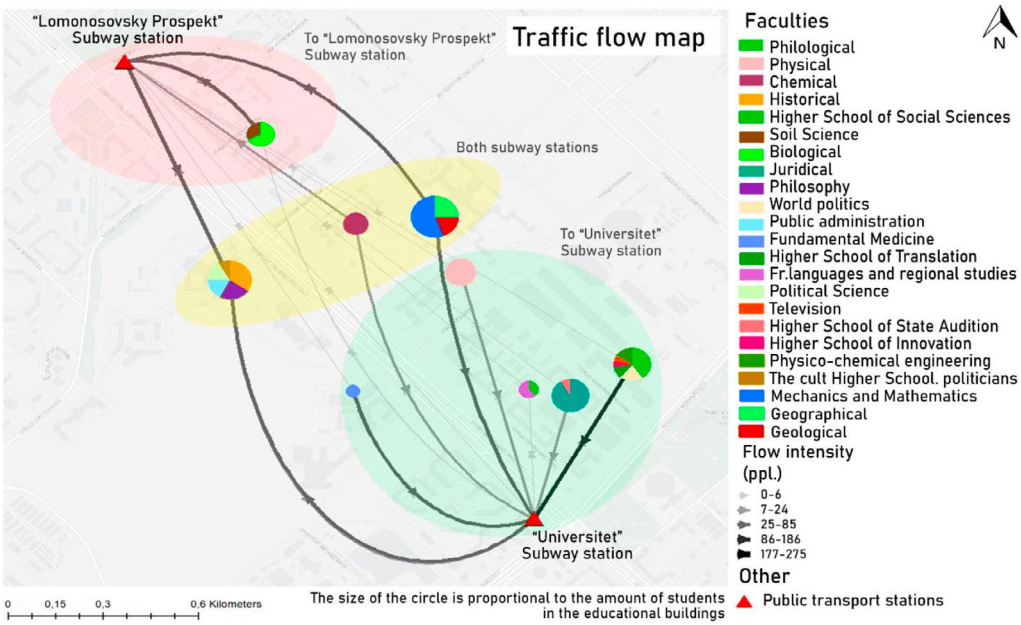

Figure 2. *The map of pedestrian flows between educational buildings and subway stations.*

Big and average flows connect those educational buildings and dormitories, where the same faculties are situated (fig. 3). There is only one exception, the flow "dormitories of the sector B (Main Building) – First Building of Humanities". These locations don't share common faculties, but the flow is really big, because students from dormitories go to sports grounds and gyms, which are situated near the First Building of Humanities. The measurement point of the First Building of Humanities was in the street in front of the entrance, so signals of sportsmen's devices were captured.

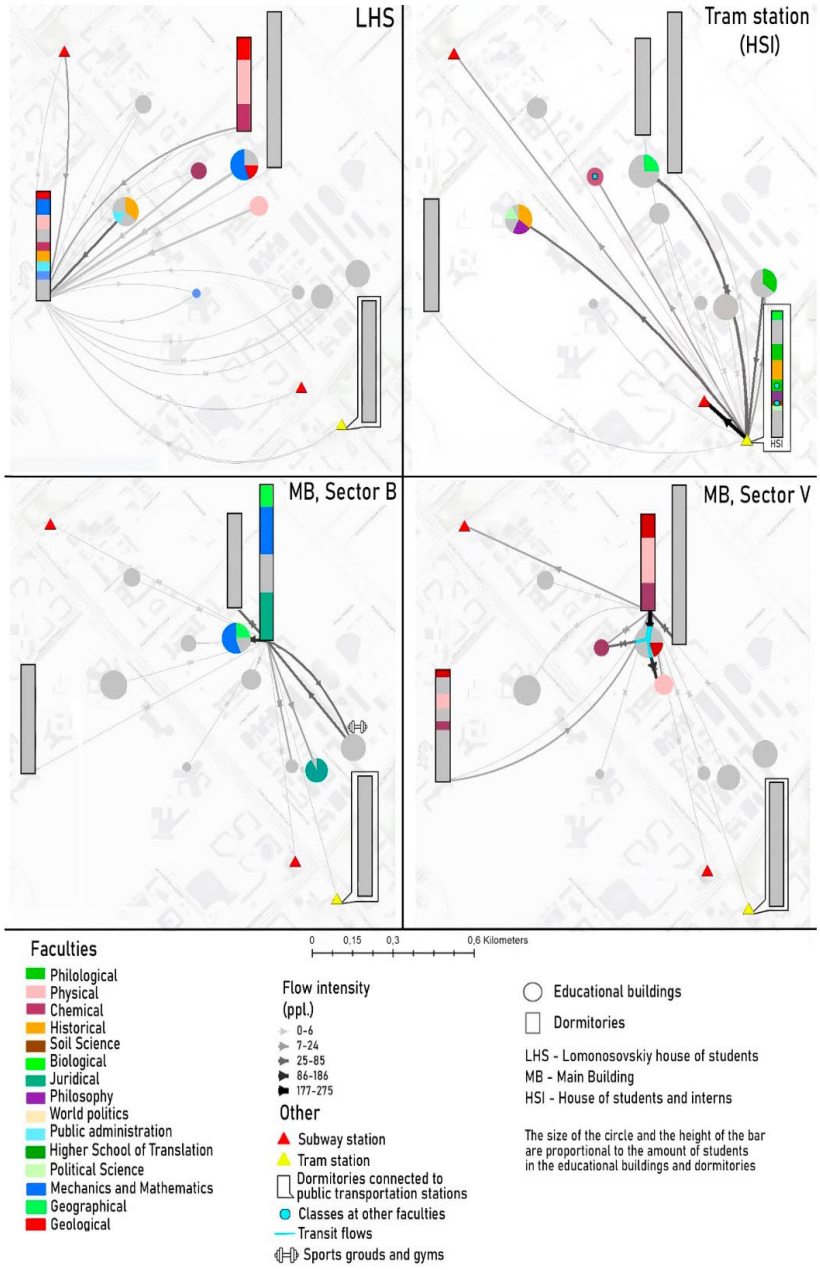

Figure 3. *The map of flows, related to dormitories.*

The radio monitoring using the Wiggle app was conducted in the village Zimnik (Ustugenskiy district, Vologda region, Russia) from July 2024 to April 2025. The measurements were performed in the middle of the month on Saturday and Sunday in the evening, after sunset (people are usually concentrated in the houses at the beginning of the dark period of the day). The Saturday data shows a weekend condition. The Sunday evening data shows weekday condition, because the majority of houses in Zimnik are used as second housing for outdoor recreation on a weekend or vacation, so many people commute to the nearest city (Cherepovets) after dinner on Sunday.

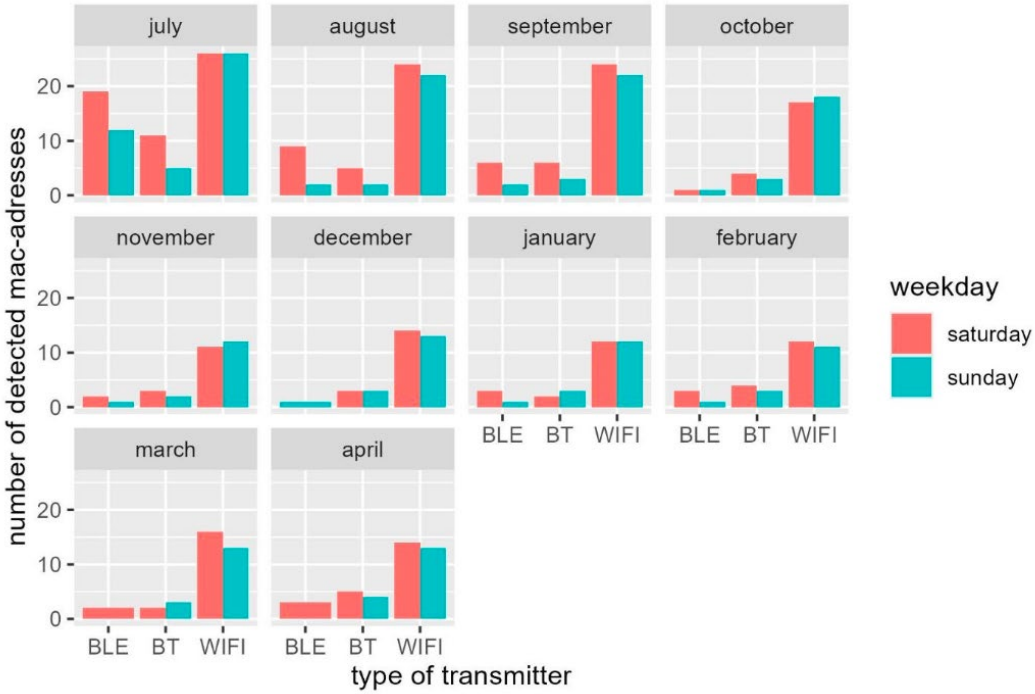

Figure 4. *The dynamics of the number of wireless devices in the village Zimnik.*

The number of Wi-Fi devices varies from 26 in July to 11 in February. The number of Bluetooth devices decreases from 10-20 in July to 1-3 in the cold period. The number of Wi-Fi devices varies slightly from weekday to weekend, but the number of Bluetooth devices on weekends could be 2-4 times greater than on weekdays during the warm season. The reasons are the following:

1. Wi-Fi routers use all people in Zimnik (the cell tower is very far, so if you want to connect with it, you must use a 4 G modem with an external MIMO antenna). Many retirees live in the village all year (according to field observations), so the number of Wi-Fi devices doesn't decrease much in winter.

2. The most popular Bluetooth devices are smartwatches and wireless headphones. The retirees usually don't use them, such devices are widespread among younger generations. The young generations live in Zimnik only on weekends or vacation during the warm season, because it takes a lot of time and resources to heat the house in winter and the daylight is very short.

So, the number of wireless devices is not only an indirect indicator of population size, but it also shows the generation structure.

The main advantage of our approach is the opportunity to perform observation without special equipment and skilled operators. The main disadvantage is the scaling problem: big territories require a lot of observers. Our approach is suitable for public spaces, towns and villages. It is a good alternative to expensive mobile data.

Keywords

wireless electronics, radio monitoring, call sings, pedestrian flows, rural studies

Analyzing Street View and Social Media Data to Evaluate the Urban Environment in Lisbon

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ABSTRACT

To define neighborhoods using social media data, researchers have developed various methodologies leveraging the rich, location-aware information generated by platforms like X (former Twitter) and Foursquare. This study aims to evaluate the urban environment of Lisbon, Portugal, by combining two key data sources: Google Street View images and social media data from platforms like Flickr and X (specifically Instagram images reposted on X).

Instagram images and their captions were used to learn the visual elements associated with different neighborhoods. By analyzing the images and text, we identify what visual elements are commonly posted about each neighborhood, which helps in understanding their identity and characteristics. This can also reveal the focal points of visual attraction in Lisbon, indicating the most active neighborhoods and parishes, helping to understand the social and cultural dynamics within different neighborhoods.

On the other hand, Flickr social network also provides rich spatial information that can be used to describe and characterize space. Its photos capture environmental features, cultural elements, and human activities, which are complementary to traditional datasets. Indeed, geo-referenced Flickr photos can be used to understand how neighborhoods are perceived by people. By analyzing these pictures, we identify appealing city photos and link them to neighborhood characteristics such as distinctiveness and beauty. This method is effective, scalable, and context-aware, considering factors like time of day, day of the week and so on.

Finally, Street View images offer a powerful tool for defining and analyzing neighborhoods through automated measurements of public space quality. They provide detailed, up-to-date visual context of urban environments, including buildings, infrastructure, green spaces, etc.

Our methodology employs the Place Pulse model, which assesses urban spaces based on five criteria: safety, liveliness, beauty, wealth, and feelings of boredom or depression. By analyzing Street View imagery, the model captures human perceptions of the environment.

To enrich this analysis, social media data is incorporated to explore how users engage with and perceive their surroundings. This data is examined through the number of likes and the NIMA (Neural Image Assessment) score, which uses deep learning to as

sess the aesthetic quality of images. The combination of likes and NIMA scores adds depth to understanding users' experiences in urban spaces, particularly by capturing the emotional and visual appeal of the environment.

By merging these datasets, the study offers a comprehensive view of both the physical characteristics of urban spaces and the social dynamics that shape users' perceptions. This integrated approach, combining Place Pulse and NIMA, provides valuable insights for urban planning and policymaking, with potential applications for improving quality of life and promoting sustainable urban development.

The methodology is scalable, making it applicable to other cities for continuous monitoring and comparison over time. As urbanization accelerates globally, the quality of urban environments becomes increasingly critical for users' well-being. This study underscores the importance of measuring urban quality using subjective indicators. The rapid growth of social media and mobile technologies has significantly increased the availability of user-generated content, offering new opportunities for urban analysis and fostering innovative approaches.

Session: 3. Sensing Functional Systems through Mobility from Big Data: From Neighbourhoods to Urban Regions and Global Networks.

Keywords

social media data, urban environment, street view, aesthetic quality

Comparing rural daily systems

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ABSTRACT

While Functional Urban Areas are well established, the logic of functional areas where people spend most of their days extends beyond cities. An internationally consistent definition of functional areas for entire territories can yield more comparable statistical indicators than administrative regions, whose sizes differ widely across countries. The "Defining Rural Daily Systems through Service Provision" project classifies spatial typologies as "daily systems" if they fulfil the following criteria:

- The delineation covers the entire population of a country.
- The delineation combines adjacent local areas (e.g., municipalities) or grid cells, each belonging to one and only one grouping.
- A grouping contains closely interlinked places with weaker links to places outside the grouping,
- All groupings correspond to areas small enough to traverse daily and large enough that people do not have to leave them for daily trips.

The project identifies three main approaches from the literature which fulfil these criterias:

- Labour Market Areas, which are based on work commuting flows between local areas and are already in use by many countries, albeit with varying parameters.
- Functional Rural Areas, a new typology proposed by Dijkstra and Jacobs-Crisioni (2023) to complement Functional Urban Areas, which relies on a population grid and driving times to population centres.
- Bassins de Vie, a typology from the French National Statistical Office Insee, which uses driving times to providers of different services.

After describing the use cases, advantages, and disadvantages of the different typologies, the project quantitatively assesses how well they do across eight statistical indicators pioneered by Martínez-Bernabeu, Coombes, and Casado-Díaz (2019). These indicators measure to which extent a functional area typology adheres to the following criteria:

- Autonomy: Most commuting flows should happen within daily systems.

- Balance: In each daily system, the number of workers should roughly equal the number of jobs.
- Cohesion: There should be many commuting flows between different local areas in the same daily system.
- Homogeneity: Daily systems should be similar in size. Most of the indicators are sensitive to size, with some favouring a partition into a few large functional areas and others a partition into many small and tightly interconnected functional areas.

This sensitivity makes it difficult to compare typologies with a varying number of daily systems. Our analysis deals with this in two distinct ways.

- First, using the example of France, it compares Labour Market Areas against a tailor-made version of Functional Rural Areas + Functional Urban Areas having (approximately) the same number of daily systems.
- Second, we randomly combine adjacent local areas into as many clusters as the number of daily systems from the typology we want to assess. Delineating these random clusters many times and computing the indicators from Martínez-Bernabeu, Coombes, & Casado-Díaz (2019) after each run results in a distribution of counterfactual indicator values that we can compare against a daily system typology.

Our results show that the three identified typologies have substantially higher values for the indicators assessing self-containment, cohesion, and balance than their counterfactuals, implying they capture informative variation that a naive random clustering approach misses. In contrast, random clustering can yield typologies as homogeneous as existing functional area typologies.

For the example of France, testing Functional Rural Areas + Functional Urban Areas and Labour Market Areas yields similar indicators for the two typologies. The only criterion where Labour Market Areas show higher values is homogeneity. The similarity of the indicators is somewhat surprising, given that Martínez-Bernabeu, Coombes, and Casado-Díaz (2019) developed these indicators using the example of Labour Market Areas and that we use work commuting flows to evaluate them – a key input for the delineation of Labour Market Areas but not of Functional Rural Areas.

There are many more bassins de vie, and comparing the corresponding indicators against the other daily system typologies reveals what one would expect from a simple size effect. However, the bassins de vie indicators also have substantially higher values than the corresponding counterfactuals. Whether a typology with smaller or larger functional areas is more appropriate depends on the policy question.

As a next step in this project, we will use mobile phone data to assess the daily system typologies described above. Unlike traditional work commuting data, mobile phone data can capture all kinds of trips, including from students or the retired population. The methodology described above will help us assess which daily system typologies are robust to a wider range of trips. Beyond the scope of our work, it is also possible to apply the methodology to different functional area typologies – for example, construct

ed entirely from mobile phone data.

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Keywords

Functional systems, Comparison metrics, Simulated counterfactuals, Mobile phone data

Removing Population Size, World Cities Leave on Land a Footprint of Wealth

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ABSTRACT

Urban expansion builds on rich and easily accessible arable land, which is a concern for agricultural production, in a context of global climate change. It also affects ecosystems, contributing to the biodiversity crisis, and human health, for instance through air pollution. Soil sealing is linked to an increased flood risk as well. Worldwide measures aim to alleviate the impacts of urban expansion and sprawl, in small and large cities. However, the link between urban extent and population size is still unclear, as the literature displays contradictory results on this matter.

In this work, we uncover a radial scaling law governing built-up land in 1800+ global urban areas, of more than 300,000 inhabitants each (gathering more than 30% of the world population in total). We use for this UN World Urbanization Prospects and Copernicus' GHSL built land data for the year 2020. We study these urban areas through a mix of radial (center-periphery) analysis and scaling laws, a method which we refer as radial scaling analysis. We observe that world cities have homothetic (or isometric) radial land use profiles, and that built-up footprint is proportional to total population. We obtain these results through two independant but coherent analyses. On the one hand, through a rescaling of radial built land profiles, which provides a nice data collapse. And on the other hand, through non-linear regression methods, which additionally show that the mathematical shape of these profiles is roughly exponential.

The spatial scaling law which we observe is important for the understanding and the definition of urban areas, to help build a science of cities using robust empirical stylized facts, and to make cities more sustainable. It implies that small and large urban areas have similar internal (radial) structures, and that built-up area per capita is constant across city sizes. This suggests that efforts to curb land take (for instance in the frame of no net land take NNLT objectives) are needed equally in large and small cities. These results also lead us to define a new scale-free indicator of urban built land per capita, which captures the remaining variations. At the national scale, we find that these variations are very strongly correlated to wealth, measured by gross domestic product per capita. This very strong link means that land take on the one side and economic activity (measured by gross domestic product) on the other side are quite fundamentally intertwined in our societies -- which is not very encouraging for NNLT objectives. This actually suggests a pick between economic development and sustainability.

Keywords: *urban scaling, radial analysis, land use, built up land, world cities, land take*

Comparing and visualizing the radial profiles of urbanised land across a worldwide sample of cities

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Kerry Schiel (*University of Luxembourg*)
Rémi Lemoy (*University of Rouen Normandy*)

ABSTRACT

The density and patterns of urbanisation as one moves away from central cores are key to urban planning and intra-urban research. They have been the subject of a vast literature, including debates on compactness and sprawl, and the causes and consequences of different urban forms. Inter-urban or urban systems research, on the other hand, focuses on the advantages or disadvantages of agglomeration, with a general view that larger cities, in population terms, are better (Glaeser, 2012) and greener in the sense of being more sustainable (Batty, 2014 p.40). However, inter-urban research is very focused on top tier cities and also remains very disconnected from intra-urban or urban form research. More generally, how the internal structure of cities changes with city size and, ultimately, how good or sustainable a city's urban pattern is - given its population size - remain largely unanswered. Investigating these questions requires either 'cross-section' analyses of the internal structures of many cities of different sizes, or analyses of the change in internal structures for many cities as their population grows.

Pooling cities of different population size in a single analysis to compare their intra-urban pattern is challenging because of their different spatial extent. For example, the delineation of cores, suburbs or exurbs in cities of different sizes can't easily be based on fixed thresholds. And Louf and Barthelemy (2014) or Cottineau (2017), for example, have warned that the definition of cities is critical in the analysis of urban scaling effect. More recently, Lemoy and Caruso (2020) have offered a way forward in bridging intra-urban and inter-urban analysis by uncovering a radial scaling law from which one can directly compare the internal profile of cities of different sizes. They have demonstrated that European cities of different sizes are homotheties of one another: the decreasing profile of the share of urbanised land as a function of distance to the main centre is the same regardless of the size of the city, after a simple rescaling of distance based on the city's population. The scaling exponent to be used in this distance rescaling is almost exactly 1/2. Similarly, population density profiles in Europe are also homothetic after a rescaling exponent of about 1/3 of both the distance from the centre and the density at the centre. Both results provide an empirical rejoinder to Nordbeck's (1971) intuition that cities can be represented as nested volcanoes, and to the subsequent allometric relationship whereby the area of a city relates to its population with an exponent of 2/3.

To date this verification has only been completed from European cities. The aim of this paper is to explore the validity of the radial scaling law for urbanised land across the world and through time. Indeed, European cities are often portrayed as more compact and less polycentric than US cities, and the European structure may not apply well to Asian cities with more recent rapid growth, or to other parts of the world. We aim to answer the following questions: Is the average European urban land profile a good fit for other cities? Where would this model differ most? Is the model valid across the urban hierarchy? Does it change over time and how?

We compute the radial profile of urbanised land for each city of a sample of 200 cities. We use the data from the Urban Expansion Atlas (Angel et al, 2016 - www.atlasofurban-expansion.org), a sample selected to represent different city sizes across different continents. The dataset also comprises a snapshot of urbanisation at 3 dates since 1990, thus permitting a change analysis. We compute the average profiles (and its variability), as well as fits for the different periods and compare cases to each other and the European case. In addition to comparisons across continents and times, we introduce a new graphical representation of the profiles, using a 'radial wheel' where the urban land at different distances is stacked clockwise so to better appreciate where cities reach a lower/higher amount of urban land at a corresponding distance, irrespective of city size.

Keywords

scaling, urban expansion, land use, radial analysis, urban form

Radial scaling of land use change in 1800+ world cities since 1975

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Rémi Lemoy (*University of Rouen, IDEES Laboratory UMR 6266 CNRS*)
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ABSTRACT

The ever-increasing urbanization of the world meets us with pressing socio-environmental challenges. The sprawl of human settlements all over the planet leads to losses of arable land and biodiversity, and increases flood risks. Furthermore, this expansion is concerning with regard to climate change. In this context and considering the developing will of limiting urban sprawl (see for example the No Net Land Take objective), we are faced with the task of understanding the fundamental structure and dynamics of cities.

The internal structure of cities unfolds radially, from center to periphery, revealing patterns that shape urban dynamics. To understand this spatial organization, we analyze how the share of built-up land evolves as we move outward. Since cities present a wide variety of sizes, scaling laws provide a powerful framework for modeling such behavior, capturing how a system's properties shift with its size. Viewing cities as systems and population as their defining scale, we study how cities sprawl as population grows, at the global scale.

