23rd European Colloquium on Theoretical and Quantitative Geography

ECTQG 2023

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14-17 September 2023 - Braga, Portugal

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Welcome

Welcome to the European Colloquium on Theoretical and Quantitative Geography 2023!

The present edition of the ECTQG takes place in Braga (Portugal) from the 14th to the 17th of September 2023, more specifically at the Vila Galé Collection Braga Hotel. It is the 23rd edition of a prestigious conference series initiated in 1978 within which a wide variety of themes is addressed, such as epistemology and theory, geographic information science, geo-visualisation, spatial statistics, spatial interactions, networks, big geo-data, agent-based models, computer simulations, artificial life and intelligence, time geography, geo-history/archaeology, urban patterns and growth, fractals, scaling laws, economic geography, environmental and social sustainability, climate change, health geography, and transport and land use (http://www.ectqg.eu/).

The venue for ECTQG 2023: Vila Galé Collection Braga Hotel

ECTQG 2023 is organized by CITTA – the Research Centre for Territory, Transport and Environment of the Universities of Coimbra and Porto (https://citta.fe.up.pt/). It is a research unit of FEUP and FCTUC (the Engineering Schools of the Universities of Porto and Coimbra) dedicated to the advancement and dissemination of knowledge in the fields of Spatial Planning, Environmental Policy, and Transport Planning and Engineering. At present, CITTA integrates around 50 researchers with a PhD and 50 PhD students with a wide variety of backgrounds: Civil Engineering in most cases, but also Spatial Planning, Architecture, Landscape Architecture, Environmental Engineering, Geography, and Sociology. Based on the Centre's achievements and also on its development strategy for 2020-2024, CITTA was recently rated as Excellent following an international research assessment exercise conducted by the Portuguese Foundation for Science and Technology.

Programme

Overview

Here is a quick view of the ECTQG 2023 schedule:

14/set	18:00-21:00	Registration
		Welcome cocktail & light dinner
15/set	08:00-09:00	Registration
	09:00-09:30	Opening session
	09:30-11:00	Keynote talk 1
	11:00-11:30	Coffee-break
	11:30-13:00	Parallel sessions 1
	13:00-14:30	Lunch-buffet
	14:30-16:00	Parallel sessions 2
	16:00-16:30	Coffee-break
	16:30-18:30	Parallel sessions 3

16/set	09:30-11:00	Keynote talk 2
	11:00-11:30	Coffee-break
	11:30-13:00	Parallel sessions 4
	13:00-14:30	Lunch-buffet
	14:30-16:00	Keynote talk 3
	16:00-16:30	Coffee-break
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	11:00-11:30	Coffee-break
	11:30-13:00	Parallel sessions 6
	13:00-14:30	Lunch-buffet
	14:30-16:30	Parallel sessions 7
	16:30-17:00	Closing session

Keynote talks

Keynote Talk 1 (15 September 2023, 09:30-11:00, Room 1)

Julie Vallée, **Everyday geographies, neighbourhood effects and urban segregation**

Dr. Julie Vallée is a social geographer working in the Géographie-cités laboratory in France and holding a senior research position at the National Centre for Scientific Research (CNRS). For the past 15 years, Julie has been using quantitative methods to explore and interconnect people's daily mobility, urban segregation, neighbourhood effects and social inequalities, especially in health. She is the scientific leader of Mobiliscope, an open tool available for a large number of city regions in France, Canada and Latin America and displaying interactive maps and graphs to explore how cities, neighbourhoods and social segregation change around the clock

Keynote Talk 2 (16 September 2023, 09:30-11:00, Room 1)

Cecília Silva, **Going Nowhere fast: the illusion of speed and the depletion of proximity**

Dr. Cecília Silva is Assistant Professor with habilitation at the Faculty of Engineering, University of Porto (FEUP), and senior researcher at CITTA – the Research Centre for Territory, Transports and Environment. She is a Civil Engineer with specialization in Spatial Planning and Urban Mobility. Her main research fields include Accessibility Planning, Sustainable Mobility, Mobility Management, and Planning Support Instruments; research developed in close connection to local planning practice. She is mainly interested in integrated land use and transport policies for human-scale cities. More information about her is at https://www.cienciavitae.pt/portal/en/031F-4F1E-765E

Keynote Talk 3 (16 September 2023,14:30-16:00, Room 1)

Stan Geertman, **Digital Planning: a usability challenge**

Prof. Dr. Stan Geertman is emeritus Professor of Urban and Regional Planning at Utrecht University in the Netherlands. He has published widely in scientific and practice-oriented journals and has published a range of (editorial) books. He is member of the editorial board of several scientific journals (e.g., CEUS). He has been member of a range of international conference organizations (EGIS; JECC; AGILE; DDSS) and was chair of the Board of Directors of CUPUM (Computational Urban Planning and Urban Management) during past 10 years. His research interests include Planning and Decision Support Systems (PSS / DSS), Digital Planning, Sustainable Urbanization, and Planning Theory and its implications for practice.

Keynote Talk 4 (17 September 2023, 09:30-11:00, Room 1)

Clémentine Cottineau, **Modelling urban economic segregation: a theoretical and quantitative quest for causal processes and their interactions across scales**

Dr. Clémentine Cottineau is a quantitative urban geographer, currently Assistant Professor of urban studies at TU-Delft. Her main area of research revolves around modelling the evolution of economic segregation and inequality between and within cities, using systematic literature reviews, longitudinal analysis of empirical microdata and generative agent-based modelling. She holds a PhD in Geography from Université Paris 1 Panthéon-Sorbonne. During previous research positions at UCL's Centre for Advanced Spatial Analysis and CNRS's Centre Maurice Halbwachs between 2014 and 2020, Clémentine has worked on the patterns and regularities of urban scaling laws, shrinking cities and industrial geographies.

Parallel Sessions

Parallel Sessions 1 (15 September 2023, 11:30-13:00)

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- Juste Raimbault, **Multiscalar models for systems of cities**
- Joao Bigotte, Susana Freiria and Antonio Pais Antunes, **Network optimization and morphological and functional polycentrism: an integrated planning approach**
- Denise Pumain, **Theories in geography: unification segmentation and hybridisation**

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- Véronique Lucas-Gabrielli, Catherine Mangeney, Marie Bonal, Laure Com-Ruelle and Fanny Duchaine, **How to improve methods for measuring accessibility to medical specialist care in France? A nationwide approach**
- Marion Le Texier, Adrien Lammoglia, Laurent Chapelon and Adrien Poisson, **Modelling individual explanatory factors of cycle commuting frequency in pre and postCovid 19 Montpellier (France)**
- Aleksey Ogulenko, Itzhak Benenson and Nir Fulman, **Assessing Parking Cruising Time: The Simple and Effective Solution**

Parallel Sessions 2 (15 September 2023, 14:30-16:00)

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- Juste Raimbault, **Validation of geosimulation models: a systematic review**

DATA-DRIVEN APPROACHES FOR UNDERSTANDING LANDSCAPES OF OUR CHANGING PLANET (ROOM 2)

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- Didier Josselin, Matthieu Vignal, Nicolas Viaux, Delphine Blanke and Céline Lacaux, **Infering meteorological information at different scales from several sources of data**
- Marj Tonini, Axelle Bersier, Jingyan Yu and François Bavaud, **An unsupervised learning approach to explore geodemographic clusters in Switzerland**

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- Axel Pécheric, Rémi Lemoy, Marion Le Texier and Sophie De Ruffray, **Built-up area use in European cities in 2020, with urban scaling laws**
- Walid Rabehi, Rémi Lemoy and Marion Le Texier, **Historical trajectory of large French cities over three centuries using radial profiles and scaling laws**
- Anasua Chakraborty, Ahmed Mustafa, Hichem Omrani and Jacques Teller, **A Multivariate Sensitivity approach for urban densification modelling**
- Geoffrey Caruso and Yong Chen, **Leapfrog sprawl across the metropolitan USA over the last 20 years**

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- Ewa Jarecka-Bidzińska, **Towards smart public spaces - interdisciplinary approach: case study**
- Maria Rosaria Stufano Melone and Domenico Camarda, **About non-knowledge in knowledge management for planning: Towards an applied ontological approach**
- Iuria Betco, **The importance of urban environment for sentiment: analysis in Lisbon using social networks**
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Parallel Sessions 3 (15 September 2023, 16:30-18:30)

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- Hendrik Herold, **Deep learning-based mapping of urban heat islands**
- Els Verachtert, Dirk Lauwaet, Tomas Crols, Lien Poelmans, Leo De Nocker, Christel Faes, Karen Van de Vel and Koen Schoeters, **Heat-related mortality in Flanders (Belgium): combining land use and climate modelling with spatial health statistics**
- Jorge Salgado, **Urban systems in the face of climate change**
- Oxana Tchepel, Noela Pina and Daniela Dias, **A GIS-based framework for urban air quality assessment and forecast: Coimbra case study**

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- Cyrille Genre-Grandpierre and Serigne Gueye, **Which (re)location of amenities, which transport speed, for which accessibility for the 15-Minute city?**

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- Francois Bavaud, **A multivariate, weighted index of spatial autocorrelation**
- Romain Loup and François Bavaud, **Analyzing Swiss popular votes: spatial autocorrelation of political patterns**
- Tom Cunningham, Nuno Pinto and Wendy Olsen, **Child labour as a spatial phenomenon: A geographically weighted regression analysis of India**
- Alfonso Annunziata, Francesco Scorza and Beniamino Murgante, **Uncovering Socio-economic Patterns via Principal Component Analysis and Clustering Algorithms: A Case Study of Southern Italy**

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- Jerome Francisco Conceicao, Ana Petrović, Maarten Van Ham and David Manley, **Exploring the Influence of the Contextual Poverty Measurement on the Neighbourhood Effect Estimation**
- Lucas Spierenburg, Sander Van Cranenburgh and Oded Cats, **Temporal evolution of residential segregation patterns between-cities and within-cities: evidence from Dutch municipalities**
- Anna Dmowska and Tomasz Stepinski, **Mapping spatio-racial pattern in the United States at different scales**
- Olena Holubowska and Ate Poorthuis, **Similarity between Residential Areas and Visited Locations: Proportion of Foreign-Born Residents**

Parallel Sessions 4 (16 September 2023, 11:30-13:00)

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- Tomas Crols, Jente Broeckx, Inge Uljee, Shu Yang, Raf Theunissen and Hafeez Rehman, **Urban growth scenarios and urban climate modelling to support heat action measures in Indian cities**
- Itzhak Benenson and Aleksey Ogulenko, **Agent-Based Modeling for Smart Transportation Practice**

- Bas van Bemmel, Bart Rijken and David Evers, **Monitoring land take in the Netherlands: an ex-ante evaluation**

SPATIO-TEMPORAL DATA SCIENCE: HARNESSING BIG DATA AND AI FOR GEOCOMPUTATION (ROOM 2)

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- Bin Zhou, Alexandra Shtein, Ian Hough, David Perlmutter, Itai Kloog and Evyatar Erell, **On the psychrometric constraints in hybrid modelling of temperature and humidity**
- Joan Perez, Guillaume Ladmiral and Giovanni Fusco, **Spatial Dimension of COVID-19. An Exploratory Approach to Investigate Spatiotemporal Profiles of Epidemiological Trajectories in Japan**
- Shiva Rahmani, Rossella Scorzelli, Beniamino Murgante, Antonio D'Angola and Francesco Scorza, **Spatial Analysis for Sustainable Urban Energy Resilience: Identifying Optimal Locations for Green Hydrogen Infrastructure**

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- Mouhamadou Ndim, Juste Raimbault, Bénédicte Bucher, Ana-Maria Raimond and Julien Perret, **A collaborative dashboard to study periurban densification**
- Alicia Blanchi, Giovanni Fusco and Karine Emsellem, **Toponymic representation of spaces within the city through real estate ads**

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- Thibault Lecourt, **Uncovering the land development potential of municipalities in France**
- Wander Demuynck, Ben Derudder and Trui Steen, **A policy tool for simulating municipal mergers**
- Jip Claassens and Eric Koomen, **The future land demand from economic activities**
- Bart Rijken, Jip Claassens and Eric Koomen, **Exploring sustainable urbanization pathways by simulating local density change**

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- Jessica Mottard and Jean-Christophe Loubier, **Crowding effect adjustment applied in population prediction**
- Ate Poorthuis and Qingqing Chen, **The variegated bias of activity spaces derived from mobility data**
- Kofoworola Modupe Osunkoya and Jenni Partanen, **Sensing diversity in Tallinn using mobile phone data**
- Olle Järv, Håvard Wallin Aagesen and Ate Poorthuis, **Understanding functional border regions in Europe through the lens of human mobility: A big data approach**

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- Estelle Mennicken, Geoffrey Caruso and Rémi Lemoy, **Road network distances and detours in European cities: the effect of internal urban structures**
- Chris Brunsdon, **Investigating Geographic Patterns in Covid- 19 Using Bayesian Model Averaging**
- Alessandro Araldi and Giovanni Fusco, **Morphological Regionalisation of French Cities – A methodology for street-based analysis of urban form**

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- Janka Lengyel, Stéphane G. Roux, Stéphane Jaffard, Olivier Bonin and Patrice Abry, **A bivariate multifractal analysis approach to understanding the dynamics of socio-spatial segregation**
- Anabela Ribeiro and Claudia Alcoforado, **Public Transport Supply - A Spatial and Social Equity Analysis in Recife, Brazil**
- Cindy Padilla, Marie Bonal, Guillaume Chevillard and Véronique Lucas, **Scale effects on medical desert classification, France**

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- Micael da Silva Sousa, António Pais Antunes and Nuno Pinto**, Comparing serious games and optimization modelling to support decision making: Planning the elementary school network of Marinha Grande**

- Gaëtan Laziou and Rémi Lemoy**, Where do people live in urban areas? A radial and scaling analysis of population density over European cities**
- Cyrille Genre-Grandpierre, Felipe Albuquerque and Rosa Figueiredo, **Combining equity and efficiency: the pmedian problem with coverage constraint. An application to public service design**

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- Céline Van Migerode, Ate Poorthuis and Ben Derudder**, Quantifying ambiguity in urban definitions: a spatially-explicit sensitivity analysis of the "Degree of Urbanisation"**
- Lucas Magalhães and Geoffrey Caruso**, Digital or local? Impacts of online shopping and teleworking on urban expansion: a theoretical spatial simulation**
- Melon Matcheke, Izelque Botha, Marubini Ramudzuli and Nerhene Davis, **Livelihood Dynamics in South African Periurban Areas: The Plight of Women in GaMothapo, Limpopo Province**
- Jaana Vanhatalo and Jenni Partanen, **Dynamic reading and delineation of urban areas – Applying cellular phone data in the case of Tallinn, Estonia**

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- Susana Freiria, Nuno Sousa and Francisco Calvo, **Transport accessibility and regional performance: a spatial analysis for Europe**
- Mikhail Topnikov and Daria Elmanova, **Commuting Patterns in the Netherlands: a Display of Polycentric Structures in Complex Networks**
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- Louisette Garcin, Didier Josselin, Fabien Palate and Jean-Baptiste Chesneau, **Simulation of home spatial distributions based on workplace**
- Xavier Lehmann, Walid Al-Shaar and Olivier Bonin, **Evaluating the accessibility of territories, a multi-scale fractal approach to proximity**
- Chiara Garau, Giulia Desogus, Tanja Congiu and Alessandro Plaisant. **Exploring the Proximity Concept for Enhancing Regional Connection. The Case Study of the Sardinia Island (Italy)**
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- Julie Gravier, **Time budgets and forms of preindustrial cities: time for empirical studies**
- Petrus J. Gerrits, Ana Basiri and M. Erdem Kabadayi, **Mapping Demographic Change: Historical Population Grids for Bulgaria and Turkey Using Geocoded 20th Century Census Records**
- Clement Prouin, Giovanni Fusco, Matteo Caglioni and Denis Overal, **Supervised classification of the French Riviera morphogenesis using a machine learning approach**
- Kerry Schiel, Geoffrey Caruso and Mirjam Schindler, **40 years of Sprawl in the USA: Scale and Geographic Effects**
- Anabela Ribeiro and Pelágio Maxlhaieie, **Sustainability Indicators for Tourism Applied to Urban Context in Mozambican Cities**

MOBILITY/ACCESSIBILITY STUDIES 3 (ROOM 3)

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- Anne S. Patricio, Gonçalo Santos and António Pais Antunes, **Exploring driverless demand-responsive transit regional systems: a comparative study of point-to-point and hub-and-spoke designs**
- Mahdi Rasoulinezhad and Jenni Partanen, **Studying city-wide speed limits for balancing pedestrian safety and travel times: the case of Tallinn**
- Alexandra Rodrigues, Hugo Silva, Fernando Fonseca, Carlos Palha and Rui Ramos, **The effect of sidewalk paving materials in the comfort and safety of walking: a case study in Braga, Portugal**
- João Lopes, Gabriel Valença, Goncalo Santos, Ana Morais de Sá, Filipe Moura and António Pais Antunes, **Spatial assessment to identify candidate areas for dynamic street space allocation solutions in the city of Coimbra**

Abstracts of Parallel Sessions 1

Long-range correlations in city systems in European countries

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Keywords: cities, network, long-range correlation

City systems are characterized by the functional organization of cities on a regional or country scale. While there is a relatively good empirical and theoretical understanding of city size distributions, insights about their spatial organization remain on a conceptual level. Here we empirically analyze the correlations between the sizes of cities (in terms of area) across long distances. Therefore, we (i) define city clusters, (ii) obtain the neighbourhood network from Voronoi cells, and (iii) apply a fluctuation analysis[1] along all shortest paths. We find that most European countries exhibit long-range correlations but, in several cases, these are anti-correlations. In an analogous way we study a model inspired by Central Places Theory and find that depending on the level of disorder, both positive and negative long-range correlations can be simulated. We conclude that the interactions between cities of different sizes extend over distances reaching the country scale.

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Multiscalar models for systems of cities

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Keywords: Systems of cities, Simulation models, Multiscalar models

Simulation models for the dynamics of systems of cities have been developed to capture salient stylised facts of such systems and understand underlying processes (Pumain & Reuillon, 2017). These agent-based models simulate the interactions between cities at the macroscopic scale, focusing on different dimensions such as innovation or economic exchanges. They correspond to the highest level of the multiscalar ontology described by Pumain (2011) for urban systems. In order to address open issues related to multi-level governance of territorial sustainable transitions, models simulating simultaneously multiple scales are however needed (Rozenblat & Pumain, 2018).

This contribution synthesises recent lessons learnt from the construction and exploration of such strongly coupled multi-scalar models. The first model couples a macroscopic population dynamics model with local urban morphogenesis models within each city (Raimbault, 2021), while the second one simulates the diffusion of innovation between urban areas and its impact on urban growth at the macroscopic scale, and innovation cluster dynamics within each area (Raimbault & Pumain, 2023).

A few pitfalls have been identified while theoretically constructing the models and empirically exploring their parameter space using advanced model validation techniques with the OpenMOLE software (Reuillon et al., 2013): (i) to obtain a strong coupling between scales, and thus effective multiscalar dynamics rather than fixed effects at the meso scale only for example, both top-down and bottom-up feedbacks have to be included explicitly, and corresponding ontologies and processes must be identified; (ii) the parametrisation or calibration with empirical data is significantly more cumbersome than with single level models, and synthetic systems are a first alternative to explore model behaviour; (iii) the convergence of model indicators regarding stochasticity seems more difficult to obtain, possibly due to non-linear noise propagation between scales; (iv) a crucial aspect remains to quantify the strength of emergence, such that these approaches are not a superfluous complication of simpler dynamics at a single scale – the indicators introduced by (Rosas et al., 2020) are good candidates for such measures but remain to be tested systematically on geosimulation models.

First simulation results show that strong emergence appears in a significant number of regimes for the innovation model, and that contradictory objectives across scales can be simultaneously

optimised using multi-objective genetic algorithms for both models. The above issues provide open research directions to develop this approach of coupling simulation models between the meso and macro scales of urban systems. Other directions to build multi-scalar models, such as heterogeneous agents at multiple scales in a single agent-based model, remain also to be explored.

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Network optimization and morphological and functional polycentrism: an integrated planning approach

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Keywords: Regional planning, Accessibility planning, Optimization model, Facility location, Network design

The European Commission has been calling for and supporting the development of "polycentric urban regions" (European Commission, 1999; 2020). Opposite to a monocentric logic (in which there is one large, dominant urban centre that polarizes a range of smaller centres with low critical mass), a polycentric structure of urban systems (that corresponds to a balanced network of regional centres and sub-centres) is seen as a way to optimize public investments, improve overall accessibility, and promote territorial cohesion and sustainable development (Marques et al., 2020; Medeiros and Rauhut, 2020;). Despite the institutional efforts and the scientific works from diverse fields of research, the operationalization of the polycentrism concept remains a goal to be achieved.

Spatial planners have addressed this issue from a socio-economic perspective with descriptive analyses based on clustering and rank-size approaches. Typically, these approaches concern the spatial distribution of population and employment (morphological polycentrism) and/or the assessment of the connectivity between urban centres considering the existing transport network (functional polycentrism) (Zhong et al., 2014; Taubenböck et al., 2017).

On the other hand, the transportation community has focused mainly on (re-)designing the transport network (i.e., the links) with a given structure of urban centres (i.e., the nodes) so as to improve accessibility, robustness, and/or environmental sustainability among other concerns (Santos et al., 2008; Monzón et al., 2019). Transport network design addresses decisions regarding the construction of new links and/or the upgrade of existing links to improve accessibility between the nodes.

Typically, these two topics – structure of urban centres and transport network design – have been addressed separately. While planners have focused on analysing the urban structure taking into consideration a given transport network, transport researchers have been concerned with improving the transport network for a given urban structure. A few exceptions include Lowry and Balling (2009) and Bigotte et al. (2010). There is, therefore, a lack of integrated approaches as well as adequate quantitative tools for planning purposes.

This work presents an optimization model for integrated planning of urban structure and transport network. The objective of the model is to optimize the aggregate accessibility in an urban system across multiple periods. The model determines: i) the nodes that should be reinforced, via public

investments on new public facilities and social infrastructure, ii) the transport links that should be upgraded, with a higher link level associated with a faster connection, and iii) when these decisions should take place. The main output consists of a multi-period optimal spatial structure of urban centres and transport links. Therefore, this novel model contributes to both the field of accessibility planning and to the operationalization of strategic planning of polycentric regions.

The model is intended as a decision-aid tool and is currently being used in studies supporting the physical planning of the Centro Region, in Portugal. The Centro Region (NUTS2) is seen as a polycentric region since it does not contain any large metropolitan area and is somewhat organized around medium-sized regional centres (NUTS3 level). The key issue is how to develop a network of sub-regional centres and improve the transport network so as to promote the territorial cohesion and increase the accessibility to services of general interest. The model allows to address this planning challenge in an integrated way, including matters of morphological and functional polycentrism as well as network design.

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Theories in geography: unification, segmentation and hybridisation

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Keywords: geographical theory, epistemology, social sciences, history of geography

Constructing theories and disseminating them is an important part of the identity and reputation of academic disciplines. Although ECTQG members are strongly committed at keeping the adjective "theoretical" in first position within the name of their colloquia, one may wonder why rather few contributions dare to exhibit an explicit theoretical concern in the titles of presentations (Cuyala 2014). In her plea for "theory, theory, theory", Rachel Franklin (2021) reminds us that "integration of theory and models represents a gold standard for research, but also because the process of conceptualization/theorization, accompanied by method development and data assimilation and wrangling, uncovers the gaps in our knowledge and the weaknesses in our assumptions that push us towards ever better understanding of the world". In other words, theory can hardly be disantangled from and is permanently supported by empirical investigation, modelling attempts and technological advances, as much as by conceptual reflexion and intellectual interaction with academics and society. The aim of my presentation is to test this idea, while briefly reviewing the history of the construction and presentation of geographical theories over the last fifty years, since the creation of our colloquia. It seems that early attempts at providing very abstract theories seemed almost abandoned for a while, but new impulses recently emerged from disciplines outside geography (Krugman 1997; Reggiani et al 2021; Schläpfer et al 2021); a series of "wars" opposing theories constructed on different disciplinary or ideological bases have been of variable intensity according to national geographical cultures (Smith 1992); this increasing segmentation partly evolves now toward hybridisation (Soja, 1989; Ginsburger 2011; Ferretti, 2020); a recent trend sustained by novel validation techniques (i.e. genetic algorithms and intense computing) would help acknowledging a plurality of theories (Pumain and Raimbault, 2020). I will try to characterise the theoretical proposals in terms of their ambition, their major source of inspiration, their practical proposal regarding models and methods and their apparent resilience until today. The investigation is about the scope of what the theories claim to explain, the broader paradigms on which they are based and the methodological tools that they propose.

A tentative tree of paths of the theoretical developments in geography will be stressed. The frequency and duration of references made to these theories or to their specific models will be very roughly quantified through a call of related keywords in four languages on a usual search engine. This method has obvious limits and provides only a preliminary approach to the question. One possible (wishful?) conclusion is that the theories that have the best chance of enduring and imposing their presence on the scientific landscape are those that choose a fairly general question of medium

importance, that are transferable to other disciplines, while having produced testable and reproducible models.

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Exploring the Distance-decay Effect in Commuting Behaviour at the Local-level with a Localised Spatial Interaction Model

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Keywords: human mobility pattern, spatial interaction model, commuting behaviour, local modelling

Background

Spatial interaction models, one of the most powerful techniques for modelling and predicting interaction flows, forecasting the strength of spatial interaction based on the influence of distance decay. The majority of existing spatial interaction models assume that the interior space of the modelling region is spatially isogenous, meaning that the distribution of trips only obeys a general distance-decay law associated with $f(dij)$. However, previous research verified that spatial heterogeneity widely exists in the spatial interaction model and may reflect the border effect of trip distribution within urban space (Zhang et al., 2022). In light of this background, "think locally" is a crucial trend in recent decades because researchers found that a global approach to spatial analysis may not be suitable for the local area within the sub-case study area due to spatial heterogeneity for the spatial interaction model (Fotheringham and Sachdeva, 2022). Previous researchers attempted different methods to highlight the local characters in spatial interaction models such as geographically weighted regression (Nakaya, 2001) Another promising study applied deep learning technics to predict flows by adding local geographical information like point of interests (POIs) (Simini et al., 2021). However, there is a lack of research to explain why variations exist in local travel behaviour within cities and the potential relationship with local residents' social-economic characteristics. By applying a localised spatial interaction model, this research proposes a novel approach to quantitatively representing the variation of distance-decay effect in commuting travel behaviour at the local level. Furthermore, this research explores the linkage between those variations and local residents' social-economic characteristics to understand the nature of human travel behaviour better.

Methodology

This research proposed a localised spatial interaction model to observe the variant of distance decay for commuting by different origins and destinations in London. This study adopted a disaggregated spatial interaction model, which divides the flows by origins then fits the flows with separate models in the formatting of the classic unconstrained gravity model. For giving specific origin, the Oi is part of the constant. Each sub-gravity model has its own distance-decay parameters and other indicators

of travel behaviour, such as average travel distance. The complexity of this model is comparable with the origin-constrained gravity model since they have a similar amount of parameters. This novel spatial interaction model has a better prediction ability by aggregating the predicted flows as one predicting O-D matrix. It performs better in statistical measurements (e.g., R-square and Root Mean Squared Error) compared with a classic constrain gravity model fitted by general linear regression models, proving the reasonability for the local distance-decay parameters.

Findings of the research

The analysis results indicate that in central London areas, the distance-decay effects for these areas are smoother. In contrast, the border area shows sharper distance-decay effects within these zones. Typically, the shaper distance-decay effect means the commuters living in these areas are more sensitive about travel distance and vice versa. Therefore, those people who are more sensitive to travel distances should live in the central areas. However, our results denied that statement. A possible explanation is most people are commuting from their residence towards city centres, but not in the opposite direction. Still, most commuters would not go beyond the central area to another side of the city. That is why the distance-decay effect of their travel behaviour looks sharp. In contrast, commuters living in the central areas would freely choose their workplace without significant limitations of specific directions or areas. Thus, the distance-decay effect for those people shows smooth trends. Based on this explanation, the affordability of housing prices would significantly affect the distance decay in their commuting behaviour, which means that socialeconomic characteristics may have a potential relationship with this phenomenon.

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How to improve methods for measuring accessibility to medical specialist care in France? A nationwide approach

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Keywords: healthcare accessibility, outpatient care, specialist, France

Background

Accessibility to medical care is a major issue for health policies, due to the increase in territorial inequalities. To achieve the best health outcomes for the population, one of the main healthcare policies consist of guaranteeing that the population has equal access to healthcare services. But all countries face with shortages of human resources in the healthcare sector for primary and/or specialized health care.

In France, these trends are threatening to increase spatial inequalities in the provision of and access to medical care, specifically for outpatient care (Anguis *et al.*, 2021). In this context, measuring levels of spatial accessibility to medical care is an issue for qualifying the situation of areas. To measure it, the « floating catchment area » (FCA) method, derived from gravity models, has found broad consensus in the international geographical literature (Neutens, 2015). It was used in the French institutional landscape from the end of the 2010s to define shortage areas for some primary care professionals.

Since then, improvements of such measures have been made focusing on one region, Ile de France (Paris region), to question the geographical grid considered (meshes versus muncipality), the mode of transport used, the effects of competition or even the consideration of the social dimension of care needs (Lucas-Gabrielli and Mangeney, 2019).

Aim

Taking advantage of these recent developments, this contribution provides a critical approach of FCA method, dimensions and parameters to be taken into account in order to measure the levels of accessibility for a selection of medical specialties in the field of ambulatory care. The aim is to outline a generic methodology that could be reproduced, or at least adapted, to other medical specialties in order to implement a decision-making tool for public authorities. The main issues

concerns definition of demand and supply and their interaction based on available data for the definition of a nationwide indicator.

Methodology

This work focuses on ophthalmologists, cardiologists and dermatologists, specialists for whom the issues of territorial distribution and demographic dynamics are particularly important in the field of "outpatient" specialized medicine. 2SFCA and 3SFCA method were performed using databases of National Health Insurance Fund, census data and accessibility matrix to define indicators at the most relevant geographical level.

Findings

Beyond the observation with an aggregate indicator, the measure of accessibility according to different scenarios (measuring the need for care in the presence of both induced demand and non-use of care, adjustment of the decay function, accessibility to health care supply without extra fees for the most deprived...) will make it to use such indicators as public policy instrument raising the question of the relevance of each hypothesis included.

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Modelling individual explanatory factors of cycle commuting frequency in pre and post-Covid 19 Montpellier (France)

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Keywords: Cycle commuting, Teleworking, COVID-19, Survey, Evolutions

The Covid crisis and the lockdowns that have been put in place to remedy it in many countries have led to changes in mobility behaviours, in particular due to the increase in teleworking in certain professions (eg. Olde Kalter et al., 2021) and a broader propensity for online activities rather than physical ones (eg. Mouratadis and Papagiannakis, 2021). One of the major risks spotted in the literature has been the more regular use of private transport, despite a general drop in the demand for travel, and in particular in the flows between home and work places (López Soler et al., 2023). As cycling is "a low-cost, low-polluting and health-improving way to travel" (Handy et al., 2014), understanding and documenting the differentials in cycle commuting frequencies that the Covid crisis and the differentiated use of telework may have led to is a major social, environmental and policy issue.

In this work, we examine the changes in cycling habits that have occurred following the pandemic using a large scale questionnaire survey conducted in Montpellier Méditerranée Métropole (south of France) in spring 2021 as part of the project ANR Velotactique led by Nathalie Ortar and Patrick Rérat. A total of 869 people aged from 15 to 90 years responded to the survey. 35% of them declared that their frequency of bicycle use in the context of home-work or home-study trips had increased following Covid-19 while 15% declared that it had decreased.

We study the declared evolution of cycle commuting frequency, and analyze how it is affected by the distance separating the home location from the workplace, the size of the municipalities of residence and employment, the frequency of teleworking, as well as the socioeconomic and demographic characteristics of the respondents. We apply an ordinal logistic regression model and analyse the individual effects of explanatory factors all other things being equal.

We notably find that an increase in the frequency of recourse to teleworking is an important factor of cycle commuting frequency changes, in one direction or another, whereas the fact of working parttime does not influence these propensities. Those declaring that they use their bikes the least frequently for their home-work commutes are also those with the most stable frequencies of use (for eg people under-19s and over-75s, driving license owners) with the clear exception of women, for whom the probability of increasing this frequency of use is higher than for men (yet more numerous to declare having recourse to it daily or every other day). Overall our findings provide new evidences

that support the role of Covid-19 as a "catalyst for transition" (Macharis et al., 2021) towards sustainable mobilities in urban areas.

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Assessing Parking Cruising Time: The Simple and Effective Solution

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Keywords: Car Parking, Queueing Theory, Transportation Modelling, Simulation, System Analysis

On-street parking dynamics are defined by three major parameters – (1) the rate of car arrivals, (2) the dwell time of already parked cars, and (3) the willingness of drivers to continue their search for a vacant parking spot if they have failed until now. An indicator of the balance between these three basic parameters of the parking search is the cruising time which becomes essentially non-zero when parking occupancy exceeds 85% (Shoup, 2011). Cruising for parking comprises a significant share of traffic on congested streets with an average of 34% (Hampshire et al, 2016), and is a key to understanding drivers' reactions to urban parking policy and pricing. We investigate a series of models, both deterministic and stochastic, that describe parking dynamics in an area as dependent on three aforementioned parameters, over the entire spectrum of the demand-to-supply ratio, focusing on the case when the demand is close to or above the supply. Different from several previous studies we reveal the analytical form of the cruising time distribution that is surprisingly simple and robust.

We start with a model of parking search within a bounded neighborhood A with c parking spots, small enough to guarantee that drivers with the destination in A may cover all of it when searching for parking. The number of parked cars $P(t)$ in A is defined by the rate λ of cars' arrivals to A per time step, the departure rate μ, per time step, of departing cars that were previously parked in A, and the renege rate α, per time step, representing the probability of drivers giving up during an unsuccessful parking search.

The state of parking in A at t can be described by the number of occupied spots $P(t)$, and the number of cruising cars $Q(t)$:

$$if\ \ \lambda/\mu \leq\ c, P(t+1) =\ (1-\mu)P(t) +\ \lambda,\quad Q(t+1) = 0, \qquad (1)$$

$$if\ \ \lambda/\mu >\ c, P(t+1) =\ c, \qquad Q(t+1) = (1-\alpha)Q(t) + \lambda - c\mu.$$

Introducing the dimensionless "Arrivals-to-Departures" ratio $\rho = \lambda/(c\mu)$, the globally stable equilibrium solution (P^*, Q^*) of (1) in the case of $\rho < 1$ is given by: $P^* = \rho c$, $Q^* = 0$. For $\rho > 1$, the globally stable equilibrium solution is $P^* = c$ and $Q^* = \frac{\lambda - c\mu}{\alpha}$.

Importantly, the deterministic analysis makes it possible to estimate the average cruising time w_κ and the equilibrium number of cruising cars Q^*:

$$Q^* = c(\rho - 1)\frac{w_\alpha}{w_\mu} \quad \text{and} \quad w_\kappa = (w_\alpha - 1)\frac{\rho - 1}{\rho}, \quad (2)$$

where $w_\mu = 1/\mu$ denotes the average dwell time, and w_α the average time that the driver is ready to spend searching, both in minutes. That is, with the growth of ρ, the number of cruising cars grows *linearly*, while the average cruising time increases *hyperbolically* to its maximal value of w_α - 1

The real parking processes are inherently more complex, stochastic, and time-dependent. However, their inherent property must reflect the fact that the chance to park on-street for a car that just arrived is the same as that for a car that was cruising for a long time. This property is reflected by the nonstandard queueing model that follows the *Service In Random Order* (SIRO) queue discipline.

We investigate a series of deterministic models and their generalizations to the stochastic SIRO queuing models, as well as simulation models of parking search. We demonstrate that the parameter estimates of the parking system, including the distribution of cruising time, remain consistent across this broad spectrum of models.

Our analysis reveals several basic and universal facts: The state of the parking system is defined by the arrivals-to-departures ratio $\rho = \lambda/(c\mu)$ which represents the "demand-to-supply" ratio for the case of the parking search. With an increase of ρ, the state of parking in A evolves from "immediate parking" to "cruising for parking," and there is no crisp boundary between these states. Blocking probability - the probability to be fully occupied - depends on the parking area size. For a small area, it becomes non-zero starting from $\rho \approx 0.7$, while in the case of a large area, this happens when ρ exceeds 0.9. Shoup's 85% threshold (Shoup, 2011) is, thus, an excellent compromise.

Based on the revealed properties of the parking process, we investigate the dynamics of the on-street parking search for many drivers whose destinations are distributed across a large parking area and present an analytical estimate of the cruising time as dependent on the driver's destination. We also extend the model to estimate the long-term effects of long cruising time on the driver's decision to arrive at the area with a car.

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Abstracts of Parallel Sessions 2

Investigating the place of theoretical geography in British SDS (spatial data science) research institutions: some draft typologies

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Keywords: theoretical geography, social history of geography, spatial data science, science-industry nexus

The availability of new techniques and datasets for the analysis of geographical information needs to be taken into account if we want to describe and explain the restructuration of geography as an academic field in the UK since the 1960s – as well as its links with related scientific and professional fields over that period of time (see Openshaw, 1991; Barnes, 2013). The rise and fall of FORTRAN in British geography departments (Unwin, 1978), the massive emergence of GIS as a 'research pipeline' in the 1990s (Johnston, 2006), the programming languages and packages mobilized today (Arribas-Bel and Reades, 2018), but also the mobilized data sources in connection with the ways of thinking eventual purposes of geographic modelling are all part of that story.

It is a story that requires us to investigate the theoretical and methodological references on which GIScientists and spatial analysts rely, but also their past and present working conditions in a particular context: neoliberalising United Kingdom and its teaching and research systems (Shattock and Horvath, 2019). My work stems from a set of traditions in science studies that attempt to move away from internalist perspectives on the production and circulation of geographic information by adopting a commodity-based perspective on these elements, which can be achieved by asking the following: which funding? which instruments? what institutional support? (Keim *et al,* 2016; Armatte and Dahan Dalmedico, 2004, within the history of models and modelisation).

In accordance with the research protocol I developed, my doctoral research revolves around the subuniversity scale (which, in plain language, amounts to departments, research centres and laboratories within larger research institutions). Since my work focuses on the United Kingdom, I decided to carry out extensive fieldwork in research centres whose scientific activity centres on the massive processing of geographical information.

The three months I have had the privilege to spend at the Centre for Advanced Spatial Analysis, London, over Spring 2023, were very much central to scientific aims of my doctoral thesis. The Bartlett Centre for Advanced Spatial Analysis (CASA), University College London, was founded in 1995, with the arrival of Prof. Michael Batty as Chair of Planning and Spatial Analysis in UCL. One of the first British research centres dedicated to Geographic Information Science, it since

then has become an international hub in the production and diffusion of knowledge about spatial data, models, simulations and prospective. In its 30-year history, it has created three different masters' degrees which today welcome more than 125 students per year, has grown to around 50 staff, research and PhD members, have collaborated with local government and urban industries (engineering, architecture, urban planning offices).

Over this period of time, I conducted semi-structured interviews (n=34) with current and former members of CASA as well as senior researchers that have witnessed in a significant way the evolution of the Centre since 1995. I also had the opportunity to attend a various panel of lectures and seminars taught in CASA, as well as a variety of internal research and administrative activities (PhD public upgrades, research seminars, a staff-only research awayday, careers events...). This interview-based and observational work was complemented by archival work conducted at the UCL Special Collections (University records) and the Royal Geographical Society - the goal of the latter being to seize in a more thorough way the theoretical and methodological reconfiguration of geography, when affected by the massive diffusion of novel quantitative methods.

During this fieldwork segment, several hypotheses about the reception and the diffusion of spatial data science in the United Kingdom were developed:

- Firstly, that the rhythm and the places of diffusion of these sets of methods was dependent on infrastructural, political and economic factors in the academic field - which would explain the centralities and peripheries of knowledge production in the field of spatial analysis and spatial data science in the UK. Discoveries about the financial state of UCL, conflictual power relations between close departments, and investments in processing units partly supports this hypothesis.

- Secondly, that the organisational structure of research centres and labs is part of the reason why spatial analysis became more central in these rather than in 'classic' research departments. Findings about epistemic values, exchanges with the industry, and the effect of 'hype cycles' on the epistemic structure of CASA also supports this hypothesis, which nevertheless needs to be tested in other environments.

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A Review of the Design and Insights of Agent-based Model Frameworks on Urban Economic Segregation

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Keywords: agent-based models, urban economic segregation, spatial dynamics, framework analysis, ODD+P

Urban economic segregation represents a complex phenomenon arising from a variety of interplayed socioeconomic processes, which could engender a series of subsequent adverse outcomes, such as crime, poverty, constrained opportunities, health disparities, and social isolation. To better understand the spatial dynamics behind it including the formation, evolution, and waning of such social phenomena, models and simulations are widely applied in computational social science. Agent-based modelling (ABM) has become one of the essential tools for its superiority in individual actions and interactions modelling, allowing the creation of a virtual environment to assess and anticipate the efficacy of policy. However, the results produced by agent-based models (ABMs) exhibit sensitivity to the selection of socioeconomic processes included, and even minor variations within the model architecture can lead to disparate outcomes, triggering cascading effects (Couclelis, 2000). Therefore, the outcomes of simulations always take the validity of design choices and presumptions for granted in the first place. The lack of comparability of the model frameworks impedes accurate assessments of outcomes and insights. In addition, the models specifically addressing urban economic segregation are still in scarcity, where the cause of it is still not well explained. The lack of causality explanations for urban economic segregation limits the ability to draw meaningful conclusions or policy inferences.

Given the increasing resources and attention devoted to developing a more realistic simulation model, it is crucial to evaluate the design, outcomes, and overall value of existing agent-based models (ABMs) from a more holistic perspective. The study aims to gain knowledge of areas for improvement in complex socioeconomic models and advance understanding of the spatial dynamics of urban economic segregation. Our goal is to provide suggestions on variable selection, architecture design, and the causal pathways leading to simulated results, particularly concerning urban economic segregation.

The early model of segregation, the Schelling segregation model developed by Schelling (1969), indicated the capability of agent-based models in explaining segregation. The later threshold model incorporates more heterogeneity of preference and interdependence of decisions in agents' behaviour (Granovetter, 1978). However, the selection of constraints, fixed assumptions, and limited practices prevent them from fully capturing the complexity of real-world situations. The drastic simplification of the realistic decision-making system strips away most of the structure of a real mobility choice (Farmer and Foley, 2009). Economic segregation is a complex pattern, and with advances in

computing, more comprehensive models with additional variables, agents, and complicated rules are emerging. For example, Kulp et al. (2023) built a large model with 100,000 agents incorporating sociodemographic heterogeneity, life cycle, and circulation of wealth across generations to address the role of taxation in wealth inequality. Perez et al. (2019) simulated the change of spatial segregation when new immigrants migrated into the system, assigning the agents' attributes based on census data with attached spatial information. Whether the early simple models or the recent complex models, they all share a similar logic in mechanism selection and framework building, allowing for comparison and induction. These recent promising efforts in building a more reliable and predictable model framework, along with the classical segregation models, will be included in the further analysis, totalling around 10 models.

In this paper, we will analyse and compare different agent-based models of urban economic segregation and similar domains based on an extended ODD protocol, ODD+P (Overview, Design Concepts, Details, and Provenance, Reinhardt et al., 2018). This approach allows us to stress both "how the result is being generated" and "what has been generated" in a structured way. Although different purposes posed in these studies will impact the inclusion and exclusion criteria of mechanisms, overall, the behaviours in these models serve the same aim: capturing the complexity of real-world decisions regarding economic segregation. Specifically, we will analyse the variables, architecture, and results. By constructing a directed graph from framework design to the results, we also aim to understand how the outcome was generated in previous research. Additionally, we will investigate limitations throughout the analysis in terms of flexibility, scalability, and interpretability. The standardized structure of evaluating models will help improve the reproducibility and extendibility of existing models. Among these model frameworks, we aim to identify a common and valid perspective for building agent-based segregation models and identify key gaps and technical challenges for future research.

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Validation of geosimulation models: a systematic review

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Keywords: Geosimulation models, Validation, Systematic review

Geosimulation models are a widely used tool in theoretical and quantitative geography, and deemed powerful for various reasons including their ability to capture spatial complexity, a heterogeneity of agent and processes, or multiple scales. One downside of their subsequent high parameter space or strong stochasticity, of the need to explicitly simulate them to understand their behaviour, and of their flexibility, is that their validation is less systematic than for their statistical, machine learning or analytical counterparts, for which robust criteria are available. Furthermore, the concept of model validation or evaluation seems to be contextual to the disciplinary environment in which the model is developed and used.

This contribution proposes a systematic review of how the concept of validation is defined and used for geosimulation models. Using the data collection tools provided by Raimbault (2019), we construct a corpus by querying google scholar. We follow the PRISMA guidelines for systematic reviews, and screen titles of a first corpus of around 1000 papers, and then abstracts, to obtain an exploitable corpus of around 200 papers with an explicit reference to validation methods for a geosimulation model. We extract from these papers characteristics including the method used, the type of model, and the discipline. We finally obtain a typology of validation methods in a broad sense, ranging from sensitivity analysis to uncertainty quantification or qualitative behavior regarding stylised facts. Methods used are correlated to the discipline and the type of model.

We then reconstruct the backward citation network from our initial corpus at depth two using the same data collection tool, to provide a more general literature mapping and an overview the diversity of disciplines using spatial simulation models, which include for example ecology, social and urban simulation or geosciences. The plurality of approaches confirms the need for a flexible concept of validation and the diversity of associated methods.

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A spatio-temporal characterisation of the development of urban settlements across the globe (1975-2014) - using a high-resolution dynamic model of urban expansion

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Keywords: global urban settlements, spatial structure and dynamics characterization, urban growth mode, clustering, urban modelling and simulation

Global urban settlements have been expanding at an unprecedented rate, converting more land to urban compared to the entire human history combined in the last four decades (European Commission. Joint Research Centre., 2016). There are significant global and regional trends, due to uneven population growth and physical urban expansion, which result in heterogeneous urban spatial structures (Chakraborty et al., 2022; Liu et al., 2020; Schiavina et al., 2022). Characterising global differences of the settlement spatial structure is a long-standing challenge due to the multidimensional nature of urbanisation. Especially, measures of the dynamic spatial structure are affected by initial patterns, rate of changes, size of settlements, and etc., making it difficult to infer about the processes underlying patterns (Behnisch et al., 2022; Chakraborty et al., 2022; Mahtta et al., 2019).

This study applies a novel data-driven and modelling-based characterization to global urban settlements, at the scale of functional urban areas (FUAs) (CEU. JRC., 2019), during three consecutive periods between 1975-2014. The methodology first extrapolates urban expansion parameters from real world settlement developments by calibrating a cellular automata model with a Bayesian estimation method (Yu et al., 2021). Then urban growth modes are identified with hierarchical clustering of expansion patterns of the parameters (Yu et al., 2022). The urban growth modes are finally used to characterize the spatial development of global urban settlements, by comparing which growth mode best describes the historic developments.

The classification method is applied to 8802 functional urban areas across six global geographical regions (Africa 1703, Asia 4928, Europe 910, Latin America and the Caribbean 928, North America 295, Oceania 38). For each period (1975-1990, 1990-2000, 2000-2014), the model is applied for each FUA for 240 times, which includes 60 realisations under each of the four urban growth modes. The classification is decided based on the 60 best fitting realisations according to their similarity to the historic development of the FUA in each time period.