In order to do so, we establish a robust radial scaling law which quantifies the connection between the distance to the city center and the amount of built-up land share, and how this relation scales with city size.
We extend the homothetic scaling obtained in previous work to a global sample of cities and at

different dates to study the evolution over time. We focus our work on the 1860 cities of the world whose population is greater than 300,000 inhabitants in 2020. This sample presents a large diversity in terms of population size, topology, land use, urbanization policies and more. Despite such a wide variety, the scaling law still applies with surprising regularity. Furthermore, looking at the data at different points in time — from 1975 to 2020, with a 5 year step — allows us to analyze the evolution of this internal urban structure and scaling law of built-up land.

The dataset used in the study comes from the Global Human Settlement Layer (GHSL), produced by the Copernicus service of the European Commission. It provides high-resolution and high-quality, globally consistent distributions of built-up areas, which we

combine with the World Urbanization Prospect database from the United Nations for trustworthy population statistics. For each city of choice and each date, we analyze this GHS BUILT-S raster layer at 100 meters resolution and compute the average built-up land share in concentric rings of 200 meters width around the city center. To ensure the viable comparability between cities, we rescale for each city the distance to the center proportionally to the square root of its population, and we use the largest one, Tokyo (with population 37 millions in 2020) as a reference.

We analyze the evolution of the mean rescaled profile, and observe that built-up land increases over time all along the center-periphery profile, even when the size effect is controlled by the homothetic scaling law. In linear scale (measuring absolute land change), the change is especially visible near the center, while it appears more clearly in the periphery on a semilog graph (measuring relative land change). This result means that the built-up surface per capita increases over time globally. We link this urban sprawl phenomenon with economic development and further analyze its geographical variations at national scale on the planet. This clearly questions the sustainability of urban expansion.

Keywords

urban scaling laws, radial analysis, urban-rural gradient, land use change, world cities, land take

Recursive City Definition

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ABSTRACT

How to define a city is a long-standing issue in geography and spatial analysis. An appropriate definition depends upon on the research question and study area. Maunier (1910) wrote that a city definition should be (1) universal and common to all cities and (2) should be uniform everywhere. Cities and their region are defined using an administrative or functional approach. The modifiable areal unit problem (MAUP) is an issue for administrative based definitions, whereas data limitations can be an issue for functional based definitions particularly in developing countries. Our method differs from previous attempts at delineating cites in that we use a convergence procedure and a scaling methodology. The convergence procedure arrives on the 'best' population and the scaling methodology ensures we control for initial city size. Eurostat GEOSTAT population data at a 1km2 resolution is downscaled at a finer 20m2 resolution using EU Copernicus Urban Atlas (UA) land use. Population is attributed to cells weighted on the land use category; this attributes the majority of a cells population into residential land use classes. We combine UA and Corine Land Cover (CLC), as theoretically a city's delineation might be larger in area than the current EU-OECD functional urban area (FUA). The population within the EU-OECD FUAs is used as the baseline starting population for a city.

Keywords

urban, cities, scaling

Maximising sunflower crop yield, pollinator diversity and carbon sequestration in the Vojvodina region (Serbia) through spatial optimisation of Nature-based Solutions

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ABSTRACT

Agriculture is under increasing pressure from climate change, as farmers are seeing their crop yields drop and become more unpredictable due to increasingly frequent droughts, loss of soil carbon and the decimation of insect pollinators. Nature-based Solutions (NbS), like embedding flower strips along field edges, protecting and expanding semi-natural grasslands, and planting new forests, provide useful ecosystem services that mitigate these pressures, enhance biodiversity and reduce net carbon emission. NbS have a positive impact on nearby fields and provide a pathway to more sustainable and climate-resilient farming. Finding optimal locations for NbS however, that maximise benefits with minimal costs, is a complex spatial exercise that is complicated further by possibly conflicting priorities of the involved stakeholders, including farmers, policy makers and nature conservation groups.

The primary aim of the research is to simulate areal demands of three types of NbS: 1. crop field with flower strips, 2. semi-natural grassland and 3. forest. These NbS are to be allocated to optimal locations in the Vojvodina region (Serbia), the study area of the ongoing SONATA project in which this work is embedded. The locations of NbS are considered optimal insofar that they maximize the three ecosystem services targeted by this study: 1. sunflower crop yield, 2. carbon sequestration and 3. pollinator diversity. A secondary aim is to provide complementary perspectives on the ecosystem services realized by alternative yet equivalent solutions.

To achieve our aims, we are developing a tool for multi-objective heuristic spatial optimisation that draws on evolutionary learning algorithms. The objective criteria to be maximised with optimisation are Ecosystem Service Indicators (ESI) that assess the three above-mentioned ecosystem services. The used ESI functions will be derived empirically from data collected during field work, that will be performed by our project partners. The field work will assess, among other things, the spatial relationship between crop yield variations, the observed local presence and abundance of pollinator species, and the interconnectivity of NbS in the vicinity of crop fields. The model space

reflects the current state of the study area in terms of land use and habitat types that can be linked to the three above-mentioned NbS. The model space will be derived from EUNIS level 3 habitat type maps, that will themselves be derived from remote sensing data by our project partners, and other GIS layers like field masks and crop classification maps. The spatial variables included in the decision functions are context-sensitive indicators that are derived from the current model space using moving window or similar operators. Examples of spatial variables that can be useful for this work are ecological connectivity and relative frequencies of NbS. The values yielded by the decision functions allow the model to generate solutions and to gradually improve initially suboptimal solutions. Given the nature of the problem and the fact that the optimisation practically comes down to finding optimal quantitative values for the weights included in the decision functions, we are exploring Multi-Objective Differential Evolution (MODE; Xue et al., 2003; Babu & Jehan, 2003; Robič & Filipič, 2005) as a potentially suitable modelling framework.

The presentation will treat the methodology, expected outcomes, and possibly some experimental results, obtained with the proposed tool. We will also cover the used techniques for evaluating the performance of the model. We pose that the proposed tool and its generated outputs will provide a sound basis to launch the development of an online geo-platform with which we aim to involve stakeholders in a second phase of the SONATA project. The presented research can support policy design, inform stakeholders and engage them to find a maximally beneficial spatial configuration of NbS.

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Keywords

Evolutionary algorithms, Ecosystem services, Multi-objective optimisation, Land use, Climate adaptation and mitigation

Access to the night-time city: temporal variability in food accessibility for night workers in London

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ABSTRACT

Background: Night-time is often considered the conclusion of formal activities, "and the start of rest, respite or fun for many" (Acuto et al., 2022:1). Commonly referred to as 'after hours', the night-time period has, until recently, been largely overlooked in urban policy, public discourse, and academic research. Despite the growing field of 'night studies' (Gwiazdzinski et al., 2018) and more inclusive strategies for the urban night (Seijas & Gelders, 2021), there is still surprisingly little GIS research on those who sustain the night-time economy — namely, night workers. Compared to their daytime counterparts, there is a lack of granular data and insight into where they work, how they commute, and what amenities they access during work hours (Kolioulis et al., 2024).
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Approximately a quarter of London's workforce (roughly 1.32 million people) falls under the definition of a night worker – an individual who typically works between 6pm and 6am (GLA Economics, 2024). Many face irregular employment conditions and unique challenges compared to daytime workers. Beyond concerns related to safety, past research highlights that access to affordable and healthy food is a key issue. A survey by the Living Wage Foundation (n=2,142) found that 52% of London's night workers struggle to access healthy food during their shifts, while 35% indicated that 24-hour availability of such options would improve their working conditions (Cottell, 2024). Robust research into the spatial and temporal dynamics of food accessibility across the night — and where demand is highest — is therefore essential to inform effective policy.

Aims

Leveraging novel mobile phone location data — which provides separate aggregate counts of residents, workers, and visitors — we develop a dynamic location-based accessibility model that explicitly accounts for the changing distribution of night workers (demand side). Alongside providing much-needed data, we aim to make a case for night-time accessibility models to explicitly focus on those active during this period, rather than the whole ambient population used in past research (including likely sleeping residents). Finally, as part of an ongoing collaboration between UCL and the Greater London Authorities, we aim to produce policy-relevant insights that highlight areas with high night-time working activity but limited access to food.

Methodology

Our dynamic-based accessibility model (see Järv et al., 2018 for an overview) for Greater London area integrates three temporal layers: the spatial distribution of night workers (derived from BT's mobile phone data), transportation (walking + public transportation), and the location and opening hours of grocery stores (sourced from the Local Data Company). Accessibility is measured as travel-time between origins (locations of night workers) and destinations (open grocery stores) for each hour between 6pm and 6am, using a granular hexagonal grid (350m edge-to-edge). The first step involves calculating travel-time matrices between the centroids of all hexagons in the study area using r5r, an R package that incorporates public transport schedules (GTFS) and street network data. These door-to-door travel-times account for walking, waiting, and transfer times. If walking is faster than taking public transport — as is often the case at night — walking time is used. The second step links these travel-time matrices with the food stores layer. Using the R accessibility package, we calculate travel-times (in minutes) from each hexagon to the nearest one containing at least one open grocery store, for each of the 12 hourly departure times. Finally, the share of workers within each hexagon during a given hour is linked to the corresponding accessibility result. This combined dataset enables us to analyse the proportion of night-time workers with access to an open grocery store within defined travel-time thresholds across the night. Additionally, using a 10-minute threshold, we also identify areas with detected night workers that do not meet this 'sufficient' access standard for each hour.

Results

Between 6 pm and 10 pm, the accessibility levels across London are very high, with over 90% of hexagons having an open shop within a 10-minute walk/PT journey (Fig. 1). By 11 pm, accessibility levels decrease, with only 75% of hexagons maintaining access within 10 minutes, and this drops further to below 70% by midnight. While central London continues to exhibit high accessibility to food services at night, travel-times in outer boroughs increase significantly. The travel-time results illustrate the spatial (in) accessibility to grocery stores but do not account for the number of individuals affected. Figure 2 presents the outcomes of the dynamic accessibility model, which considers the spatial distribution of workers over time. Between 6 pm and 10 pm, over 90% of workers can access the nearest store within 10 minutes. However, this proportion decreases to approximately 65% at midnight and 58% at 2 am. The findings are anticipated to be particularly relevant for workers outside the public sector, a group that is often less institutionally supported and more likely to lack access to alternative food sources such as canteens.

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Keywords

night workers, spatial accessibility, spatial justice, food deserts, N-minute city

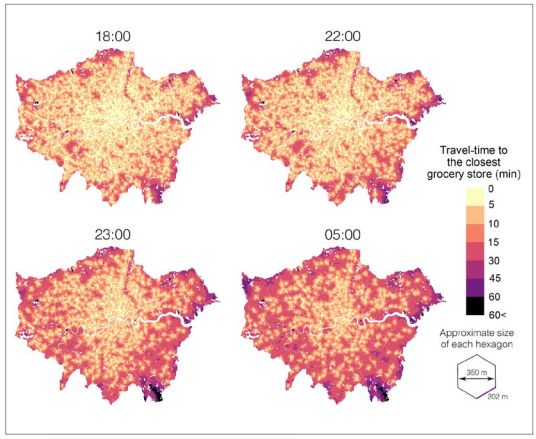

Figure 1. *Spatial variation of travel-times to the closest grocery store at four chosen hours.*

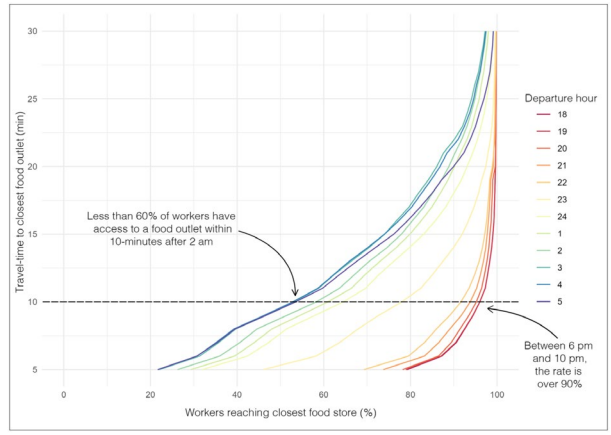

Figure 2. *Dynamic accessibility model results. Lines indicate the share of workers that can access the closest grocery store within a given travel-time, broken down by hour of the day. The horizontal dashed line marks the 10-minute threshold.*

Morphological analysis and Geographical Information System (GIS) tools in exploration of green cities, food production and distribution within the urban environment

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ABSTRACT

In the green city vision, human society and nature thrive together. One of the strategies to build sustainable cities with self-sufficient communities is exploring urban agriculture (UA) as a critical part in the long-term urban development. This integration of the food system in the urban fabric can be studied through examples of its spatial and morphological structure and positioning in the cities, especially the dynamic interaction between built environments and open spaces. Geographic Information Systems (GIS) offer powerful analytical tools such as network and spatial analysis as well as map algebra and Multi-Criteria Evaluation (MCE) to model and visualize Production (P), Retail (R) and Transformation (T) interactions of the food systems, facilitating data-driven and evidence-based planning and policy-making for sustainable urban development.

Urban morphology studies the physical form of cities, and social and economic conditions that drive emergence and changes in the urban fabric defined as streets, plots and buildings and their utilization as land uses. This paper will combine qualitative methods from urban morphology such as classification and creation of typologies of PRT sites of the food system, with quantitative GIS research to map, model and visualize their interactions. It will create a typology of GIS methods and juxtapose it with the PRT-sites classifications to discuss convergence and mixed methodology to address the food productivity of urban environments (by looking at productive landscapes, described by Andres Viljon, including indoor and vertical farms advocated by Dickson Dispommier, as well as a range of new urban agriculture technologies at architectural scale.)

Quantitative research in the field of agricultural geography concentrated in the cities and surrounding area, combined with analysis for distribution and transport, can provide improved understanding and indicate feasible and functional guidelines for urban farming. Elements such as building density, land use patterns and infrastructure networks, combined with further identification of underutilized or vacant land parcels and usable rooftop spaces that can be repurposed for agricultural use, may offer suggestions and practical solutions in policy-making and planning of urban agriculture. Subsequent investigations including: land-use change detection (e.g., NDVI time-series/land-use change' time series spatial analysis using remote sensing) to track

the impact on urban greenery, and analysis on the agricultural suitability of land (e.g., Multi-Criteria Decision Analysis: MCDA) can support the assessment of the volume, accessibility, and functionality of urban agriculture infrastructure.

The complementary approach, including morphological analyses and the three-dimensional aspects of architecture aided by GIS mapping tools, enables a multidimensional analysis of the urban space and its use in regards to the food production and mobility systems that enable interactions between PRT sites. Exploring the capacity of adaptation of the productive urban space can have varying socio-environmental benefits including food security, improved air quality, microclimate regulation, and increased green space. This also relates to the urban metabolism theory where the dynamics of the green city in regards to consumption of resources and production of waste is addressed. The eco-systems impact on the urban morphology and landscape, viewed through morphological patterns and their emergence can be used as forethought for the next stage in urban planning.

The aim of the suggested research agenda is to converge qualitative methods in architecture and urban morphology with quantitative GIS methodology. By integrating urban morphology analysis with GIS-based spatial and network assessments, this research seeks to highlight the potential for urban agriculture to become an intentional and integral part of urban planning. The use of geographical theory in combination with architectural theory and morphological knowledge on cities helps demonstrate how urban agriculture is an essential component for productive landscapes and resilient urban ecosystems in green cities.

Keywords

Urban Agriculture (UA), Geographic Information Systems (GIS), Urban Morphology, Sustainable Cities, PRT Interactions, Spatial Analysis, Food Systems, Productive Landscapes, Green City

Mapping the Human Dimension of Urban Flood Risk: A Qualitative Framework for Citizen Engagement in Nature-Based Solutions

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ABSTRACT

As climate change accelerates, cities like Dublin face increasing exposure to urban flooding—exacerbated by rapid urbanisation, rising impervious surface coverage, and declining green space. Addressing this risk requires not only technical interventions but also deep engagement with communities and stakeholders to understand their lived experiences, values, and behavioural drivers. This paper presents the qualitative research dimension of the RESTORATION project, which places citizen engagement at the centre of urban flood mitigation strategy development. Grounded in a participatory, multi-method research design, this study involved over 50 semi-structured interviews with diverse stakeholder groups including NGOs, residents, local authorities, environmental advisors, business representatives, and policymakers. The interviews explored perceptions of flood risk, attitudes toward nature-based solutions (NBS), and trust in institutional responses. Insights from this qualitative phase shaped the development of a structured homeowner survey (n≈100), designed to assess community awareness, preferences, and perceived barriers to sustainable garden modifications—a key intervention area. In parallel, we facilitated the installation of 42 low-cost citizen-collected weather stations (CCWS) across Dublin to enable participatory environmental monitoring. Residents reported increased environmental awareness and motivation to maintain pervious surfaces as a mitigation measure. Notably, 78.6% of survey respondents expressed greater interest in climate resilience, and over 92% indicated willingness to take local action following project engagement. The findings highlight the essential role of qualitative methods in capturing diverse perspectives, building trust, and co-producing socially acceptable solutions. The study underscores that participatory research—when grounded in rigorous qualitative engagement—can inform scalable, community-led strategies for flood risk mitigation through nature-based solutions. It also offers a replicable model for integrating citizen science, behavioural data, and spatial analysis in urban climate adaptation planning.

Keywords

Citizen Engagement, Urban Flood Risk, Nature-Based Solutions (NBS), Participatory Mapping, Environmental Behaviour

Context Comes to Mind: Evidence and Implications for Protection against Catastrophes

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ABSTRACT

Natural disasters, particularly in the Asia-Pacific region, are causing increasing uninsured losses, with Japan facing high seismic risks. Despite an affordable national earthquake insurance program introduced in 1966, take-up rates remain low, likely due to public underestimation of earthquake probabilities. This study investigates how subjective risk perceptions are updated after disasters, focusing on Japan's earthquake insurance uptake following the 1995 Great Hanshin-Awaji Earthquake (Kobe earthquake).

The Kobe earthquake, which primarily affected the city of Kobe, had significant implications for earthquake insurance purchases in other major Japanese cities, such as Tokyo and Nagoya, despite these areas being physically unaffected by the event. Our analysis reveals that the urban context of the Kobe earthquake played a crucial role in influencing insurance uptake in these cities. Specifically, we find that population size had a greater impact on insurance purchases than urban density, indicating that larger populations may amplify media coverage, collective memory, and social learning, making the disaster feel more personally relevant even for those not directly affected. This suggests that the representativeness heuristic of "urban-ness" rather than risk aversion was at play.

Our findings highlight the importance of heuristics in shaping risk perceptions and insurance decisions. The representativeness heuristic, which involves judging the probability of an event by its similarity to a prototype, appears to have influenced individuals in urban areas to update their subjective earthquake probabilities and purchase insurance. This heuristic process can help reduce the protection gap by encouraging more people to buy insurance, thereby enhancing disaster resilience.

The study also examines the impact of the Kobe earthquake on insurance purchases in non-urban areas and finds no significant effects, suggesting that the urban context was a key factor in driving the observed changes in insurance behavior. This underscores the need for targeted policies that consider the unique characteristics of urban and non-urban areas to effectively address the protection gap.

Furthermore, our research contributes to the theoretical and empirical literature by providing new insights into how indirect experiences of severe disasters shape risk perceptions and insurance decisions. We demonstrate that the representativeness heuristic can lead to rapid increases in catastrophe insurance consumption following a disaster, and that these changes in insurance take-up are not merely transitory but can have lasting effects.

In addition to examining earthquake insurance, we also investigate whether the Kobe earthquake affected demand for other types of insurance, such as auto insurance, and for lottery purchases. Our results show that the post-Kobe urban effect on auto insurance take-up was negative, while the effect on lottery purchases was positive, which contradicts an increase in risk aversion. Instead, these findings are consistent with recent studies suggesting that people may become more risk-tolerant after experiencing natural disasters and pandemics.

Our study employs a Bayesian approach to jointly evaluate the contribution of urban characteristics, designated cities, urban population density, and population size to the post-quake change in insurance take-up determinants. This data-driven statistical method allows us to identify when and where the urban context affects protection decisions, providing a better understanding of the channels at the finest granularity for available data.

Overall, our findings have significant implications for policymakers and insurance providers. By understanding the role of heuristics in shaping risk perceptions and insurance decisions, they can develop more effective strategies to increase insurance uptake and enhance disaster resilience. For example, public awareness campaigns that highlight the relevance of urban disasters to individuals in similar urban contexts could help bridge the protection gap and encourage more people to purchase insurance.
In conclusion, this study provides valuable insights into the factors influencing earthquake insurance uptake in Japan, particularly the role of the urban context and the representativeness heuristic. Our findings suggest that targeted policies and public awareness campaigns that leverage these insights can help reduce the protection gap and improve disaster resilience in high-risk areas.

Keywords

catastrophe, earthquake, context, representativeness heuristic, insurance, JEL Classification D12 D81 D83 G2

Intraurban Spatial Evolution and Clustering Trends in the Software Industry

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ABSTRACT

Digitalization disrupts some established mechanisms affecting location patterns in cities while others persist. This makes traditional urban location-based models and theories harder to rely on. While not entirely straightforward, digitalization is often assumed to weaken the location anchoring mechanisms in urban economies and to reduce the need for particular locations through increasingly flexible communication and interaction between firms using digital technologies.

To understand these emerging spatial logics, some existing studies have focused on the location patterns of ICT-intensive and software industries, which are assumed to be more footloose in their readiness to choose a location more freely. This research has focused more on the regional and national scales, with less attention given to the intraurban scale. However, factors influencing company locations differ across scales and are also relevant on highly localized scales.

Furthermore, while digitalization is a complex dynamic process, few studies have taken a temporal perspective. In this article, we therefore examine the intraurban spatio-temporal evolution of the digital economy by analyzing data on software company locations in Tallinn, Estonia, from 1997 to 2023.

We examine temporal clustering behavior of firms visually, using tests for global and local spatial autocorrelation, and by estimating kernel density. We also model the statistical dependence of some internal and external factors such as industrial diversity within close proximity, the role of accessibility, and age on the centrality of software company locations in the Tallinn road network. For our modelling approach, we employ a spatial analysis approach, namely a Spatial Autoregressive (SAR) modelling technique.

Our empirical results indicate a dual trend, where intensifying clustering over time plays the primary, and the overall diversification of intraurban locations a secondary role. We also find some differences in location principles between new and mature companies, and a changing relationship of software company locations with external environmental factors, particularly the growing role of industrial diversity, on software company locations during the study period.

These results help to understand evolutionary location dynamics of potentially footloose firms (such as software firms) within cities, enrich urban theories for digitalizing cities, and inform the urban planning policies aimed at these industries. They also highlight a need for more studies focusing especially on the factors behind the observed dual trend and the mechanisms behind them.

Keywords

Software Industry, Digital Economy, Industrial Location, Clustering, Agglomeration, Urban Theories

Residential Mobility and the Contribution of Population Flows to Micro-Local Socio-Economic Dynamics

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ABSTRACT

In the 21st century, French cities exhibit diverse urban structures, yet they are systematically marked by social fragmentation (Cusin, 2016). This fragmentation is reflected in practices of consumption, leisure, and, notably, residential choices. Marseille offers a telling example of this, as a legacy of both historical dynamics and successive urban policies (Roncayolo, 1996). Today, the city is fully embedded in a process of metropolisation, which comes up against a specific socio-urban model that concentrates a significant share of poverty within the city center, and even within the historical hyper center (Peraldi, Duport, and Samson, 2015).