The spatio-temporal characterisation yields the following findings: globally, urban settlements have been developing in an increasingly dispersed manner, as the dominant spatial development mode

switched from the medium compact mode in the first two periods 1975-1990, 1990-2000, to the dispersed in the third period (2000-2014).

- Regions show a higher mix of development patterns in earlier periods, ranging from compact to dispersed. The dispersed development is more prominent in the developed regions while the medium compact development is more prominent in the developing regions. - Over time, there is a global trend towards more dispersed development, which can be seen as two effects:

    o As FUAs grow larger (in terms of area of urban land), they tend to develop in an increasingly dispersed manner, hence larger FUAs can be expected to be more dispersed.

    o Over time, FUAs across different sizes (large, medium, small) have all been developing in an increasingly dispersed manner, hence the global trend towards more dispersed urban expansion.

- A positive correlation is found between the national income level and the national spatial dispersion level, with high-income countries having more dispersed developments than the low-income country.

In conclusion, this study characterises the spatial development of global urban settlements with quantitative measurements and spatially explicitly regional profiling. The findings offer a starting point for the further discussions:

- The identified global urban settlement dispersion is in line with earlier findings (Strano et al., 2021; van Vliet et al., 2019), which causes the concern of fragmenting landscapes and undesirable sustainability impacts. This study is the first to couple the phenomenon with a dynamic urban expansion model, enabling exploration of future development by extrapolating current trends.

- The relation between spatial development and settlement sizes suggests a connection between spatial dispersion and the urbanization process. Earlier research understand urban expansion as a diffusion-coalesence process (Dietzel et al., 2005; He et al., 2017). This global analysis shows little evidence of this process. Instead, urban expansion seems as a nucleationdispersion: an FUA develops first a compact core, then away from the compact core, without a return to compact growth.

- The relation between the national income level and spatial development suggests a link of the global dispersion to economic development, where more prosperous countries witness more dispersed development. This may further indicate different spatial development regimes: the widely accepted driver of urban expansion - population growth, may not predict well in the regions where income level and lifestyle preferences may be more important. Especially for Europe, which witnesses population stagnation and is found to be the most dispersed and dispersing region, spatial development processes imply a more than proportional effect on the landscape.

- Finally, the results indicate an ineffectiveness of spatial planning and regulation in the past decades to constrain urban sprawl.

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The Urban Carbon Budget (UCB) Model: a high resolution spatio-temporal model of CO2 emissions and sequestration in European cities

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Keywords: arbon balance, anthropogenic emissions, modelling, urban areas

1. Background

The ongoing climate change is a global phenomenon induced by human activities (IPCC, 2021). It results from the accumulation of greenhouse gases (GHG) in the atmosphere, mainly since the industrial revolution (IPCC, 2014, 2019, 2021). Carbon dioxide (CO2) is one of the major GHG, as highlighted by the Kyoto Protocol (United Nations, 1998). It is also the most important GHG in the atmosphere in terms of proportion (IPCC, 2014). Before the pre-industrial era, the global average concentration of CO2 was about 280 ppm (Lindsay, 2020). The concentration has increased by 51% since 1750 and April 2023 to reach 423.28 ppm in April 2023 (NOAA, 2023). Anthropogenic CO2 emissions are mainly released into the atmosphere through the combustion of fossil fuels to produce energy (IPCC, 2014). Since the 1990s, the global demand for energy and energyrelated CO2 emissions have increased steadily (IEA, 2021).With the process of urbanisation, human settlements are agglomerating but still represent a tiny proportion of the emerged land (Liu *et al.*, 2014). Yet the IEA, (2008) projects that cities will be responsible for about three quarters of global CO2 emissions by 2030. It has therefore become clear that cities must drastically reduce their emissions. More and more cities and metropolitan areas are now taking action around the world (see C40 Cities, Covenant of Mayors or Under2 Coalition). Previous large-scale studies focussed on regional to global scales (Hutyra *et al.*, 2014) such that spatial and temporal resolutions were rarely meaningful to local or urban areas (Super, 2018). Therefore, the urban carbon cycle must be properly assessed as it impacts regional and global carbon cycles (Hutyra *et al.*, 2014).

We propose a method to obtain disaggregated estimates for CO2 emissions, sequestration and balance. The method is built on three types of data: land use, sectoral emissions and sequestration parameters. In addition, factors of temporal decomposition are applied. It aims at being easily replicable for a large number of areas (for instance cities) at one or multiple time periods. Estimates are available at a high spatial resolution (1 ha) and high temporal resolutions (year, month and weekday). So far, the alternatives are global and regional transport models, eddy-covariance

measurements, urban carbon metabolism, remote sensing or field measurements. Yet they are not appropriate for applications on multiple large urban areas for various reasons.

2. **Method**

The High Resolution Urban Carbon Balance (UCB) model allows downscaling anthropogenic CO2 emissions and their sequestration. From these outputs, the aggregated and disaggregated urban carbon balance are then assessed using different metrics. We developed estimates of anthropogenic carbon emissions and natural carbon sequestration at a spatial resolution of 1 ha and with annual, monthly and daily temporal resolutions. The carbon balance is then expressed in two ways: in absolute terms (*i.e.* the total amount sequestered over a day) and in relative terms (*i.e.* the percentage of emissions sequestered over a day). Therefore, the uniqueness of this work comes from multiple aspects: (i) the sectoral CO2 emissions were downscaled spatially using a high resolution urban land use database for 802 urban areas; (ii) the seasonality of CO2 emissions is accounted across country-, sector-, and yearspecific time profiles; (iii) the urban carbon sequestration capacity was estimated at a high spatial resolution for these 802 urban areas; (iv) the seasonality of the sequestration process is accounted with location-specific monthly factors; (v) the carbon balance estimates allow comparison across a wide range of urban areas.

The method can be easily replicated at different locations or time periods. We showcase the UCB model on four cities which represent different degrees of integration of LU. The method is built on three types of data: LU, localised emissions, and factors of decompositions and sequestration parameters.

3. Conclusion

The High Resolution Urban Carbon Balance (UCB) model allowed to create the first European high resolution CO2 emissions sequestration and balance database for urban areas. The method to do so considers sectoral emissions, applies spatial downscaling based on land use data, and temporal downscaling based on sectors, year and country. The UCB model can be replicated for other locations or time periods. Moreover, the emission part is not limited to CO2 emissions and could be used to downscale other gases and air pollutants from a LU dataset and emission or concentration data only. The resulting carbon balance provides a strong indication of the contribution of each urban area to the carbon cycles at the regional and global scales. Our High Resolution Urban Carbon Balance (UCB) Model relies on open source data for replicability and the resulting database is available for 802 cities and showcased for 4 illustrative cities in this article.

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Infering meteorological information at different scales from several sources of data

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Keywords: scales, climate change modelling, Modifiable Areal Unit Problem, data-driven approach, temperature

One of the major challenges to monitor, foresee and anticipate the landscape evolution is to understand the climate change geographical effects (Aspinal, 2012) on different, especially local, scales (Martin et al., 2013; Barry & Blanken, 2016). For instance, measuring the evolution of temperature is possible, one the one hand, using a series of (often spatially accurate, but irregular) sensors spread over a given territory (e.g. a watershed). On another hand, we have today a large access to climate models, providing meteorological projections at a certain (generally coarse, but regular) spatial and temporal granularity. From both those types of data, scientist can infer information at different (nested) scales, applying upscaling (by spatial data aggregation) or downscaling (assuming some disaggregation hypothesis) processes.

This work deals with this issue: how can we infer a reliable spatial information from meteorological data provided from two different levels and methodologies? More precisely, can we provide relevant estimations on climate drivers at different scales, in the particular case of meteorological data (illustrated by temperature)? To answer to these two questions, we face two problems: (i) how to combine these two sources of data (ii) and how to deal with the Ecological Effect (Holt, 1996; King, 1997) or the Modifiable Areal Unit Problem (Openshaw, 1984), that may strongly impair the estimate reliability and usability to forecast the likely climate landscapes for the future?

In this work, we present recent results obtained by studying temperatures measurements from a set of meteorological stations and the ALADIN model grid on long time series in the French southern region of Provence Alpes Côte d'Azur (Figure 1). Using those two sources of data, we aggregate temperature values and observe their variation through different administrative territorial partitions (somehow French delineations under the regional scale NUTS2 : "départements", "arrondissements", "cantons", "communes" and "EPCI", *i.e.* groups of communes).

This leads us to draw what we call "scalograms" (Figure 2) which plot average or median temperatures according to the different nested levels of scale. Those are provided for both the gridded ALADIN model and the series of local meteorological stations, and compared. We notice some differences in the estimations that show the necessary caution to pay for generating meteorological data using a multiple scale approach. A method, published a few year ago, based on

spatial random permutation (Josselin *et al.*, 2008) and generalized to any data (Josselin *et al.*, 2023), is applied on this kind of climate data to mitigate the change of support problem and to improve the data reliability to potentially characterize more accurately the landscapes at different scales.

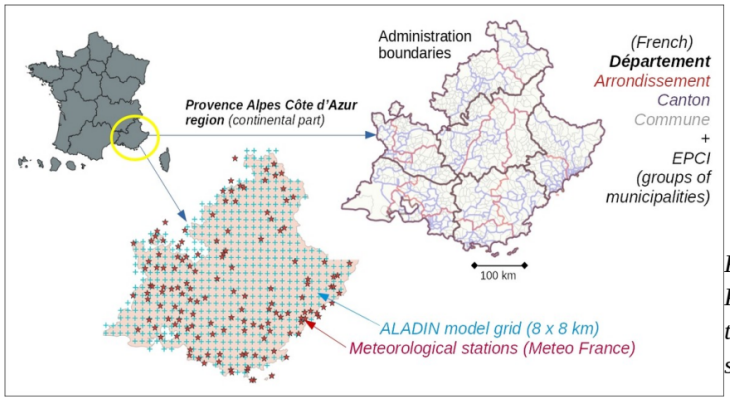

Figure 1. Two types of data in the French region Provence Alpes Côte d'Azur to upscale temperature assessment through administrative scales

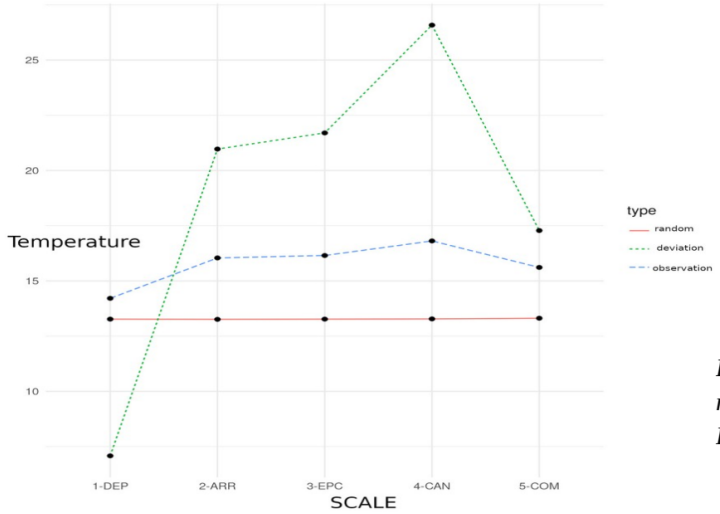

Figure 2. A scalogram, crossing a variable (i.e. the median aggregated temperature) by several French partitions

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An unsupervised learning approach to explore geodemographic clusters in Switzerland

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Keywords: Self Organizing Map, population census, clustering, heatmaps

Geodemographic segmentation is a technique used in marketing to classify a populations based on input data describing the administrative units and people living there (Spielman and Thill, 2008). Small areas can thus be classified into discrete categories using demographic data by means of data reduction techniques. Labels are finally attributed to each category to characterize them (Harris, Sleight and Webber, 2005). The principal limitation of classical geodemographic systems is the problem of communicating the multidimensional complexity characterizing the different classes. In addition, with the increasing availability of huge amount of heterogeneous information, the modern data-intensive science claims for the development of new techniques that differ from those utilized in earlier scientific paradigms (Amato *et al.*, 2022). Machine learning approaches can help in this context, as they are designed to enable to extract useful formation and insight from the interaction of the variables describing the complex structure of a given phenomenon. In the present study we implemented an unsupervised learning procedure based on Self-Organizing Map (SOM) (Kohonen, 1982), allowing detecting clusters and characterizing the pattern of population dynamic in Switzerland in the recent period.

Switzerland has the highest life expectancies in the world. It counts about 8,5 million inhabitants (official census data 2020), twice as much as at the beginning of the 20th century, mainly because of the hight level of immigration. The number of foreigners that currently reside in the county corresponds to about one quarter of the total population. Most of the population (85%) lives in cities. Population aging increased over the course of the 20th century, with one in five person of retirement age today. In the present study we developed a machine learning based approach to understand and describe the population patterns in different geographic areas. Namely we used SOM, an unsupervised competitive learning neural network allowing representing a high-dimensional space, defined by the multivariate input dataset, as two-dimensional discretized pattern. In SOM the proximity of the units in the output grid reflects the similarity of the corresponding input observations, so to guarantee the preservation of the topological structure of the input data. Compared to other approaches, SOM is very efficient for data visualization (Vesanto, 1999). Indeed it provides additional outputs such as the heatmaps, representing the distribution of each input feature across the SOM grid, extremely useful to visually explore the relationship between the variables.

Input data come from the national population census, provided by the Swiss Federal Statistical Office (https://www.bfs.admin.ch/bfs/en/home.html) and containing information on the

socioeconomic status of the population and surveyed land use and land cover. This information has been aggregated to the municipality level for the purpose of the present investigation. Census data 2020 have been considered to analyse the current pattern, while the former census survey has been considered to assess transitions and evaluate population dynamics. SOM allowed to aggregate input data into close units on the base of the proximity between the associated variables. Finally, these units have been partitioned into discrete pattern structures (i.e., main clusters) and mapped back to the geographical space.

Results of the present study reveal the main patterns of the Swiss population. To characterise the final main clusters and verify their consistency at global level, we evaluated the distribution of each variable within the clusters by using box plots. It resulted, for example, main clusters including the most developed and active cities with higher income, the peri-urbans areas mostly devoted to the agricultural activity, or the areas with higher levels of migration. SOM heatmaps allowed to display the pattern distribution of each input variable over the SOM-grid and how values change in space. Visualized side by side, heatmaps show a picture of the different areas and their characteristics: in this way it is possible to explore the level of complementarity that links one or more variables among them. In conclusion, in the present study we propose a performant data-driven approach based on unsupervised learning allowing to extract useful information from a huge volume of multivariate population census data. Our approach led to represent and interpret the main patterns characterizing the dynamic of population in Switzerland in the recent period.

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Built-up area use in European cities in 2020, with urban scaling laws

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Keywords: Built-up area use, European urban areas, urban scaling laws, radial analysis

1. Introduction

Most cities in Europe, even those with a decreasing population, tend to spread out with a growing urbanization. The constant growth of cities reveals sustainability issues in the housing and transport sectors by challenging the spatial organization of cities, for example by increasing travel times (Weiss et al., 2018) and car use. Cities are major sources of pollution, even more in the context of climate change and the health of city residents. Moreover, heavy urbanization and the constant increase in built-up area create profound environmental consequences (impacts on fauna and flora, urban heat islands...). The desire to have a more sustainable management of urban space, for example by reducing artificial land use, has been at the heart of urban development policies for decades now. To gain a deeper understanding of built-up land in urban areas, it is important to compare cities and identify general forms and patterns on a large scale.

2. Methods and data

We use a comparative analysis of the evolution of built-up area in the largest European cities, focusing on center-periphery organization. The objective is to analyze how urban structure changes with distance from the main center. The center-periphery analysis constitutes the first spatial differentiation for cities (Guérois and Pumain, 2008). We use urban scaling laws to compare cities that are difficult to match in terms of size. Urban scaling laws make it possible to transform a set of objects from one spatial scale to another without changing their structure, thus facilitating comparative analyses of cities (Batty, 2015). The large corpus of cities to be treated reinforces the relevance of the use of this approach.

This study focuses on built-up area in 2020, in 786 European urban areas with more than 50,000 inhabitants. We use GHSL built-up data (a globally harmonized database) at a spatial resolution of 100m. The built-up area is expressed as a continuous value representing the proportion of building footprint in the total cell size. We use Urban Atlas 2018 population values for each urban area. To enable comparisons across our extensive dataset, we designate the city hall as the reference geographical center. Then, concentric rings of 200 m are made around the city hall to calculate the share of built-up area in these rings. The average share of built-up land in the city center of European cities is 37.5%, irrespective of city size.

3. Results

The main result of this work is that the center-periphery organization of built-up land successions occurs at the same rate if we cancel out the size effect of urban areas. Thus, the built-up area per inhabitant is generally the same for all cities and is proportional to the population. These results are quite similar to those found by Lemoy and Caruso (2020) if only the built-up area is considered. Indeed, they study artificial land uses in European urban areas with Urban Atlas 2006 data.

Up to the first 30 kilometers, there is a fairly significant decrease in the built-up area. There is a common (exponential) characteristic shape that is more or less the same in all cities. It is a fundamental characteristic of the internal structure of cities, which can be measured by a characteristic decrease distance l.

However, coastal cities have on average a characteristically low distance l. This indicates that the share of built-up land decreases rapidly away from the city center. In contrast, polycentric cities have a high characteristic distance l, which indicates that the share of built-up land decreases more slowly away from the city center. This is because the share of built-up areas of several large agglomerations is taken into account in the data.

Coastal cities stand out in the analysis because the presence of water near the city center is a major source of divergence from general behavior. It is therefore necessary to add large aquatic areas to the analysis in order to treat coastal cities satisfactorily. We use OpenStreetMap data for seas, and HydroSHEDS data for water bodies of at least 10 hectares in size. We then cut the GHSL raster across these two layers to remove areas covered by water. This shows that coastal cities are less exceptional in the analysis of results.

These urban scaling laws point interesting phenomena: some cities stand out. Notably, two large countries stand out: French cities have more built-up areas than the average while Spanish cities have less, especially in the first 10-30 kilometers (rescaled distance with London as reference). According to the first analysis, in France, there are fewer people per household than in Spain (2.1 people in France in 2019 and 2.5 people in Spain). There are also characteristics specific to France, such as commercial areas on the outskirts of urban areas or a large number of concerted development zones.

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Historical trajectory of large French cities over three centuries using radial profiles and scaling laws

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Keywords: Historical maps, Remote sensing, France, Scaling laws, GIS

The present contribution is part of a historical analysis of urbanization in France, conducted through the research project "SUCHIES" (Compared Urban Structure through History and Scales 2021-2023), which aims to achieve two objectives. The first is the production of urban layers from various historical maps on the three main time periods: the Cassini maps (1750), Etat Major maps (1850) and Scan Histo (1950) maps. The second product is an analysis of the centre-periphery gradient, in particular through the population (city size) variable. For the first objective, the urban extraction methodology is a semiautomatic approach, starting with a radiometric data-mining of the urban pixel thresholds, supported by morphological correction and convolution filters (Xie *et al.*, 2020). A manual digitization is also operated, in particular for the Cassini maps as well as for the city center blocks for the two other layers. Indeed, the automatic approaches generate important confusion rates in the extraction of these objects, due to the geometrical variability of the urban object, but also regarding the specific artifacts of historical maps, in particular fading, degradation of the ink. This requires at the end a large manual correction campaign.

Regarding the analysis of the centre-periphery gradient, our aim is to compare big cities and small ones when subtracting the population variable through a convenient scaling law (Lemoy and Caruso, 2020). In fact, this scaling law of urban land use has been observed at the European scale of 300 cities in 2006 (Lemoy and Caruso, 2021). Through this multitemporal case study, we check its validity in time, especially in the 18th and 19th centuries. We also propose a historical description of urbanisation, in particular regarding multi-date area statistics, the evolution of the hierarchy of cities in France over time and the dynamics of the compact urban core. We assess quantitatively the decadence/ascendancy of certain agglomerations, highlighting territorial dynamics that were previously unknown or described in a qualitative manner.

This historical analysis is an original contribution due to the scarcity of historical digital data on a national scale (Ignjatić *et al.*, 2018; Combes, Gobillon and Zylberberg, 2022), but also regarding the assessment of the scaling law and the definition of the city using historical data.

The first objective is to provide an efficient urban database, using a simple reproducible approach, and less time consuming for generic GIS users. Indeed, while a machine learning approach requires

important computing power and also a time-consuming sampling campaign, semi-automatic approaches offer as in this study the ideal compromise, with simple algorithms supported at the end by a quick and efficient correction of main errors.

In perspective, the results of this contribution will be to compare these historical scaling laws on a European scale (comparison with Great Britain and Belgium), in collaboration with the Cambridge University (Dr Alexis Lietvine), using historical maps of the Geological Survey, as well as for Belgium (Ferrari maps 1750 and Van Der Maelen, 1850 of Wallonia), made available by the Geoportail of Wallonia.

The produced data will be made freely available by the end of the project (October 2023), in a participatory server (https://www.openhistoricalmap.org/), as well as through a code (R© script) for the image processing part with a Creative Commons license in an open access deposit (https://github.com/users/wilius47/projects/2).

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A Multivariate Sensitivity approach for urban densification modelling

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Keywords: Sensitivity Analysis, Land use modelling , Urban densification, urban development

Urban land use planning plays a critical role in sustainable urban development, requiring accurate prediction models to inform decision-making processes(Razavi et al., 2021). This study employs sensitivity analysis to investigate the robustness and reliability of a multi-logistic regression models in predicting urban land use patterns. Sensitivity analysis enables the exploration of the influence of input variables on model outputs, thus providing insights into the model's performance and potential uncertainties(Li et al., 2019).

Several studies have employed sensitivity analysis techniques to evaluate the performance of various predictive models in urban planning and land use studies. For example, used SA for land use and land cover probability assessment for Lake Balaton watershed in Hungary. Brändle et al., 2015 used SA to investigate the impact of land use policy to assess land abandonment in Swiss Mountain Region. (Stickler et al., 2009)used SA to investigate the impact of climate change on urban land use change in the Amazon rainforest. The results of these studies have shown that SA can be a valuable tool for understanding the factors that influence urban land use change. However, there are a number of gaps in the literature on SA and urban land use change. First, most studies have focused on a single factor, such as population growth, economic development, or climate change. Second, most studies have used simple SA methods, such as univariate sensitivity analysis.

This study addresses the gaps in the literature by suggesting a comprehensive multilogisticmultivariate sensitivity analysis [MLR_MVSA] method to investigate the factors that influence urban densification in Belgium. The study uses a set of geophysical and socioeconomic variables to train a logistic regression model. The analysis is being done for three areas of Belgium, namely Brussels capital region and its associated Brabant of Flanders and Walloon for the year of 2010. This is because of availability of census based data with accurate precision. Earlier, a multinomial logistic regression was employed to evaluate the impact of variables on the urban built up densification with four level of density class at a scale of 100*100m. However, it is crucial to understand the nature of model outcome, if there is a change in terms of spatial resolution, density classes and neighbourhood size simultaneously.

Therefore, our study considers the various combination of spatial resolution at 50m, 100m, 300m and 500m.Alongside, the spatial resolution, the density classes were classified into 3,7,9 number of classes.

Interestingly , in our study a changing moving windows were also employed in three different combinations of 3×3, 5×5 , 7×7 and 9×9 cells. In order to evaluate the model's outcome, three different metrices were used to confirm the best possible combination. Receiver operating characteristics (ROC) curve was used to evaluate the model's outcome based on the same evaluation process used for reference model. Other than that, metrices like producers accuracy, overall accuracy, figure of merit (FoM) were also calculated. This shows that even if the accuracy does not vividly vary over density classes and neighbourhood size, but change in spatial resolution shows significant differences in accuracy of model resulting into the best result with combination of a raster cell at 50m with 4 density class and 3×3 neighbourhood cells. It is imperative to understand the behaviour of model parameters for simulating a near realistic scenarios through modelling which is why study like this will help the data analyst, urban modellers and environmentalist to have an in depth understanding of data and their interactions(Wu et al., 2019).