This presentation draws on research conducted as part of my doctoral work. I propose an analysis of the evolution of internal residential mobility flows in Marseille between 2015 and 2022, within a context where urban socio-spatial structures are undergoing significant transformations, notably due to urban renewal projects. While residential mobility is widely recognized as a major factor in local territorial dynamics (Lévy, 1998), its specific contribution remains rarely quantified. My analysis seeks to address this issue by distinguishing the effects of supra- and intra-municipal residential mobility on the evolution of living standards, combining a citywide perspective with a fine-grained intra-municipal analysis to identify differentiated dynamics according to specific socio-spatial contexts.

Beyond the analytical dimension, this research also addresses a methodological challenge: the quantitative treatment of intra-municipal residential mobility. While such mobility has been widely studied in the social sciences, methodological approaches continue to evolve. The quantitative analysis of intra-urban mobility still faces difficulties, primarily due to the scarcity of data that allows for the spatial reconstruction and detailed analysis of these flows.

In this context, the increasing availability of fiscal and administrative data in France opens new opportunities for reconstructing residential mobility at very fine administrative scales. This enables the identification of trends that remain invisible at more aggregated levels of analysis. The French population census, while commonly used to study inter-regional or inter-municipal mobility, is ill-suited to the analysis of intra-municipal mobility, which requires high temporal and spatial precision (Damais, 1986).

In Marseille, distinct patterns emerge from a dual spatial reading. On the one hand, a

center–periphery logic structures the types of mobility—whether intra- or supra-municipal—across the city center, the first urban ring, and the second. On the other hand, a sectoral logic—north, east, south—relates more directly to income levels. This analysis sheds light on the complexity of intra-urban residential dynamics and highlights their role in shaping socio-economic change at the micro-local scale.

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Keywords

Marseille, residential mobility, intra-urban redistribution, residential segregation

Mobility potential: towards an accessibility indicator accounting for the individual ability to move through motility

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Vincent Kaufmann (*Professeur*)
Samuel Carpentier-Postel (*Professeur*)

ABSTRACT

Promoting public transport accessibility, which refers to the mobility potential arising from the ease of reaching opportunities, is often employed by public authorities as a planning tool to encourage a modal shift toward alternative modes of transport (Banister, 2008; Curtis and Scheurer, 2010). The 15-minute city illustrates a recent policy initiative to enhance accessibility to basic services and amenities locally via walking, biking, or public transport (Moreno et al., 2021). However, accessibility studies frequently overlook individual factors, even though disaggregated personal characteristics significantly affect overall local accessibility outcomes (Shen, 1998; Handy, 2005; Grengs, 2010). Furthermore, although some accessibility studies sometimes consider individual mobility preferences (Neutens et al., 2011), most accessibility studies often have limited emphasis on the individual's ability to move and to effectively use various transportation options. This work aims to incorporate motility, i.e., the individual ability to move (Kaufmann et al., 2004), as a complementary mobility potential mitigating the effect of daily amenities access on mobility behavior. Integrating motility alongside accessibility metrics may offer a more comprehensive understanding of mobility potentials, accounting for personal experiences. Empirical evidence has shown that individuals with low motility towards alternative transportation modes often do not perceive their benefits, even if they are environmentally conscious (Gumy et al., 2025). Given that motility is unevenly distributed across the population (Kaufmann et al., 2004), failing to consider motility could hinder an ecological transition focused on sustainable transportation practices and hinder equity in access to mobility and services.

Based on the Greater Geneva region located in Switzerland and France, this work is developed as a 3-step study: (i) developing an accessibility indicator to daily amenities, (ii) spatializing an individual's motility index, and (iii) combining the accessibility indicator according to the localized motility index. First, the accessibility indicator has been created according to activity-based measures (Hansen, 1959) by using the frequency of amenity visits as a weight factor and the human need it satisfies as an attractiveness factor. To do so, we selected 73'061 amenities accessible from residential areas within 15 minutes on public transport (PT), and we classified them according to the amenity typology developed by Frankhauser and Bonin (2025). This typology is constructed following the theory of needs developed by Max-Need (1991), which identifies people's needs from an anthropological perspective and clarifies the links between amenities

and services and people's basic needs in a social justice framework. The amenity accessibility indicator, which is discretized on a 1km-by-1km grid, reflects a potential for mobility towards a diversity of needs reachable in 15 minutes by PT, showing high scores in Swiss rural centers —in addition to large agglomerations—where only French agglomerations achieve high scores. Secondly, this study develops a motility index based on data from the 2023 Panel Lémanique Mobility Survey, which includes 10,349 individuals that are representative of the total French and Swiss population — nearly 2 million inhabitants — residing in the Greater Geneva region. Based on the individual's scores obtained thanks to a factor analysis including a selection of variables representing motility components (i.e., individual access to transport, skills, and appropriation), a synthetic motility index is computed and aggregated on the same 1km-by-1km grid. It reveals spatial structures between urban and rural areas as well as contrasts between French and Swiss secondary centers. The motility in Swiss secondary centers and, therefore, their mobility potential to engage with amenities, is higher than in France. Third, we adjust the accessibility indicator score according to the localized motility index, following the methodology proposed by Frankhauser and Bonin (2025), to create an indicator combining the two measures. This approach leads us to identify areas where low-motility respondents benefit from a high PT offer (Accessibility+/Motility-) and, conversely, where high-motility respondents benefit from a poor PT offer (Accessibility-/Motility+). To make the 15-minute city concept more accessible, combining Accessibility and Motility can be used by public authorities to (i) implement transport education and support measures for Accessibility+/Motility- zones or to (ii) develop the public transport offer for Accessibility-/Motility+ zones.

Keywords

15-minute city, Mobility potential, Accessibility, Motility, Social justice, Sustainability

Recurrent visitations expose the paradox of human mobility in the 15-Minute City vision

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ABSTRACT

The concept of the 15-minute City (15mC), where residents live within a short distance of their daily needs, has gained traction globally. With its alignments with global challenges like net zero transition and post-pandemic recovery, many mayors around the world are embracing it as a key planning principle. However, this concept faces debates regarding its feasibility beyond densely populated city centres , and its decentralised vision contrasts with traditional hierarchical urban spatial structures. As scholars have sought to transform cities towards the 15mC vision, examining human mobility patterns can provide deeper insights into how accessibility is shaped by behavioural tendencies, uncovering potential gaps between theoretical framework and real-world urban usage.

In this study, we leverage large-scale human mobility data, spanning 18 months and over 1 million users in Finland, to measure deviations from recurrent visitations and proximity-based trips envisioned by the 15mC concept. By extracting frequently visited places (FVPs) from residents' stay locations, we introduce a novel indicator, K-Frequency (K-freq), which measures the minimum number of FVPs required to access all types of daily amenities, ranked by visitation frequency. This is contrasted with K-Distance (K-dist), another indicator inspired by the 15mC vision, which measures the number of FVPs ranked by proximity. The alignment between K-freq and K-dist indicates the extent to which recurrent visitations fit within the 15mC vision.

We systematically quantify K-freq and K-dist across Finnish cities to assess how the congruence to the 15mC model varies between and within cities. Our findings first reveal a high correlation between both indicators in urban cores, which diminishes as the distance from the centre increases, reinforcing existing debates regarding the 15mC model. Furthermore, by compute travel time to specific FVPs within K-freq and K-dist, we assess the temporal scales of urban neighbourhoods. We discover that, while in central areas it usually takes less than 15 minutes to reach a wide range of amenities, residents' recurring visitation patterns do not fully conform to this expectation of local accessibility. In fact, residents in larger cities and the urban core spend more time travelling for their recurrent visitations—a pattern typically associated with peripheral areas. Additionally, by linking visitation patterns with socioeconomic status and points of interest (POIs), we find that a shift to proximity living without adequate planning interventions may lead to reduced POI exposure and increased segregation for most

income groups.

These findings suggest that mere proximity to POIs does not guarantee alignment with the 15mC behavioural vision. This research provides insights into the need for a more nuanced understanding of mobility that goes beyond spatial accessibility for planners. Furthermore, it contributes to a unified analytical framework integrating human behaviours with spatial analytics, offering insights to inform sustainable urban policy and facilitate transitions towards proximate, local-based cities.

Keywords

15-Minute City, Human mobility, Frequently visited places, Urban planning

Service provision in a regional perspective: a trilemma of densities, accessibility and cost-efficiency

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ABSTRACT

The 15-minute city concept emphasizes proximity of the services necessary for daily life. It thus depends on the local presence of public services such as schools and hospitals. Where such service locations are too far away, active transport modes are not an attractive transport mode, and users will need to rely on public transport or private cars. However, having a sufficiently fine-mazed services network is not without caveats. Most services are subject to economies of scale, meaning that they need sufficient critical mass to be operated cost-effectively. The consequence is that warranting adequate proximity of services may be excessively expensive in areas with low demand densities.

Service provision thus represents a trilemma between demand densities, proximity and cost efficiency. Services can be run efficiently and in good proximity in case of high demand densities; but if demand densities are low, services are either far apart or costly. Because of for example depopulation and ageing, demand densities will dwindle in many areas in the European Union, likely forcing service location closures in many territories. In the meantime, austerity measures already put a strain on local service provision. Thus citizens will likely have to make do with less service locations as service providers concentrate. City councils may have to make difficult choices to maintain proximity for its residents and improve accessibility for a growing number of users from the hinterland who depend on service locations in the city.

Earlier research has explored the implications of depopulation and ageing on the costs and accessibility of service provision. Notably, a joint OECD-JRC report applied a simulation approach to estimate present and future school and hospital locations, their attendance, service location costs, and travel (OECD and JRC 2021). These simulations were based on 1km population grids indicating population per 5-year age class in 2011 and 2050, and travel times and connectivity characteristics of European roads according to Tom Tom. The simulations yielded a distribution of services assuming decentralised governance, in which every location may obtain a school or hospital if minimum market conditions are met. Thus no overarching limits were set on number of services or maximum travel times. In cascade, the simulation results represent an equilibrium rather than an optimum.

This presentation focuses on a parallel modelling exercise in which service locations are distributed in an optimal manner, given centralised limits on resources. Various optimisation approaches could maximise equitable access or cost-efficiency. Such a

parallel exercise is useful in a narrow sense to explore what optimal service distributions look like for Europe's territories. And it is useful more broadly to explore plausible bandwidths of service accessibility and proximity, allowing for a benchmark of current and future expected access.

Note: intended for inclusion in the special session on "Novel spatial data and indicators for assessing the reality of 15-minute cities"

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Keywords

Service provision, Accessibility, Equity, 15-minute cities

Comparative Inference of Urban Functional Systems Through Large Movements Datasets and Network Analysis in Delhi, Cairo, and Bangkok

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Eric Denis (*UMR Géographie-Cités*)
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ABSTRACT

This communication proposes to investigate the delimitation and analysis of urban systems using a combined functional and topological approach. We intend to make full use of some novel datasets capturing the movement of hundreds of thousands of individuals, to decode the complex networks of flows that shape and sustain the production of urban space —while maintaining a critical perspective on the limitations of such mobility proxies. These gridded datasets, provided by Meta (formerly Facebook) within their « Data for Good » framework, offer near real-time insights into users movements across a relatively fine spatial resolution (2 km), tracking flows from one tile to another.

Unlike many existing works that focus on a single case-study, this contribution will adopt a comparative approach, expanding our methodology to three main metropolitan areas: Delhi, Cairo and Bangkok. These three cities share some key characteristics: a very large population, a fast-paced urbanisation, and a general scarcity of available data to monitor the ongoing territorial dynamics. By examining them in parallel, we aim to highlight both shared patterns and unique local processes shaping urban growth and function, that can be discussed in light of field knowledge and relevant scientific literature. Our objective is also to develop a rigorous, replicable, and largely automated method for urban area analysis, built entirely with open-source programming tools. We compare our results with existing methodologies developed in the field of urban systems delineation—such as Géopolis (Moriconi-Ebrard 1994), Global Human Settlement's degree of urbanization (Melchiorri et al. 2018), Functional urban areas (FUA) (Dijkstra et al. 2019), Larger Urban Regions (LUR) (Rozenblat 2020) etc. While these approaches primarily focus on defining outer boundaries, our analysis also considers the internal organization of the selected urban systems. To this end, we implement a step-by-step network analysis to identify both global structures and local patterns of centrality, as well as sub-structures that concentrate higher levels of interconnection.

Importantly, our analysis is not restricted to the recurring structures of commuting flows. It also explores more specific temporalities that might transform the network structure in temporary or lasting ways. These include: week-ends, holidays, religious festivals, as well as major disruptions like epidemics and natural disasters.

The presentation will thus display infra-urban maps comparing the extent and organisation of three selected urban areas at different point of time. Showing different indicators and communities partitioning performed through a graph analysis.

The presentation will showcase maps comparing the extent and organization of the three selected urban areas at different points in time, as inferred from the large datasets. Particular emphasis will be placed on graph-based modeling, with mapped indicators highlighting the influence and centrality of different components, as well as their patterns of activity throughout the day. We will also present a partitioning of the network into communities and offer interpretations of the resulting geographies.
Overall, we develop a vision of cities as living spatial objects, shaped by the superposition of daily activity networks. Additionally, spatial components within the urban fabric are considered in terms of their actual relation to other components, rather than through their formal or statutory definitions. This perspective, grounded in the observation of daily mobility patterns rather than normative assumptions about what a city should look like, engages in dialogue with several bodies of work. These include Henri Lefebvre's rhythmanalysis (1992), time-geography (Lenntorp 1977), the mobility turn (Urry 2002), or actor-network theory (Mol & Law 1999), among others. It is also informed by the concept of the ordinary city—with a comparative focus on urban areas in the Global South, without defaulting to a Western-centric urban ideal (Robinson 2013).

Finally, the presentation will also offer a critical reflection on the limitations of using such massive datasets, which often obfuscate spatial practices that fall outside their scope, as well as key determinants underlying individual mobility behaviors. It raises important challenges related to data representativity—particularly in relation to marginalized segments of the population who are frequently rendered invisible in contexts marked by a strong digital divide. We will also address ethical concerns related to the use of large-scale datasets produced by commercial actors, including issues of privacy and the challenges of integrating these datasets with other available sources.

Finally, we will reflect on the broader implications of this work. Theoretically, we ask: how can datasets derived from social media enhance our understanding of functional urban systems? Operationally, we consider the disconnect between functional urban geographies and the administrative boundaries that typically guide public policy intervention — units that often fail to capture the spatial extent of actual urban dynamics. Our approach also contributes to a more dynamic understanding of cities, moving beyond a purely residential lens that defines populations solely by where they sleep. At the same time, we remain attentive to persistent forms of immobility—rooted in social heterogeneity and spatial segregation—that continue to shape city dwellers trajectories across space and time.

To participate in the special session 3: Sensing Functional Systems through Mobility from Big Data: From Neighbourhoods to Urban Regions and Global Networks.

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Keywords

mobility, networks, social media data, functional urban areas, comparative approach, global south

Open-source, continent-scale human mobility datasets derived from geotagged social media

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ABSTRACT

This paper presents two large-scale, ethically-processed datasets derived from publicly posted and geotagged social media content. The first dataset captures historical patterns of activity spaces within the United States between 2012 and 2019. It comprises approximately 1.2 billion geolocated data points from around 2 million users. The data have been de-identified and spatially aggregated to ensure privacy and enable broad accessibility within the research community. The second dataset documents human movement across Europe, defined as sequential observations from individual users in distinct locations. It includes roughly 800 million recorded movements made by 10 million users, also de-identified and spatially aggregated to preserve user anonymity.

These datasets are intended to support a wide range of spatial and mobility research, including intra-urban studies on, for example, segregation dynamics, and larger-scale investigations of functional regions and cross-border flows. By offering ready-to-use, pre-processed data, this work aims to reduce entry barriers for researchers interested in studying human mobility at varying spatial and temporal scales.

The presentation outlines the methods used for data collection, de-identification, and spatial aggregation, and discusses key characteristics of each dataset. Additionally, it addresses potential limitations, particularly those related to representativeness and selection bias inherent in social media-based data. An illustrative analysis is included to demonstrate how such biases can manifest and how researchers might account for them in their own work.

Overall, the release of these datasets is intended to facilitate new research opportunities by providing a large-scale and ethical foundation for the analysis of human movement. By making these resources openly available, we hope to encourage new applications across geographic disciplines.

Submission for Special Session: Sensing Functional Systems through Mobility from Big Data: From Neighbourhoods to Urban Regions and Global Networks

Keywords

geotagged social media, human mobility, activity space, functional regions, cross-border mobility

Tracking Migration Shifts During Covid-19: A Time-Series Clustering Study of English Local Authorities (2017–2022)

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ABSTRACT

Understanding regional migration patterns is crucial for urban planning and policy-making, particularly in times of major social disruption such as the Covid-19 pandemic. The widespread adoption of work-from-home (WFH) policies during this period significantly influenced where people chose to live, raising key questions about how migration patterns have evolved. While studies from different countries have reported an overall decline in internal migration during the pandemic , and others have explored socio-economic and environment factors shaping individual migration decisions, relatively few have systematically examined how these patterns vary across different types of regions before and after the pandemic. This study aims to fill that gap by exploring how different kinds of areas showed distinct migration trends under the impact of the COVID-19 pandemic. It also investigates the underlying drivers of these migration patterns by incorporating a range of socioeconomic factors.

This study employs K-means time-series clustering to analyse temporal trends in net migration rates across Local Authority Districts (LADs) in England from 2017 to 2022. Net migration and population data were obtained from the ONS population statistics website. The net migration rate for each LAD was calculated as the ratio of the net migration volume in a given year to the LAD's population in the previous year. Additionally, we collected data on nine socioeconomic factors that may influence net migration rates—such as median age, education level, and crime rate etc.—from various departmental websites in England. K-means time-series clustering is used to classify time-series data into distinct groups, where each group shares a similar pattern of change over time. The Elbow method and Silhouette score were used to identify the optimal cluster number firstly. The results of both methods indicated that the optimal number of clusters is three. After grouping LADs into three distinct clusters, we obtained line charts showing the temporal trends of net migration rates for each LAD cluster. In order to investigate the distinctions among the three LAD clusters, we computed the six-year averages of various key socioeconomic indicators for each cluster. Boxplots were also produced for each indicator to compare the distribution of values across the clusters.

The three clusters exhibit distinctly different temporal trends. Cluster 1 shows a consistent year-on-year decline in net migration rates. Cluster 2 experienced a decline starting in 2017, reaching a trough between 2019 and 2020, followed by an upward trend

beginning in 2021 after the outbreak of the pandemic. In contrast, Cluster 3 saw a steady increase in net migration rates from 2017 to 2021 and reached its peak in 2021, but this trend reversed sharply after 2021. A comparison of socioeconomic characteristics across the three clusters reveals that they broadly correspond to: (1) core urban areas with high population density and the youngest populations; (2) medium-sized towns or suburbs of core cities with moderate population density and age, higher education level; and (3) suburban areas or rural areas characterized by the highest green space ratios, the oldest populations, and the lowest crime rates. These results highlight the profound impact of WFH policies on regional migration patterns.

In conclusion, the clustering results show that different types of areas responded very differently to Covid-19. Large cities continued to see people moving out, while suburban areas experienced a drop in migration surges after the pandemic. Meanwhile, medium-sized cities may be emerging as new migration hotspots. The study also highlights the value of time-series clustering methods in migration research and points to the need for targeted policies to improve local liveability and help retain populations.

Keywords

Migration Pattern, Work-From-Home, Covid-19, Time-Series Clustering

Toward a systemic understanding of mobility patterns: modular modeling and cross-territorial validation

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ABSTRACT

1. Introduction

Modeling daily mobility practices offers a valuable entry point to investigate the relationships between social structures, territorial dynamics, and individual behaviors. In this perspective, our research mobilizes modeling as a tool for formalization, aiming to explore the social and spatial regularities underlying everyday displacements. We adopt a modular approach in which each component of mobility behavior — activity purpose, temporality, destination, distance, and travel mode — is addressed through a dedicated model, each structured around explicit hypotheses. This approach pursues a dual objective: to identify territorial configurations relevant to explaining the diversity of individual practices, and to question the scientific validity of such models within an exploratory framework.

2. Methods

Our methodological framework is based on a chain of articulated predictive models, each targeting a specific dimension of daily mobility: the type of daily schedule followed by an individual, the type of spatial destination associated with each trip, the distance traveled, and finally the mode of transport used. Each module is built on hypotheses relating sociodemographic variables, temporal constraints, and spatial contexts, and mobilizes both statistical methods (logistic regression, additive models) and supervised learning techniques (decision trees, gradient boosting).
The modular structure of the system allows for the formalization of plausible causal sequences while maintaining transparency in the hypotheses made. It also facilitates the identification of the individual effects of explanatory variables and a better understanding of the mechanisms underlying modeled behaviors. The entire framework relies on disaggregated individual mobility data drawn from several French Household Travel Surveys (Cerema, 2021), cross-referenced with territorial indicators constructed from an independently developed typology of urban spaces.

3. Validation

Validation constitutes an essential component of our modeling approach. Rather than being treated as a terminal verification step, it is conceived as a transversal process that structures each stage of the modeling chain. The diversity of modeled dimensions requires the use of a broad array of indicators, adapted to the nature of the predicted

variables (categorical, continuous, spatialized).

For classification-based modules — such as those predicting daily schedule types, destination types, or travel modes — we relied on global goodness-of-fit measures such as McFadden's pseudo-R^2 (McFadden, 1974), alongside predictive accuracy metrics like overall accuracy (Kuhn & Johnson, 2013) and Cohen's Kappa (Cohen, 1960; Vieira et al., 2010). These indicators assess both the internal explanatory power of the models and their capacity to replicate empirically observed categories.

For continuous outcome modules, such as the one predicting travel distances between activity locations, we used standard measures of fit such as the coefficient of determination (R^2), as well as absolute and quadratic error metrics (MAE and RMSE) (Chai & Draxler, 2014; Willmott et al., 1985; Willmott & Matsuura, 2005). These allow for evaluating both the dispersion and bias in model predictions and their stability across varying territorial contexts.

Particular attention was also given to the robustness of the models with respect to the assumptions made and their ability to generalize beyond the training contexts . To this end, we implemented a cross-validation strategy across three territories with contrasting characteristics, in order to assess the transferability of modeled relationships. This protocol tests the stability of model performance when trained on data from one set of territories and applied to others with differing spatial and social configurations. It thus provides a basis for evaluating the generalization capacity of the models and identifying the territorial conditions under which the modeled mechanisms hold.

This multi-criteria and multi-level approach allows us to conceptualize validation not merely as empirical comparison, but as a systematic assessment of the coherence, transferability, and plausibility of modeled processes. By incorporating cross-validation across heterogeneous territorial settings, it highlights both the generalization margins of the models and the areas of uncertainty or fragility, thus revealing the specific conditions under which formalized mechanisms remain valid. This strategy contributes to a more systemic and controlled understanding of how the overall model functions.

4. Discussion and conclusions

This research aims to contribute to current debates on how to model and validate spatialized social processes within an exploratory and theoretically informed framework. The modular design of our approach allows for both analytical flexibility and conceptual clarity, offering a structured way to investigate the interplay between individual characteristics and territorial contexts. It also encourages a critical reflection on the explanatory scope and limitations of stylized models.

By integrating model performance evaluation with a cross-territorial validation strategy, we emphasize the importance of testing generalizability across diverse empirical settings. Rather than seeking universal predictive accuracy, our focus is on the conditions under which models remain meaningful and informative. Our approach treats validation as an integral part of model development, supporting both the robustness of results and the transparency of modeling choices.

Keywords

daily mobility modeling, modular approach, statistical validation, cross-territorial comparaison

Participatory validation of land-use simulation models for Cultural Ecosystem Services

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ABSTRACT

Cultural Ecosystem Services (CES) — such as recreation, aesthetics, and cultural heritage—are often overlooked in spatial simulation models due to their subjective and spatially heterogeneous nature. This study presents a participatory modelling approach to assess and validate the impacts of land-use and land-cover change (LULCC) on CES in the Alqueva region, Alentejo (Portugal), under a Business as Usual (BAU) 2040 scenario. Alqueva has undergone significant landscape transformation following the expansion of irrigation infrastructure and a transition towards intensive agriculture, threatening multifunctional systems like Montado and associated CES.

To simulate future land-use dynamics, we used the spatially explicit platform Dinamica EGO, integrating drivers of agricultural intensification identified through a participatory workshop with experts. This process followed principles of companion modelling, enabling participants to define key processes, feedback, and assumptions to guide scenario development. Following the simulation, a Participatory GIS (PPGIS) exercise was conducted with the local population, who mapped areas of cultural significance based on their experience and attachment to the landscape. This included locations perceived as valuable for cultural heritage, aesthetics, and recreation.

The resulting spatial data allowed us to compare simulated LULC changes with community-based CES hotspots. The validation approach combined technical validation—through traditional spatial accuracy metrics—with social validation based on stakeholder perceptions, map agreement, and perceived plausibility. Preliminary results indicate that the BAU trajectory leads to a reduction in CES, driven by landscape homogenization and the decline of traditional agro-silvo-pastoral systems. However, areas where traditional land uses persist continue to support CES, reinforcing the importance of preserving multifunctional landscapes.

This study contributes to the ongoing discussion on validation of geosimulation models, particularly in contexts where subjective, non-material values are essential. By integrating expert-informed scenario design with PPGIS-based community validation, we demonstrate a methodology that bridges quantitative simulation with qualitative spa

tial knowledge. The approach aligns with broader sustainability agendas such as the EU Biodiversity Strategy 2030 and the UN Decade on Ecosystem Restoration. Overall, this case study showcases how spatial simulation models can be validated not only for technical robustness, but also for social legitimacy and relevance, offering a replicable approach for integrating CES into land-use planning and restoration strategies.

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Keywords

Cultural Ecosystem Services, Participatory Modelling, Land-Use Simulation, Model Validation

Modelling cities transitioning to a green economy: a multilevel complex approach

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ABSTRACT

The aftermath of the 2008 crisis saw a rise in the appeal of the green economy, which offers a human developmental framework that tries to conserve the integrity of the components and processes of natural ecosystems. Cities play a crucial role in addressing these sustainability challenges as central locations where fundamental aspects of capitalism are reproduced, making them significant sources of various pollution types and associated market failures (Meng et al., 2021; Prendeville et al., 2018; Shutters, 2023). Indeed, cities host approximately 55% of the global population, generate about 80% of global GDP, and account for 65% of global energy consumption and 75% of carbon dioxide emissions (United Nations, 2019; World Bank, 2020, Creutzig et al., 2019; IPCC, 2022).

To better understand the cities' economic complex mechanisms and the broader implications of their transitions driven by climate change, we developed an agent-based model. This model is characterized by its highly decentralized nature, integrating multiple cities system' levels (micro, meso, and macro) and featuring heterogeneous consumers, firms, and urban entities. It simulates several scenarios wherein the green transition in largest cities emerges through shifts in consumer behavior, changes in labor skill demand, technological advancements in production, meso and macro levels cities' interactions, and targeted local or national economic policies.

Empirical data underpinning the model include the Orbis, Bvd, UNIL Multinational Firms Database (2010-2022), the United Nations population data for cities (2020), The European Skills, Competences, Qualifications and Occupations (2023), and the Internation Labor data (2022-2023) covering by estimations major functional urban areas worldwide. The results will allow to understand: (i) under which conditions the emerging technologies and evolving skill demands could reshape more equally the economic specialization of cities and their exchange of inputs and outputs under varying scenarios? (ii) How emerge social justice concerns, particularly those related to income distribution both within and across cities?

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Keywords

cities, multilevel, modelling, complexity, system, transition, economy

Dynamic Construction and Optimization of Ecological Networks in Coastal Regions Under Multi-Objective Scenarios: A Case Study of Gulei Port Economic Development Zone, China

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ABSTRACT

Rapid urbanization and industrialization in coastal regions have intensified habitat fragmentation and ecological connectivity loss. Focusing on Gulei Port Economic Development Zone, China, this study integrates multi-temporal habitat suitability analysis (1986–2020) and scenario-based simulations to propose adaptive strategies for balancing ecological conservation and development. Ecological sources were identified using a habitat suitability index (HSI) incorporating land use, vegetation, topography, and human disturbance, with weights assigned via the Analytic Hierarchy Process. Results revealed a 30% decline in high-suitability habitats, driven by urban encroachment and industrial expansion. Stable ecological sources (107.47 km^2) persisted in northern mountainous areas, while coastal wetlands exhibited fragmentation due to land reclamation. Three scenarios—historical restoration, ecological stability, and status quo—were simulated using the Minimum Cumulative Resistance (MCR) model. The historical scenario achieved optimal connectivity (10 corridors) but faced implementation barriers. The stable scenario generated excessive corridors (253) with structural redundancy, while the baseline scenario (55 corridors) lacked coastal connectivity. A phased optimization approach was designed: (1) augmenting coastal sources (Scheme 1), (2) prioritizing critical corridors via gravity modeling (Scheme 2), and (3) integrating low-resistance pathways (Scheme 3). Scheme 3 enhanced connectivity and achieved full node coverage, demonstrating cost-effective trade-offs. Spatially heterogeneous degradation patterns emerged: urbanized areas required corridor reconstruction to address ”restoration lag,” industrial zones demanded source protection against systemic collapse, and coastal regions necessitated hybrid strategies (e.g., mangrove restoration and artificial barriers) to mitigate disturbance cascades. The dynamic framework advances traditional static models by embedding temporal habitat stability, yet future studies should incorporate urbanization projections and anthropogenic metrics (e.g., nighttime lights) to refine resistance surfaces. This study provides methodological insights for optimizing ecological networks in high-intensity coastal development zones. Its phased, spatially differentiated management framework supports the implementation of national policies such as the coastal resilience planning, offering transferable lessons for sustainable development in similar global regions.

Keywords

Ecological networks optimization, Coastal habitat connectivity, Multi-scenarios

modeling, Dynamic habitat stability, Minimum Cumulative Resistance (MCR) model

Projecting possible future trajectories for systems of cities

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ABSTRACT

Designing sustainable policies for territorial systems requires an approach encompassing both generic processes and geographical peculiarities of diverse urban systems across the world, in a multi-level way [Rozenblat and Pumain, 2018]. This can be achieved using simulation models for systems of cities [Raimbault and Pumain, 2021]. An evolutionary theory of urban systems has been developed to that end the last 30 years [Pumain, 1997, Pumain and Reuillon, 2017], in parallel to several simulation models for systems of cities [Pumain, 2011]. Methods for exploring various contingencies in such simulation models have been developed in close link to the validation of these models: for example the MARIUS model family coupling population growth with economic exchanges has been challenged into "unexpected" behaviours with the Pattern Space Exploration (PSE) algorithm [Chérel et al., 2015]. Similarly, the SimpopNet model for the co-evolution of transportation infrastructure networks and cities has been generalised into a synthetic setup by [Raimbault, 2020b] to compute its sensitivity to the spatial configuration [Raimbault et al., 2019].

We build in this contribution on such validation methods [Raimbault and Pumain, 2019], to introduce a new composite method for projecting possible future plausible trajectories in simulation models for system of cities. Given a simulation model which can be calibrated on real world data, the method proceeds

in three steps: (i) calibrate the model with specified objectives (in practice we follow [Raimbault, 2020a] and use two dimension capturing errors on population trajectories, what produces large sets of solution across Pareto fronts); (ii) from the set of solutions, extract parameter values to obtain plausible parameter ranges for past trajectories; (iii) run the PSE diversity search algorithm on dynamic trajectories a few time steps in the future with the previously obtained parameter bounds.

Our method is applied to a multi-model introduced by [Raimbault and Pumain, 2022] combining several dimensions of urban interactions (infrastructure, economics, innovation) and computing many indicators for Sustainable Development Goals (up to five indicators [Raimbault and Pumain, 2024]). This model is calibrated on population trajectories but can be used to study sustainability issues including proxies for emissions and inequalities, in a very stylised way. We run the model with this model for the European and Chinese system of cities, using harmonised datasets for population trajectories of cities constructed by [Cura et al., 2017], and in particular the ChinaCities database [Swerts, 2017].

First results show that the method is well suited to project future trajectories, with a ensemble of plausible trajectories obtained and the most probable one. In that sense, it provides an alternative to ensemble model approaches or Bayesian approaches. For the systems studied and population trajectories, we obtain less uncertainty in parameters for Europe compared to China, and therefore much broader potential futures for China.

Future work includes (i) the calibration on other dimensions than population, in particular innovation and emissions, to allow a robust interpretability of output future trajectories for these dimensions; (ii) the use of more realistic submodel couplings to include interactions between dimensions (for example innovation reducing emissions); (iii) test of the method with other simulation models and comparison with similar methods.

Keywords

Systems of Cities, Model Validation, Future Trajectories

Is the 15-minute city feasible? Assessing the role of the built environment through actual travel behaviour in Alkmaar, the Netherlands

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ABSTRACT

The 15-minute city (15mC) concept has gained attention from practitioners, policymakers, and researchers globally for its potential to create a sustainable living environment and promote sustainable mobility. This model envisions cities where residents can access essential services and amenities within 15 minutes of active travel. While growing research interest focuses on 15mC's theoretical principles and conceptual dimensions, a critical gap remains in understanding its relation with peoples' actual travel behaviour. This study aims to bridge this gap by investigating the extent to which actual travel behaviour aligns with the 15mC objectives and examining the influence of socioeconomic factors and the built environment on this alignment. We use GPS-tracked mobility data from the Dutch Mobility Panel (2024) that records the daily movements of approximately 10,000 participants. With this data, we set up a cross-sectional analysis that averages the travel time of all individual journeys made by the respondents per neighbourhood of origin to ensure privacy compliance. In this paper, we focus on the city of Alkmaar that has just under 100,000 inhabitants and is represented by 46,317 journeys in our database.

Compliance with15mC objectives is represented by the percentage of all journeys completed within a 15-minute active travel (i.e., walking or cycling) threshold. Findings reveal spatial heterogeneity in 15mC compliance. In Alkmaar, 12 out of 66 neighbourhoods (18%) achieved over 50% of journeys meeting the 15mC criteria, while 16 neighbourhoods fall within the 30%-50% range. Most neighbourhoods (58%), however, recorded less than 30% of journeys aligning with the 15mC objectives. Compliance is highest in central neighbourhoods and much lower in the extensive more rural neighbourhoods south of the urban core. In a regression analysis we looked at the spatial and socio-economic factors that contribute to higher shares of journeys made within 15 minutes with active travel modes. We find positive associations with the length of cycling lanes and sidewalks, higher population density, and greater average income per capita. However, we observed null associations with land-use mix, green space, street connectivity, which were are suggested to associated with walking behaviour positively.

This study contributes to the existing literature by providing empirical evidence on the alignment of actual travel behaviour with the 15mC concept, highlighting the critical

role of transport infrastructure and socioeconomic factors in compliance with 15mC objectives. The results can be used to design more sustainable urban environments that allow for shorter and more active travel.

Keywords

15-minute city, travel behaviour, active travel, built environment

Spatial Justice and Urban Accessibility: Evaluating the 15-Minute City Metrics for Vulnerable Groups in Tallinn, Estonia

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Jenni Partanen (*Aalto University*)

ABSTRACT

The 15-Minute City concept has emerged as a progressive framework in urban planning, aiming to decentralize cities and ensure that residents can access essential services within a 15-minute walk or bike ride. While the concept promises to sustainable urban living, there is limited empirical understanding of how its benefits are spatially distributed, particularly among vulnerable populations. This study investigates the intersection of spatial justice and urban accessibility through the lens of the 15-Minute City concept in Tallinn, Estonia. We place a dual emphasis on distributional and recognitional justice, seeking to uncover disparities in service access and the inclusiveness of urban design across demographic groups. Therefore, the main aim of this study is to address the 15-Minute City distributional and recognitional justice by analyzing accessibility disparities for vulnerable groups in Tallinn, Estonia, and proposing strategies to foster creating inclusive urban spaces.

We conducted a grid-based spatial analysis at a 500 × 500-meter resolution across Tallinn. Using geographic information systems (GIS), we evaluated proximity-based accessibility to key urban services, including schools, healthcare facilities, shops, green spaces, and public transport. Accessibility metrics were combined with a composite vulnerability index constructed from multidimensional variables such as age, income, education, and language proficiency. Moreover, we employ regression modeling and hotspot analysis to statistically examine the correlation between service accessibility and vulnerability indicators. This allowed for the identification of spatial clusters of cumulative disadvantage and facilitated comparisons between high- and low-accessibility 15-Minute City grids across the city.

Our findings reveal significant spatial inequalities in Tallinn, where vulnerable populations are disproportionately concentrated in areas with limited access to essential services. Findings indicate that high-vulnerability grids, particularly in Lasnamäe, a high-density Soviet-era suburb, lack adequate access to essential services. In contrast, low-vulnerability grids, predominantly found in Kristiine, a middle-class residential district, benefit from better service accessibility. Regression results confirm strong negative associations between vulnerability indicators and service accessibility, substantiating a pattern of urban inequality. Hotspot analysis further underscores these findings by spatially delineating the most underserved grids.

This uneven spatial distribution raises critical questions regarding who benefits from 15-Minute City planning and whose needs are overlooked. The analysis indicates the

risk of maintaining or even increasing urban inequalities if the 15-Minute City framework is implemented without targeted attention to vulnerable groups. Recognitional justice is further evaluated and findings point to a need for inclusive planning practices that extend beyond spatial metrics to embrace cultural and functional accessibility.

Our findings also show that some of the most readily implementable and cost-efficient 15-Minute City grids, those requiring minimal infrastructure investment, do not align with areas of greatest need. This disjunction suggests that while these areas may be prioritized for early implementation due to economic feasibility, they risk supporting patterns of spatial exclusion unless equity-based criteria are integrated into decision-making processes.

Based on these understandings, the study proposes a set of strategic interventions to better align the 15-Minute City vision with principles of spatial justice. These include equity-weighted accessibility scoring, targeted investment in underserved and high-vulnerability neighborhoods, participatory planning approaches that elevate marginalized voices, and the inclusion of affordability metrics in urban design. By addressing both physical proximity and social inclusivity, these recommendations aim to promote a more just urban planning that supports the everyday needs of all residents, particularly those historically marginalized.

This research demonstrates that while the 15-Minute City holds promise as a proximity-base planning idea for sustainable and resilient urbanism, its benefits are not automatically equitable and requires strategies that prioritize both distributional and recognitional justice. Our analysis of Tallinn indicates a justice-oriented approach is required to explicitly accounts for the spatial distribution of vulnerable populations, recognize their diverse needs, and incorporate them into planning frameworks, therefore, translating the 15-Minute City vision into a truly inclusive and sustainable urban reality.

Keywords

Spatial Justice, 15-Minute City, Urban Accessibility, Vulnerable Populations, Equitable Urban Planning

Friendship in the 15-minute city: Social interaction as a key urban resource

Cate Heine (*University College London*)
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ABSTRACT

The 15-minute city planning paradigm holds that cities should be designed in such a way that their residents have access to key urban resources within a 15-minute walk, bike ride, or transit journey from home. However, one critical urban resource remains understudied with respect to the idea of the 15-minute city: social interaction with other people. In this paper, we use a 15-minute city lens to explore accessibility to social interaction with others, focusing on a case study of London. For residents of any given neighborhood (proxied by lower super output area, or LSOA) in London, we ask how many people they would have the potential to interact with if everyone spent their daily activities primarily within a 15-minute walking or biking radius of home. Then, we use fine-grained mobility data to estimate actual social interactions with others and how they fit within the 15-minute city ideal. The interplay of these two metrics --- access to potential social interaction and observed social interaction within a 15-minute active transport radius --- helps to shed light on how friendship and social interaction play into the idea of the 15-minute city.
**We wish to submit to the following special session: Novel spatial data and indicators for assessing the reality of 15-minute cities.

Keywords

sustainable transportation, social interaction, 15-minute city

The discreet intelligence of transport accessibility maps

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Itzhak Benenson (*Tel Aviv University*)

ABSTRACT

The goal of the transportation system is to provide access to activities, distributed in space and time. Transport accessibility is thus defined as the ease of reaching activities with a certain transport system or mode (Ahuja & Tiwari, 2021). The prerequisite for accessibility is mobility, the ability to move between locations, and transportation planning of the XX century was focused at enhancing just that. However, in the XXI century it became clear that enforcing a modal shift from private cars to transit – main problem of urban transportation – demands a paradigmatic turn from mobility- to accessibility-focused planning (Litman, 2024). The latter requires computational tools for accessibility assessment that account for the network structure, functioning, transportation modes, and travel demand.

Accessibility assessment tools are just perfect when personal accessibility is questioned – the navigation applications offer a congestion-aware optimal routing, for all possible modes, accompanied by the number of transfers, and transit fees. A step to transportation planning is made with the Service Area (SA) maps of the travelers' travel time, from one or several locations to each location reachable in T minutes or faster (Benenson et al, 2017; Boisjoly, El-Geneidy, 2016). The raster- and vector-based tools for computing SA maps are part of all modern GIS software (O'Dell, 2024, p. 11).

Do SA maps satisfy planner's needs? A transportation planner who approaches an accessibility analysis faces four major problems:

1. What aspects of accessibility should be evaluated on the way to the planning solution?
2. What accessibility measures should be chosen to adequately represent these aspects?
3. Is the data necessary for the evaluation available?
4. Are the computational tools available?

The planning-oriented Accessibility Calculator (AC) plugin for QGIS that we developed aims at resolving the last of these four problems. It calculates transit and car accessibility at a resolution of a single building (1) in from- and to- directions; (2) accounting for travelers' knowledge of transit timetable; (3) for every building in the city; (4) based on the freely available OSM and GTFS datasets, see https://plugins.qgis.org/plugins/tau_net_calc. Importantly, it allows comparing and visualizing the results. For the tech

nical summary and examples see ishusterman.github.io/tutorial.
Let us illustrate the use of AC with a typical planner's question: How has a new Light Rail Transit (LRT) line in Tel Aviv improved accessibility in the city? The reply demands an essential step ahead of the SA maps.

Location accessibility

To investigate the effect of a new line on the accessibility of a given location, a planner must evaluate the roundtrip accessibility - the ability of individuals located elsewhere to reach the activities located at this location (TO-accessibility) and the ability of individuals located there to reach activities elsewhere (FROM-accessibility). For example, transit TO-accessibility of a theater at 20:00, when the performance begins, and FROM-accessibility at 22:30, when it ends, or the TO- and FROM- accessibility of a mall during the whole day, or TO-accessibility of the industrial area in the morning when the working activity starts and FROM-accessibility in ~8 hours later, where it ends.

The planner-oriented solution of the AC is computing roundtrip TO- and FROM-accessibility maps for location every 5 minutes during the day and considering roundtrip time as a combination of the TO- and FROM- travel times that match the desired activity duration. Then, roundtrip accessibility with the transportation system before and after the change must be compared. In Figure 1, one can see where and why accessibility of the selected location has/has not improved.

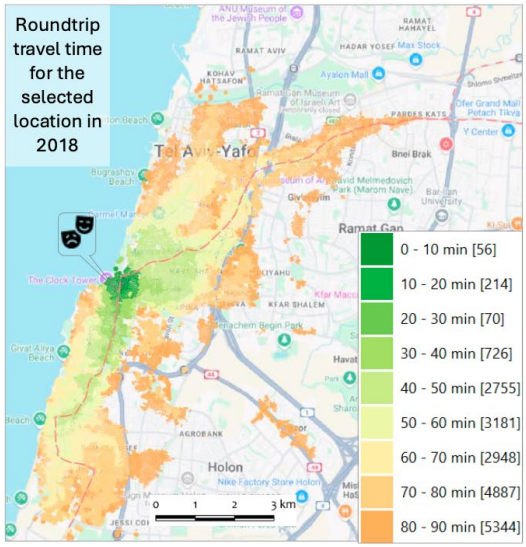
Region accessibility

The goal of a planner is to assess the effect of a new line on the accessibility of the entire region. To preserve a high-resolution view of Figure 1, a planner must aggregate numerous accessibility maps for each region's location. AC plugin implements this assessment based on the number of activities (possibly split by type) that a traveler can reach with the return trip with a total travel time of T or less. These computations take time, and our example (Figure 2) presents the number of buildings that can be visited with a return trip of 90 minutes, starting in various places in the Tel Aviv city at the resolution of hexagons of 100m side.

What are the next steps? The roundtrip accessibility maps are critical for the project's economic model, e.g., for assessment of the real-estate price increase versus the costs of the line construction and management. Further on, higher accessibility may cause travelers to switch from buses to the LRT line. If essential, this switch will demand changes in bus routes, stops, or schedules, or even line cancellation. Comparing accessibility maps for various scenarios, planners may estimate the economic effect of the network modifications. More advanced tools can automate such analysis and search for the balance between the costs of adjustments and the quality of service. At the conference, we will present the advances in this direction.