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Leapfrog sprawl across the metropolitan USA over the last 20 years

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Keywords: leapfrogging, land use, sprawl, metropolitan USA

Urbanisation is growing faster than the population, despite the climate emergency and policies to encourage frugality in land use. There has been an increased focus on urban density, compactness and containment in recent decades, but many cities are still expanding outwards in a discontinuous fashion, leaving some land 'leaped over' in the process, fragmenting natural habitats and imposing additional costs on society. The problem of direct land loss is worrying, but so are the amounts of land that are 'leapfrogged' between the previous and the new urbanisation, whether in the form of very small patches or very large stretches of land.

In addition to its environmental and social impacts, leapfrog sprawl is puzzling as a process because it represents an additional distance that imposes unnecessary transport costs on individuals. Theoretical research has shown how leapfrogging can arise from individual decisions, either temporarily or in the long term. Suggested reasons include growth expectations of landowners who hold back land closer to the city in anticipation of future income (Capozza and Helsley, 1990), and more recently the effect of spatial differentiation of demand along household heterogeneity (thin markets, Chen et al., 2017) or household valuation of local green space (Caruso et al., 2007).

Empirically, while the literature on measuring sprawl is vast, the literature on measuring this particular aspect of leapfrogging, which has a directional aspect (land is leapfrogged as one moves away from the centre) and requires spatial granularity, is tiny. Burchfield et al. (2006) is now a classic example of a directional sprawl metric aggregated across metropolitan areas. Zhang et al (2017) proposed perhaps the only direct measure of leapfrogging, using the shortest commuting routes to the CBD, which they applied to the case of Baltimore.

We contribute the first analysis of leapfrogging sprawl for all US metropolitan areas. In contrast to Burchfield et al. (2006) and Zhang et al. (2017), who focus on the total undeveloped land bypassed by the developed cells, we propose alternative leapfrog measures that focus on the distance of new development to the existing urban land footprint and take into account its direction. With these new leapfrogging measures, we provide quantified evidence of the extent of leapfrogging, its change, and spatial structure across US metropolitan areas and examine factors associated with leapfrogging.

Using 30-metre resolution satellite imagery (7 NLCD images from 2001 to 2019), we find that the conversion of undeveloped land to urban uses over the last 20 years in the US metropolitan area amounted to 2,649,134 ha. A striking 63% of this development was not contiguous with the previous urban footprint. We also find that the average distance between existing and new development is about 100 m. This may seem negligible at the local scale, but given the sheer scale of urbanisation, it has huge implications for the environment at the urban fringe and for society.

We then estimate a series of models on the 29 million newly urbanised cells to identify potential sources of leapfrogging. We include both disaggregated, i.e. pixel scale, and MSA scale variables. Our results suggest that city size tends to increase leapfrogging, but reduces the length of leaps. Faster urbanisation has the strongest effect on increasing leapfrogging distances, which we attribute to the expectation that these leaps will be filled later. We also find contradictory effects of density at the city and local level, suggesting that higher-density cities have a push effect that encourages leapfrogging, while locally dense clusters are attractive and eventually form after leapfrogging. We find no apparent effect of income growth or inequality that would push households further away to find affordable land. While most leapfrogging appears to be temporary on a 20-year scale at 30m resolution, its periodic volume remains a concern, as does the fact that it is a dynamic process that continually creates a fragmented pattern at the fringe.

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Towards smart public spaces - interdisciplinary approach: case study

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Keywords: public spaces, smart spaces, sustainable development, smart city, spatial planning

The main aim of the article is to make a comparative analysis and show the potential of selected smart public spaces in selected Western and Central European cities, as important forms of urbanity. Such places, are not an additional function in the city but have an essential influence on sustainable development, social awareness, and future eco-friendly trends. In all cases, smart solutions and their important role in these cities might trigger the regeneration and development process and refer to many factors: social, economic, environmental, living, spatial, mobility, and government. The key factors of a city's resilience, well-being, and sustainable development are smart future urban solutions. Such areas can have a great opportunity to become the best exemplary places of innovation that shape the global directions of contemporary public spaces transformation with not only a social, economic, and physical dimension but also a virtual and specialized technological one.

An important role in the development of the smart city is played by contemporary infrastructure such as renewable energy solutions, intelligent and autonomous transport, intelligent information and communication technologies, and high-tech complexes related to the research community or innovation laboratories. Selected examples encountered a number of solutions such as among others protection of the natural environment, development of tourist infrastructure as well as basic amenities, elements of intelligent transport systems and mobility, artificial intelligence in environmental applications, energy technologies, and also the great vision of development strategy regarding the importance of the adapting to climate change.

Other significant issues covered by smart solutions include also social aspects like participation or placemaking. The analyzed solutions allow for greater accessibility of public spaces and the creation of interactions with people that facilitates communication processes not only with the community, and mutual understanding in the relationship between citizens, authorities, and services but also between people and the space. Such a solution also enables residents to contribute and to be actively engaged in sustainable development, when they can see and act on the available data reducing pollution or lowering environmental impact.

The article examines smart public spaces with the following issues: types of places and solutions introduced, their period and method of implementation, potential users and stakeholders, and then identifies good practices or problems. Numerous research methods were used: analysis and examination of cartographic sources, urban plans or documents, geospatial data analysis, collecting and studying literature, comparative method, discussions with experts, and on-site inspections. A

diagram with key components analysis and a comparison table with introduced universal solutions have been drawn up.

Conclusions are divided into aspects of future general guidelines for the development and redevelopment process towards smart public spaces in the context of land use, urban neighborhood, and shaping an appropriate spatial policy including best practices with inclusiveness and efficient spatial planning, management, and use of resources. Smart public spaces are complexed, sustainable, resilient, and versatile solutions that can support the local economy, be quick responses to social problems, governance challenges, and local environmental threats, reduce traffic congestion, improve transport and energy use efficiency, or even climate change interventions. Smart public spaces can also support a healthy lifestyle and good habits, raise awareness and knowledge, and improve the well-being of residents, but also give them a contemporary sense of community and coworking together for a common goal by using recommendations based on factor data.

About non-knowledge in knowledge management for planning: Towards an applied ontological approach

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Keywords: spatial planning; uncertainty; knowledge management; ontology

A planning process of strategic decisions affecting a space, or an environmental system, or a community organization typically manages data. These are also very extensive datasets, which can include numerous results of even very diversified analyses. Following an abstract reasoning, the process aims to represent this large extension of outcomes and data in terms of the set of what we know. However, such a set is located in the world together with at least another equivalent set, which is the set of what we don't know. It is clear that this second set also exists, at the very moment in which we decide. In knowledge management another facet appears, that of non-knowledge. It is made up of uncertainties, ambiguities, deep unknowns that fatally affect the results of a strategic plan or, more generally, the effectiveness of environmental and design choices.

This issue came out dramatically after the outbreak of the recent pandemic. The SARS-COVID-19 disease hit us unexpectedly, and found in particular population unprepared, as well as unaware of the problem. In addition, the sequence of events showed that public and administrative decision-makers ignored even the possibility of such a dramatic pandemic event. Decision-makers could be said as being previously unprepared, if not short-sighted, in grasping so many small clues already circulating together all over the planet. These appeared as unrelated and subtle clues at a superficial glance, being in a chain of causes in space and time that could not be systematically read in a coherent perspective. Some literature, both scientific and informational, had tried to argue and speculate about it, in order to forward the message to the communities. Yet no operational decisions or choices appear to have been developed to change course.

Yet in general, human agents are able to imagine perspectives and scenarios even without current indicators of possible futures (Suddendorf and Redshaw, 2017). Human agents, researchers, planners, whether consciously or not, normally face great uncertainties, ambiguities, ignorance, unexpected events. They do normally deal with the non-knowledge. And research in various scientific domains attempts to support public administrators in developing their decisions in an uncertain or not-known context (Walker et al., 2003; Buurman and Babovic, 2016; Marchau et al., 2019). Both planners and decision-makers typically face the complexity of spatial and environmental decisions. In recent decades there has been a high degree of uncertainty and rapid environmental changes. It required policy-making and planning approaches useful for making effective, robust and resilient or antifragile choices with a final far-sighted look at the environment as a system (Taleb, 2012; Buurman and Babovic, 2016).

But it is a complex system, full of complexity in the issues and problems of decision-making and planning activities. This drives planners and decision-makers to face radical uncertainty and even ignorance of policy and decision-making processes. Systems theory gives an insight into the limits and potential of planning in contemporary society and therefore allows for a complex and subtle analysis of planning practice. Luhmann's arguments show how over decades planning had to face the problem of complexity using approximate methods of modeling or simulations. It was actually a slow adaptation of society to planning (Luhmann, 1997; Van Assche and Verschraegen, 2008). His reflections could instead suggest a path for considering the planning activity according to the awareness of not-knowing, particularly toward resilience aims (Camarda, 2018).

The present work is indeed a position paper. The reflections concern non-knowledge, and its possible management perspectives in the face of spatial, urban, regional and environmental planning actions. Certainly the decision under uncertainty is a classic problem in the literature on decision theory. However, we will try to further investigate the identification of the problem, its epistemological positioning and consequently the possible response that may derive from it. First it will be a question of seeking a theoretical answer, but then hopefully also an implementation one. In this context, the paper will reflect about an example of unexpected events occurred as a consequence of a famous planned development strategy. This is the case of the steelworks of Taranto (Italy), as contextualized in the multiple planning strategies developed over time. In this case it was not a sudden outbreak, differently from the case of the Covid pandemic. Yet, the scale of seemingly unexpected events has sadly led to dramatic long-term environmental and health consequences (Camarda, 2018). In particular, we will investigate the potential of some methodological approaches towards the identification and management of uncertain or not-known scenarios toward urban resilience objectives. We will explore perspectives about possibility theory (Zadeh, 2014), as well as models for the management of complex systems, based on applied ontologies (Borgo and Guarino, 2015).

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The importance of urban environment for sentiment: analysis in Lisbon using social networks

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Keywords: urban environment, sentiment analysis, machine learning, big data

Mental health problems have been rising worldwide, possibly associated with urban population growth and lifestyles (Chen, Niu and Silva, 2023). The recognition that the various aspects of the urban environment can affect the mental health of individuals has been increasing since they are responsible for facilitating or inhibiting behaviors and lifestyles that impact the sentiment.

In this context, it is essential to understand the potential impact that the urban environment of the city of Lisbon may have on the sentiments of those who "live the space". To do so, we resorted to sentiment analysis based on data from the social network Twitter (Chen *et al.*, 2022; Liu *et al.*, 2023), using a Sentiment and Emotion lexicon from the Canadian National Research Council (NRC) (Mohammad and Turney, 2013). This enabled the identification of places where both positive and negative sentiment prevail; this is an easily replicable process with a more direct association to sentiment and emotions (*e.g.*, Plutchik's wheel of emotions).

For the impact identification, was considered a set of explanatory variables that characterize the morphology of the city of Lisbon: the popularity of the places, indexes of urban shape, shadow areas, the width of the street, green and blue infrastructure, the average age of the building, and others. However, people receive different sensory information from space, making it challenging to determine which aspects of the experience in the urban environment affected the sentiment. A Machine Learning (ML) model associated with an agnostic model was used to increase understanding of the factors in the urban environment that can explain sentiment. ML is recognized for superior accuracy results to traditional methods. These models have advantages, such as the ability to handle data of different types, structures, and quantities (i.e., big data) (Molnar, 2019). Four ML models were tested, Random Forest (RF), Extreme Gradient Boosting (XGBoost), Neural Network (NN), and K-Nearest Neighbour (KNN), which is one of the simplest algorithms used, and a linear model for comparison (Generalized Linear Model - GLM). Using positive/negative sentiment as dependent variable and 30 explanatory variables related to the urban environment, it was found that RF is the model with the highest predictive ability.

Twitter data is a good proxy for sentiment analysis since users are assigned codes, it is possible to know how many there are but not know who they are, and there are no confidentiality issues. The permission to access the user's location at the time of publication, besides being an advantage in the context of data protection, is a disadvantage for sentiment analysis because most users do not authorize access, ending up not considering a large part of the comments for the sentiment analysis.

Through the sentiment analysis, it was possible to verify that the areas with high scores of words associated with positive sentiment include the stores and restaurants of Avenida da Liberdade, Praça Dom Pedro IV, Elevador de Santa Justa, Armazéns do Chiado, Rua Augusta and Aeroporto Humberto Delgado. The MAAT, Doca de Santo Amaro, Centro de Congressos de Lisboa, Village Underground Lisboa, LxFactory, SUD Lisboa, Jardim Guerra Junqueiro (Jardim da Estrela), Centro Comercial do Colombo, Centro Comercial Vasco da Gama, Altice Arena, and Feira Internacional de Lisboa (FIL) are associated with moderate sentiment scores. It is viable to conclude that the Portuguese are happy in spaces associated with leisure and consumption, such as museums, event venues, gardens, shopping centers, stores, and restaurants.

The agnostic models applied, the Local Interpretable Model-Agnostic Explanations (LIME), and the SHapley Additive exPlanation (SHAP), which is based on game theory, played a crucial role in this study. Thus, answering the starting question "To what extent do urban environment variables impact the sentiment of individuals in the city of Lisbon?", the explanatory variables that are most related to sentiment are distance to fitness equipment, distance to green spaces, the popularity of locations, and distance to the cycling network.

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Analog Twins: building stakeholders trust and engagement in the digital planning era

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Keywords: analog twins, digital twins, planning-support systems, urban modelling, urban simulation

"Digital Twins" (DT) is the latest buzzword in many areas of human activity, in particular in urban analytics, attracting the attention of researchers and policymakers (Caldarelli et al., 2023). A search on ScienceDirect ("digital twins" AND urban) returns 8 or less references before 2018, 39 in 2019, 96 in 2020, 224 in 2021 and 495 in 2022. A generic DT can be defined as "a mirror image of a physical process that is articulated alongside the process in question, usually matching exactly the operation of the physical process which takes place in real time" (Batty, 2018). This is a very attractive concept for urban and spatial systems. It encompasses the concept of simulating in depth the components, diversity and complexities of such systems, an aim behind traditional methods used in urban studies for decades now such as GIS, simulation models or virtual reality systems. Urban DT clearly derives from the data driven agenda that cascaded from computer/data sciences to urban studies in the last decade, when for example sensors, IoT, bigdata and now AI became standards not only in academic research but increasingly more so in practice. The many "city in a box" technology-based solutions, made available from local urban innovators to big tech providers, generated for example city dashboards or urban control centres, which are now being coupled with urban DT systems. This coupling is expected to help simulate or forecast these systems in more depth and with faster outputs.

Urban DT tend to be top-down systems (Schrotter and Hürzeler, 2020), perhaps depending more on data-driven mechanisms than on the complexities of human behaviours that drive the evolution of cities. This approach risks to ignore the important contribution of stakeholders to developing possibly powerful urban DT that can act as planning-support systems (PSS) and/or decision-support systems (DSS). If urban DT are to be fully representative of the feature they want to replicate, the city, they need to incorporate human behaviour: "If SDTs [spatial digital twins] are to be anything more than an ephemeral means to publications and grants, they need to incorporate realistic models of human processes" (Fotheringham, 2023). The conceptual and technical complexities of urban DT encompass many of the shortfalls that are identified in the literature as bottlenecks for adopting PSS and DSS (Vonk, 2005). The "implementation gap" (Geertman, 2017) can be an analytical lens for understanding the value of DT in urban. The mix of low awareness among practitioners, the low level of literacy on DT, the lack of technical and/or financial resources to acquire and use them and,

more recently, the fragmentation of professional and institutional knowledge on decision-making, all these factors apply to a substantial mistrust in the use of DT among stakeholders and practitioners.

Precisely because stakeholders are humans, fostering trust and increasing transparency and engagement of stakeholders are key for inducing urban DT uptake. For that, we propose the use of what we call "Analog Twins" (AT). AT can be defined as conceptual proposals of complex DT systems (or, in broad terms, any simulation model) that are designed to explain and demonstrate, at early DT design stages, the components, mechanisms, data requirements, outputs and usability of DT.

AT are "pen and paper" features, done preferably with stakeholders in co-produced processes, that aim at effectively integrate their interest, requirements and knowledge. Consequently, AT will incorporate a mix of stakeholders' and experts' knowledge and will speak to both communities, thus breaking discourse barriers. In turn, this will foster trust, transparency and, ultimately, engagement with all the agents involved in urban planning or decision-making processes.

We discuss the role of AT as a key step to develop trust and transparency in developing and deploying any type of DT into any form of use in everyday spatial planning or decision-making practices. We propose a framework for ATs with design principles, guidelines for implementation and examples of ATs in the development of different models for different topics in urban analytics.

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Abstracts of Parallel Sessions 3

Evaluating the Impact of Added Greenery on Perceived Factors of an Urban Environment in Virtual Reality

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Keywords: perceived greenness, immersive virtual environment, perception, virtual reality, urban environment

The wellbeing effects of urban greenspace and roadside greenery are well established [1-5]. However, they may be more attributable to a pedestrian's perceptions than the objective levels of greenery present [6-13]. Recent research trends have shown immersive virtual environments to be potentially the most suitable research tools when examining an individual's perceptions of their environment [14-17]. We designed an immersive virtual environment (seen in Figure 1) with three levels of road-side greenery - no trees, approximately 200 trees, and approximately 400 trees - and asked participants to rate each of those environments for safety, beauty, density, greenness, building height, and road width on a scale of 1 to 7. Safety, beauty, density, and greenness for their perceptive subjectivity and connections to urban greenspace and wellbeing, and building height and road width for their objective quantifiability as differentiator between perception and reality. 34 participants' answers were collected, alongside their years of lived experience in urban, suburban, and rural environments, to assess the relationships between environmental background and perceptions of urban environments.

The immersive virtual environment was built in Unity game engine and run on a Meta Quest 2 head-mounted display. Participants could move through the environment by means of the thumb-sticks provided on the Quest's controllers, and questions were presented within the virtual environment to prevent breaks in presence or immersion.

This study finds that the introduction and addition of trees to an urban environment greatly impacts perceptions of beauty and greenness (coefficients > 2, p-values < 0.01), and slightly impacts perceptions of building height (coefficient of 0.56, p-value of 0.05). Years lived experience in urban, suburban, and rural environments had a significant effect on perceived safety, building height, and road width (coefficients ranging from 0.5 to 3.02, with p-values < 0.01), and controlling for the effect of years lived experience in urban environments significantly lowered the impact of number of trees as a predictor. The effect on greenness indirectly affects other outcomes, as perceived greenness

(the rating given for it in each environment) has higher significant correlations to all other outcomes than objective number of trees does, when years lived experience in urban environments is controlled for.

Conclusions are therefore drawn to emphasise the need for further research differentiating the wellbeing effects of perceived greenness from those of objective greenness, and the ecological validity of immersive virtual environments as research tools.

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Deep learning-based mapping of urban heat islands

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Keywords: urban heat islands (UHI), sensor networks, modelling, deep learning (DL), spatial prediction

Urban heat islands pose a serious problem for urban populations worldwide. In the view of global warming, cities face the challenge of counteracting the increasing overheating of their densely built centres during summer heat waves. In order to be able to take efficient countermeasures, city administrations and urban planners need to know the cooling effect of individual measures. However, empirical data on the effects or possibilities of ex-ante simulations of planned actions are often lacking.

To support urban planners with this task, we propose a deep learning-based approach to high resolution mapping and prediction of local UHIs. For this, we employ a dense medium-cost sensor network distributed throughout the city of Dresden, Germany. With the gained temperature sensor measurements, we train a DL model against various data from the environment of the sensors, such as land use and cover, built-up density, building heights, and urban greenery. The trained model is subsequently applied to city-wide available land use data to enable spatially high-resolution mapping and prediction of local UHIs. We test the prediction accuracy of the model against different sensor network layouts in terms of the spatial distribution, the number, the location, and the random failure of individual sensors to provide guidance for optimal sensor network configuration and the transfer to other cities. Finally, we demonstrate the possibilities of simulating the effects of local countermeasures by feeding the trained model with alternative local urban configurations.

Heat-related mortality in Flanders (Belgium): combining land use and climate modelling with spatial health statistics

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Keywords: health geography, land use modelling, climate modelling, heat

In Flanders, more and longer heat waves will increase the risk of heat stroke, cardiovascular or respiratory disorders, as well as the risk of premature death. The most vulnerable groups will be disproportionately affected, further exacerbating social inequality. Mapping the health impact of heat, now and in the future, is an important step for preventive climate-health policy and aims to identify priority locations and vulnerable groups.

First, dosis-effect relations are established. The data contains daily observation of overall and causespecific mortality, weather and population data per municipality for the period 2010-2019. We focus on the summer period from May 15 - September 30. A Poisson regression with distributed lag nonlinear models (DLNM) is applied to investigate the effect of temperature on the mortality in Flanders. Extra attention goes to the impact of age on the dosis-effect relation with heat.

The dose-effect relationships (relative risks) are used to determine heat-related mortality, for allcause mortality, as well as cardiovascular and respiratory causes. The methodology uses the population attributable fraction, taking into account the background incidence, which is the mortality not caused by heat exposure. The VITO-UrbClim climate model provides both short and long-term predictions about heat stress conditions. The calculations are made on an hourly basis on a grid of 100 x 100 m². The spatial distribution of the vulnerable population is determined by combining the population density per ha (reference year 2019) with population data for different age categories per municipality. For different geographical levels (municipalities, provinces, region), the heat-related mortality is calculated based on the relative risks at daily mean, minimum or maximum temperature. The Disability Adjusted Life Years (DALY's, as a measure for the burden of disease) and economical cost are determined as well for provinces and region.

The future heat-related mortality is also estimated by a second approach in which the prognosis for the demography of the Flemish population (growth and aging of the population) is included.

Therefore, we use the demography forecasts of the Federal Planning Bureau for 2050 and mortality coefficients of the Flemish population in 2050. These population forecasts are used in the GeoDynamix land-use model (‘RuimteModel’ Flanders), an activity based cellular automata landuse model operating at a mid-level resolution (1 ha). A spatial policy scenario for Flanders is available with as a result the land use and the spatial distribution of the population in 2050. When working with the population density of 2050, a correction of the land use used in the UrbClim climate modelling is necessary.

Our quantifications can be regarded as a conservative, rather low estimate of the heat impact on health. No morbidity, only mortality is taken into account. The results will be used to direct the prevention action to the most prone areas and target groups (based on physical or social-economical vulnerability and/or unequal exposure to heat). The project was funded by the Flemish Department of Care to enable health professionals to take more targeted heat action plans.

Urban systems in the face of climate change

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Keywords: urban, system, climate, change, modelling

1. Introduction

Cities are places where most of the fundamental aspects of the capitalism are reproduced (Harvey, 2007), occupying a major role in the greening of the economy (Meng et al. 2021, Shutters, 2023). Sustainability have been pushed in practice mainly by global agendas, public policies, and regulations which seek cleaner technologies, inputs and outputs, as well as behaviors, to mitigate the effects of climate change. The necessities related to sustainability have already begun to be visualized in the cornerstones of the economy system -i.e., households and firms-(Ivanova et al., 2020; Buturri, 2019; Domenech et al. 2019) and leads to an indispensable question about the future of the cities: How could the transition to sustainability change the setting urban systems' levels ?

2. **Conceptual background**

Following Rozenblat and Neal (2021) 'the level of an urban network characterizes the extent to which the node represent aggregations of the smallest distinct entities capable of participating in the relationship under study to larger systems that transform their individual actions and interactions. Proceeding from this, three main levels could be identified when we analyze cities from a systemic approach: micro, meso and macro. The micro level of organization includes the interacting basic entities of the system, as well as their behaviors and decisions. From their local interactions, a set of complex phenomena emerge, the meso level. Simultaneously, long distance relations, connections, and networks between cities, give rise to the macro level (Bida and Rozenblat, 2020).

2.1.Micro-level

At the micro level, Porter (1990) suggested that it is not only the size of demand that is important for firms' location decisions, but also the overall sophistication of consumers. For him, consumers force firms to constantly innovate and improve their level of competitiveness. In this sense, he argues that differentiated demand conditions between regions - in terms of their sophistication - would lead to different demand structures, which would determine the main features of regional 'localization economies'. The sophistication of consumption in the context of the transition to sustainability could be understood as a shift in consumption preferences from a highly polluting set of goods and services to another set produced by cleaner modes of production.

2.2.**Meso-level**

At the meso level, the 'industrial district' criteria developed by Marshall (1890) provides three main reasons for spatial concentration: (i) a labour force endowed with specialised skills and knowledge, (ii) technological spillovers from neighbouring firms, and (iii) the sharing of specialised inputs and

services. The after mentioned commonly referred to as localisation economies, are thought to increase the productivity and specialisation of places, thereby reducing operating costs.

From a different perspective, Jacobs (1969) proposed that agglomeration is driven by sectoral diversity rather than geographical specialisation. Her theory emphasised that the exchange of knowledge from sectoral diversity is the key to innovation and drives regional growth. The above literature did not deal with the phenomena of climate change and green growth efforts. However, more recent research (e.g., Aluko, Opoku, & Acheampong, 2022 and You et al., 2022) has showed that environmental degradation is influenced by the economic complexity produced at this mesolevel.

2.3.Macro-level

From a macro and top-down perspective, it is also important to consider the role of public policies in transforming economic and urban systems to make them compatible with sustainability goals. It is well known that green fiscal policies, especially environmental taxes such as carbon pricing, are effective and efficient initiatives to support pollution reduction, improve water and air quality, and consequently promote improvements in human health and well-being (World Bank, 2018).

3. Research questions and aim

Considering the multi-level conceptual framework presented above, this research mainly focuses on the following questions:

a. How could changes in household preferences for location and goods as a result of the

transition to sustainability, change the setting of urban systems' levels?

b. How environmental taxation policies could foster the emerging of green urban systems?

The aim of this research is to bring a novel agent-based model to face urban system transitions and equilibria through sustainable changes in microeconomic behavior and environmental policies.

4. Methods

To answer the above questions, we will develop an agent-based model using a multi-level complex adaptive system framework that provides insights into the reconfiguration of urban systems due to changes in consumer behaviour and/or government action through green taxation. This system will integrate micro-based theories from the New Economic Geography tradition, extended with key features of sustainable transition and green pollution taxation.

5. Results

The proposed model will provide insights into the extent to which consumer preferences for green consumption at the micro level and government action - through taxation - at the macro level are relevant to achieving a green urban system. From a theoretical perspective, the results will also focus on how economic geography models can be integrated into a multi-level conceptual framework, and how complexity and economic geography could together address the transition to sustainability.

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A GIS-based framework for urban air quality assessment and forecast: Coimbra case study

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Keywords: GIS, integrated modelling, air pollution, road traffic, emission modelling

Geographical Information Systems (GIS) is a valuable tool for spatial analysis and data processing that became a key component for integrated modelling in different research fields, particularly in environmental studies. One of the areas where GIS may provide a powerful framework is air quality assessment based on complex modelling approaches that involves spatial and temporal analysis of multiple data.

Despite a great effort to improve air quality and reduce emissions from the pollution sources, most European cities still have exceedances of legal limits presenting threats for public health. In this context, assessment and forecasting of air quality plays an important role in air quality management and provides valuable information for timing warnings of the population when air pollution levels are high. Additionally to air quality studies based on historical data, air quality forecast provides information on pollution levels over next days that requires implementation of integrated modelling system able to characterise pollution sources, dispersion conditions and long range transport of the pollution. Implementation of air quality forecast for urban areas is a big challenge due to complexity of urban morphology affecting pollution dispersion, complexity of road network and inhomogeneity of population distribution affecting spatial pattern of the emissions.

The main objective of the current research is developing of a GIS-based framework allowing to integrate several modelling tools for air quality forecast at urban scale (Figure 1). For this purpose, transportation modelling (VISUM), emission modelling (QTraffic) and air pollution dispersion modelling (ADMS-Roads) are linked providing the dataflow between modelling tools and allowing data processing and spatial analysis in a GIS environment.

Transportation modelling is the first step in the modelling chain. A macroscopic transportation model VISUM is used to estimate the number of vehicles and average vehicle speed for each road segment required for the emission quantification. The Traffic Emission and Energy Consumption Model (QTraffic) used for the emission quantification is developed as a plugin for QGIS (Dias et al, 2019) allowing estimation of emissions at urban scale with hourly resolution and at road segment level. The QTraffic model requires information on: road network (type, length, and gradient of each road), vehicle fleet composition (emission reduction technology, engine capacity, engine age, and fuel

type), and transport activity data for each road (traffic volume and average vehicle speed). The emission data are used as an input for air pollution dispersion model. An advanced Gaussian plume air dispersion model ADMS-Roads is implemented in the modelling framework. Additionally to the emissions from road traffic (line sources), residential combustion (area sources) is also considered due to important contribution to urban air pollution. For this purpose, detailed information on spatial distribution of population and dwellings is used in combination with the heating degree days obtained from the weather forecast.

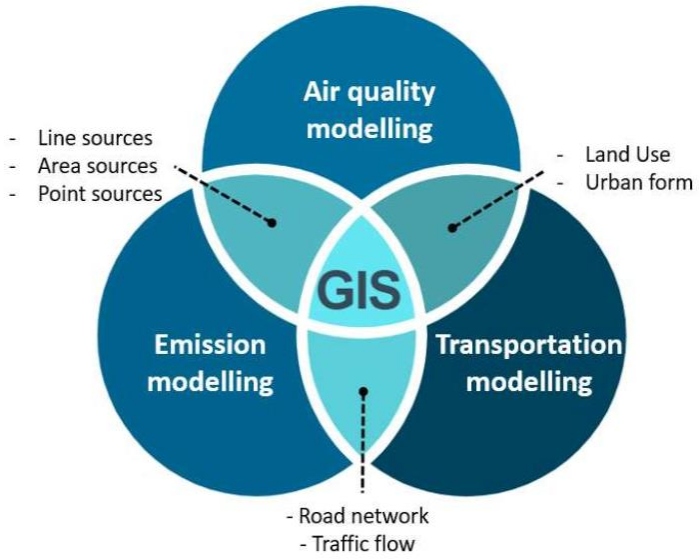

Figure 1. A GIS-based framework for integrated modelling of air pollution

The methodology is applied for air quality assessment and forecast in the urban area of Coimbra, Portugal, as a continuation of the previous research focused on aerosols only (Tchepel et al, 2020). The GIS is used for the processing and analysis of spatial data, including population distribution, road network, characterization of street canyons, surface roughness and topography, among others. Moreover, the modelling tools are linked to GIS through attribute tables providing dataflow within the defined framework. Hourly air quality data obtained for the study area are analysed in GIS allowing an overlay with other layers, such as population data, preparing a basis for the following research steps.

The results obtained from the integrated modelling approach provide information on spatial and temporal distribution of the pollutants allowing their analysis in terms of historical time series and in forecast regime, depending on the meteorological inputs. The methodology presented and applied in this study demonstrates an important contribution of GIS technology for air quality management.

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The Evolutive Meshed Compact City – A new framework for the 15mC in peripheral areas

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Keywords: 15-minute City, Suburbs, Networked Densification, Human-Centred Morphological Assessment

The 15mC concept is shaping new policies to improve quality of life and accomplish the energy and ecological transition of 21st-century cities. Through pedestrian-based proximity, inhabitants and city users should be able to walk to destinations catering for most of their daily needs (Moreno et al. 2021). Motorised traffic will be reduced, public space will find new patronage, retail and services will become viable at the proximity scale. The 15mC is partly based on previous planning models such as the Neighbourhood Unit (Perry 1929) and Transit-Oriented Development (Cervero et al. 2004), building on the same planning principles as the Compact City: density, proximity and mixed land use (EIT Urban Mobility 2022). Compact European urban cores already implemented 15mC solutions with some success, as in Paris and Barcelona.

The transition to a 15mC is much harder in post-war car-dependent outskirts and suburbs, where two main shortcomings of the model must be overcome. First, the 15mC is currently conceived as a selfcontained "walkable neighbourhood" overlooking that cities work as open networks, even more in metropolitan contexts. Networks influence the localisation of retail and services, which are only viable where human flows concentrate within a movement economy (Hillier 1996, Berghauser-Pont et al. 2019, Araldi 2020). Secondly, in the suburbs and outskirts the "walkable neighbourhood" is challenged by the lack of key morphological pre-conditions: density, proximity to services and public transport, mixed land use, quality of walking and cycling and attractive public spaces. These pre-conditions influence people's behaviours, through intermediate concepts like walkability, sense of place, ease of reach, liveliness (Gehl 2011, Dovey et al. 2017). The successful implementation of the 15mC in traditional urban cores could even exacerbate tensions between gentrifying metropolitan centres and left-behind outskirts and suburbs, undermining the needed unity of urban space with polarising outcomes on the socio-political arena.

This presentation will focus on a new proposal to overcome the limits of the 15mC in the suburban and peripheral areas. The starting point is the sheer impossibility (let alone the acceptability) of transforming our peripheries, made of modernist projects, residential subdivisions and activity areas, in traditional compact cities. Demographic scenarios in Europe foresee population stagnation and

ageing, with possible marginal growth in some metropolitan areas. The underlying demographic driver of massive densification of today's suburbs is simply not there. Therefore, densification should be canalised to streets where the impact is highest.

Crucially, urban peripheries and suburbs must be rethought from a human-centred point of view. The creation of compact nuclei by transit-oriented development seems at odds with the networked fabric of the pedestrian-centred 15mC. The human scale is considered only around relatively distant hubs connected by light railways. The continuity of the pedestrian flow is interrupted and opportunities for retail and services are limited to the hubs. Instead, we propose to distribute compact urban form as corridor development, along pre-existing main roads connected to wider-range mobility options and forming a meshed structure across the metropolitan area. This requires smart densification along these streets, which are further redesigned for pedestrians to become lively main streets offering a great variety of services, shops and even small-scale manufacturing. Experiments and guidelines for this transformation of public space are already available (Bertolini 2020, Ståhle et al. 2022, ADEME 2023).

Inside the meshes, the existing urban and suburban forms can be kept, with minor improvements to their internal connectivity for pedestrians and bicycles. The interaction of the meshed network of pedestrian-friendly, multifunctional and multimodal main streets, with green and blue networks is important to avoid decline of ecosystem services. The network of main streets, green/blue networks, long range transportation networks and the inside of the mesh, make up the Evolutive Meshed Compact City (EMC2). Many European urban outskirts already possess incipient networks of main streets, inherited from spontaneous growth, including pre-existing rural settlements. We need to assess the potential of these structures and propose guidelines to favour their evolution towards the EMC2.

We see the EMC2 model as a pragmatic 15mC solution for European urban outskirts and suburbs, recognizing constraints and opportunities offered by their networked nature. It also addresses the possible evolutions of the network of main streets over time: extension and retraction (as population increases or decreases), changing dynamics of usage during the day, the week or the year, acknowledging the polychronic nature of the 15mC (Moreno et al. 2021).

Research is being carried out on six European case studies in France, Italy, Sweden and Austria, to evaluate the potential of the EMC2 model and better specify it to adapt to local conditions. This contribution will thus present both the general specification of the EMC2 model and the research design which is presently employed to assess it with real-world data. Potential for the EMC2 model will first be evaluated using configurational analysis to identify the foreground network of main streets. Subsequently, morphological analysis of the streetscape and socio-functional analysis of its usage will confirm their present role as main streets. Micro-scale analysis of human usage and of urban interfaces with the public space will be used to assess the present functioning of the study areas and to identify the range of possible interventions towards a complete EMC2 model.

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Which (re)location of amenities, which transport speed, for which accessibility for the 15-Minute city?

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Keywords: 15-Minute City, Social Interaction Potential, density, travel speed, optimization methods

The 15-minute city model proposes a redesign of the urban system to provide access to daily needs or destinations (work, food, health, education, culture and leisure) within a 15-minute walk, cycle or public transport journey (Moreno, 2020). One of the main objectives is to reduce car dependency and it's side effects (noise and air pollution, space consumption, etc...). In the 15-minute city concept, cities can be seen as a collection of "small villages" as autonomous as possible, as proposed decades ago by the "new urbanism" movement, which advocates a so-called human scale for urbanism.

However, if the simplicity of the concept ensures its "success", it is accompanied by many weaknesses, as noted by Cremashi (2022) or Veltz (2021). For example, it is very unlikely that both members of a couple will be able to find a job within 15 minutes of their home. Another question is how to multiply the number of shops in order to ensure that they are easily accessible by bike or on foot, while at the same time ensuring their economic viability, given their reduced catchment area. More fundamentally, a city is not a collection of small villages. It's above all a possibility of choice, a potential: a social interaction potential (SIP) (Farber et al., 2014), i.e. the possibility of easily reaching numerous and diverse people; a potential of jobs, to ensure that the right person is in the right place, but also a potential of other amenities. These potentials allow the emergence of agglomeration economies by ensuring a wide labour market as well as the transmission of new ideas, thus promoting innovation and consequently economic growth and competitiveness (Prudhomme and Lee, 1999; Glaeser, 2011). Hence, accessibility lie at the heart of urban form development (Batty, 2013). The problem is that the high level of these potentials, of accessibility, which depend on density and transport speed (Handy and Niemeier, 1997), has been achieved for decades mainly thanks to the speed of the car. Cities are now built on temporal proximity (by car) rather than physical proximity, which generates car dependency (Dupuy, 1999). However, in order to move towards sustainability (at least a more sustainable mobility), it seems imperative to return to more physical proximity, to a functioning based more on short distances, which is the idea of the 15-minute city. The question, then, is how to return to an urban functioning based on short distances without abandoning the essence of cities, in particular a high level of SIP.

In this context, it is first necessary to :

- assess the current level of SIP (and job potential) for cities of different sizes, in order to calibrate what the level should be for the different potentials for the 15-minute city ?

- to know what changes are needed in terms of (re)location of population, jobs and other amenities, to reach these desired levels of potential with low (non-motorised) transport modes ?

The question here is therefore about the conditions of possibility of slow but accessible urban areas, the conditions of possibility of the 15-minute city, if we limit the travel time to 15 minutes in the calculation of potentials.

In 2020, we have developed a simulation model, OPTIDENS (Genre-Grandpierre et al., 2020), based on optimisation methods, which allows us to answer these questions. The basic ideas are:

- we collect in a square grid for a given city (the user chooses the resolution of the grid according to the data available) the current location of the population, workplaces (and/or shops, leisure facilities, etc.) and we compute the current network distances (in time and kilometres) between all the cells of the grid.

- We define a set of constraints (objectives) for the city we want to reach:

o level of population and jobs that can be reached in x minutes or in y kilometres by a given mode of transport from any location, or from specific locations (city center for example)

o maximum level of local density (in a given radius, e.g. 1000 metres) and local compactness of buildings, to avoid all resources being concentrated in one cell and as too high levels of density and compactness can be rejected by the people

Optidens then tries to solve the problem, that is to say to relocate resources (population, jobs, etc.) to satisfy the constraints, while finding the lowest travel speed to satisfy these constraints. Note, that the model offers the possibility to relocate all or a given percentage of the amenities, to produce more realistic simulations.

Optidens thus makes it possible to explore the feasibility of the 15-minute city (or other accessibility planning concepts):

- what is the lower transport speed required to achieve a given level of accessibility (to population, jobs, shops, etc.) and to respect other constraints (e.g. maximum local density), with or without allowing the relocation of facilities?

- In the case where relocation is not allowed, Opidens allows to calculate how many new amenities are needed and to find their location to satisfy the constraints (here we simulate the growth of cities rather than their replanning).

The main quality of Opidens is to consider simultaneously the location of amenities and the transport system (Urry, 2002), whose speed is not given.

In this paper, the model, which is already operational, will be used for cities of different sizes (so far only agglomerations up to 100000 inhabitants have been tested) and for different geographical contexts. The result will be a discussion, for different types of cities, on the transport speed and the shifts required to achieve different levels of accessibility to different amenities, such as those of the 15 minute city concept

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Class intervals for thematic mapping: implementations in R

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Keywords: Class intervals, Thematic mapping, R programming language

A useful discussion around a github issue raised about the R package **classInt** (https://github.com/r-spatial/classInt/issues/41) highlighted the desirability of deeper reflection about the role played by class intervals in contemporary thematic cartography. In Pebesma and Bivand (2023, https://r-spatial.org/book/08-Plotting.html#sec-classintervals), only a brief paragraph is devoted to this topic, despite the use of the classInt classIntervals() function in thematic mapping in the **sf**, **stars**, **tmap**, **mapsf**, and other R packages. Similarly, the Python module **mapclassify** is a helper in the background rather than being offered the attention it arguably deserves. While many users will be more familiar with graphical user interfaces for choosing how to construct class intervals, programmatic interfaces reveal a good deal of what is happening when choices are made.

At present, only Head/Tails breaks are discursively documented in **classInt** package documentation, with other styles briefly described (https://r-spatial.github.io/classInt/reference/classIntervals.html) in the details section of the help page. The **sf** package documentation provides figures showing consequences of different choices: https://r-spatial.github.io/sf/articles/sf5.html#class-intervals, supplemented for **stars** by https://r-spatial.github.io/stars/reference/plot.html. The mapsf has more detailed documentation, including https://riatelab.github.io/mapsf/articles/mapsf.html#choropleth-map and mapsf::mf_get_breaks() extending classInt::classIntervals() (https://riatelab.github.io/mapsf/reference/mf_get_breaks.html). A work-in-progress bookdown book is available at https://rcarto.github.io/cartographie_avec_r/. The tmap package is evolving towards version 4, which is to be documented in a work-in-progress bookdown book, with class intervals presented in this section: https://r-tmap.github.io/tmap-book/visual-variables.html#color-scale-styles. Earlier versions of tmap are covered by Tennekes (2018), and a section in the second edition of the bookdown book https://r.geocompx.org/adv-map.html#color-settings (Lovelace, Nowosad and Muenchow, 2019).

From Dickinson (1973, pp. 82-91) to Tyler (2010, pp. 160-170), via Slocum et al. (2005, pp. 250-270), similar lists of ways of creating class intervals have been presented. These authorities stress the need for the creator of the thematic map to consider the message(s) being conveyed. One of the choices facing us is whether to use class intervals or rather represent the variability of the variable being mapped by continuous variations in shading or colour (unclassed), or rather to choose class intervals. When class intervals are chosen, the legend constitutes a look-up table, from which the observer can readily read off which shading or colour corresponds to which value interval.

This presentation gives a brief review of the cartographic background for using class intervals, and describes the implementation of methods available in implementations in R, in particular in **classInt** and associated packages.

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A multivariate, weighted index of spatial autocorrelation

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Keywords: spatial autocorrelation, spatial weights, multivariate weighted configurations

In quantitative Geography, the paradigm and practice of spatial autocorrelation has arguably started to stabilize in the eighties, following the seminal works of Cliff and Ord (1973; 1981) and Anselin (1995), as well as the contributions of authors such as Getis, Tiefelsdorf, Griffith, Bivand, and many others: quantifying the spatial autocorrelation of a univariate numerical variable **x** measured on **n** regions requires to dispose of a **n** x **n** matrix **W** of spatial weights. The canonical measure of spatial autocorrelation is provided by Moran's *I*, proportional to the covariance between **x** and the lagged variable **Wx**, and whose first and second null moments under normal approximation depend upon **n** and **W** only, permitting to test its significance.

More often than not, regions are of unequal importance, as quantified by a vector **f** of regional relative weights. Also, regions are frequently characterized by multivariate profiles rather than univariate features **x**. The present proposition defines and investigates the properties of a multivariate, weighted index of spatial autocorrelation, denoted d , generalizing Moran's *I*, decomposable into local contributions as well as into spectral components (spatial filtering), and amenable to statistical testing.

Row-standardized spatial weights constitute transition matrices of a Markov chain (Bavaud, 1998). Calibrating **W** in such a way that it possesses **f** as stationary distribution decisively simplifies the formalism. In particular, the distinction between Moran and Geary indices becomes immaterial. Remarkably, the d autocorrelation index turns out to be proportional to the weighted version of the so-called *RV* index, measuring the similarity between two multivariate configurations, themselves expressed as **n** x **n** *kernels* (that is weighted scalar products). Moreover, the first four null moments of *RV* can be exactly computed by invariant orthogonal integration (Bavaud 2022). As a consequence, the Cornell-Fisher expansion of order four provides an accurate way of testing the significance of d beyond the usual second order expansion, taking into account its expected skewness and kurtosis.

More general *spatial kernels*, based upon regional distances, proximities, adjacencies or flows can also be considered, beyond the traditional specification based upon spatial weights. They yield alternative measures d of spatial autocorrelation, again amenable to local and spectral decompositions, and significance testing exact up to the fourth order.

Spatial autocorrelation of regional socio-economic features (five numerical variables) for the French departments, as well as political autocorrelation (categorical departmental votes for the ten candidates of the 2012 French presidential primary election), using varying spatial kernels, illustrate the proposal.

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Analyzing Swiss popular votes: spatial autocorrelation of political patterns

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Keywords: spatial autocorrelation, spatial pattern, political distances, multivariate weighted configurations

Background. Swiss popular votes constitute a fundamental aspect of political decision-making in Switzerland where citizens directly participate in the democratic process through a range of referendums and initiatives. During these votes, citizens cast their votes on various issues, ranging from social and economic policies to constitutional amendments. Switzerland has four official languages, namely German, French, Italian, and Romansh, and its territory is contrasted, neighboring areas being possibly disconnected by road due to geographical barriers. There is a wide variety of communes (municipalities) throughout the country that differ in terms of size, primary language, and level of urban development. This includes both densely populated urban areas and remote rural villages, providing various spatial contexts for studying Switzerland's geography and political behavior. Given the direct impact of these votes on Swiss politics, the objective is to analyze the spatial patterns of political behavior and factors that shape them.

Spatial autocorrelation is a commonly performed to analyze voting patterns. To conduct this analysis, a **n** times **p** dataset had been compiled, containing the proportion of 'yes' for each of the **p**=352 federal votes from 1971 to 2021 and for each of the **n**=2158 Swiss communes. In addition, relative weights **f** of the municipalities were set as proportional to the total number of voters in the period under consideration. Pairwise political distances between communes were computed using a set of standard measures (chi-squared, Euclidean proportions, standardized Euclidean proportions).

In addition, various spatial inter-communes distances were considered and extracted (geodesic, travel time, road distance, and adjacency-based distances), and were used to analyze the geographic and ideological patterns of political behavior.

Quantitative treatments. Both political and spatial configurations of Swiss communes were first transformed into weighted scalar products or kernels, whose spectral decomposition permits to extract factor coordinates for communes by means of a weighted multidimensional scaling, as illustrated in this contribution. Moreover, spatial and political kernels, can be compared to each other, yielding a d index of spatial autocorrelation, generalizing the well-known Moran's I, which turns out to be a close relative of the RV coefficient used in multivariate data analyses (Bavaud, 2022). These results were then mapped at the Swiss level.

Pre-treatments. The results of the 352 votes were obtained from the Swiss Federal Statistical Office (FSO) and aggregated into a single dataset. Votes with more than 1% missing data were removed, and the remaining missing data for isolated communes were interpolated using the raw average of adjacent communes. Adjacencies and distances between communes were calculated on geographic

data also provided by the FSO. Using the R package ‘tidygeocoder’, the representative point of each commune was determined based on the center of activity, rather than the geographical centroid, to ensure coherence of accessibility measures. Among various tools, the R package ‘sf’ was used to determine the Euclidean distance between communes and the R package ‘OpenTripPlanner’ was used to compute travel times and road distances. Both political and spatial configurations were finally each represented as a 2158 × 2158 dissimilarity matrix **D**, with the same vector of weights **f** based on the number of voters per commune. To visualize the spatial relationships between communes, weighted multidimensional scaling (MDS) was performed, using not only Euclidean distances, but also road distances and travel time as measures of spatial proximity. Finally, the generalized d index of spatial autocorrelation was computed and tested by considering its exact moments up to order four.