Keywords

Transport accessibility, Accessibility maps, Transportation planning, Big spatial data, High-resolution spatial analysis, QGIS plugin



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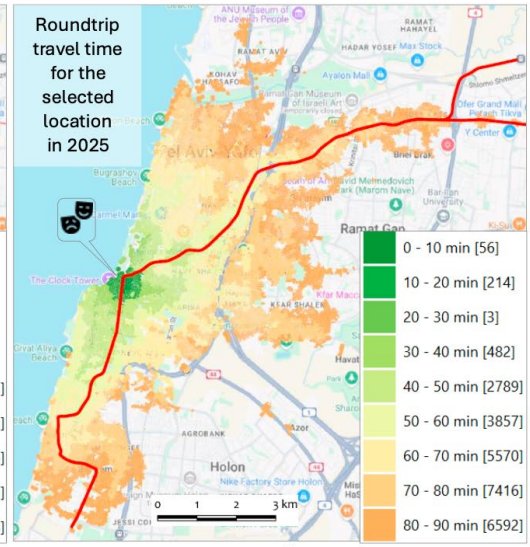

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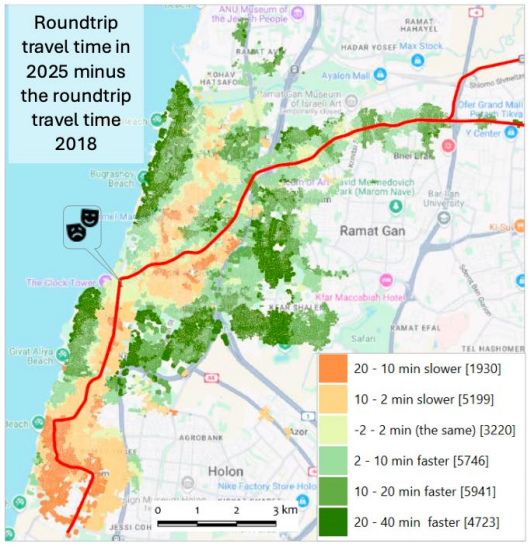

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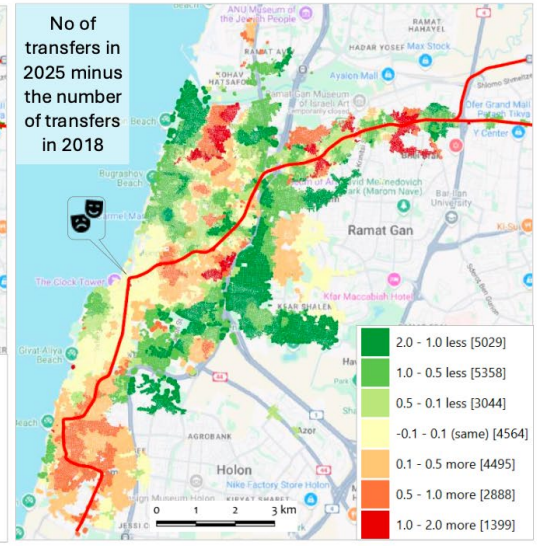

d

Figures 1a, 1b, 1c, 1d

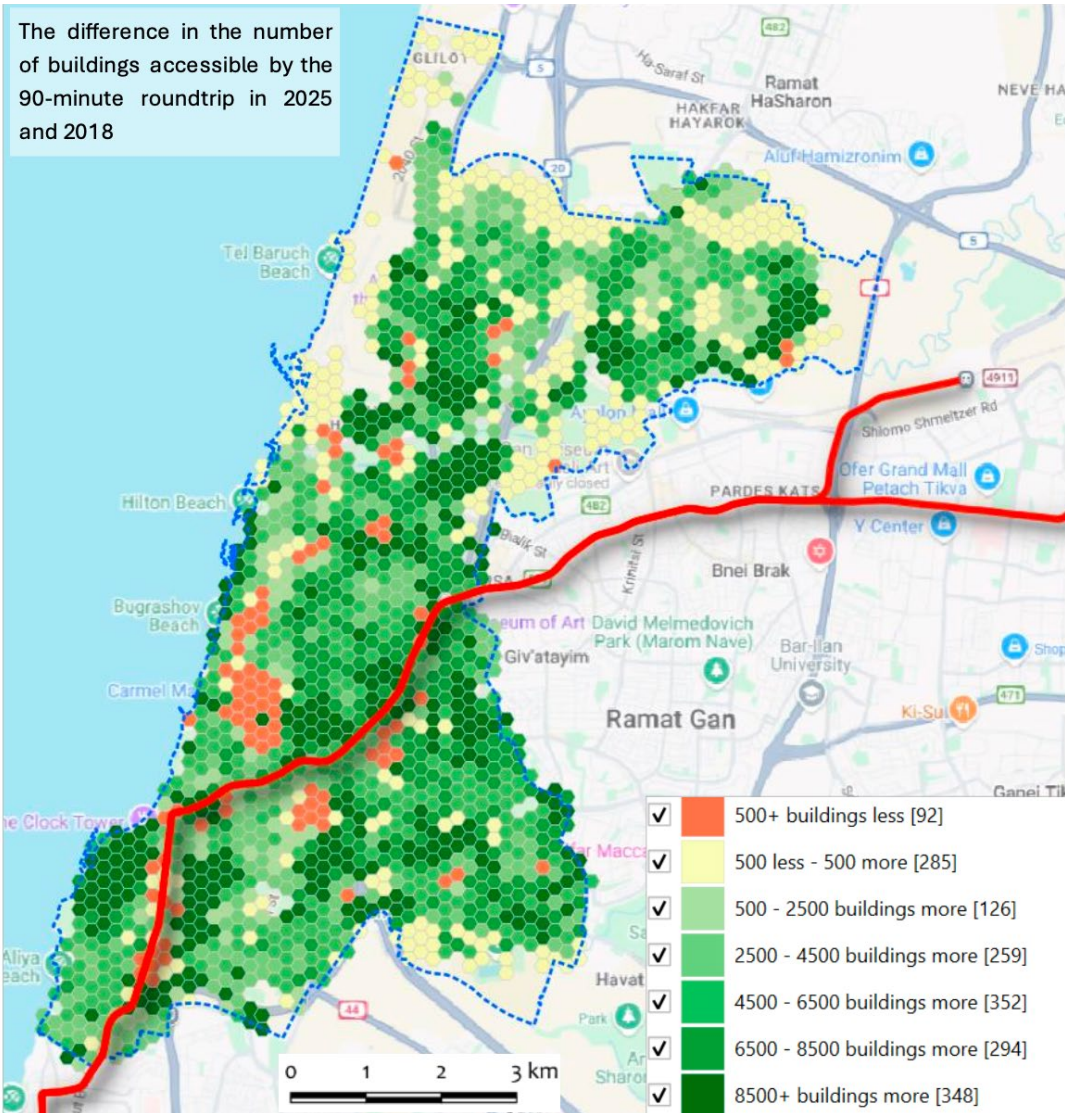
The difference in the number of buildings accessible by the 90-minute roundtrip in 2025 and 2018
Ramat HaSharon
HAKFAR HAYAROK
Aluf Hamizronim
Tel Baruch Beach
Hilton Beach
Bugrashov Beach
Shlomo Shmeltzer Rd
Ofer Grand Mall Petach Tikva
PARDES KATS
V Center
Bnei Brak
David Melmedovich Park (Marom Nave)
Giv'atayim
Bar-Ilan University
Ramat Gan
Havat
0 1 2 3 km
500+ buildings less [92]
500 less - 500 more [285]
500 - 2500 buildings more [126]
2500 - 4500 buildings more [259]
4500 - 6500 buildings more [352]
6500 - 8500 buildings more [294]
8500+ buildings more [348]

Figure 2.

Structural changes in the catchment areas of student mobility in Europe: Case COVID-19

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Milad Malekzadeh (*University of Helsinki*),
Oula Inkeröinen (*Statistics Finland / University of Helsinki*)
Olle Järv (*University of Helsinki*)

ABSTRACT

Student mobility is a distinct form of human movement. It is the temporary migration of highly-skilled individuals to another country for a fixed period of time for the purpose to expand their academic skills, thinking and networks, and eventually bringing the expanded knowledge back. Student mobility can indicate attractiveness of regions and specific characteristics of the regions causing geographical dynamics of brain gain and brain drain regions, which is highly relevant for governance, policy, and planning. In Europe, the Erasmus+ programme has facilitated the mobility of over 16 million students since its inception, and is a key instrument in supporting academic exchange of ideas in Europe and also in regional integration through building a shared European identity for its participants. While Covid-19 impacted Erasmus+ mobility, drastically reducing the number of mobile students, it is still unknown how the pandemic changed the regional structure of the Erasmus+ student mobility network and which regional characteristics play a key role in attracting students. New knowledge is desperately needed to identify which makes regions resilient as Europe is facing an era of geopolitical uncertainty.

In this work, we present our analysis of how Covid-19 affected the catchment regions of student mobility within Europe using the spatially enriched Erasmus+ student mobility data. The data contains the regional mobility of over 2.2 million individuals between 2014 and 2023 on the LAU and NUTS 3 level. We capture the catchment areas of European student mobility by using kernel density estimation to map changes in major origins of exchange students caused by the Covid-19 pandemic. This provides understanding on the geographical changes in the structure of student mobility. To understand temporal changes in the numbers of mobile students, we perform clustering analyses on the regional time series data describing outgoing and incoming students. We perform the clustering in two phases to identify the types of clusters present before and after the pandemic, and how the hierarchy between the regions is changing. Finally, we perform exploratory analysis to gain insights in which types of regional characteristics are associated with regional resilience in terms of student mobility.

Through our analyses, we find that while mobility is recovering to pre-pandemic levels, there is a clear a typology of regions in Europe showing varying trajectories, and new regional hierarchies forming after the pandemic and Brexit. Furthermore, our find

ings suggest some general patterns in terms of regional characteristics hold, such as how higher GDP, life expectancy, urbanization rate, and warmer climate tend to attract more students overall, whereas lower employment rate and higher median age tend to push students to have exchanges. Our findings have implications for regional planning for regions that want to increase their share of incoming and outgoing students.

Keywords

GIScience, Regional Geography, Mobility, Covid-19, Europe, Open data

Multi-Scale Analysis of Local Labour Market Areas Using Complex Network Methods: Focusing on the Issue of Excess Commuting

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Konstadinos Goulias (*UC Santa Barbara*)

ABSTRACT

Introduction

Kropp and Schwengler (2016) highlighted that functional regions offer advantages over administrative boundaries by better capturing the spatial distribution of economic activities through strong internal interactions and limited external connections. As a result, geographers have increasingly focused on identifying problems caused by inappropriate analysis scales and on delineating functional regions, particularly in fields related to human activities and the built environment. Among these, Local Labour Market Areas (LLMAs), defined by commute-to-work patterns, serve as key analytical units for understanding travel behaviour and economic agglomeration.

However, when defining LLMAs, challenges arise due to the diversity of socio-economic structures and geographical heterogeneity across cities and countries. This difficulty is compounded by the inconsistency of administrative hierarchies globally. Manual delineation also faces issues like the Modifiable Areal Unit Problem (MAUP), as Openshaw (1984) has noted, when aggregating small spatial units into larger zones.

Following Tolbert and Killian's (1987) definition, a local labour market is an area where most residents both live and work, with minimal cross-boundary commuting, aligning with Goodman's (1970) emphasis on high intra-market movement. Given the focus on connectivity and coherence, network analysis offers a promising approach for delineating LLMAs, with modularity serving as a key metric for measuring the strength of connections within network partitions. Accordingly, previous studies on boundary delineation have widely adopted modularity-based community detection methods, with early works such as Farmer and Fotheringham's dissusion (2011) providing foundational approaches for this research.

Specifically, this study uses the United States as a case study to develop a framework for exploring LLMAs. It aims to address the gap between census subdivisions and administrative units such as counties, where the existing scales are often either too small or too large for studies of travel behaviour and mobility (Poorthuis, 2018). This presentation addresses two main questions:

(1) Can network-derived partitions help overcome the lack of suitable zones for geog

raphy research in the U.S.?

(2) Are LLMAs identified through journey-to-work data more effective and flexible than administrative boundaries for analysing commuting patterns and excess commuting?

Data and Methodology

To answer these questions, we use the Longitudinal Employer-Household Dynamics (LEHD) data, which records commuting flows between US Census blocks across the U.S. The pilot study here is Santa Barbara County in Southern California, with a population of approximately 448,000. The block is the smallest administrative unit in the U.S., and most commute records involve fewer than five individuals, often just one, suggesting that the findings could also apply to other fine-scale datasets such as Geographic Positioning System trace data.

All the blocks in Santa Barbara and the flows among them are viewed as a network of nodes and links, with a weight assigned to each link based on the number of person living in one block and working at the same or another block. Then, groups of blocks are identified based on the origin and destination flows to represent LLMAs and called communities. For community detection, the Leiden algorithm is used due to its efficiency with large datasets and its ability to avoid poorly connected or disconnected communities, an issue with some other methods (Traag, Waltman and Van Eck, 2019) . Particular attention is paid to the gamma (resolution) parameter, which influences the density threshold for forming partitions, to explore whether flexible and appropriate delineations of LLMAs can be achieved.

We then compare the resulting LLMAs to traditional administrative boundaries, focusing on their ability to interpret excess commuting patterns. The definitions of minimum commuting distance and excess commuting follow the framework summarised by Kanaroglou, Higgins and Chowdhury (2015), and workers are categorised into three industry groups to facilitate better job and or residence reallocation analyses. Additional demographic characteristics are also considered to assess whether LLMAs offer a more detailed description of regional differences.

Results and Conclusion

The contributions of this study are threefold: First, LLMAs reveal well-connected block structures across the study area, including cities and incorporated areas, where administrative boundaries often fragment real-world commuting patterns. This suggests LLMAs could serve as intermediate geographic units between census blocks and counties, useful for studying issues at the county level or for comparing internal structures across regions.

Second, the resolution parameter proves critical in enabling multi-scale analysis. By examining commuting distance distributions across different LLMAs and resolution levels, we find that adjusting the resolution provides flexibility to match the spatial granularity to specific research goals.

Third, compared to administrative boundaries, LLMAs align more closely with actual commuting origin-destination flows and spatial interactions, offering clearer interpretations of the Excess Commuting Index (ECI). This demonstrates that delineation of LLMAs is both feasible and flexible for analysing commuting patterns and related issues. Furthermore, with the availability of fine-grained spatial data, such as GPS traces, this framework can be extended to wider study areas for future research.

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Keywords

Local Labour Market Areas, Excess Commuting, Network Analysis

Categorical independent variables and spatial regression: interpretation and reporting

Roger Bivand (*NHH*)

ABSTRACT

While researchers have addressed some of the challenges raised by limited dependent variables in spatial regression, the interpretation of independent categorical variables has not been given much attention. This question appears when the spatial lag of an independent variable is included, as would typically be the case in what are known as Durbin models. The spatial lag is usually taken as the mean of the values of the variable at neighbouring observations for row-standardised spatial weights, or the sum for binary spatial weights, neither of which permit intuitive interpretation for categorical variables. For unordered categorical variables, output coefficients and other measures are reported in relation to the reference category, often the first category listed. In spatial regression, reporting marginal effects has reasonably presumed that coefficients may be treated as slopes, the change in the continuous dependent variable when a chosen continuous independent variable is changed. However, this presumption arguably does not extend to categorical independent variables. Examples in R will be given, and attempts to adapt the R spatialreg package to handle categorical independent variables more adequately will be presented.

Keywords

Categorical independent variables, Spatial regression, Durbin terms, Spatial weights

Integrating equity into efficiency: the p-Median problem with territorial coverage constraint

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Cyrille Genre-Grandpierre (*UMR 7300 ESPACE Avignon University*)
Rosa Figueiredo (*LIA, Avignon University*).

ABSTRACT

The optimal location of services of general interest involves balancing efficiency (minimizing travel distances) and equity (maximizing territorial coverage), a combination rarely tackled in traditional location models. We propose the Capacitated p-Median Problem with Territorial Coverage Constraint, extending the classical model to include facility capacities and territorial equity dimension. Now the problem ensures that each spatial unit is covered by a facility or maximizes the number of units covered when full coverage is not feasible. It integrates both efficiency logic and territorial priorities within a single problem. We develop optimization methods for the problem and apply them to real-world data on cinema services in the PACA region of France. Our analysis explores different spatial divisions and highlights the influence of spatial morphology, population distribution, and travel dynamics. The results emphasize the impact of incorporating territorial divisions in location-allocation models for spatial planning.

Keywords

Optimal location, Spatial analysis, p-Median, Coverage constraint, Allocation strategies

Geographically Context Sensitive Weighted Indicators: Using The Benefit-of-Doubt Approach

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ABSTRACT

Rethinking Composite Indicators: A Geographical Perspective

Composite indicators, which aggregate multiple variables into a single score, are commonly used across domains such as policy evaluation, economic assessments, and quality-of-life studies. While convenient, these indicators often rely on fixed weighting schemes that oversimplify complex geographical realities. Uniform weights applied across diverse regions can mask local disparities and distort the true nature of spatial inequalities. This paper critiques traditional composite indicators using the English Index of Multiple Deprivation (IMD) as a case study and proposes an alternative approach that better captures regional differences.

Conventional indicators are particularly problematic when applied to varied geographical contexts where the relevance of individual factors differs considerably. For instance, the UK Index of Multiple Deprivation (IMD)'s Living Environment Deprivation Domain includes variables such as housing quality, air quality, and road traffic accidents. As a hypothetical example, inner city areas may prioritize air quality concerns, while peripheral areas may more likely to be affected by poor housing conditions. A uniform weighting scheme fails to reflect these distinctions, leading to misleading indices that overlook genuine local conditions.

The limitations of traditional indicators include:
+ One-size-fits-all approach: Uniform weighting schemes ignore local variations, producing oversimplified representations of complex phenomena.
+ Promotion of the use of rankings: Fixed indicators encourage rankings and 'League Tables' that obscure multidimensional differences, emphasizing competition over insight.
+ Geographical insensitivity: Static weights do not consider regional contexts, leading to poorly targeted policy interventions.

This study primarily explores Benefit-of-Doubt (BoD) analysis, a method that allows regions to determine their own optimal weights for various indicators, resulting in scores that better reflect local circumstances. BoD analysis offers a powerful alternative to conventional methods by allowing each area to emphasize the variables most relevant to its deprivation profile. Unlike traditional approaches, it employs linear programming to optimize these weights, producing a composite score that is tailored to the region's specific conditions.

Other methods addressing these issues include Order Weighted Averaging (OWA), which applies weights based on variable rankings within each area, and Geographically Weighted Principal Component Analysis (GWPCA), which assigns weights based on local conditions rather than globally. While these also require study, here the focus is on the tailored, place-specific optimization achieved by BoD analysis.

BoD analysis involves benchmarking each area (the subject area)'s weighted score against the maximum score obtained by applying those weights to all areas, and scaling to a range from 0 to 100. Linear programming techniques identify the set of weights maximising the score that a subject area can achieve. By applying this method treating each area in turn as the subject area, this process ensures comparability in scoring while allowing for locally tailored weighting schemes. Applied to the Living Environment Deprivation Domain of the IMD, BoD analysis utilizes four variables:

- Houses without central heating,
- Housing in poor condition,
- Air quality (based on pollutant emissions),
- Road traffic accidents involving pedestrians and cyclists.

Results reveal notable spatial variation. Air quality issues are most pronounced near central London and Heathrow Airport, while poor housing conditions cluster south of the River Thames. The BoD approach reveals localized deprivation patterns often obscured by conventional indices, highlighting the value of flexible weighting schemes.

Mapping the weights applied to each variable across regions provides further insights. Air quality, for example, is a more significant factor in central London than in rural areas. Such spatial patterns remain undetected when using static weighting schemes.

These findings suggest that composite indicators should be treated as exploratory tools rather than rigid ranking mechanisms. The ability to adjust weights locally provides a more accurate representation of regional disparities, enhancing the effectiveness of targeted interventions. Future work could involve clustering techniques to identify recurring patterns of deprivation or limiting the influence of dominant variables to prevent skewed results.

This paper demonstrates that spatially adaptive indicators, particularly those produced through BoD analysis, offer a more revealing representation of complex geographical realities. By providing context-sensitive insights, these methods can guide policymakers toward interventions that are both regionally relevant and effective.

Keywords

Spatial Analysis, Benefit-of-Doubt Analysis, Composite Indicators, Spatial Heterogeneity

How the perimeter and the area of urban patches relate across Europe

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Geoffrey Caruso (*Department of Geography and Spatial Planning, University of Luxembourg***)**

ABSTRACT

1. Introduction

Urban development significantly impacts the natural environment by fragmenting natural areas, affecting quality of life and social cohesion. Thus, reducing urban fragmentation is a central objective of sustainable urban planning, aiming to create a balance ”between” natural and urban environments. In this study, we focus only on urban areas (perimeter and area) measured over their basic units, i.e. urban patches.

The perimeter-to-area ratio is a common metric used to analyse the structure of landscapes in ecology from an aerial perspective. Measuring the complexity of patches of artificial land and their arrangement within a particular urban region, i.e. the complexity of a physical urban footprint, is key to understanding the impact of urbanisation patterns and their change on ecological habitats and on the functioning of the city itself. The P/A ratio is a simple and intuitive indicator of shape complexity. When the square root of the area is used as denominator, this complexity indicator is made independent of the size (area) of the patch and sometimes called `shape-index'.

Our goal is to address those issues head-on by assessing the robustness of the `shape-index' to the definition of patches and to the aggregation methods. We suggest that instead of using arithmetic mean averages, we should look at the entire relationship between perimeter and square root of the area of all European urban patches.

1.1 Urban P/A

In urban planning, a simple uniform shape is favorable, indicating a compact city, while a complex shape signals high fragmentation. Without indicating whether the link between the `shape-index' and urban areas is relevant, it is a fact that this index is commonly used, but the effect of the index is still unclear. Eventually, it is difficult to say whether a complex urban form is good or bad. There are no agreed reference values for the shape of cities with which we can confront case studies, and more importantly, the field lacks clarity in defining the patches that make up an urban footprint and lacks a unified methodology to aggregate the description of the patch level to the urban region level.

2. Method

This study analyses urban patches based on Urban Atlas 2018 (Copernicus), covering 785 functional urban areas (FUAs) in Europe. We classified 23 land cover categories into 2 classes to create the urban footprint with u = 1 for urban and u = 0 otherwise. Urban patches are defined by 3 spatial analyses i, j and g to test the robustness s as the 'shape-index'.

- case i: using original patches
- case j: using merging patches that touch each other after a road neighboring cell analysis
- case g: all patches j are merged into a single patch

Linear models have enabled us to identify the most pertinent patch definition and provide better spatial adjustment ofthe relationship between the perimeter p and the effect of the square root of the area √a. The case i does not accurately represent the actual trend of the overall shape of the city, but is still used in the literature. We now understand that we need to focus on the case j, which considers the spatial distribution of the urban aggregated patches.

3. Results

The area of urban patches ranges from slightly more than 0 to 662,719,786 m^2 and shows a positively skewed distribution. However, even when considering a subset of patches smaller than 100,000,000 m^2 (ref: Paris Intramuros size), these fits are highly influenced by outlier values (dominant patches) in case j. The observation point appears to fit the models well, but the distribution shows that 89% of the urban patches range from 2,500 m^2 to 100,000 m^2, which can define our limit to adjust the model. The lower limit was defined by a visual gap at 2,500 m^2, as most of the smaller patches are interpreted as artifacts of geoprocessing. We placed an upper limit to remove outlier surface values that disturb the model, which was defined by the mean Cook's distance multiplied by 30, calculated for each city. After computing several linear models, p-a (R^2 = 0.86), p -√a (R^2 = 0.78), the best relationship between p and a is log(p) - log(a) (R^2 = 0.94). The function log(p) - log(a), being sublinear, represents an exponential model where the relation p = a^0.65 reflecting the multiplicative effect and complexity of urban patches.