First findings. As a preliminary result, the mapping of the first two dimensions of the MDS analysis of the political data reveals distinct clusters of communes that correspond to the three main languages spoken in Switzerland, thus materializing the so-called ‘Röstigraben’, which is a cultural boundary between German-speaking and French-speaking parts of Switzerland, clearly visible on the factor map. Even without taking into consideration any spatial information, neighboring communes appear very close on the scatter plot, in accordance with the strong spatial autocorrelation exhibited by the political data. The first dimension can be interpreted as a measure of urbanization level, while the second dimension reflects the predominant spoken language in the region. Future work will consider, among other things, the local and spectral decomposition of various indices of spatial autocorrelation (such as δ), as well as alternative spatial kernels based on commuter flows.

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Child labour as a spatial phenomenon: A geographically weighted regression analysis of India

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Keywords: geographically weighted regression, child labour, open data, India

Despite its prevalence declining over recent decades, child labour is still an urgent global problem, with the ILO reporting that 160 million children were engaged in child labour as of 2020 (ILO & UNICEF, 2021). Worryingly, this number is an increase of 8.4 million on the previous estimate in 2016 – the first time an increase has been recorded in two decades. The ILO defines child labour according to the age of a child, the number of hours they work and the type of work they undertake.

While some research into child labour and its causes has framed the phenomenon as purely economic, such as Basu & Van's (1998) influential theoretical model, recent research has argued that other factors have a role in the likelihood of a child to be engaged with child labour. For example, in Asia, the gender of a child has commonly been found to influence the amount and type of child labour they engage with, with boys more likely to conduct paid work and girls more likely to undertake household chores (e.g. Webbink et al. (2015)). The education of a child's parents has also been found to have an effect on a child engaging in child labour (e.g. Kurosaki et al. (2006)). Furthermore, a systematic review of literature relating to the influence of social norms on child labour conducted by Abdullah et al. (2022) found that several various norms influenced child labour practices across different contexts.

Geographical location has also been found to be an indicator of child labour, with Krauss (2017) finding that "household wealth in Ghana appears to have weaker effects [on child labour than] geographic location". Despite this, little research into child labour has engaged with methods of spatial analysis. Prashad et al. (2021) used Moran's I statistics to find evidence of spatial autocorrelation of child labour in India and Gaku & Tsyawo (2021) developed an autoregressive model that found children being neighbours increased their chances of being engaged in child labour in Ghana. However, these are the only examples of research that use spatial methods and neither model child labour as a function of its explanatory variables and location.

Using India Census data from 2011 as a case study, this project seeks to address the gap in knowledge around the effect geographical space can have on child labour and its explanatory factors. Specifically, multi-scale geographically weighted regression (MGWR) is used to identify to what extent spatial non-stationarity is present in the relationships between child labour and related factors.

Geographically weighted regression (GWR) methods are used to analyse how the relationships between dependent and independent variables change across geographical space. The multi-scale adaptation of GWR removes the restriction that all independent variables operate on the same spatial scale, including allowing for variables to take a global scale, and so it is this more flexible approach that is used here. The use of (M)GWR methods is deemed to be especially suited to a country as large and culturally heterogeneous as India, where the reasons for a child engaging in child labour may vary significantly between areas.

While at the time of writing the project has not yet been completed, initial results show significant spatial autocorrelation in the residuals of a global regression model of child labour, suggesting the need for a model with a spatial focus. The Local Moran's I statistic for the residuals of the global model reveals several clusters where the model particularly under- and over-predicts the prevalence of child labour. Monte Carlo tests also suggest there is significant spatial non-stationarity between the prevalence of child labour and several independent variables, further motivating the application of GWR methods to this context.

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Uncovering Socio-economic Patterns via Principal Component Analysis and Clustering Algorithms: A Case Study of Southern Italy

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Keywords: Inland Areas, Principal Component Analysis, Spatial Analysis, Clustering, Open Data

The decline and marginalization of rural internal areas emerge as a central aspect of disparities and spatial injustice across the European Union. As a result, the implementation of strategies for adapting to or mitigating decline are fundamental components of European and national Policies.

The 2019 Political Guidelines for the European Commission underline the importance of rural areas: over 50% of the European population, in fact, reside in rural areas, and the rural landscapes are central elements of European identity, society, and economy. Consequently, preserving the landscape, cultural heritage, and socio-economic structures of rural areas, as well as investing in their development, are crucial objectives of European policies [1] . Similarly, the Italian strategy for internal areas underlines the centrality of policies aimed at improving social inclusion, development, and quality of life in these regions [2]. Internal areas account for 60% of the Italy's land surface, including 52% of municipalities and 22% of the population. Moreover, the Italian strategy for internal areas underlines the significance of the environmental and cultural resources of rural landscapes. European and National Institutions, thus consider depopulation, marginalization, locational disadvantages, and the decline of economic activities as the primary issues facing rural areas, and they are the target of cohesion policies [3–5].

Moreover, there is an increasing consensus on the necessity of targeted and coordinated strategies that integrate adaptation and mitigation efforts. This perspective recognizes rural decline as a multidimensional process resulting from a combination of social, economic, and spatial trends specific to each area [2, 6–9]. Therefore, the understanding of the unique aspects and local specificity of rural areas is a fundamental pre-condition for the development of effective policies. This study proposes a set of metrics based on validated open data sets. It utilizes Principal Component Analysis (PCA) and clustering functions to identify regions presenting distinct configurations of social and economic conditions [10]. The study focuses on four socio-economic conditions: i) depopulation tendencies; ii) levels and composition of income; iii) levels of education and iv) structure of the local economic structures.

The article describes the preliminary stages of a study conducted within the framework of the research project "Mitigo," which aims to investigate the conditions of marginality in the municipalities of the Basilicata Region. This study focuses on six Italian regions, including Abruzzo, Basilicata, Calabria, Campania, Molise, and Puglia, with municipalities as the unit of analysis. Its objective is to develop a set of metrics that can discern the social, economic, and spatial conditions unique to individual clusters of municipalities.

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Unveiling the Urban Divide: Novel Insights into Economic Segregation Using Fine-Grained Data

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Keywords: segregation, income inequality, spatial inequalities, spatial segregation indexes, register data

Urban economic segregation is on the rise. Despite its very pernicious effects on social cohesion and the equality of opportunities, cities throughout the world have generally recorded increasing spatial divisions between the rich and the poor during the recent decades (Musterd *et al*., 2017). This pattern parallels the expanding levels of economic inequality that characterizes many societies nowadays (OECD, 2015). As differences in wealth and income amplify in the contemporary era, so do the disparate concentration of poverty and affluence in distinct areas of our cities. Yet, this relationship is extremely intricate when empirically studied. In the first place, contextual and contingent factors of particular cities, such as local housing policies and historical concentrations of wealth, play a notable role (Musterd *et al*., 2017), blurring the association between observed economic inequality and economic segregation. Furthermore, some metropolitan areas exhibit unexpectedly increasing levels of income disparities coupled with decreasing urban segregation (Feitosa *et al*., 2021; Mohamed & Stanek, 2021). Some of this puzzle stems from the complicated longitudinal nature of the phenomenon: increases in economic inequality seem to be translated into space with a time lag (Musterd *et al*., 2017). Indeed, residential choices of households and individual are sticky and do not adjust instantly to new economic circumstances (moving is costly, people have emotional and social attachment to places, the housing market is not fluid everywhere, etc.). Intriguingly, the length of the delay in the materialisation of inequality into urban segregation is not identical in every metropolitan area, ranging from less than a decade to more than 20 years (Tammaru *et al*., 2020). Overall, levels of urban segregation vary considerably within and between countries for reasons not very well understood (Comandon & Veneri, 2021), but not necessarily linked to evolution of economic inequality.

The convoluted empirical state of the field is partly derived from the absence of good quality data on indicators of urban economic segregation. Cross-country comparisons are usually performed using on decennial census data, analysis of economic segregation often need to employ occupation and education as proxies of income and individual, geo-coded and longitudinal microdata are scarce. Consequently, empirical analyses on the relationship between economic inequality and urban segregation rely on sources of information that considerably limit the range of insights that can be extracted. In order to fill in this gap, this paper presents a novel and detailed characterization of

urban economic segregation in the Netherlands. Taking advantage of granular and nation-wide microdata from the Dutch Statistical Agency (CBS), levels of income segregation in the biggest metropolitan areas of the country are calculated for every year between 2003 and 2020, using the Spatial Information Theory Index (Reardon, 2004) on household data available within very disaggregated areal units (100m x 100m cells), together with other spatial and aspatial measurements of segregation.

Furthermore, this paper delves into the study of social and spatial heterogeneity of urban economic segregation. On the one hand, it distinguishes between the so-called segregation of affluence and segregation of poverty and evaluates their differential evolution. On the other hand, it examines the geographical patterns of segregation. As a result, the paper assesses the extent to which segregation is produced by large-scale or small-scale patterns of spatial disparities (e.g, between-cities vs. betweenblocks differences), using the Spatial Information Theory Index for every metropolitan area at two different radii (500m and 4000m) and their ratio as a measurement of macro-micro segregation. The paper finally estimates the relationship between economic inequality and segregation through a fixedeffects regression model, which also incorporates a time lag factor to evaluate the existence and length of the temporal delay between increases of economic inequality and surges of income segregation.

In sum, this paper aims to provide a more comprehensive empirical picture of urban economic segregation. Exploiting the detailed data of the Netherlands, it calculates the evolution of income inequality and income segregation disaggregated for every metropolitan area of the country during the last two decades. It also analyses the methodological, spatial and social heterogeneity of segregation, checking differences in estimates depending on place, social group and index employed. Finally, it introduces a time-lag element and checks whether income inequality and economic segregation are related with a temporal delay that has been overlooked by the literature.

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Exploring the Influence of the Contextual Poverty Measurement on the Neighbourhood Effect Estimation

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Keywords: Neighbourhood effect, Poverty measurements, Operationalisation biases, spatial inequalities, Income.

Since Wilson's 'The Truly Disadvantaged', the academic literature has been concerned with providing empirical evidence to support or challenge the perceived negative impact of contextual poverty on the economic situation of individuals. However, comparing the results from this substantial literature is challenging due to the different methodological approaches employed. For example, studies have operationalised the residential context at various scales, considered different urban regions over different periods of time and employed diverse econometric models.

In this regard, scholars have paid close attention to the effect of the areal units size (Manley, 2014; Petrović et al., 2022), the selection of econometric models (Galster et al., 2016), and time (Miltenburg & Van Der Meer, 2018) on the estimation of the contextual poverty effect. However, they have overlooked the role of the operationalisation of contextual deprivation. Some sparse empirical evidence suggests that the choice of a spatial inequality measure can influence the studies' outcomes (Andersson & Musterd, 2010; Andrews et al., 2004). For instance, the study of Andersson and Musterd (2010), focusing on three metropolitan areas of Sweden, revealed that the shares of low-income individuals and non-western migrants have a stronger impact on individual income than the proportion of unemployed, high-income, or non-western residents. However, these studies only accounted for a few contextual conditions, and their results might not be generalisable to other cases.

The study addresses this gap by investigating the variations in the contextual poverty effect originating from the operationalisation of poverty. Specifically, it examines four key parameters: the dimensions of poverty, the reference groups, the poverty threshold, and the summary statistics used in the aggregation of data. The paper answers the following question: **'To what extent does the selection of a poverty measurement impact the relationship between contextual poverty and the income of Dutch residents?'.**

This study uses longitudinal micro-data regarding all individuals between the age of 25 and 65 who resided in the Netherlands from 2011 to 2020. A systematic analysis is conducted to evaluate the effect of the operationalisation of contextual poverty in comparison to two wellknown factors for

impacting the contextual effect estimation, i.e., the residential context's size and the study's geographical scope. We provide a regression model for each modification made to the

operationalisation of these three dimensions while keeping all other factors constant. We employ within-individual fixed-effects models to minimise potential unobserved heterogeneity and omitted variables biases.

The results reveal that the choice of measure with which we operationalise contextual poverty significantly influences its estimated effect. For the analysis undertaken, the operationalisation of poverty appears to introduce more uncertainty than the residential context's scale or the geographical extent of the study. The highest variations in results are found across the socioeconomic dimensions of contextual poverty. However, we can notice that selecting a poverty line and a summary statistic also generates variations in the estimated effect of contextual poverty. Additionally, the scale of the residential context and the operationalisation of poverty appear to have an interaction effect on the study's outcome. While for some poverty indicators, the negative relationship between contextual poverty and the individual's income weakens when we increase the scale of residential context (from 100m-by-100m to 500m-by-500m), for others, this association remains constant.

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Temporal evolution of residential segregation patterns between-cities and within-cities: evidence from Dutch municipalities

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Keywords: Residential segregation, Regionalization, Temporal evolution

Introduction

Residential segregation is a major concern for public authorities, as it reflects and exacerbates undesirable inequalities across groups. To develop policies reducing residential segregation, authorities need to collect evidence from past experiences and analyze the underlying factors contributing to a change in segregation. This is usually done in the literature by assessing residential segregation in one or several cities before and after the implementation of a certain policy. However, the indicators used generally measure residential segregation at the city level, obscuring local changes within different regions of the city. The evolution of segregation could diverge at the subcity level: an overall decrease in segregation may hide an increase in segregation in particular regions of the city. For instance, targeted urban renewal in disadvantaged neighborhoods may induce gentrification and improve locally social mixing, while part of the minority group is displaced to other neighborhoods in which they are already over-represented, decreasing social mixing in these locations. Such a regional divergence, if substantial compared to the overall city evolution, may undermine the analysis of the policy. The existing literature lacks sufficient documentation on the extent to which city-level indicators accurately reflect the dynamics of segregation within cities. Our work aims to address this knowledge gap. To this end, we characterize residential segregation at the sub-city level for a large set of cities for two time periods, measure the temporal evolution, and compare within-cities variations to between-cities variations. We apply this approach to the evolution of residential segregation of individuals with a non-western migration background in all Dutch municipalities between 2015 and 2020.

Method

Our method to assess residential segregation at the sub-city level is inspired by Chodrow's regionalization method (Chodrow, 2017). For each city in our dataset, we aggregate spatial units to form regions that are homogeneous in terms of demographics. The aggregation process stops when the heterogeneity of the regions exceeds a certain threshold tuned empirically. We label these regions and track their evolution between 2015 and 2020 along three dimensions: the extent to which the group of interest is over-represented in the region, the size of the region, and the centrality of the region; hereafter called intensity, scale, and centrality. Segregation intensity is the share of the group

of interest in the region population minus the city average, expressed in percentage points. The scale is the region's total population relative to the city population. The centrality of the region is the region's average distance to the city center, relative to the city's average distance from its center. Finally, we compare the within-cities sum-of-squares to the between-cities sum-of-squares of the indicators' temporal evolution in all regions. By examining the proportion of total variance attributed to between-cities and within-cities variations, we can investigate the extent to which city-level indicators capture the evolution of residential segregation patterns. The larger is the within-cities sum-of-squares compared to the between-cities sum-of-squares, the more the evolution of segregation diverges within cities.

Results

In Dutch municipalities, we identify around 8 regions per city on average, of which 3 are overrepresenting the group of interest. We observe a marginal increase in intensity of 0.01 percentage points (pp), a decrease in average distance to the city center of 0.04 pp, and a relative scale increase of 0.8 pp. The overall increase in the relative scale indicator is the only statistically significant evolution observed (at the 0.05 level). Considerable variations emerge when comparing cities. For instance, in Rotterdam, intensity decreased by 2 pp, scale decreased by 0.5 pp, and centrality increased by 2 pp. Conversely, in Leeuwarden, intensity increased by 0.7 pp, scale increased by 2 pp, and centrality decreased by 2 pp. Finally, our sum-of-squares analysis reveals that the between-cities variance accounts for 78% of total variance for the evolution of scale, 44% for the evolution of intensity, and 25% for the evolution of centrality.

Discussion

Our analysis reveals not only strong differences in the evolution of residential segregation between cities but also notable divergences in the evolution of segregation within cities. While the evolution of scale appears to be quite consistent within cities, we observe more significant variations in the changes of intensity and centrality within cities compared to between cities. These findings emphasize the nuanced dynamics of residential segregation, indicating that the changes in segregation patterns can differ substantially even within the same city. It underscores the importance of considering local variations when formulating policies to address residential segregation.

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Mapping spatio-racial pattern in the United States at different scales

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In demographic studies, spatio-racial pattern is commonly summarized using the concepts of racial residential segregation or diversity. Racial diversity describes the level of the inhomogeneity of population, whereas residential segregation is considered as a spatial concept that identifies how people of different ethnoracial groups are spatially redistributed within the analyzed area. However, the level of segregation is commonly assessed using segregation indices (Reardon and Firebaugh, 2002) that are based on aggregated census data presented in census tables. The results are also provided in tabular form and do not offer any insights about the spatio-racial distribution within an analyzed area. The format of available data imposes many limitations for assessing segregation, such as (1) mostly aspatial assessment of segregation, (2) the inability to define the geographical scale of segregation as the census units even at the same level of aggregation differ in terms of size, and (3) an inability to connect the numerical assessment of segregation given by the indices with the visualization how racial groups are spatially distributed within an analyzed area. Moreover, the indices are usually calculated for the set of the largest metropolitan areas and mainly are used to rank cities based on their level of segregation. Therefore, they do not provide broader information about the spatio-racial pattern of racial segregation and diversity in the United States.

Over the years, different approaches were introduced to overcome the aforementioned limitations, including spatial indices (Yao et al, 2019) and multiscale segregation measures. However, to the best of our knowledge, the only approach that allows for quantification and visualization of spatio-racial pattern for the user-defined area at different spatial scales is a racial landscape method (Dmowska et al, 2020).

The RL method introduces a consistent framework for visualization and quantification of the spatial distribution of racial subpopulations in arbitrary, user-defined regions by using highresolution race-specific grids instead of census subdivisions. The race-specific grid means that the region is divided into small (smaller than the smallest census aggregation area) cells that are racially homogeneous. A cell has two attributes, race category and its population density. Such a grid visualizes racial distribution, but at the same time provides also geospatial data to calculate two metrics derived from the Information Theory – entropy, and mutual information. Entropy is a measure of racial diversity, and mutual information quantifies racial segregation. Both metrics can be calculated directly from high resolution grids for any user-defined region. The region can be also divided into local square areas (much smaller than the region but much larger than the cell), and the metrics can be calculated

for each local square. This enables mapping spatial distribution of racial segregation and diversity on the user-defined local scale.

The RL method was implemented in the R package raceland that provides a complete computational framework and allows to perform calculations for the area of the size of a single city (https://cran.r-project.org/web/packages/raceland/). Here, using the R computational environment and the raceland package we extended the framework to allow the calculation for the larger areas, such as the entire state or the entire conterminous United States. We present maps of spatial distribution of a multiracial population, racial diversity, and racial segregation for the entire conterminous United States at geographical scales of 1.5 km, 3 km, 6 km, 12 km, and 36 km.

The examples of the three different maps that show spatio-racial pattern in 2020 are shown on the SocScape project website (http://www.socscape.edu.pl/index.php?id=racial-landscapes). The examples include (1) the racial map, where the color indicates the racial category and the shade corresponds to the population density; (2) the spatial distribution of racial diversity on the scale of 1.5km, 6km, 24km; (3) racial segregation calculated for 3 different spatial scales (1.5km, 6 km, and 24 km). These maps presented in this work provide more meaningful insights into the spatial pattern not only in large US cities but also in suburban and rural areas.

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Similarity between Residential Areas and Visited Locations: Proportion of Foreign-Born Residents

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Keywords: Human mobility, Segregation, Diversity, Activity Spaces

Traditionally, urban segregation has been measured by examining the overrepresentation of certain groups in specific areas of a city. This approach has highlighted the significant impact that residential segregation can have on individuals' life opportunities. However, it remains unclear whether one's place of residence is an accurate representation of the overall environment encountered during daily activities. This is particularly relevant in modern cities where diverse groups may live in close proximity to each other, yet still remain socially isolated. Daily mobility presents an opportunity for individuals to interact with residents from other neighbourhoods, potentially reducing the negative effects of residential segregation. However, if activity spaces have similar demographic composition to residential areas, segregation can be reinforced, as individuals may encounter the same groups in both settings.

Thus, understanding the disparities between residential areas and resident's overall activity spaces is crucial. However, research examining the direct role of mobility in promoting social mixing between ethnically diverse groups has produced contradictory results (Jones and Pebley, 2014; Tan, Kwan and Chen, 2020; Hedman *et al.*, 2021). This highlights the need for further investigation into the relationship between residential and activity space segregation. Additionally, when exploring potential factors to explain these findings, such as the typical distance travelled, the results are also inconsistent. For instance, Hedman *et al.* (2021) found that the level of experienced segregation was higher for groups travelling longer distances. However, Järv *et al.* (2015) associated the limited integration of Russian-speaking groups with their more concentrated spatial mobility.

Therefore, **the objective of this study is to extend our existing understanding of the dissimilarities between residential and activity spaces by investigating the variations in the proportion of foreign-born residents in New Zealand in both these domains**. This study drew upon two distinct datasets. The first dataset was acquired from Stats NZ, the national statistics agency, and describes the demographic characteristics of New Zealand. More specifically, this dataset provides insight into the proportion of foreign-born residents at the mesh-block level, which denotes geographical subdivisions that vary in size across the country. The second dataset was collected by a third-party mobile app location vendor and covers the entire country registered over a six-month period from September 2019 to February 2020 from 1,544,792 users with the accuracy below 100 m. Initially, mobile app data was utilized to identify the most likely home locations of users and infer their entire activity space. Subsequently, this information was combined with the

demographic data related to the mesh-block where the home location was situated. Similarly, visited locations were extracted and merged with the demographic data at the mesh-block level. This allowed to build a comparative analysis of the demographic composition of the home mesh-block with that of the visited mesh-block. By aggregating this information across multiple users residing in the same mesh-block, we were able to draw comparisons between the demographic composition of the home mesh-block and the mesh-blocks that were visited.

Our study reveals that the proportion of foreign-born residents in visited locations accurately mirrors the corresponding demographic characteristic in users' residential areas. Specifically, we find that individuals residing in areas with a high proportion of foreign-born residents tend to visit places with a similar demographic composition, and the same holds true for individuals living in areas with a low proportion of foreign-born residents. This contradicts the notion that mobility inevitably leads to increased inter-group mixing. Furthermore, this research investigates the role of intra-urban mobility characteristics in understanding the observed patterns. To this end, we examine various factors, including typical travel distances, proximity of areas, and urban area types, to elucidate their contribution to our primary outcomes.

To evaluate the influence of typical travel distances on our findings, we examine the relationship between the difference in the proportion of foreign-born residents at home and visited locations and the typical distance travelled. Our analysis indicates little correlation between these two factors. Subsequently, we investigate the role of mobility characteristics and proximity of areas by comparing the observed data with a "random walk" model. This model assumes that users have constant mobility characteristics, and the visited locations are randomly shuffled, reflecting how individuals would move if they had the same mobility characteristics but chose their locations randomly. Our comparison reveals that the observed similarity between residential and visited areas is higher than that in the random model. Specifically, individuals tend to make location choices that align with the percentage of foreign-born residents in their home mesh block, rather than the average of the directly surrounding area of their home. This suggests that users exhibit a preference for familiar demographics when selecting destinations for their visits

In our final analysis, we contextualize our findings with respect to varying types of urban areas and observe that the strongest similarity between individuals' residential and visited areas is observed in larger urban areas. This suggests that the process of deliberately selecting destinations that exhibit similarities to one's home area is more pronounced in such contexts.

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Abstracts of Parallel Sessions 4

Energy Transition in the Portuguese context - Competing versus Sustainability Outlooks

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Keywords: GIS, multi-criteria analysis, solar energy, land-use planning, sustainability assessment

The post-pandemic economic recovery, the increasingly ambitious society decarbonization targets and the uncertainty about the energy crisis in the context of the war in Europe are accelerating the energy transition. Renewable energy production (REP) plays a crucial role in sustainable development, but its spatial aspects and complex interactions with energy systems, land management, and sustainability, present significant challenges. These challenges are further intensified by the low land-use efficiency of renewable sources (Lovering *et al.*, 2022) and the potential emergence of conflicts and externalities (Scheidel and Sorman, 2012). Maximizing energy-environment-economy trade-offs in energy infrastructure deployment is essential for achieving sustainability (Moore-O'Leary *et al.*, 2017). However, determining the compatibility and optimal locations for REP remains debatable because the sustainability conceptualization (Waas *et al.*, 2014) is dependent on different outlooks and spatial constraints (Delafield *et al.*, 2023; Hernandez *et al.*, 2019; Geoghegan and O'Donoghue, 2023). The anticipated growth of REP in Portugal, particularly in solar energy (SolarPower Europe, 2021), is expected to lead to a substantial increase in the area occupied by power plants. This growth raises concerns since solar power facilities in the country have caused deforestation and the occupation of agricultural land (Alves *et al.*, 2023). Without an effective monitoring and assessment strategy for finding optimal locations for REP, the allocation of land could conflict with a sustainable use of the territory. This study develops a proposal of model to identify optimal locations for a sustainable energy transition considering the following key assumptions: (i) prioritizing sites with the highest production potential, (ii) minimizing land transformation, (iii) protecting relevant land uses and natural areas, and (iv) avoiding spatial concentration. A spatial index is proposed using multi-criteria decision analysis in geographic information systems (GIS), which represents the Portuguese continental territory according to its degree of sustainability for the energy transition. The results highlight that the siting of solar power plants has primarily prioritized production potential, emphasizing the economic dimension of

exploitation, while giving relatively less consideration to the environmental implications of land transformation. This insight suggests the (un)integration of energy planning and land use, calling into question the implications of current decision-making processes for land allocation to renewable energy projects and recommending more comprehensive approaches to promote optimal decisions to assist planners for sustainable energy development.

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Urban growth scenarios and urban climate modelling to support heat action measures in Indian cities

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Keywords: urban growth, climate change, urban heat island, urban green

Climate change will lead to extreme heat waves, especially in warm, humid regions such as the Indian subcontinent, where severe health risks for the vulnerable population are expected (Im, Pal and Eltahir, 2017). Simultaneously, by 2050 the world's urban population is expected to reach 6.7 billion, constituting 70% of the population. Africa and Asia will account for 90% of this increase in population. In India alone the urban population is expected to double by 2050, reaching approximately 800 million. Because of the urban heat island effect, the impact of climate change in terms of heat stress is even intensified in cities. Local and national governments should thus be informed of the present and future risks of this urban climate for their population to engage in sustainable and climate-resilient urbanisation based on reliable and scientifically valid data.

In the CHARISMA project, supported through international climate financing from the Flemish Government, we have combined urban growth modelling, urban climate modelling and vector-borne disease risk mapping in selected Indian cities. This presentation will focus on different policy scenarios of urban growth in 5 Indian cities (Lucknow, Ahmedabad, Guwahati, Bangalore and Ayodhya) towards 2050 and ensuing impact in terms of heat-stress. The novelty of the work lies in the derivation and use of land-use data pertinent to climate analyses, for urban growth simulations.

Urban growth in all cities was modelled with the GeoDynamiX model, a cellular automata (CA) land-use change model (Crols, 2017). Instead of using traditional land-use maps we have used remote sensing data to develop Local Climate Zone (LCZ) maps, which can be directly used as input by UrbClim, an urban climate model (De Ridder, Lauwaet and Maiheu, 2015) yielding data at typically 100-200 m resolution. LCZ maps were firstly defined by the "World Urban Database and Access Portal Tools" (WUDAPT) project (Stewart and Oke, 2012). In a LCZ map each category contains information on climate-relevant surface properties such as the density and height of the built-up land. Confusion between the different categories is an important limitation of this approach, yet maps were improved through combination with urban masks and open GIS data. LCZ maps were developed at 30 m resolution for two years (2011 and 2021), generalised to 100 m and subsequently used to calibrate the GeoDynamiX model in a semi-automated calibration with a CMA-ES algorithm.

Next to a business-as-usual (BAU) simulation driven by population growth towards 2050, we have also run a growth-as-usual (GAU) simulation driven by the current growth of the urban extent in the

calibration period. Finally, for most cities we have compared these to a run in which the location of growth is constrained within areas determined by a Masterplan of the local government. The resulting future LCZ maps were used as input to simulate the future urban climate at a resolution of 200 m.

There are clear differences between more compact or more disperse growth patterns in the 5 cities, but while the population is still strongly increasing, all cities might expand fast during the next decades. Fighting urban sprawl is not the only challenge in India, but also making sure that there are enough climate adaptation measures in dense neighbourhoods. The urban heat island effect will clearly be stronger in such areas and therefore we have calculated urban and demographic statistics as well as the availability (per person) and accessibility of green areas for all wards in Lucknow and Guwahati, the pilot cities of the project. The spatially explicit data generated in the current work addresses some of the current shortcomings of Heat Action Plans (Pillai and Dala, 2023) in terms of spatial resolution and timescale, enabling cities to develop more effective and robust adaptation actions, inform policy decisions and alter their Heat Action Plans accordingly.

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Agent-Based Modeling for Smart Transportation Practice

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Keywords: Agent-Based Modelling, Transportation Algorithms, Public Transport, Accessibility

Urban GIS databases are on the constant rise and today we possess all the data necessary for the representation of urban transportation infrastructure and travel demand at their inherent resolution of buildings, car parking facilities, and public transport (PT) lines and stops. This includes high-quality data on the road network, buildings' location, height and usage, on-street and off-street parking facilities, parking prices, static GTFS database of the PT network, and real-time data on traffic speed and PT delays. We also know transportation demand in the form of the Origin-Destination matrices at high resolution in space and in time, generated based on mobile phone data, travel behavior surveys, and PT smartcard transactions.

Unprecedented data availability makes policymakers and city managers eager to use them in urban transportation planning. Yet the analysis of the big data on the current state of the transportation system, however sophisticated it may be, is just a first step. To anticipate the effects of the infrastructure and policy changes, one needs to take a step toward and assess possible urban transportation futures. This is where dynamic Agent-Based Modeling (ABM) comes to the front. ABM combines data and knowledge on (1) urban infrastructure and (2) the behavior of the city's residents, visitors, and institutions and merges these two sources of knowledge at a high spatial and temporal resolution to assess modal choice, traffic congestion, trips travel time, and convenience during and after the period of plan implementation. We need these data-driven dynamic ABM to estimate the consequences of a complex interplay between the proposed policies and infrastructure changes and travelers' willingness to accept them.

We unleash the pros and cons of various alternatives for the future strategic bus network with a datadriven agent-based model of the Tel Aviv Metropolitan area with its 4.5M population and 1M external travelers entering the area daily. The model was established within the MATSim simulation environment (Horni et al, 2016) and calibrated and validated based on the data on Tel-Aviv Metropolitan traffic. The alternatives, each comprising tens of strategic bus lines, were proposed by transportation planners based on different design principles and differ in the number of bus lines, lines' routes, and length.

The model provided explicit replies to the planners' major inquiry: Given the financial and structural limitations, which of numerous possible alternative network designs will, simultaneously, be most attractive for travelers, escalate accessibility, and decrease congestion? Importantly, the model enables disaggregating this inquiry in space and in time and estimating network alternatives'

advantages and disadvantages over metropolitan space during the long period of the network implementation.

The study of the proposed network designs, compared by the provided accessibility, attractiveness for travelers, and the possibility of substituting the existing PT lines with the new ones have demonstrated that according to the average values of the criteria, *all* network alternatives will provide, when fully implemented, very high level of service. The differences between the alternatives are in the spatial pattern of the PT service and, importantly, in the level of service during the period of the network establishment. The differences between the network alternatives, regarding different regions of the city, or socio-economic groups, cannot be caught at the level of averages. Transport accessibility and the attractiveness of the PT for private car users are mainly defined by the congestion pattern that, in a loop, is defined by the PT network attractiveness. As a result, an "optimal" PT network that improves accessibility everywhere and is attractive to everyone is impossible, while the variety of *suboptimal* network solutions is vast. We thus conclude that the process of the plan implementation is the key to its success and present model results that confirm this declaration.

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Monitoring land take in the Netherlands: an ex-ante evaluation

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Keywords: No net land take, land use scanner, EU, ex-ante evaluation, scenarios

A legislative proposal from the European Commission for a Soil Health Law in 2023 is expected to contain a target of achieving No Net Land Take (NNLT) by 2050 (European Commission, 2011). To comply with this objective, a uniform land use monitoring system is deemed crucial. Some member states, such as Italy and France, have already set up monitoring and reporting systems to this end. The Netherlands is still exploring which options are feasible and desirable, as many issues are still unresolved (Evers, Van Bemmel and Spoon, 2023). These include: a lack of conceptual clarity on definitions (Marquard et al., 2020), land-use classification issues, questions on how to deal with green urban areas, compensation/negative land take (the 'net' aspect), and land cover (soil sealing) versus functional (land use) approaches. This paper discusses how these issues became manifest during an ex-ante evaluation of NNLT by the Netherlands Environmental Assessment Agency (PBL).

As a basis for the analysis, the PBL drew on its work in the ESPON SUPER-project (Sustainable Urbanization and land use Practices in European Regions) (ESPON, 2020) that had created urbanization scenarios at the European level. It used the Joint Research Centre's LUISETTA model to estimate land use in 2050 in three scenarios: Compact, Polycentric, and Diffuse. This model proved to be inadequate for measuring future land take because it cannot vary urban land use densities in a straightforward manner, making it difficult to incorporate densification strategies in the scenarios; it is more useful for illustrating future differences in morphology than land take.

Domestic scenarios drawn up in the PBL's biannual 2023 Spatial Outlook (SO23) (PBL, 2023) proved more useful in this regard. The study combines four policy scenarios with two context scenarios (high vs. low socio-economic growth), resulting in 8 scenarios in total. The four policy scenarios, loosely translated from Dutch, were the following:

• Global enterprise: big corporations take the lead

• Cyberworld: where digitalization rules supreme

• Green land: government takes the lead towards sustainability

• Regionally rooted: communities take the lead

The Land Use Scanner Model (Koomen, Hilferink and Borsboom-van Beurden, 2011) was used to simulate land use in 2050. The model allocates functions (e.g. residential, commercial, utilities) according to the availability and suitability of locations and uses sectoral land-use demand derived from other sources/models as input. Unlike the aforementioned LUISETTA model, Land Use Scanner allows for building in existing urban areas and at varying densities. The scenarios produce large differences regarding land take (about a factor four between the two extremes). The scenario 'GreenLand–low pressure' has the least land take, about 16,000 hectares, as new buildings are built at high densities around infrastructural nodes. The scenario 'Regionally Rooted-high pressure', on the other hand, results in the most land take of the eight scenarios (about 66,000 hectares).

There are some shortcomings that still need to be overcome. For example, the model does not take processes of land re-naturalization into account, so the 'net' aspect of the NNLT target is not sufficiently accounted for. An expanded definition of 'urban' in the Corine 2018 base year map (i.e. including CLC classes 'Green urban areas', 'Sport and leisure facilities' and some less occurring classes) results in less land take overall: 14,000 ha for 'GreenLand–low pressure' and 61,000 ha for 'Regional Rooted-high pressure'. Potential re-naturalization or restoration of developed land within urban area was estimated to be in the 13,000- 49,000 ha range, indicating a potential to reach the EU target within the scenarios. To determine the rate of net land use change more precisely the Land Use Scanner could be expanded with more timesteps, although this requires more information about sectoral claims. Finally, the land-use classes of national datasets were not completely compatible with the CLC nomenclature, which will complicate a monitoring system using national data. In both the SUPER and SO project, this was dealt with via aggregation and disaggregation, but it can create scope for misinterpretation or even manipulation.

In conclusion, while not designed to explore the widest plausible range of land take, the eight SO23 scenarios show considerable variation in this respect. In this sense, they can be useful for the land take debate in the Netherlands. If the European Commission were to demand that member states produce plausible storylines for reducing land take, the technical specifications of the current models will need to be improved. It is important to bear in mind that land take in the next 10 years in the Netherlands is relatively certain, given reasonably accurate information about plans in the pipeline. In this sense, the variable scenario timeline is only about 20 years, which decreases the scope for plausible differentiation. This is most likely the case in other member states as well. This not only has implications for modelling, but for achieving the NNLT target as well.

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Geography of musical listening: variations in scale and time

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Keywords: musical streaming platform, big data, multiscalar, cultural differentiation

The geography of music, in contrast to sociology of music, is still a very underdeveloped research area in social sciences, despite attempts in different times and places to propose possible lines of research in this field (Kong, 1995; Connell and Gibson, 2004).

Music listening on the one hand and music production on the other are very geographically marked phenomena. This explains that scholars specialised in Social Network Analysis and/or in the diffusion of innovation have sometimes been interested in the phenomenon of local music scenes (Crossley, 2015; Klement and Strambach, 2019). In this proposal, we start from the postulate that music listening can be a good proxy of socio-spatial differentiations and we intend to verify this postulate by varying the geographical scales of our analysis. Secondly, we show that on a bounded territory (Reunion island, a French-oversea territory within the Indian Ocean), small scale differences in music listening practices can help to differentiate between cultural local peculiarities. Finally, we consider the moments of listening to music vary according to the daily rhythms of life, which, in our opinion, means that traces of musical listening (whatever the content that is listened to) can also serve as a proxy for the study of the rhythms of life of populations in space and time.

The digital traces available, for example via the music listening platforms YouTube (The Pudding and Daniel, 2018), Spotify (Way, Garcia-Gathright and Cramer, 2020) or Deezer (Louail and Barthelemy, 2017; Cura, 2021; Cura *et al.*, 2022), can be precisely located thanks to the georeferencing of users' IP addresses, thus making it a great source of Big spatial Data that could be categorized as “Interaction data” in Kitchin's (2014) typology of big data sources. However, there are three obstacles that need to be overcome regarding the use of this type of data: firstly, the access and the use of these data for research purposes since these data are owned by private companies; secondly, the size of these data, since the billions of streams generated daily does not make it straightforward to store and process them on a personal microcomputer; thirdly, the degree of precision of the geo-referencing of IP addresses which is an object of research in its own right and poses extremely specific questions linked to the unequal geographical coverage of telephone operators and Internet access providers (Cura, 2021; Callejo *et al.*, 2022).

In this article, we use Deezer data to analyse the distribution of music listening traces, at several aggregation scales (MAUP-related), as a proxy of cultural territories.

In a first step, we are interested in the distribution of the top 10,000 listened artists at several spatial aggregation levels: country and region (using the NUTS-2 level) at the European scale. Moving from one spatial level to another allows us to highlight phenomena of cross-border proximity between European regions that would not be possible to identify by considering only the national level. This does furthermore fits the data peculiarities, as IP-adresses geolocation have widely heterogeneous precision, and thus need to be aggregated on varying-size spatial units.

In a second step, we propose to reduce the focus on an insular territory - the island of Réunion – which has the particularity of being both French and located in the southern hemisphere. Narrowing the focus on this restrained territory allows us to examine the distribution of music listening at the finer level of the urban area, while controlling the effects of the imprecision of the geocoding of IP addresses and working on a smaller sample size. Working with a smaller amount of data appears to be ideal at the exploratory stage in which our research is still at.

From a thematic point of view, Reunion Island offers stimulating questions from a cultural point of view because as an isolated and insular territory, the island has its own musical history. A musical genre was born there and was recognized as intangible cultural heritage of humanity in 2009: the maloya. At the same time, the island is a French territory, connected to the French and transnational music industry. As such, we can place the results obtained in our research within the framework of the geography of islands, which considers the question of island music as a research question in its own right (Hayward and Konishi, 2017).

In conclusion, we propose an analysis of listening rhythms by looking at the hourly distribution of listening. Applied on a global scale, this analysis allows us to highlight different rhythms by country and region of the world. This raises the question of the specificity of music listening data compared to other types of digital traces to study the rhythms of human activity.

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On the psychrometric constraints in hybrid modelling of temperature and humidity

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Keywords: psychrometry, machine learning, hybrid model, temperature model, humidity model

Background: Studies addressing health impacts of environmental stressors, such as temperature extremes and air pollution, require high-resolution ground level meteorological data (e.g., air temperature, humidity, particulate matters). Conventional observational networks often fail to provide such detailed information. In the last years, machine learning (ML)-based models of various complexity have been proposed to interpolate discrete ground-truth measurements spatio-temporally. Despite their stunning performance, ML-based models have faced criticism for their lack of transparency and accountability for the underlying physical processes. ML-based models applied to independently predict meteorological parameters at the same location can yield incongruent outcomes that violate the laws of physics, e.g., with a wet-bulb temperature exceeding the dry-bulb temperature, or a relative humidity higher than 100%.

Aims: In this study, we present a multi-stage ML-based hybrid approach to predict temperature and humidity variables at high spatio-temporal resolution. We use high-level knowledge of psychrometry (psychrometric constraints) to regularize and optimize the model outcomes, ensuring the proper consideration of physical laws.

Methodology: Our approach involves using a previously described ML-based hybrid model (Zhou et al., 2020) to independently predict dry-bulb temperature (Ta), wet-bulb temperature (Tw), dew-point temperature (Td), humidity ratio (W), and relative humidity (RH) hourly at a 1 x 1 km2 resolution. The model incorporates a collection of geospatial and climate reanalysis data (ERA5-land) originally available or interpolated to the same resolution, as well as observations from weather stations. We then cross-check the internal consistency of predicted variables from individual ML-based models based on two criteria: 1) adherence to the laws of physics and 2) a high degree of psychrometric conformance within a certain tolerance range. Incompatible predictions are progressively optimized

until the criteria are satisfied or the maximum number of iterations is reached. The performance of each stage is estimated using cross-validation with spatial blocking.

Results: Applying the proposed model to Israel for the period 2004-2020, we find that it demonstrates overall good cross-validated performance in imputing all target variables at each stage. For example, the root mean square error (RMSE) of Ta and RH are approximately 1.1 ˚C and 8 %, respectively, while the corresponding R2 are 0.97 and 0.87. The optimization stage based on psychrometric constraints converges normally within 20 iterations and improves the original predictions, particularly for humidity measures. The generated high-resolution hourly data of ambient air temperature and humidity measures aid in minimizing exposure misclassification in epidemiological studies and provide better estimates of the health impacts of compound heat-humidity extremes on human health.

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Spatial Dimension of COVID-19. An Exploratory Approach to Investigate Spatiotemporal Profiles of Epidemiological Trajectories in Japan

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Keywords: Clustering, COVID-19, Cartogram, Spatiotemporal data, Japan

The COVID-19 pandemic constituted an exogenous shock with multidimensional effects on geographical systems. The heterogeneity of economic, social, political contexts, and phases of the disease's spread extends to the heterogeneity of epidemiological data. Studies dealing with the socioeconomic and spatial factors of disease diffusion do not provide clear and unambiguous conclusions. Furthermore, with the overrepresentation of the United States of America in case studies, a confirmatory bias is created in the hypotheses and conclusions of studies examining other comparable countries (OECD) (Brodeur et al., 2021; Ladmiral, 2021). However, it can be questioned whether different systems of social protection and public health similarly expose or protect different segments of populations. Japan, along with Sweden, is the only OECD country that did not impose strict coercive measures (lockdown) in controlling the COVID-19 epidemic. Additionally, the Japanese political system, characterized by strong decentralization of legislative and executive powers, has led to significant variations in the definition and implementation of control measures across the country's 47 prefectures. The case of Japan is interesting in many ways but remains insufficiently studied.

Factors influencing the spread of COVID-19 in Japan have so far been analysed using epidemiological data aggregated at the administrative level of prefectures (都道府県 – Todofuken) (Yoshikawa and Kawachi, 2021; Kondo, 2021). However, in Japan or elsewhere, such level of aggregation does not allow for a precise study of the disease's propagation process. The significant loss of information due to aggregation at this scale, coupled with the small sample size resulting from it, reduces the power of analysis methods and the reliability of the results. Moreover, the treatment of the spatial dimension in relation to the COVID-19 epidemic is primarily descriptive in the academic literature. Spatial analysis often focuses on the identification of hot and cold spots (Yabe et al., 2022), clustering of contaminated areas (Andrews et al., 2021), or the identification of spatial autocorrelations in affected/spared zones (Elarde et al., 2021). Hence, the main objective of this research is to identify epidemic trajectories during different "waves" of COVID-19 and construct a typology of socio-spatial profiles of epidemiological curves. The results shall contribute to a better understanding of the functional relationships between the municipalities in Japan during the 2020-

2021 health crisis. The originality of this project lies not only in the possession of precise and costly data or the study of an underexplored case but also in the development of new analysis protocols through the hybridization of spatial analysis and epidemiological methods. Indeed, this research project benefits from the epidemiological dataset constructed by the Pandemics and Societies group[1] thanks to a funding provided by Kyoto University (GAP Fund 2020/09-2022/01). This dataset, which has yet to be published, collects epidemiological data at the level of over 1700 municipalities (市区町村 - Shikuchoson) in Japan, as well as from approximately 450 health insurance and surveillance centers (保健所 - Hokensho) throughout the entire period from 2020/01 to 2021/11. The founding has also facilitated the acquisition of a mobile phone dataset that depicts mobility within the 1700 municipalities in 2019, 2020, and 2021 on a weekly basis.

In order to identify epidemic trajectories and define a typology of socio-spatial profiles of epidemiological curves, several protocols are being developed, including the conception of a pair-wise matrix of weekly flows (146 weeks) for the 1700 municipalities, the use of statistical scanning windows and finally the clustering of observation based on spatiotemporal trajectories. In spatial epidemiology, statistical scanning windows (e.g Takahashi et al., 2008) allow for the detection of anomalies in the distribution of variables associated with nodes based on a graph of connected regions (based on border contiguity). The search for associations is conducted in a circular manner (connected nodes within a varying radius) or linearly (projection of node-to-node on the graph). These methods are suitable for detecting spatial clusters of count data (deviations from an expected distribution, such as Poisson). Our team is currently exploring an approach that involves substituting the physical space with a relational space defined by the bidirectional mobilities available in the pair-wise matrix. In order to do so, the municipalities are transformed into non-overlapping circles (cartogram, Dorling, 1996) before being rearranged during a pair-repulsion step. The connected nodes on the graph are then defined based on the obtained rearrangement, and these connections are used to run the statistical scanning windows. The detection of clusters of incidence/prevalence obtained on the physical and on the relational space are compared and analysed for different epidemic waves. A second clustering is then be applied for all weeks defining a particular epidemic wave on the categorical states identified through the statistical scanning windows (primary cluster of incidence/prevalence, secondary cluster and no cluster) to obtain spatiotemporal profiles of epidemiological trajectories. This exploratory approach allows deriving spatiotemporal profiles of epidemiological trajectories, shedding light on the intricate dynamics of the COVID-19 pandemic in Japan. Methodological advances and thematic results will be presented at the conference, focusing on specific subsets, regions and profiles of epidemiological trajectories.

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Spatial Analysis for Sustainable Urban Energy Resilience: Identifying Optimal Locations for Green Hydrogen Infrastructure

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Keywords: Green Hydrogen Infrastructure (GHI), the Analytic Hierarchy Process (AHP), Geographic Information System (GIS)

Green hydrogen has emerged as a promising solution for addressing the challenges associated with urban regional planning and energy resilience. Its production and utilization as a renewable energy carrier can play a crucial role in achieving these objectives, particularly as cities worldwide strive to reduce their carbon emissions and enhance energy security. However, a key challenge lies in identifying the most suitable locations for establishing Green Hydrogen Infrastructure (GHI) to ensure efficient distribution and accessibility.

This study proposes a spatial multi-criteria analysis that integrates the Analytic Hierarchy Process (AHP) method within the Geographic Information System (GIS) framework to address this challenge. By considering multiple criteria such as demand, accessibility, environmental impact, and cost, this approach aims to identify optimal locations for hydrogen production, storage, and distribution facilities. The GIS component enables spatial analysis, allowing for the visualization and examination of spatial relationships between potential locations and other relevant factors.