4. Conclusion

Future planning strategies are required to address questions related to land fragmentation by urban complexity. The selected global model log(p) - log(a) with a coefficient of 0.65, allowing us to predict how p responds to changes in a as a complexity 'shape-index', the problem is that it mixes the dispersion of all patches across Europe. Further research will look at the relationship within each city in Europe to identify the shapes that are clearly different (dominant and simple patches).

Keywords

fragmentation, landscape, urban, perimeter, area, shape-index

The impact of the 15-minute city on the spatial planning policy of a sprawled region

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ABSTRACT

The 15-minute city has been a hot topic over the last years, mainly focusing at the quality of neighbourhoods in larger cities. In Flanders, Belgium, spatial planning policy is looking at the topic from a different angle during the last 10 years. Since the region is known for urban sprawl and ribbon development, and in a context where space for (environmentally sustainable) urban growth has become limited, it is important to decide in which exact locations densification and urban growth are still to be supported. Accessibility mapping can help to achieve this goal to evolve towards net-zero land take.

In this presentation we will first briefly explain how we calculate a combined proximity map of public and private services, retail and public transport for the whole region of Flanders since 2015 with a regular update cycle (Verachtert et al., 2023). The study starts from a large database of retail and services, maps different types of local, regional and metropolitan services, and finally combines them into a categorical proximity score for all services. The same is done for the proximity of all railway stations and a selection of bus stations which have a service at least every 30 minutes. Scores for the stations are depending on a list of indicators, including their connectivity, and on the walking and cycling distance towards them. The final map gives every location in Flanders a score in a matrix with 16 (4 x 4) categories, with service proximity on one axis and public transport on the other axis. In 2022 around 4.2 million inhabitants (62.4 %) were living in the top 4 (2 x 2) matrix categories of public transport accessibility and service proximity.

Directly the results can be used to track the best locations and the evolution of public transport accessibility and the proximity of different services. One of the derived indicators of the study is a map of basic amenity proximity that is quite similar to the 15-minute city, but then applied to a full region including peri-urban areas and excluding employment (as employment can be reached by public transport). Specifically, the indicator looks at the proximity of food shops, health care (GPs and pharmacies) and primary education. In 2022 around 4.6 million inhabitants (68.9 %) had these basic amenities at 15-minute walking time, and even 6.5 million (97.6 %) at 15-minute cycling time.

Indirectly, the indicator map has been used in a large set of scientific and policy studies to define the optimal locations for densification. Indeed, the map is rather a guideline

to highlight in which areas the current conditions are optimal to host a growing proportion of the population, compared to trying to improve the accessibility and services of the whole region. As such, potential policy maps were derived with densification scores for the whole region within settlement area, and positive or negative areas for urban growth outside settlement area. These scores are subsequently an input to urban growth modelling, but also to more specific policy studies, like the potential to develop brownfields and landfills, densify well-located suburban residential areas, densify or expand social housing neighbourhoods, and assist provinces in updating their regional spatial planning. Finally, the Flemish Government has also published a tool (Mobiscore) where people can check the environmental costs of their house related to transport, with input data based on this study.

Keywords

15-minute city, accessibility, urban planning, urban growth, densification

Assessing urban scenes for the 15-minute city through SAGAI (Streetscape Analysis with Generative AI)

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ABSTRACT

Assessing the qualities and functions of urban streetscapes is crucial to understanding walkability, safety, and social life (Gehl & Svarre 2013; Harvey & Aultman-Hall 2016; Dovey et al. 2018). Traditional methods—like field surveys or manual audits—remain labor-intensive and hard to scale. While geoprocessing of 2.5D vector models supports analysis of morphometric properties (Harvey et al. 2017; Araldi et al. 2025), finer details—the "skin" of the streetscape, including façades, sidewalks, greenery, and materials—remain difficult to assess automatically (Harvey et al. 2017).

Early efforts (Clarke et al. 2011; Rundle et al. 2011) used online imagery for remote audits but still relied on manual methods. More recently, CNNs and object detection have enabled partial automation, though limited by high labeling costs and narrow scope.

Generative vision-language models (VLMs), like LLaVA, offer a promising shift: they combine image understanding and natural language prompting to extract structured data from street-level images, enabling rapid, scalable analysis via platforms like Google Street View.

This contribution presents SAGAI (Streetscape Analysis with Generative AI), a four-step workflow linking OpenStreetMap, Street View, and LLaVA to automate streetscape assessment. Fully open-source and deployable in Google Colab, SAGAI includes modules for point generation, image retrieval, model inference, and spatial aggregation, producing interpretable indicators across large urban areas.

Recent projects echo similar approaches: StreetViewLLM (Li et al. 2024) uses geographic metadata and chain-of-thought prompting; CityLLaVA (Duan et al. 2024) adapts vision-language tools to safety analysis; others like Blečić et al. (2024), Wei et al. (2024), and Schmidt et al. (2025) explore multimodal LLMs for planning and geospatial reasoning. While none offer fully integrated workflows, they highlight growing interest in applying VLMs to urban analysis.

SAGAI advances this field by linking generative reasoning to spatial datasets and planning theory. Developed within the EMC2 project (Fusco et al. 2024), it supports the evaluation of the qualities of a human-centred suburban 15-minute city using pattern-based analysis of streetscape "skins." By operationalizing tasks such as object detection, counting, and dimensional measurement, SAGAI enables interpretable

indicators—e.g., walkability or safety scores—that align with urban morphology and planning models (Alexander et al. 1977; Gehl 2010).

SAGAI comprises four Python modules designed for Google Colab:

1. OSM Point Generator, to generate sample points along the OSM street network of a user-defined area.
2. Street View Batch Downloader, to automate the retrieval of street-level imagery from Google Street View.
3. Scene Assessment with LLaVA, the core of the SAGAI pipeline performing automated image-based scoring using the LLaVA v1.6 model with a Mistral-7B backbone.
4. Geospatial Scoring Aggregation and Mapping, to aggregate the image-based scores within a geospatial dataset.

To illustrate the capabilities of the SAGAI workflow, two contrasting urban environments were selected in Nice, France, and in Vienna, Austria. Both areas present complex spatial structures but differ significantly in morphology, density, and land use.

To evaluate the SAGAI workflow, three predefined tasks are deployed in both case studies: (T1) a categorization task to classify scenes as either urban or rural; (T2) a counting task to detect the number of visible commercial storefronts; and (T3) a measurament task to estimate the visible width of sidewalks. A manual validation procedure was conducted across the three predefined scoring tasks by comparing image-level predictions and human annotations over a stratified random sample of 300 street views.

Empirical results across two distinct urban settings, Nice and Vienna, show that the system achieves high accuracy in scene classification (over 90%), moderate precision in storefront detection, and lower—but still informative—performance in estimating sidewalk width. These outcomes illustrate both the promise and the current limits of zero-shot VLMs in urban contexts.

Future developments will focus on integrating few-shot tuning modules, supporting alternative imagery sources and vision language models, and expanding the library of scoring prompts. As such, SAGAI provides both a methodological contribution and a practical foundation for the next generation of geospatial research using generative multimodal AI in streetscape analysis. As generative AI continues to evolve, SAGAI exemplifies a transparent, open-source geospatial workflow that leverages generative AI for applied research and planning assessments.

Acknowledgments. This work was supported by the emc2 project under the DUT Partnership, co-funded by ANR (France), FFG (Austria), MUR (Italy), Vinnova (Sweden) and the EU Commission.

Keywords

Vision-Language Models, Street View Imagery, Streetscape Analysis, Geospatial AI, Zero-shot Inference

Enhancing compactness, connectivity, and accessibility in Korea

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ABSTRACT

Korea's population peaked in 2020 and is expected to decline by around 15 million by 2070, equivalent to nearly one-third of today's population. The Seoul Metropolitan Area, which already hosts half of Korea's population, is expected to remain at around 26 million by 2040. In contrast, towns (between 5 000 and 50 000 inhabitants) and villages (500 to 5 000 inhabitants) face the fastest population decline, especially those furthest away from major cities. On top of the high concentration in the Seoul Metropolitan Area, the share of working-age people is expected to drop to 46% by 2070, compared to around 71% today, which translates into more demand for health and care services and fewer resources to finance service provision from work-related tax collection.

Ensuring quality infrastructure and service provision for people of all ages across the country can help plan a future with more balanced urban development. Korea is considering implementing a compact-and-connected strategy anchored in transit-oriented development. In this context, regional hubs - well-connected places offering education, healthcare, retail, and leisure services to their inhabitants and people in their surroundings – can play a role.

Our analysis introduces a novel methodology to identify 37 regional hubs across Korea. Our unit of analysis is the settlement, i.e. urban centres, towns and villages defined in level 2 of the degree of urbanisation. The methodology involves:

1) Defining education, healthcare, commercial, leisure, and general hubs from rich point-of-interest data. For example, education hubs include all settlements that host at least six of the following seven service types: childcare, an elementary school, a high school, a kindergarten, a language school, a middle school, and a university. Equivalent definitions apply to the other four kinds of hubs.

2) Defining service hubs as settlements that are education, healthcare, commercial, leisure, and general hubs simultaneously. In other words, a settlement needs to host a variety of services to classify as a service hub, both within kinds of services and across them.

3) Identifying regional centres that are the largest settlements within 30 minutes of car driving time. Incorporating such a definition can provide insights into a settlement's

role within the broader settlement network.
4) Classifying settlements as regional hubs when they are both service hubs and regional centres.

The resulting list of 37 regional hubs includes Korea's most significant urban centres, as well as towns exerting a centre function for nearby rural populations.

We then assess the accessibility to childcare facilities, doctors, and pharmacies within a 15-minute walk within the regional hubs. The accessibility indicator estimates walking time from each 1 km x 1 km grid cell to the nearest service point using the r5py package. The analysis focuses on travel times by walking to highlight inequalities faced by individuals without car access and those with limited mobility. We document that overall service accessibility is high in Korean regional hubs, albeit there is heterogeneity between the hubs. Service accessibility tends to increase in settlement size, even though services in large cities might be subject to overcrowding, which is something our analysis cannot capture.

Fine-grided 1km x 1km population data per age group allow us to measure differences in service accessibility for different population subgroups. In most regional hubs, a larger share of preschool children lives within 15 minutes of walking time from a childcare facility, compared to the overall population. This difference is to be expected, given that people choose their home location accordingly when they have or expect small children, and at the same time, facilities (public and private) open in places close to where families with children concentrate. We also document cases where there seems to be a spatial mismatch between the supply and demand for childcare services.

In contrast, in almost all regional hubs below 250 000 inhabitants, the share of adults above 65 years living within 15 minutes walking time from doctors and pharmacies is smaller than the share of the overall population. This can create accessibility challenges, particularly for seniors who rely on walking access due to mobility restrictions—such as the inability to drive or difficulties using public transport that is not adapted to their needs. Given the many benefits of easy access to healthcare services for older individuals, this difference in walking access merits future inspection.

Keywords

Service accessibility, 15-minute cities, Demographic disaggregation, Novel spatial data

Using interpretative machine learning to analyze spatial distribution of socio-demographic profiles influencing voting patterns in U.S. presidential elections (2008-2024)

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ABSTRACT

Election outcomes are influenced by many agents, with various socio-demographic factors playing a key role. The challenge is identifying these factors correctly and studying how voters' preferences change over time and space. Spatial changes in voting patterns result from changes in preferences and responses to evolving social, economic, and political patterns. The relationship between voting patterns and socio-demographic factors can be studied using the direct method, i.e., individual survey data. The main limitations of such studies are cost and limited availability of data. The second method is indirect and is based on analyzing aggregated data collected on a large scale within administrative or census units. The disadvantage of research based on aggregated data is that it does not provide information on individual choices. Instead, it presents the relationship between socio-demographic and voting patterns at the territorial unit level. The advantage of this approach is the wide availability and completeness of the data. Our research aims to develop a spatial socio-demographic profile that influences voting patterns in U.S. presidential elections between 2008 and 2024 at the county level. We used county-level data on presidential election results along with a wide range of socioeconomic characteristics provided by the American Community Survey.

We used interpretive machine learning to analyze the relationship between socio-economic characteristics and presidential election outcomes. The methodological assumption of the research is that the nonlinear model of the relationship between variables reflects, to some extent, the relationship between social processes. For this reason, interpretative machine learning focuses on interpreting model structures rather than on their performance. Due to the large number of variables, which are usually correlated, we decided to investigate the relationships between the dependent variable (presidential election outcomes) and the explanatory variables expressed in the form of principal components. The process of selecting socio-economic characteristics involved three steps. First, we pre-selected 77 variables grouped into five categories: gender, education, income, race and ethnicity, and occupation and employment status. Secondly, using principal component analysis, we reduced the set to 39 variables with the most significant impact on PC variance. Finally, principal component analysis allowed us to reduce 39 variables to 12 uncorrelated principal components.

Using the random forest learning model, we found that only five components are key

to describing changes in voting patterns. These are components 1 and 12, complemented by 5, 3, and 2. Each component is expressed by a gradient of changes driven by different variables. For example, the first component describes the gradient between two groups of counties. One group consists of counties with an above-average share of residents with a high school education and low individual and household incomes (below $30,000 per year). The other group includes counties with above-average share of naturalized U.S. citizens who possess a college education and household income above $75,000, typically working in fields such as management, business, science, arts, and services. The other components show the contrasts between different socio-demographic patterns, including interrelated characteristics describing gradients in education, mobility, income, age, and race and ethnicity.

Analyzing the impact of each component on the election results, we found that all five components played a similar role in 2008 and 2012, and the largest, though not dominant, influence was exerted by component 12. This component represents the gradient between counties with a higher share of middle-aged and older people with a stable life position and counties with a higher-than-average share of young people with low incomes. In the period 2016-24, component 1 played a dominant role, while the role of component 12 gradually decreased. Components 5, 3, and 2 maintain the same level of explanation throughout the period. By examining the spatial variability of the component values, we hypothesize that changes in electoral preferences examined at the county level are largely derived from changes in socio-demographic spatial patterns.

Keywords

Interpretative machine learning, Spatial voting patterns, Socio-demographic profiles

Unfolding the black box: Modelling Community-Acquired Pneumonia drivers in mainland Portugal with Explainable-AI

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ABSTRACT

Pneumonia is a respiratory infection of the lower respiratory tract, that is, relating to the area of the trachea, bronchi and lungs (Respiratory System, undated). Common symptoms include fever, cough, fatigue, vomiting and diarrhea and are typically contracted through contact with bacteria, viruses and fungi. Some risk factors include the existence of previous chronic diseases, such as cardiovascular disease, asthma and chronic obstructive pulmonary disease (COPD), smoking and a weak immune system. Its classification is commonly defined by the physical location where the disease was contracted, being divided into nosocomial pneumonia, if acquired through hospital means, and community-acquired pneumonia (CAP), the latter being more common worldwide.

CAP is a common and serious infectious disease with various causative agents. In Portugal, some studies have already been carried out to understand the evolution and spread of CAP, which, in general, concluded that the elderly, especially those >85 years old, and individuals with low socioeconomic conditions are the groups most susceptible to this infection. This fact becomes especially worrying when considering the growing trend of population aging in developed countries, as is the case in Portugal. Due to this fact, the average age of those hospitalized and their mortality rates have shown increasing trends. Vaccination, although efficient in the country, is not enough to combat the adverse effects of Pneumonia, especially in immunocompromised individuals, such as the elderly.

In this context, understanding the risk factors associated with different pathogens is crucial for effective treatment and management strategies. The incidence of CAP increases with age, with the highest rates seen in individuals over 65 years old. Environmental factors play a role in the development of CAP. Exposure to tobacco smoke, air pollution, and overcrowded living conditions increase the risk of acquiring pneumonia. Machine learning (ML) models, particularly the XGBoost algorithm, have shown effectiveness in predicting adverse outcomes in CAP patients, such as hospital admission

and mortality. These models outperformed traditional clinical stratification tools, like the Pneumonia Severity Index (PSI), in terms of prediction accuracy. However, limitations of using ML for CAP diagnosis include the need for reliable and balanced datasets, potential biases in training data, and the black-box nature of artificial intelligence models.

As such, we analyzed a set of more than 30 spatial determinants at a municipality level for Portugal mainland (chosen through bibliographic review) and after eliminating multicollinearity problems using Variance Inflation Factor (VIF) we tested Geographical Random Forest (GRF) which is a spatial extension of the random forest algorithm to address spatial heterogeneity in population modelling, Traditional RF, Support vector machines (SVM) and Extreme Gradient Boosting (XG-Boost). In the end, GRF performed better, and we used explainable Artificial Intelligence (xAI), i.e., an agnostic model, for evaluating the importance of each variable, namely Triplot, that considers the hierarchical correlation structure of variables.

In relation to the explanatory factors that identify possible causes of the disease and resulting hospitalization, we have living and housing conditions, with the models giving high importance to these factors.

The use of predictive models such as machine Learning ones is useful for the study and understanding of spatial phenomena, especially in health with the study of the most diverse diseases, not only in the case of pneumonia, but those that most affect the Portuguese population. Using these methods, it is possible to identify areas of concentration of cases and identify risk factors, thus contributing to better management of available resources in the prevention and mitigation of cases of pneumonia or other diseases. Overall, a comprehensive understanding of the driving factors of CAP is essential for improving public health.

Special Session: 1. Environmental health studies

Keywords

Community-acquired pneumonia, Machine learning, Explainable Artificial Intelligence, Agnostic models

Assessing 250 years of land use changes in Flanders through GeoAI

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ABSTRACT

Historical topographical maps offer valuable, spatially-explicit and thematically detailed insights about past land use and land-use changes. Until recently, manual vectorization to some extent was needed to create land-use maps that allowed spatially-explicit, quantitative analyses of historical land-use changes. As a consequence, studies that applied this labour-intensive method have often focused on relatively small study areas or few different land-use categories (see e.g. Cousins et al., 2015 & Lathouwers et al., 2023). Recent developments in GeoAI, however, have opened up possibilities to automatically convert these historical maps into land-use maps in a fast and efficient way

We utilized OrthoSeg (Roggemans, 2024), an open source GeoAI software package, to process three historical topographic maps of Flanders, the northern part of Belgium, corresponding to the years 1774, 1873, and 1969. This approach enabled the generation of land use maps for the whole of the Flemish region (around 13.800 km^2) encompassing nine distinct categories: arable land, orchards, grasslands, built-up areas and gardens, forests, freshwater marshes, heathlands, intertidal zones, and water bodies. The land-use on the 1774, 1873, and 1969 maps was detected with overall accuracies of 94%, 91% and 93%, respectively.

A comparison with a contemporary land-use map of Flanders for 2022 revealed the most dominant land-use dynamics in the last 250 years. During the period 1774-1873, distinct spatial patterns of land-use changes could be discovered in the eastern part and the western part of Flanders. While the eastern part of Flanders was dominated by transitions from heathland to forest—driven by the emerging mining industry—forests in the southern and western parts of Flanders were cleared to make way for agriculture (arable land and grassland). In the subsequent period (1873-1969), a large part of the arable land was converted to grasslands, causing the grassland area to more than double (from 13% in 1873 to over 28% in 1969). This shift aligned with the agricultural intensification of Flemish agriculture, which resulted in a reorientation from arable farming to livestock farming. Since 1969, urbanization processes have again reduced the agricultural land-use in favour of built-up areas. The results also show a homoge

nization of the Flemish landscape throughout time. While landscapes in the 18th and 19th century exhibited significant variation across different geophysical regions, influenced by distinct soil conditions, they increasingly became more similar throughout the 20th century: e.g. grasslands expanded beyond their original river valleys and more recent urbanization processes took place disregarding soils.

We conclude that GeoAI-based production of land-use maps from historical topographical maps offers a resource-efficient alternative to manual vectorisation and is particularly useful for spatially-explicit assessments of long-term landscape dynamics at a regional scale level.

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Keywords

Historical land use, GeoAI, Flanders

Tracing Agricultural System through Geospatial Theory and Historical Sources: Insights from Portugal

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ABSTRACT

Theoretical reflections in geography increasingly require a synthesis between long-term empirical knowledge and formal approaches to complex spatial systems. This paper contributes to that dialogue by exploring how agricultural systems, understood as adaptive socio-environmental complexes, have been historically modelled and interpreted through geospatial research. Drawing on the case of mainland Portugal, we reflect on the theoretical and methodological developments in modelling land-use dynamics, particularly in agricultural contexts, using both historical and contemporary geospatial data.

We begin by revisiting the conceptual evolution of agricultural system modelling, situating it within broader trends in geographical theory—from von Thünen's early spatial economic models to recent advances in geocomputation, simulation, and land-use change analysis. We argue that agricultural systems are ideal "knowledge objects" for theoretical geography: they are spatially explicit, historically layered, and governed by feedback across environmental, socio-political, and economic domains.

Building on this theoretical framing, the paper explores how geospatial methods, particularly spatial analysis, land-use simulation, and historical GIS, have been used to capture the complexity and temporality of agricultural transformations. The Portuguese case provides a valuable lens to understand these dynamics, especially given its rich historical documentation, diverse agroecological regions, and significant policy transitions (e.g., European integration, agricultural abandonment, climate variability).

We demonstrate how historical agricultural sources, such as national agricultural statistics, agrarian surveys, and historical cartography, can be transformed into structured geospatial datasets. This approach benefits from methodological intersections with data science, historical studies, stakeholder engagement, and systems modelling, intersections that are actively being developed through research projects such as AgroecoDecipher (2022.09372.PTDC), ML-SOIL (2024.00178.S4P24), Land2scape (2023.11164.PEX), and MonLand (2024.00129.S4P24). These projects collectively reflect an emerging research agenda that positions geospatial historical modelling as a key contribution to theoretical and applied geography.

The paper also engages with the theoretical implications of using historical sources

in geographical modelling. It discusses how spatial models grounded in past land-use transitions can inform future scenarios, and how the act of digitising and simulating historical data reshapes the epistemological status of such data, from narrative archives to empirical evidence. In doing so, we contribute to ongoing debates around the epistemic role of data in geography: what constitutes valid knowledge, how it is shaped by disciplinary practices, and how it interacts with emerging formal theories of complexity, system dynamics, and spatial organisation.

In conclusion, we argue that geospatial approaches, especially when applied to historical and long-term agricultural data, offer a ground for theoretical innovation in geography. They enable the construction of spatially explicit, temporally rich representations of human–environment interactions, contributing to both retrospective understanding and prospective modelling. More broadly, the Portuguese case illustrates how theoretically informed, data-intensive geography can address pressing global challenges such as food security, land sustainability, and socio-ecological resilience.

Keywords

LULC, modelling, GIS, historical GIS

Impact of Temporary Location Visitors on Mobile App Usage in French Cities: Implications for Socio-Economic Segregation Studies

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ABSTRACT

This study investigates the determinants of mobile app usage patterns in a 4G network across 20 French cities, focusing on the relative influence of socioeconomic characteristics of temporary visitors and locals. Using the NetMob23 dataset and a range of spatial and socioeconomic data sources, we apply random forest models to predict mobile traffic. Our results indicate that accessibility-based variables, which reflect potential visitors, provide a better explanation of 4G data usage patterns compared to demographic characteristics of residents and the composition of land use. This suggests that mobile data traffic reflects temporary visitor behaviour rather than the socioeconomic profile of residents, challenging conventional interpretations of 4G usage data in studies on urban socio-economic segregation and inequalities.

Full abstract attached. We kindly ask that our abstract is also considered for the Special Session on Sensing Functional Systems through Mobility from Big Data: From Neighbourhoods to Urban Regions and Global Networks.

Keywords

mobile app usage, accessibility, human mobility, segregation

Sensing Cross-Border Integration of Border Regions in Europe from the Mobilities of People: A Mobile Big Data Approach

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ABSTRACT

One of the main objectives for the EU is to enhance integration and cohesion within internal border regions by strengthening political, economic, and social ties through cross-border cooperation and governance. While institutional and economic ties and networks across borders are well examined and understood, the perspective of people are less known. Besides potential access to cross borders, actual interactions of people and their cross-border practices are challenging to capture. Yet, these social interactions contribute to the (re)production of functional systems – single integrated cross-border regions.

To narrow this research gap, we stem from the conceptual framework of mobility as a tool to understand society and consider mobilities of people as an indicator for a functioning system. For this, we propose to use mobile big data sources to capture mobilities of people across country borders. Our objective is to reveal cross-border interactions of local people from their mobilities to further capture how border regions in Europe are functioning across the border from the perspective of local community. For this, we ask two research questions:

1) How can the degree of cross-border integration of border regions be assessed through cross-border mobility?
2) Which insights into cross-border integration of European border regions can be gained from cross-border mobility patterns?

This provides new insights on understanding the level and specifics of integration by cross-border region in Europe.

We operationalize our framework by studying all internal border regions in Europe using social media (Twitter) data as an example to empirically examine flows of cross-border mobilities between 2012-2022. We study empirically four spatiotemporal dimensions of mobility flows to characterize the integration of cross-border regions. We examine seasonal variation, weekly rhythm and the spatial distribution of cross-border mobility flows by border region in Europe (n=72). For the fourth dimension, we examine the directionality of flows from both side of a border by assigning respondents' home locations to mobility data.

The multilayered spatiotemporal analysis of given interactions reveals various clusters to characterize integration levels of cross-border regions – e.g. higher integration levels with mutual interactions, average integration level with mixed interactions, lower and emerging integration with one-way dominant interaction, and limited integration level. The sensitivity analysis regarding methodological criteria and clustering method do play a role in our results, however, the main division of clusters with distinctive characteristics remain stable to show the robustness and feasibility of our approach. We conclude that digital footprints from mobile big data can improve research and practice to understand how cross-border regions function regarding local community and support better policy and planning of cross-border regions in the European Union and beyond.

I would like to present this as a part of a Special Session 3.

Keywords

cross-border mobility, functional region, border region, big data approach, mobile big data, clustering, integration, Europe

Mapping Vital Urban Areas Through Social Media Activity: A Case of Tallinn, Estonia

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Olle Järv (*University of Helsinki*)
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ABSTRACT

Urban vitality is a commonly used concept that describes the liveliness, diversity, and attractiveness of urban spaces, fostering social interactions and activities. Urban vitality is a spatio-temporally dynamic phenomenon measured using traditional and big data sources. Big data sources, such as social media, can capture the short-term spatio-temporal dynamics of people's activities and provide additional perspectives on long-term trends studied with traditional data sources like population registers and census data. Twitter, now X, can provide a rich repository of geolocated content through which we can capture the pulse of a city and its vibrant areas. While urban vitality has gained attention from researchers, examining it through a combination of big data and traditional data sources remains an under-explored perspective. This approach opens the possibility of revealing urban dynamics and introducing an additional layer of information to the complex representation of what occurs in the built environment.

In this study, we asked: (1) What are the spatial and temporal patterns of urban vitality across different domains in Tallinn, Estonia, as indicated by geo-referenced social media data? (2) What constitutes different types of urban vitality (temporally, spatially, qualitatively)? (3) How does linguistic diversity correlate with the spatial distribution of urban vitality?. To do that, we applied our conceptual framework to measure and map urban vitality, using statistical data on the built environment, socio-economic characteristics of residents, and geo-referenced social media content to represent distinct vitality domains. Second, we extended Sulis et al.'s (2018) interpretation of Jane Jacobs's concept of urban vitality. We adopted a fourth variable, linguistic diversity, to Sulis et al.'s (2018) three key variables: intensity, variability, and consistency for identifying vitality. We retrieved 155,000 geo-tagged tweets from Tallinn, Estonia, from October 09, 2020, to February 08, 2023, with a fastText language identification model to detect the tweet languages posted from Tallinn, then aggregated into a 500-meter grid and measured diversity using the Shannon Entropy (H) and Simpson's Index (S). Third, we explored the spatio-temporal patterns of urban vitality by performing cluster analyses to identify spatial hierarchies in urban vitality across the urban space of Tallinn, Estonia. Our results demonstrate how urban vitality is distributed spatio-temporally across the urban space of Tallinn, how different perspectives on urban vitality emphasize different aspects, and how using information on the diversity of languages can provide a

more holistic understanding of urban vitality. Our model highlights places of interaction in the built environment, aligning with different urban theories such as land use and urban hierarchy. The dynamic population exhibits complex spatial relationships contributing to the city's spatial structure. The initial model describing urban vitality without linguistic diversity emphasizes the role of the city center as the most dynamic and diverse area. In contrast, from a dynamic population perspective, the different population groups reveal a more dynamic presence.

Our findings can provide insights and an improved understanding of human presence by extending existing methods with an examination of the linguistic diversity of the dynamic population. A combination of data sources supports data-driven and evidence-based urban planning, which is essential for future research in urban vitality.

Keywords

twitter, urban vitality, big data, social media, geo-tagged

Conceptualizing Functional Neighborhood Boundary Intensities

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ABSTRACT

Neighborhood boundaries are typically represented as solid monotone lines of equal thickness. Such representations might inadvertently suggest that boundaries are homogeneous, and thus have the same effect on people's lives regardless of local contexts and variations. Some recent work has conceptualized boundaries as having different intensities as a way of understanding the uneven influences they might have on proximate populations (Legewie & Schaeffer, 2016). So far, these boundary intensities have been estimated based on the extent of differences in neighborhoods' demographic compositions, i.e., by 'formal' means (Legewie & Schaeffer, 2016) with greater differences resulting in higher boundary intensities. Boundaries with the highest intensities, termed social frontiers, are thought to limit interaction between members of different social groups (Dean et al., 2019; Iyer & Pryce, 2023). Over time, this lack of interaction is thought to exacerbate segregation and contribute to the propagation of socio-spatial inequalities.

We suggest that 'formal' approaches of estimating boundary intensities capture only part of the picture. For example, frontiers may be identified between neighborhoods with different ethnic compositions. But, residents of these neighborhoods interact with each other, for example, during their daily mobility (Shelton et al., 2015). In fact, their mobility helps 'bridge' divides borne of their ethnic group and neighborhood memberships. Relatedly, individuals from different neighborhoods but the same ethnic groups may not interact. This absence of interactions may result in intense frontier-like boundaries that may not be identified through formal methods.

Using prior work on mobility-based functional regionalization as a starting point (Govind et al., 2024), we advance the idea of 'functional' boundary intensities and answer four questions: What are functional boundary intensities? How do they differ from formal boundary intensities? How can they be captured empirically? And lastly, how can they contribute to our understanding of neighborhoods and socio-spatial processes?

We develop conceptual functional counterpoints to existing 'formal' research. Specifically, we conceptualize functional boundary intensities based on people's mobility flows — as proxies for social interactions — and suggest that many flows between adjacent neighborhoods will result in low boundary intensities. Similarly, few flows will result in high boundary intensities. Extending this line of thinking, boundaries with the

fewest flows (i.e., the highest intensities) represent functional frontiers. We introduce the metaphor of bridges to describe the converse: boundaries with the lowest intensities borne of many flows. We also conceptualize the co-occurrence of formal and functional boundaries, which, at times, may be contradictory. For example, a formal frontier may co-occur with a functional bridge. Here, the former conceptualization expects few interactions, while the latter is identified by many interactions. In fact, such contradictory co-occurrences can help us rethink the geographies of segregation.

We support these conceptualizations with empirical analyses of neighborhoods in the Dutch cities of The Hague and Rotterdam. Using a dataset of geo-located tweets to proxy mobility, we compute the ratio of the total weight of trips between an origin and a destination neighborhood to the total weight of trips originating from the origin neighborhood. We aggregate these values per shared boundary to obtain functional boundary intensities. We visualize them using color gradients and varying line thicknesses. We then use these aggregated boundary intensities to study neighborhood segregation using data on people's ethnicities. We identify instances where interactions between members of different ethnics groups are distinct from those expected based on formal boundary intensities. We examine the co-occurrence of formal and functional boundaries. We find little alignment (0.08%) in the co-occurrence of formal and functional frontiers, and the greatest alignment in the co-occurrence of formal and functional bridges (74.31%). The remaining 25.25% of boundaries represent the contradictory permutations of bridges and frontier through formal and functional conceptualizations. Through a case-by-case examination, we offer explanations in support of the validity of both formal and functional boundary intensities. Through this, we emphasize the need for greater nuance in the conceptualization of boundary intensities.

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Submission for the special session titled "Sensing Functional Systems through Mobility from Big Data: From Neighbourhoods to Urban Regions and Global Networks"

Keywords

boundary intensities and social frontiers, mobility and functional systems, neighborhood boundaries

Redefining a strategy for assessing urban mobility resilience from an equity perspective

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ABSTRACT

In recent decades, researchers and transport policymakers have increasingly turned their attention to equity issues. Nevertheless, despite their unquestionable importance, translating normative principles into practical interventions that genuinely promote equity remains a significant challenge. Within this context, the aim of this study is to integrate equity considerations into a strategy for assessing resilience in urban mobility under conditions of restricted fossil fuel supply. The proposed approach involves analysing the behaviour of public transport (PT) line prioritisation in a scenario where only the main lines could operate due to fuel shortages.

Initially, a baseline scenario is developed without considering equity criteria, followed by alternative scenarios that incorporate equity, enabling an analysis of the differences and the importance of accounting for this aspect. Using data from an Origin-Destination survey and the public transport system itineraries of São Carlos, São Paulo, Brazil, 10 scenarios were developed incorporating different personas. These personas represent vulnerable groups recognised in the literature, taking into account variables such as sex, travel purpose, and age. After defining the personas, eleven experts were selected to collaborate in defining the weights to rank them according to the relative importance of these personas to be served by the PT lines, using the Delphi method. In the questionnaire, experts ranked the personas in order of importance (high or low) of each in relation to the next, using the Structured Pairwise Comparison method. A judgement of "low" importance resulted in a sequential positioning on the list; for instance, if persona x was deemed "low" more important than persona y, x would occupy 1st place and y 2nd place. Conversely, a judgement of "high" importance generated a gap of two positions: in this case, persona x would occupy 1 st place and persona y 3rd place. In a second round of assessment, the experts received an anonymous summary of the group's responses and were invited to reassess their initial answers, with the option to either maintain or modify them. The two rounds of assessment achieved a moderate level of agreement achieved (Kendall's W = 0.526). The positions defined by the participants were then standardised and converted into a scale where the total sum of points attributed to the personas equalled 100. The average score assigned to each persona was subsequently calculated, enabling the application of these weights in the construction of the scenarios.
The scenarios were structured to progressively incorporate the personas, allowing for a more detailed and transparent analysis of the changes introduced by this approach.

The results revealed significant changes in the prioritisation of public transport lines when the equity perspective was incorporated using these personas. Some examples are presented in Figure 1.

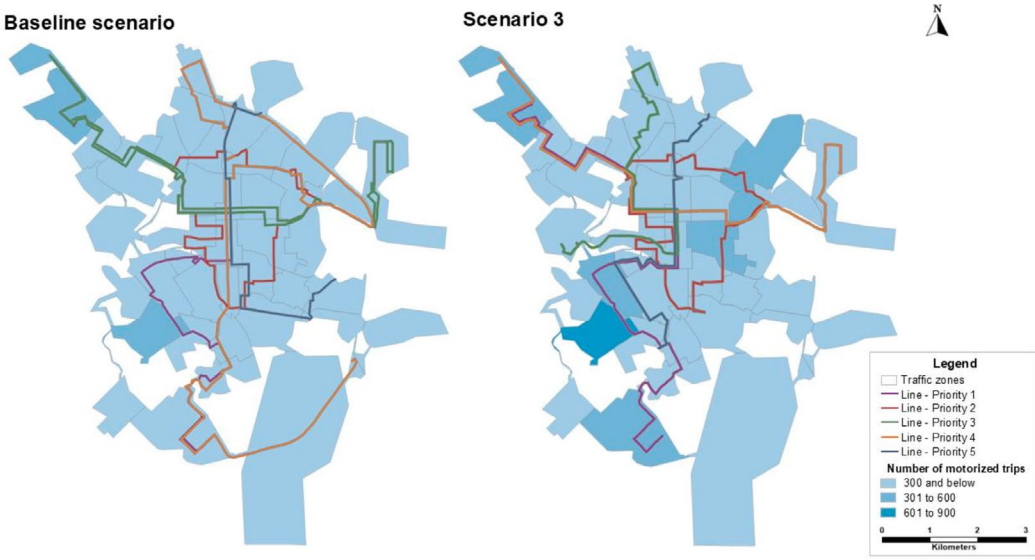

Figure 1. *Comparison between baseline scenario (without equity criteria) and scenario 3 (where the most significant changes were observed)*

In Scenario 1, which incorporates the persona considered to be of greatest importance – women aged 60 or over, traveling for health reasons – it is possible to notice some small changes in the priorities of the lines. The most pronounced changes occurred in Scenario 3, which included women aged between 18 and 44 travelling for work, in which line 1578, previously ranked 21st without the inclusion of equity criteria, rose to 5th place; and line 0637, formerly 20th, advanced to 8th position, representing the most significant reclassifications.

These findings highlight the importance of considering who makes the journeys, going beyond simply counting trips, in order to promote greater inclusivity in transport prioritisation decisions.

Keywords

Equity, Public Transport, Urban Mobility

Gender and mobility: Intersectional inequalities of accessibility in São Paulo, Brazil

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ABSTRACT

Gender equality is not only one of the 17 Sustainable Development Goals, but also integral to other goals, including SDG 11, which focuses on sustainable cities and communities. This highlights the need to better understand how differences in gender shapes the experience of women in cities and how they relate to other systemic urban inequalities. SDG Goal 11.2, which focuses on access to transport, specifically addresses the needs of women, while SDG 5 directly addresses the need to achieve gender equality and empower women and girls, for which mobility is key. It is known that although gender inequality can be found in all classes and places, it is often aggravated when intersecting with other inequalities such as of socio-economic nature, which are the hallmark of cities in the Global South.

The present study measures gender inequalities in transport accessibility across socio-economic classes in São Paulo, Brazil. There have been limited quantitative studies focusing on gender differences in transport accessibility. This is mainly due to limitations in traditional accessibility measurement methods that do not allow for the differentiation of accessibility levels of people who live in the same spatial unit, nor account for specific needs, capabilities, and responsibilities that can impact an individual's accessibility.

Space-time accessibility metrics, based on Hägerstrand's Time Geography, allow for those limitations to be overcome by focusing on individual's constraints on space and time. These metrics, however, tend to require high computational power and data requirements that limit their application, in particular to case studies in the Global South which tend to have poorer data availability.

This paper adopts a metric of space-time accessibility, which can be computed at individual level with minimum data requirements (OD datasets, travel time matrices, and basic land use data). Individual accessibility metrics allow analysis at high level of detail and, more importantly, the investigation of intersectional inequalities via the aggregation of individuals in different groups based on their characteristics.

This study explores the intersectional inequalities of accessibility by gender and socio-economic groups in São Paulo, Brazil. Data from São Paulo Metro Origin-Destination survey were used to calculate the accessibility of 4.5 million individuals to urban opportunities that represent activities, services and amenities people can access in the

city, such as shops, restaurants, healthcare facilities, schools, parks, and so on, which were obtained from the Brazilian census.

Results revealed the dimensions of the gender gap in accessibility in São Paulo where, on average, men's levels of accessibility are 1.8 times higher than women's. When gender groups are further disaggregated by economic class, it is clear that gender inequality is aggravated by socio-economic class. The lower the economic class, the greater the gender gap and lower accessibility. While the upper classes present similar levels of accessibility for men and women, the gender gap gradually increases for lower economic classes culminating in a gap of 5.59 times for class D – E. This is evidence of the impact of intersecting inequalities, with low-income women being particularly disadvantaged. The paper discusses these results in the context of the literature on gender and mobility and the reality of the Brazilian society.

Keywords

gender, accessibility, economic classes, intersectionality, inequalities

Modelling Elderly Accessibility to Pharmacies by Integrating Vertical Mobility Constraints into Network-Based Spatial Analysis

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ABSTRACT

The 15-minute city aims to ensure that all essential services and amenities are accessible within a 15-minute walk or bike ride from any residence. This includes a variety of services such as education, healthcare, shopping, leisure, and more. In this context, pharmacies are considered a critical component of healthcare services. Ensuring their accessibility is vital for the well-being of residents, especially for those who require regular medication. Given their importance, they are typically prioritized in the planning of 15-minute cities to ensure they are within easy reach for all residents, including vulnerable populations such as the elderly and those with disabilities.

Other typical features within 15-minute city concept (e.g. coffee shops) while important for social interaction and leisure, are not classified as essential services. Their presence contributes to the vibrancy and livability of a neighborhood and are typically integrated into mixed-use developments, contributing to the diversity and attractiveness of urban areas. They are part of the broader goal of creating lively, walkable neighborhoods. Unlike pharmacies, these features may not be as uniformly distributed. Their locations can be more flexible, often clustered in commercial or high-footfall areas to maximize business opportunities.

The 15-minute city concept generally focuses on one-way travel time to services. However, for practical daily use, the round-trip time could be significant, especially for activities implying a short time between going and returning. Including return trips in these models could enhance their accuracy and applicability because ignoring the return trip might underestimate the actual time residents spend traveling, potentially affecting the perceived convenience and efficiency of the 15-minute city model.

Moreover, common models usually ignore differences in walking capabilities among residents (e.g. elderly) can lead to inequitable access to services. These differences could be due to physical conditions and/or buildings characteristics like the number

of floors. Also, in multi-floor buildings, the presence of elevators and escalators can significantly impact accessibility, especially for elderly individuals.

In conclusion, to better model elderly accessibility to pharmacies, it is critical to integrate building-level characteristics—specifically, the number of floors and the presence or absence of elevators—into the spatial analysis. Residents living on upper floors in walk-up buildings encounter a compounded accessibility burden, particularly those with limited mobility. By assigning a ”vertical mobility cost” or penalty based on floor height and elevator availability, we recalibrate accessibility measures to reflect the actual physical effort required to reach street level before even beginning the journey to a pharmacy.

This enriched accessibility framework was operationalized using network analysis techniques. By leveraging detailed pedestrian network data for the city of Lisbon (Portugal), we calculate more realistic routes between residential buildings and nearby pharmacies. To do so we create a refined modelling framework that integrates vertical mobility constraints—specifically the number of floors in residential buildings and the presence or absence of elevators—into a network-based spatial accessibility analysis. Buildings are assigned a vertical impedance value based on their floor count, with higher penalties applied to those lacking elevators. This impedance is conceptualized as a proxy for the physical effort or time delay required for an elderly resident to descend to ground level, forming a precondition for engaging with the street-level pedestrian network.

The approach employs a cost-distance network analysis, implemented using ArcGIS Network Analyst, where origin nodes (residential buildings) are linked to destination nodes (pharmacies) via the pedestrian street network. The routing algorithm incorporates not only standard edge weights (e.g., distance, slope, travel time) but also an origin-specific cost modifier representing vertical impedance. This results in a building-specific accessibility surface that reflects both micro-scale vertical constraints and macro-scale urban connectivity.

By synthesizing geospatial building data (e.g., LiDAR), elevator presence (where available), and population age distribution, this model supports the computation of adjusted isochrones and refined accessibility scores at the building or block level. Such outputs enable the spatial identification of accessibility deficits, particularly in clusters where elderly populations reside in high-floor, non-elevator buildings distant from pharmacies. The result is a more accurate measure of effective access—one that moves beyond simple proximity and captures the layered spatial inequities present in the urban fabric.

Such an approach offers practical benefits for urban health policy and planning. It enables the identification of areas where elderly populations face disproportionately high access barriers and supports scenario modeling—such as evaluating the impact of installing elevators, optimizing pharmacy locations, or targeting home delivery services. Finally, by merging building-level data with advanced network analysis, this methodology fosters a more inclusive and realistic understanding of healthcare accessibility regarding urban aging.

Special Session: Novel spatial data and indicators for assessing the reality of 15-minute cities

Keywords

Accessibility, 15-minute city, Spatial Modeling, Elderly

Investigating a double vulnerability of accessibility poverty in European urban areas

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ABSTRACT

Persistent spatial disparities are increasingly becoming evident across European regions and cities, highlighting the risk for marginalised, disconnected and deprived areas to become left-behind places. Spatial patterns of inequality in terms of accessibility to essential services are an important matter for policy to understand and address, since they have consequences on people's quality of life and direct effects on their daily opportunities in terms of health, personal growth and wealth. Moreover, the digital transformation occurring across European territories might introduce a new layer of potential inequality, represented by geographical differences in digitalisation and broadband accessibility. This uneven pattern can further deepen the existing urban-rural divide and reinforce the geography of inequality across places. The objective of this study is to identify areas where individuals can experience a greater risk of social exclusion in terms of accessibility to opportunities and essential services. This includes investigating both physical and digital access to either people or services, such as (tele)medicine, (online) education, shopping, and (remote) work.

The work presents an analysis investigating the co-occurrence of poor digital and physical accessibility in European Functional Urban Areas (FUAs). The goal is to combine these findings into composite indicators that can help recognise instances of double vulnerability created by being in both physical and digital accessibility poverty, thereby supporting policies aimed at mitigating social exclusion in Europe. By employing a high-resolution and data-driven approach, it analyses access to opportunities using data from transport networks, broadband performance and populated grid cells from GISCO (Geographic Information Service of the Commission) to develop composite indicators that enable a better understanding of the "double vulnerability" of accessibility poverty.

To measure transport availability poverty, we run earliest-arrival routing problems on either road or multimodal public transport networks. For private car accessibility assessments, we consider both free-flow speeds and congestion scenarios, while we model public transport networks using timetable schedules of the services, accounting for short walks between stops and the first and last miles of the trips. We then combine the results of a number of services, or opportunities, the resident population can reach within a travel-time interval budget of 40-50 minutes with destination-specific sufficiency thresholds, defined as population-weighted 50th percentiles of nationwide reachable destinations by public transport within 45 minutes.

To measure digital accessibility, we analysed the availability and performance of the broadband network in the study area, considering actual speed and responsiveness of fixed and mobile broadband networks recorded by users. The high granularity of broadband performance data makes it possible to identify underserved areas and possible digital disparities between places within the same countries.

Preliminary findings from FUAs located in different EU countries suggest a compounding effect of exclusion for areas lacking both transport and digital connectivity. Results suggest that accessibility poverty can also affect urban areas generally considered as well-endowed places, raising concerns about potential socio-economic consequences such as socio-spatial segregation and marginalisation, and piling up on access to opportunities for people living there to the detriment of those in disconnected urban places. To the authors' knowledge, this is the first effort to combine digital and physical indicators to evaluate accessibility poverty, leading to a more comprehensive examination of social exclusion across Europe, and ultimately supporting policies aimed at reducing accessibility inequalities and promoting equity measures in urban planning.

Keywords

Transport poverty, Digital accessibility, Population grids, Access to opportunities

The spatial relay roles in ownership linkage network: from individual firms to cities' properties

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ABSTRACT

Many global corporations have several levels of ownership going through some cities which constitute "mandatory pathways" to reach other ones. The position of "relay", "intermediate" or "bridge", affords cities better access to the whole network as well as increased control over information transfers (Burt, 1992, 2007, 2015). One can interpret this cumulative process of concentration as a reinforcement of "social capital" of big cities as sociologists do at the micro level (Gould, Fernandez, 1989; Walker et al., 1997). The position of relay should be more precisely defined in urban geography, as in sociology this concept integrates the role of "tertius Gaudens" or structural hole (Simmel, 1922; Merton, 1957; Granovetter, 1973; Hannan & Freeman, 1977).

At the micro level, the firms playing this role of relay are on one hand, subsidiaries of headquarters situated in other cities, and on the other hand, they are headquarters of subsidiaries situated in other cities (a and b in Fig.1).

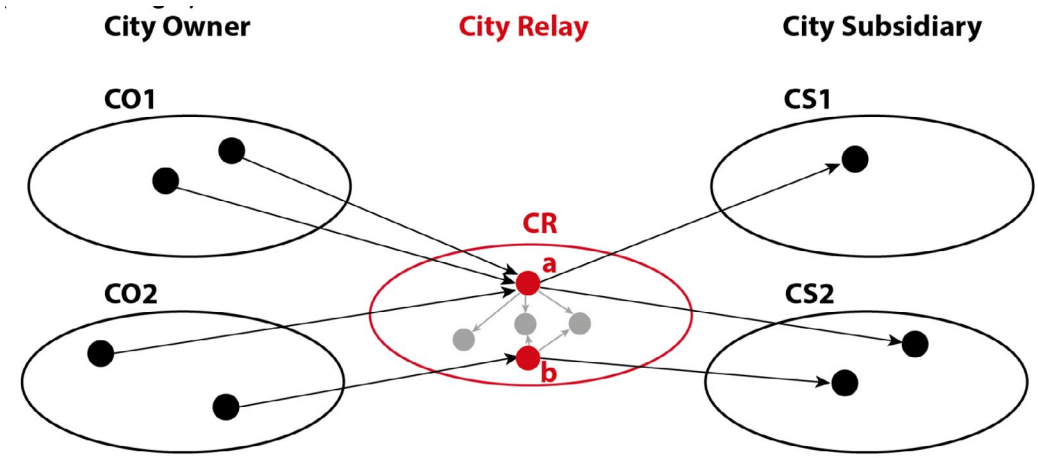

Figure 1. *General scheme of city relays through micro-level networks.*

The relay firms are supposed to lean their relay role against local firms, most of them being financial and management services, or against institutional networking (grey nodes in the city relay CR), therefore participating in many forms of local agglomeration economies, beyond the classic production firms. Therefore, the local number of firms which play this relay role, and their capacity to have many links with other cities, reveal the city capacity to support such functions in its own regional or national context, and at the scale of the whole world: this is what we call "relay city" (CR in Fig.1).

To emphasize the relay-cities of the world, we will work on a sample that we develop for many years on the first 3,000 first multinational firms (every 3 years from 2010 to 2022: ORBIS database), including all their direct and indirect subsidiaries with more than 10% ownership links. The amount of data grew in time: 2010: 600,000 Entr. / 800,000 links; 2013: 800,000 Entr. / 1.2 M. links; 2016: 1.2 M. Entr. / 2 M. links; 2019: 1.5 M. Entr. / 2.5 M. links; 2022: 1.7 M. Entr. / 2.9 M. links.

Observing the relays at the micro level of companies, but building indexes at the city level, numerous possibilities exist to reveal the size and the specialization of cities in these roles. Beyond the main results of this empirical implementation, the purpose of the presentation will be to discuss how far different indexes evaluated at different spatial scales, could reveal diverse aspects of this spatial role for cities and for their dynamics. Which indices reflect the best the attractiveness and power dynamics of the cities? Which ones could reveal resilience properties or spatial balance? How making vary the geographical scope of this role offers complementary visions of this relay role? We will discuss these measures to progress in the identification of the city-relays' properties and in their communication for possible urban policies.

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Keywords

Cities, networks, multinational firms, ownership linkages, relay functions

Synthetic cities to support the development of advanced urban models

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ABSTRACT

Census data are very important datasets that characterises entire countries every ten years by giving a comprehensive and detailed review of various aspects of a country in multiple domains including demography, migrations, economics, commuting or poverty and ethnicity. It is conducted periodically with the purpose of enumerating the entire population of a country and collecting detailed information about their demographic, social, and economic characteristics. This data plays a crucial role in comprehending population dynamics, migration patterns, employment trends, and urban growth, and it informs policy making and resource allocation (Wesolowski et al., 2013; O'Hare, 2019). Collecting such socio-economic data poses significant challenges and is a costly activity. At the same time, using this data to develop and test urban and transport simulation models to inform decision-making and policy design and testing for urban issues is key for developing accurate models that effectively assist these processes.

Synthetic data serves as a solution to better develop urban models. The potential of synthetic census data to enhance the development and testing of data-driven urban models has great potential, as it creates generalizable datasets free of potential location-specific bias, errors or data quality issues. It gives freedom to model developers to conceptualise and implement modelling concepts focusing on validation rather than immediate calibration. These models can be tested against more unconstrained assumptions, allowing model users to develop a deeper understanding of urban phenomena. Which in turn may empower stakeholders and policymakers with the ability to assess policy impacts prior to implementation.

While Generative Adversarial Networks (GANs) have received extensive research attention with focus on generating synthetic images rather than alphanumeric data. Attempts have been made to generate synthetic tabular data through GANs, yet limited, particularly with regard to census data. This limitation highlights the novelty of our study, which is aimed towards the generation of synthetic census data.
Our study is a long term project coordinated by Pinto with model development implemented by Jamilah and Xiao. It aims at developing a robust model that produces synthetic data that mimics different types of census dat from different statistical and policy contexts. This model will generate datasets that can be used to develop new urban models, allowing free testing of theories and hypothesis, as well as breaing existent barriers to modelling associated with morphology, function and data availability

and reliability.

We have developed a GAN capable of producing synthetic census statistics comprising key demographic, economic, deprivation, and transportation variables. The state-of-the-art DATGAN architecture served as the foundational framework for our model (Lederrey et al., 2022). We used English census data to train the model. Additionally, we created synthetic spatial boundaries using Thiessen polygons corresponding to the generated census data at various spatial aggregation levels to replicate census units, local, regional and national administrative boundaries.

We developed a tool using a user-friendly Jupyter notebook that enables the simulation of the entire workflow. This tool facilitates the generation of synthetic census statistics and spatial boundaries at various spatial scales through user-defined inputs.

The current version of the model has also been tested to different configurations of the training data in different census contexts, using Brazilian, Portuguese and UK census data with different size and different attributes, representing different ways in which census data contributes to policy making.

Keywords

Synthetic data, urban simulation, Urban model, generative adversarial networks GANs

Quality of personal time as a universal metric: a Telegram bot solution for the spatial assessment of cultural ecosystem services in Ukrainian city during the Russian invasion

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ABSTRACT

Introduction

The concept of cultural ecosystem services (CES) has evolved significantly. Saint Marc (1971) highlighted non-material values of nature as integral to human well-being. Later economic frameworks established CES as an important research niche, integrating recreational, aesthetic, and spiritual contributions of nature into many national assessments. However, such frameworks have been criticised for reducing the plurality of CES to straightforward benefits, often overlooking less discernible aspects (e.g., identity or social cohesion). In response, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has adopted a more holistic approach, emphasising indigenous and local knowledge to capture the relational values of nature better. From a geographical perspective, these values are deeply tied to the spatial quality of the urban environment, reinforcing the need for location-based analysis.

Despite theoretical advances, CES assessments still struggle with uncertainties, often limiting their spatially explicit indicators to outdoor visitation. In Ukrainian cities lacking ecosystem service assessments, this issue is exacerbated by the environmental impacts of the Russian invasion (Pereira et al. 2022). Existing CES studies in Ukraine remain sparse, necessitating urgent action to address the data desert. Social media platforms such as Flickr, Twitter, and Instagram, along with active crowdsourcing techniques, offer promising avenues for rapid CES mapping. Among these, Telegram, the most popular messaging app in Ukraine (Internews 2023), stands out for its accessibility and ease of use. Its functionality makes it an ideal tool for real-time field data collection with a low learning curve for participants. This work-in-progress study demonstrates the potential of a Telegram bot for spatially explicit CES assessments.

Methodology

Concept: cultural ecosystem services are cultural

Currently, there is no universal indicator for mapping CES with crowdsourced data. Photo-user days are widely used, followed by content analysis of social media posts

(Karasov et al. 2022). While these methods provide valuable spatiotemporal insights, they are limited by difficulties in capturing less discernible aspects of outdoor experiences. Participatory mapping addresses some of these limitations by enriching the range of activities captured, but they often require offline engagement, limiting their spatial and temporal coverage and comparability.

To address these issues, this study theoretically frames CES as the quality of personal time spent outdoors in a certain location, a concept inspired by Alexander Dolgin's (2012) idea of the quality of personal time, which links the economic and, overall, quantitative value of cultural experience to the perceived quality of time spent on this experience.

Telegram bot solution

To enable pluralistic, democratic, and spatially explicit CES mapping, we developed a Telegram bot with spatial submission functionality. The bot, created using the pyTelegramBotAPI library, operates in Ukrainian and English. It complies with GDPR and offers a user-friendly interface for real-time data collection. It also supports voice message submissions, which are transcribed to text before the original audio is deleted to ensure privacy. Informed consent is explicitly sought at the start, and users are informed of the project's goals and data handling practices. All data are encrypted using Fernet symmetric encryption and securely stored on CSC's cPouta service in Finland. A data collection campaign is ongoing in Kremenchuk City (central Ukraine) within the local urban development project by the Ro3kvit coalition for Ukraine.

Results

Preliminary data collected by 15.04.2025 include 181 responses submitted by 169 unique users in Kremenchuk. Working-age users (predominantly females) report mostly enjoyable and very enjoyable personal quality of time (with older users, 41-60 years old, more frequently referring to 'very enjoyable' than younger respondents). Enjoyable locations are clustered around two anchor locations: Prydniprovskyi and Studentskiy parks. Participants predominantly engage in relaxation (nature, sunbathing), communication (meetings, holidays), walking, cycling, and bird watching. Activity variety significantly influenced enjoyment, with respondents involved in two to five activities reporting higher enjoyment. Frequent visitors (weekly or monthly) consistently rated their experiences as more enjoyable.

Conclusion

We propose a Telegram-based solution as the most feasible way to do participatory mapping and assess CES in Ukraine during the Russian invasion by focusing on the theory of time quality as a universal metric of spatial experience. The bot is currently in its testing phase in Ukraine in collaboration with the Ro3kvit coalition for Ukraine and the municipal government of Kremenchuk. Once sufficient data is collected, the findings will inform recommendations for policymakers on urban restoration and protected area management.

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Keywords

non-material nature's contributions to people, war context, crowdsourcing, participatory mapping, spatio-temporal analysis

From understanding road networks patterns to modeling their evolution

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Abstract

Urban morphology results from complex processes that can be understood by identifying characteristics of the spatial structure. The intricate organization of this structure reveals an underlying order in urban evolution. Road networks are among the urban components that endure over time, presenting a challenging yet fascinating subject for study. Graph theory provides a mathematical formalization of road networks, thereby enhancing our spatial understanding.

Our research takes an analytical approach to urban morphology, focusing on road networks and emphasizing the historical context and structural features induced by their physical layout. Our research unfolds in four stages: (1) Identifying a relevant element with which to analyze road networks ('the Way') ; (2) Finding indicators with which to characterize the structure of road networks and reveal common properties over space and time ; (3) Pinpointing morphotypes within the road network associated with morphological evolution processes ; and (4) Proposing a simulation model ("WayMorph").

Our findings reveal that urban morphology is the result of complex processes that can be identified by analyzing spatial structure. Understanding urban morphogenesis and past evolution is pivotal for addressing future developmental challenges and informing the decision-making of city stakeholders. The choices made regarding territorial development, as reflected in road network morphologies, influence disparities in accessibility and territorial development dynamics. Thus, a profound understanding of the morphology and dynamics of road network evolution can significantly support territorial planning.

Keywords

Road Network, Graph Theory, Morphogenesis modelisation, Serious Game, Complex Systems

Mapping Regional Connectivity: Identifying Mobility Hubs Through Multi-Dimensional Movement Networks in Europe (2012–2022)

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ABSTRACT

Understanding which regions serve as strategic connectors in Europe's human mobility systems is critical for designing effective policies in spatial planning, regional development, labor market integration, and transnational cooperation. Yet, most mobility research to date has remained siloed, examining individual movement types, such as migration, commuting, or student mobility, in isolation. This fragmented perspective risks overlooking the complex and overlapping patterns of regional interactions that shape socio-spatial dynamics and spatial cohesion in Europe.

In this study, we move beyond mono-dimensional analyses by adopting a multi-layered network approach to regional connectivity, focusing on the 2012–2022 period. We assemble and analyze interregional mobility flows across all NUTS-2 regions in Europe, drawing on a unique and harmonized dataset that captures diverse mobility forms: permanent migration, long- and short-term student mobility, seasonal labor, long-distance and cross-border commuting, and multilocal living arrangements. Each of these mobility types reflects different socio-economic logics and temporalities, from educational trajectories to labor market flexibility and lifestyle-driven spatial practices. For each mobility stream, we construct a separate directed network in which nodes represent regions and edges reflect the intensity of population flows between them. To identify cohesive regional subsystems within each mobility network, we apply community detection algorithms, revealing clusters of strongly interconnected regions. These mobility-based communities often diverge from administrative boundaries, pointing to functional geographies that are shaped by lived mobilities rather than governance structures. This distinction is crucial for policymakers who wish to align interventions with actual patterns of regional interdependence. To identify Europe's key mobility hubs, we compute PageRank centrality for each community within each network. Unlike simple degree-based measures, PageRank captures both direct mobility ties and the broader positionality of a region within the network. This allows us to distinguish between regions that are merely well-connected and those that exert broader systemic influence due to their embeddedness in regional flows.

Through comparative analysis, we identify regions that consistently act as central hubs across multiple mobility layers, places that serve as structural anchors in the European

mobility system, as well as those that play specialized roles within particular type of mobility, such as student migration corridors or cross-border labor zones. Our findings offer a multi-dimensional portrait of regional connectivity in Europe. Some regions, such as metropolitan areas and border regions with high economic dynamism, emerge as recurrent hubs across multiple mobility types, highlighting their strategic importance for integration and cohesion. Others play more niche but no less critical roles, facilitating specific forms of transnational movement. By conceptualizing mobility as a layered and dynamic network phenomenon, this study contributes a novel analytical framework for understanding how population flows co-produce regional interdependencies. The results provide both theoretical insights and practical tools for spatially sensitive policymaking, from rethinking cohesion policy to improving higher education and labor mobility strategies.

Keywords

Interregional Mobility, Functional Regions, Mobility Hubs, Spatial Network Analysis, Spatial Interaction Patterns

The nature of urban area boundaries: concepts, dichotomic definitions and reality, case Finland

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ABSTRACT

The dichotomy between urban and rural areas is controversial. Already for couple of decades research has pointed out that the nature of urban and rural has changed and instead of dichotomic nature there is transition between them: for example gradient, fuzzy or a continuum (see e.g. Asher 2004; Champion&Hugo 2004; Oswald&Baccini 2003; Pagliacci 2017; Sieverts 2003; Woods 2009). Nevertheless, the urban area definitions based on this dichotomy are still used behind urban figures, for example urban population percentages, which are, furthermore, varying nationally. In prior research it has been shown that the different definitions produce varying outputs (see e.g. Vanhatalo&Partanen 2022). Therefore, closer research should be done on their capability of being able to mirror the actual urban areas, as the definitions should capture the actual nature of built environment and urbanity. Essential part related to their functionality are the boundaries: is the boundary produced by them in correct location, managing to separate the urban and non-urban.

To explore the boundaries of the urban areas produced by the dichotomic definitions, this study will have two parts. Firstly, the study is going to delve into the concept of boundary not only in urban studies, but also in other fields, illuminating the varying nature and components of boundaries. This part will also act as theoretical background for the second part, in which the actual boundaries produced by the urban area definitions are studied. I plan to explore six different sets of urban areas formed according to European national definitions in case of Finland. By analysing the boundaries of these urban areas, the aim is to show how well they are capable of mirroring the actual boundary between the urban and non-urban. The boundary areas are analysed both statistically and spatially based on GIS analyses. This is done by comparing numerous different key figures such as for example population, buildings, workplaces and land use class related aspects. Based on analyses the functionality of them is estimated. In addition, these results are mirrored to the concepts of boundaries, revealing the

nature of the boundaries produced by these different type of urban area definitions.

This study is work in progress and therefore this presentation will discuss the workplan of this study. Furthermore, some preliminary analysis results are presented, which have been steering further selection of analysis methods and indicators.

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Keywords

Urban area, Definitions, Urban population percentage, Boundaries, Concept of boundary, GIS, Quantitative analysis

Cities divided by rivers; how water bodies steer urban expansion

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ABSTRACT

Many cities were founded on the borders of rivers, yet the same water bodies that initiated and sustained their presence may inhibit their further growth. This study explores the barrier effect of rivers, canals and other large water bodies on the development of urban agglomerations. The main research questions in this paper are: 1) under what circumstances do urban agglomerations expand across a river?; and 2) to what extent does the width of rivers limit this expansion? We focus on the water-rich Netherlands and analyse over a century of urban development in relation to the water bodies that cross or border a large sample of 122 agglomerations. The Netherlands offers an interesting test bed as many urban agglomerations centre around rivers, while other natural barriers are absent in this predominantly flat country, thus minimising other variations in natural condition on opposite riverbanks.

The main dataset in our analysis describes the built-up areas of the Netherlands at approximately 10 year-intervals, starting from 1900. The original vectorised dataset is converted into 50x50 metres grid cells for subsequent distance calculations. Furthermore, we use detailed river maps to measure river width and distinguish the built-up areas on either side of the river they border. As a final data set, we use a map of historic churches to identify the oldest part of the agglomeration where urban development most likely started. Based on these spatial datasets we identify the core riverbank where the first urban area was formed, and the centre point of the initial urban area. In addition, we compute several distance metrics that characterise urban form: the average distance from all built-up area grid cells to the city centre; the average distance from all built-up area grid cells to the river; and the distance from the city centre to the river.

Using a logistic regression model with a Mundlak approach, we analyse the probability of urban expansion across river as well as the probability of unequal development on two riverbanks. Our models incorporate a set of variables, including river width, urban growth, land availability, and proximity to the river. By analysing urban development in the Netherlands, we reveal that urban areas closer to rivers have a higher likelihood of expanding across them. We also find that larger urban agglomerations are more likely to develop on both sides of rivers, with land availability on the non-core bank positively influencing the probability of expansion across the river. This development is, however, strongly dependent on the width of the separating water bodies. A one metre increase in river width is associated with a 6.6% decrease in the odds that urban agglomeration expands across the river. Rivers wider than 250m can be considered

a physical barrier to urban expansion. The models show strong classification performance with AUC values of 0.90 and the overall accuracy above 80%.

Keywords

urban development, physical barriers, rivers, explanatory analysis, the Netherlands

Examining spatio-racial patterns at various scales in U.S. metropolitan areas using segregation profiles

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ABSTRACT

Traditionally, the distribution of racial subpopulations within cities is summarized using single-number residential segregation indices derived from aggregated census units. While these indices allow for ranking cities based on their levels of segregation, they do not provide insights into the spatial racial patterns within each city. An alternative approach for analyzing racial distribution was introduced by Dmowska et al. (2020) and is referred to as the Racial Landscape method. The Racial Landscape (RL) is a high-resolution grid composed of small, racially homogeneous cells. This grid not only visualizes racial distribution but also provides geospatial data that allows for the calculation of two important metrics: mutual information, which assesses the level of racial segregation, and entropy, which measures racial diversity. Both metrics can be directly calculated from high-resolution grids for any user-defined region. Recently, Dmowska and Stepinski (2024) applied the RL method to create the National Racial Geography Dataset (NRGD2020). This dataset consists of a collection of pre-calculated GIS layers that serve as ready-to-use resources for visualizing and quantitatively analyzing spatio-racial patterns across the conterminous United States. The NRGD2020 also includes US-wide segregation grids that illustrate the variability of segregation at ten different spatial scales. The segregation grids consist of tiles with resolutions of 750 m, 1.5km, 3km, 6 km, 9km, 12km, 18 km, 24km, 36km, and 72km. For instance, a scale of 3 kilometers means the area is divided into tiles of 3x3 kilometers, and the segregation metrics are calculated for each tile, resulting in a grid with a resolution of 3x3 kilometers.

I utilized segregation grids with a scale ranging from 750m to 18km to create segregation profiles. The concept of segregation profiles was introduced by Reardon et al. (2008) and refers to a function that describes the level of segregation across different scales. In my analysis, I used segregation profiles to illustrate how segregation changes with scale in the most segregated metropolitan areas in the United States. The segregation profiles are constructed by plotting the scale on the x-axis and the median values of segregation metrics calculated from all cells in the city for that particular scale on the y-axis. These segregation profiles enable comparison of how segregation varies within a city, as well as how segregation levels differ between cities at specific scales. My analysis of segregation profiles in the most segregated metropolitan areas revealed significant differences. We can categorize the profiles into two main groups: one group shows a flat trend where the median segregation level remains relatively low across scales, while the other group displays a trend where segregation increases with scale. The results indicate that the overall high level of segregation in these

metropolitan areas is characterized by distinct spatio-racial patterns. The first group includes, for example, Milwaukee, Detroit, and Cleveland. The flat segregation profiles indicate that the tiles remain relatively monoracial regardless of their size. This suggests that the overall high level of segregation results from large monoracial enclaves situated in different parts of the cities. An example of this pattern can be observed in Detroit, where the central area is inhabited by the Black population, while the suburban areas are occupied by white residents. Examples of the second group include Chicago, Atlanta, New Orleans, and Memphis. This group highlights the presence of racial enclaves observable within these urban regions at a localized scale of different sizes.

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Keywords

residential segregation, racial distribution, racial landscape method, National Racial Geography Dataset

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