Through this approach, urban planners, decision-makers, and stakeholders can receive valuable insights to support developing and utilizing green hydrogen as a sustainable energy source. The findings suggest that green hydrogen has the potential to significantly enhance energy resilience in the face of climate change and other global concerns, while also facilitating the transformation of energy systems.

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Identification of urban centers and subcenters in the urban growth process of Greater Accra Metropolitan Area: a fractal dimension approach

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Keywords: Fractal dimensions; Landcover; Urban growth; Logistic regression; Mathematical morphology

Urban centers and subcenters play a crucial role in the growth and development of cities. However, identifying them can be challenging, especially in cities where data availability is limited. The objective of this study was to address the challenge of limited data availability in the identification of urban centers and subcenters by proposing a novel approach that utilizes freely available remote sensing data and fractal analysis.

The study area, Greater Accra Metropolitan Area (GAMA), was chosen because it presented an ideal location for conducting this study due to its status as the fastest growing city in a developing country with limited official statistical data on identifying urban centers and sub-centers.

The built-up pattern of GAMA from 1991 to 2022 was extracted from land cover maps generated by classifying Landsat images, and the box-counting method was employed to understand how the built-up area was consuming space. A logistic growth model was established to demonstrate the evolution of fractal dimensions in GAMA from 1991 to 2022, which allowed for the identification of a logistic equation for predicting fractal dimensions. A multi-radial fractal analysis was performed to differentiate areas with higher fractal dimensions from those with lower dimensions, and the obtained fractal dimensions were categorized into four classes to signify the spatial organization of the built-up pattern.

The combination of multi-radial fractal analyses and mathematical morphological operations allowed for the revealing of urban centers/subcenters that would otherwise remain hidden in the built-up patterns extracted from the remote sensing images. This study provides a promising method for characterizing the evolution of urban centers and subcenters and could provide more comprehensive insights for urban growth modeling.

Modelling the dynamics of morphological urban areas: considering random accumulation of vacant plots and infrastructure cost

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Keywords: morphological urban area, cost, building, road network, perforation, expansion

In the era of increasing population, urban areas in general expand to the suburbs for meeting high demands for residence along with the construction of road networks to provide residential places with urban infrastructure, such as a water supply system, sewage system and electric power supply. The expansion of urban areas without sufficient and organised urban infrastructure is accompanied by urban sprawl where residential areas consisting of small number of detached housings were developed spontaneously. As a result, urban areas delineated by considering road networks and the patterns of building locations, called *morphological urban areas*, tend to be not only irregular but also sparse and the management cost of urban infrastructure is less efficient than that in organised and densely built urban areas.

In the era of decreasing population, however, morphological urban areas do not always shrink in the same way as the reverse process of expanding urban areas. Rather, vacant plots after building demolition tend to be generated and accumulated in spatially and temporally random way called *urban perforation* (Reis, 2016; Usui, 2023b; Usui and Perez, 2022). In this process, the management cost of urban infrastructure also become inefficient. To address these issues, policies for making morphological urban areas spatially compact and cost-efficient have been implemented. However, the relationship between the dynamics of morphological urban areas and the management cost of urban infrastructure has yet to be understood considering both urban expansion and perforation, which makes it challenging for us to evaluate the effectiveness of the policies.

Morphological urban areas tend to be different from *conventional urban areas* which are defined as a set of predetermined basic spatial units (e.g., census units) where population density is greater than a criterion and census units are adjacent to one another (Usui, 2019; 2023a; Usui and Perez, 2022). Conventional urban areas delineated in this way depend on how to determine the set of census units and population density criterion.

Therefore, urban areas should be delineated in a consistent way from the past, present to future focusing on morphological aspect and bottom-up way based on finer basic spatial units than census units (e.g. buildings) (Caruso et al., 2017; Montero et al., 2021; Reis, 2016; Usui, 2019). In the literature, these problems on conventional ways in delineating urban areas have been addressed and alternative methods have been developed. However, the existing methods fail to consider (1) the dynamics of both expanding and shrinking morphological urban areas; and (2) the relationship

between the dynamics of morphological urban areas and the management cost of urban infrastructure.

Understanding the relationship between the dynamics of morphological urban areas in the process of urban perforation as well as expansion and their management cost is more essential than ever. Nevertheless, this relationship has not been sufficiently investigated from the dynamic point of view in a consistent way. This is the motivation for answering the following research questions: (1) *how do morphological urban areas change in the process of random generation and accumulation of vacant plots from the past, present and future?* and (2) *how do the management cost of morphological urban areas change in this process?*

To answer these questions is the objective of this paper along with developing a new method for investigating this relationship. In the future, urban perforation must become more prominent than in the present. The findings of this paper are expected to practically contribute to providing urban planners not only for a new method for evaluating the effectiveness of the policies on compact city and urban shrinkage but also for several alternatives of the future morphological urban areas and their management cost in a consistent and bottom-up way based on finer basic spatial units (e.g., buildings) than census units. Such alternatives are important in consensus-building regarding how to make morphological urban areas compact.

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A collaborative dashboard to study periurban densification

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Keywords: Suburban densification, collaborative dashboard, data heterogeneity and integration

Suburban densification is an opportunity for more sustainable cities while avoiding many negative externalities linked to centre densification, such as scarcity of space, price increase, or housing shortage (Jehling et al., 2020). However, considerable planning challenges are met when confronting the multiple rationalities of involved stakeholders. The SubDense European project aims in that context at better understanding the polyrationalities of space, actors and policies on suburban densification, by exploring how diverse strategies of land policy interact with landowners' and local stakeholders' interest and agency to shape suburban densification and their impact on suburbia across different planning systems (France, Germany, UK). The project combines quantitative approaches (geodata analysis and geosimulation) with qualitative approaches (social and policy science and planning).

When working on such diverse case studies at a large scale, many issues arise, such as how to share analysis and methods for reproduction on other case studies, or how to integrate knowledge on data specification which changes can strongly bias the densification analysis. There is also a need for sharing tools and methods for building change detection, such as polygon matching algorithms. We propose to tackle these difficulties by constructing a collaborative dashboard, which will act as a medium to facilitate collaboration between project partners, will enable the sharing of methods, data and metadata (Bucher et al, 2020), and will allow reproducibility.

We use a git-based architecture for the core dashboard to ensure tractability, full history, reproducibility, flexibility, and collaboration through branching and a shared remote repository (https://github.com/subdense). Clients will implement interactions with the core and functionalities needed by partners for data analysis and integration (running change detection algorithms, adding data, exploring results and maps). An iterative process to produce user stories is currently implemented, to finally lead to final specifications for the core architecture and functionalities of clients. A first version of the dashboard has already been deployed, through which partners have shared first densification analysis and data expertises.

Future developments and analysis to be integrated through the dashboard will include heterogeneous data integration (Bucher et al., 2021), to couple densification analysis with socio-economic data, and the development and exploration of simulation models for the impact of policies on densification

processes. These models will act as bridges between quantitative analysis and the qualitative data obtained through interviews during the project.

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Toponymic representation of spaces within the city through real estate ads

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Keywords: Spatial analysis, real estate ads, toponym, spatial representation, fuzzy geographical location

Toponyms mark, segment and organise the urban space since their creation. They evolve with time and space, reflecting the historical, social, and cultural evolution of cities, including in terms of urban planning (Le Squère, 2006; Jordan, 2020; Giraut & al. 2016). They are perceived and identified by populations, thus contributing to the social representation of the different subspaces that compose the city. Toponyms respond to both spatial and social dimensions, making them difficult to identify. Their location and characterization present blurred and uncertain boundaries (Bunel, 2021). Several studies have dealt with the delimitation of fuzzy socio-spatial phenomena (Hu & al. 2019, Vasardani & al. 2013).

In this direction, we propose to reconstruct and characterise the toponymic landscape of the city from geolocated real estate ads, using an appropriate spatial analysis of the pieces of information on the urban space present in their text.

A geographic database was used, containing tens of thousands of pieces of geographic information extracted from real estate ads texts of the French Riviera through a combination of natural language processing (NLP) and artificial intelligence (Cadorel & al., 2021). The geographical information extracted, cleaned, and structured, is based on the places and their socio-spatial context, made of spatial relationships and associated attributes, recognizable in expressions like "*in the residential neighbourhood of Cimiez*".

The naming and delimitation of places based on a multitude of extracted information are complex processes, leading to blurred toponyms with unclear boundaries, even if spatial barriers can sometimes segment their use. To model the significance of toponyms in space, we have developed a protocol based on spatial analysis of geographical information extracted and geolocated with decametric precision on the street network. The street network is a fundamental feature for the perception and cognition of urban space (Lynch 1960), and we can assume that it can be a pertinent basis for its segmentation through toponymy.

Geolocated ads can be seen as a spatial sampling of toponym use. We thus interpolated toponym use with a kernel density-based approach on the street network with adaptive parameters for each toponym (Gelb, 2021; Lachance-Bernard & al., 2011). The toponyms are those present in the

database of extracted geographical information associated with a relationship of spatial situation (Blanchi & al., 2022).

From there, we extracted the relevant phenomenon (use of a given toponym) by imposing a minimal threshold and some spatial coherence in toponym use. Artefacts linked to erroneous geolocations or low presence of ads (a known bias introduced by the real estate market) could thus be reduced. Nevertheless, the presence of toponym use in space is not sufficiently indicative of its representation within the urban toponymic landscape. We therefore also assessed its absence within the same space, using the same interpolation method of all geolocated real estate ads that do not mention the toponym through a notion of situation.

Finally, we assessed the strength of a toponym in space using the concepts of core-space and support-space, derived from fuzzy set theory. First, the ratio between the kernel densities of presence and absence of toponym use on each street segment is used to model graduated presence of the phenomenon. Then, using the equivalent of an alpha-cut approach, the core was defined as the space where toponym use was predominant, and the support as the space of extended but more contested use. More precisely, morphological closures and connection checks were also carried out to impose spatial coherence on core- and support-spaces. Their mapping reveals how place-name usage produces meaningful patterns in intra-urban space, independently of administrative constraints.

However, some subspaces can be shared by different place names. Within the context of real-estate valorisation, some toponyms can be used more widely beyond their core. Supports overlap cores in an asymmetric way, showing the different power exerted by toponyms in the social representation of space. A local hierarchy among neighbouring toponyms can thus be calculated and mapped, producing new insight in the social meaning of the identified spatial patterns.

It was also possible to further characterise toponyms through their associated geographic entities. Entities like "*neighbourhood*", "*sector*", "*street*", "*hill*" have different meanings in social perception and cognition. Finally, a correspondence analysis was carried out using toponyms, associated attributes, and localisation factors (features of space put forward by real estate ads, including proximity to interest points, urban services and environmental amenities and view factors). The interpretation of the factorial axes allowed for the identification of main oppositions within the toponymic landscapes of the cities of the French Riviera. In Nice, for example, a first major opposition is between what are perceived as toponyms of residential places on the hills surrounding the city, and two different subspaces within the latter: the historic and tourist-oriented city and the more utilitarian city signified by the presence of urban facilities and services.

In conclusion, the spatial analysis of toponyms and their relationships in space allowed us to represent the patterns of toponymic landscape as they are perceived, appreciated, and identified by people. However, it is important to note that our data comes from real estate ads, which are punctual data influenced by the dynamics of the real estate market and real estate valorisation.

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Abstracts of Parallel Sessions 5

Projecting future urban density change

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Keywords: urban density, urban area, global development, panel regression, scenario simulation

This study aims to enrich our understanding of urban expansion at a global scale and focusses on the importance of changes in urban density to explain urban area development. The presented analysis supports the development of country-specific, future projections of total urban area that can be used in global assessment models. Such projections typically calculate urban area demand as a function of total urban population and an assumed urban land take per person. While population projections are well-established (e.g., Chen et al., 2020), urban density projections have received much less research attention.

As we are interested in understanding changes in urban density over time, we have set up a time series representing 134 countries around the globe for which we describe urban density and several explanatory variables. In this case the observations of the dependent variable (urban density) are related across time because each individual country is included multiple times. This makes it inappropriate to apply regular (OLS) regression analysis. Instead, we use a panel regression approach with country-fixed effects. This setup fits our purpose as we are not interested in explaining the variation in density levels between countries but want to know what is driving changes in density. So, our focus is on understanding what is affecting changes in density levels over time and not so much on replicating how differences between countries arose.

To characterise urban density, we rely on the global built-up area and population data distribution as provided by the European Commission's-Joint Research Centre. This so-called Global Human Settlement Layer (GHSL) offers a long and consistent time series capturing four moments in time: 1975, 1990, 2000 and 2015 (Florczyk et al., 2019). While this data set is known to contain inaccuracies (see, e.g., Kuffer et al., 2022), we consider this the best possible data set for our analysis. As our analysis results are intended to be applicable in the global 2UP model that simulates land use and population, we follow the model's definition of urban area: any 30 x 30 arc seconds grid cell where the percentage built up of the total land area is 50% or higher (for more details, see: Koomen et al., 2023). So, our urban areas are clusters of built-up area pixels in the original GHSL data set (with a 38-metres resolution) that cover at least around 0.5 km2 within a larger grid cell of circa 1 km2. Smaller clusters are considered to represent non-urban areas. All population within the urban cells is counted as urban population, while the population in the remaining grid cells qualifies as non-urban population. This approach has the advantage that we do not follow administrative definitions of urban areas that may differ per country.

In addition to the (urban) area and population data originating from the GHSL-source, our regressions include GDP per capita that we can match to the four years observed in the GHSL (1975, 1990, 2000 and 2015). Applying fixed effects per country yields coefficients that control for any unobserved heterogeneity per country, in addition to absorbing any time-invariant variables. This makes it impossible (and irrelevant) to include specific reference to local geographic conditions such as average elevation, climatic conditions etc.

The regression results indicate that urban density increases with increasing total urban population, but decreases, with increasing national income per capita, suggesting that higher incomes enable suburbanisation with more dispersed urban areas. We, furthermore, find that increasing levels of urbanity (proxies by higher shares of urban population) correspond to lower densities. A result that may hint at increased low-density suburbanisation when countries become more urbanised. The basic effect of the urban population fraction gets more pronounced when we add an interaction with total urban population. The interaction term itself indicates that the urban population fraction impact is less prominent for countries with larger urban populations.

Using our explanatory model of urban density we determine country-specific future urban areas per shared socioeconomic pathway (SSP, see: O'Neill et al., 2014). These resulting national area estimates are subsequently used as input in the 2UP model to simulate local urban area change. These high resolution results help analyse , amongst others, future climate impacts. For this study, we use the SSP database hosted by the International Institute for Applied Systems Analysis (IIASA, 2016). This presentation discusses the regression results, its application in the 2UP model and the future urban area projections this generates. We present several alternative specifications and show how data formatting, explanatory variables and scenario-specific assumptions impact the outcomes.

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Uncovering the land development potential of municipalities in France

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Keywords: land management, land registry, land reserve, local government, urban development

In France, municipalities play a fundamental role in land use planning. They have three powers at their disposal for this purpose: a regulatory power that allows them to define the rules of urbanization and building permits; an incentive power through the tax lever but also by playing a role of animator of the local market with calls for projects, co-financing and communication campaigns; and finally power through land ownership which allows control of the location and destination of a development project. The first two powers – regulatory and incentive – are widely used but urban development depends on the willingness of investors to comply with the rules of the game or withdraw from the market, while land control through ownership often provides a greater control over projects and the allocation of land resources. As the first public owner on the land markets, the municipal block – municipalities and their groups – seems to have significant resources to guide land use planning. However, the current economic context is pushing public actors to sell their land assets and therefore to deprive themselves of this power of development. Indeed, the spread of the neoliberal management model and the resulting austerity policies (Peck, 2012) are pushing public authorities to reduce their expenditure and generate new revenue. In a context of rising land prices since the 2000s, they are all the more tempted to sell their assets. The privatization of public land is a well-documented and observed phenomenon in Canada, the United Kingdom, Italy and France (Adisson and Artioli, 2020; Christophers, 2018; Whiteside, 2020), mainly concerning state railway and military land. If it turns out that the municipalities are part of the same movement, then it is crucial to question their future ability to control the development of their territory without land control as landowners. In order to shed light on this question for decision-makers, this communication proposes to evaluate the land ownership of the municipal block which could be mobilized for development operations, based on an analysis of land-registry tax-based data – les Fichiers Fonciers – at the scale of metropolitan France.

The first stage of this work consists in drawing the contours and the content of municipal land ownership as it can be apprehended in the land registry. Municipalities often directly own land parcels but this ownership is sometimes delegated to a municipal service (social housing organization, school, etc.) or even to an external body dedicated to development operations (semipublic company, local public development company…). Finally, some plots may be held in multiownership by different actors and it is then necessary to determine a method to analyze the level of control that the municipality has.

Then, we seek to divide the land ownership of municipalities into different market segments based on the typology of Joseph Comby (Comby, 2010) adapted to our objective of evaluating the development potential of municipalities through land ownership. Indeed, owning built heritage and assigned to a use does not confer the same development potential as having a vacant plot (Casanova Enault et al., 2021). By harvesting with exogenous public data, the plots are qualified according to four determining indicators for their potential mobilization: their morphology, their topography, their use assignment and their state of pollution. This qualification work carried out on a national scale, at the granularity of the plot and on a large volume of data involves specific methods of spatial database management and automated processing powered by PostgreSQL, PostGIS and Python.

This leads to a scoring of municipal land plots according to a gradient of potential mobilization for development operations, ranging from the value 1 for plots with a very low probability of being mobilized to 5 for plots that can be easily and directly mobilized without major constraint. After a work of quantification and spatialization of these levels of property showing their concentration and their dispersion, we propose an explanatory analysis of their unequal distribution between the municipalities. With the analysis of the residuals of a Chi-square test of independence, we show that urban municipalities have for their future development mainly land already assigned to an urban service (urban parks, sports fields, etc.), which raises interrogations about their future. While the land ownership of rural municipalities is over-represented by non-mobilizable land – mainly forest and mountain –, the suburban municipalities own large land deposits available for urbanization and for which we can expect future privatization and artificialization.

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A policy tool for simulating municipal mergers

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Keywords: municipal mergers, service provision catchment areas, spatial-functional patterns, Belgium

Many European countries have recently undergone, or are planning to undergo, processes of spatialadministrative upscaling through municipal mergers. Finding the 'optimal' scale and geographical outline of the ensuing spatial-administrative units is a recurring topic in regional studies (HortasRico and Rios, 2020, p.958) and entails a balancing act between (1) respecting the principle of subsidiarity, (2) achieving sufficient governance power, and (3) forming territorial units that align with relevant geographic realities. The former two aspects are often tackled by experts in the field of public administration, whereas the latter entails engaging in geographical analyses. In this paper, we contribute to this literature by presenting a tool that allows policy makers and other stakeholders to simulate, evaluate and compare the impact of municipal mergers, each reflecting a particular vision on what should drive spatial allocations when deciding on municipal mergers. The tool was developed to help structure the often intricate political and societal discussions surrounding the (likely) upcoming municipal mergers in Flanders (Belgium). However, the tool's logic and operationalisation is – barring some operational amendments – applicable to spatial-administrative upscaling and mergers in other geographical contexts.

The tool's broader applicability results from the fact that decisions on which municipalities should merge and with whom they should do so are typically rooted in a generic set of economic, managerial, and democratic motives derived from the public administration literature (Tavares, 2018, pp.6-8). In addition, ideally the spatial configuration of municipalities in a post-merger administrative landscape considers the many, sometimes contrasting geographic relations and patterns that occur and structure everyday life. For example, mergers between suburban municipalities and the central city may be inadvisable from a democratic viewpoint but advisable from a functional-transactional perspective. On the one hand, a suburb-city merger could lead to policies that are less tailored to the policy preferences of a politically more homogeneous population (Tavares, 2018, p.7). On the other hand, services provided by urban municipalities tend to spill over their jurisdictional boundaries into nearby suburbs that are dependent on them in terms of employment, education, and other daily services (Hortas-Rico and Rios, 2020, p.958). From this perspective, mergers present an opportunity to match the jurisdiction of a municipality with the daily urban system that constitutes its service provision catchment area.

The tool we have developed allows policy makers to simulate scenarios for municipal mergers according to different (combinations of) merger motives. A scenario is defined by a series of parameters that determine (1) which municipalities should merge and (2) with whom they should merge. The first step implies setting a requirement which all merged municipalities should meet (e.g., a minimum population size threshold). The second step entails selecting the optimal partner of a municipality-to-merge, either based on indicators of governance complementarity (e.g., fiscal similarities and existing intermunicipal cooperations), of spatial-functional dependence (e.g., commuting relations, residential relocation patterns and hospital market areas), or a weighted combination thereof. As such, the parameter selection reflects a particular perspective on which kind of territorial vision should guide municipal mergers.

The result of a scenario is a hypothetical restructuring of the current spatial-administrative landscape in which municipalities have merged according to a particular (set of) merger motive(s). By comparing results across simulations, policy makers can gain insight into which municipalities are consistently being formed across different simulations and which mergers tend to be more ambiguous and therefore 'political'. Taken together, the tool aims to bridge the gap between regional studies, public administration and policy practice as it allows different, theoretically informed merger motives to be simulated, evaluated and compared *before* they are put into practice.

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The future land demand from economic activities

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Keywords: urban land demand, trend analysis, land use

Assessments of urban land demand mostly focus on growth in residential land, which is typically determined by projected household growth in a region. This implies that other types of urban land demand, e.g., for industries, retail, and services, are often neglected. This may be due to limited data availability on the land claimed by economic activities, or to their assumed limited importance relative to residential land demand. Batista e Silva et al. (2014) offer one of the few exceptions of studies that investigate the land demand for economic activities, but they distinguish only two economic sectors: industries and commercial services. Other studies focus on individual economic sectors such as logistic services (Tare et al., 2023).

In this research, we look at the specific developments of a wide range of economic sectors in the Netherlands between 1996 and 2015 that together comprise all land developed for economic activities other than agriculture and mining. We distinguish between changes in gross land use (inferred from national land-use statistics), net land use (inferred from building footprints) and number of employees (from firm registration databases). Following an extensive data fusion approach, we are able to link gross and net area changes per sector to employment changes and establish changing land intensity measures per job in specific sectors.

We find that the gross area associated with economic activities grew by 22% between 1996 and 2015. This is more than the growth in residential areas over the same period, which was 14%. Most of this increase came from the logistics sector. Interestingly, employment in this sector was roughly stable, indicating a large increase in the land area per job. On the other hand, employment in public and business services increased substantially, while their area only grew marginally. So, while we see extensification in industry, we see intensification in offices. These insights are applied to construct assessments of future urban land demand until 2050 relying on scenario-specific employment projections. The total national urban area growth associated with economic development is close to 380 km^2 (1.18% of the Dutch land area), slightly more than the urban area growth associated with a slowly stagnating population growth.

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Exploring sustainable urbanization pathways by simulating local density change

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Keywords: urbanization, densification, urban density, sustainability, land-use modelling.

Geographical information and decision support systems are a well established part of the spatial and environmental planning process in The Netherlands (e.g. Geertman and Stillwell, 2009). An example of a land-use model which is applied particularly widely is Land Use Scanner (e.g., Koomen and Borsboom-van Beurden, 2011). Modelling approaches like these have so far focused mainly on urban expansion or, in more recent terms, land take (European Commission, 2011). Densification, defined as the share of buildings allocated to existing built-up areas instead of locations outside the city, is often treated as a given (exogeneous). Local density change and the underlying demolition and construction of buildings are only accounted for in an aggregated form, or remain wholly implicit.

This study introduces an applied model which simulates the processes of construction and demolition explicitly, and does so on a highly disaggregated level (i.e. 25 x 25 meter grid cells). Construction and demolition are functions of regional projections of population (households) and economic (jobs) growth on the one hand, and empirically established ‘suitability maps’ viz. a discrete set of urban (re)construction options on the other. The practical use of the model is demonstrated by applying it in a broad, integrated scenario study (PBL, 2023). It shows that explicitly simulating the underlying processes that make up the urban fabric allows us to consistently account for a wide range of societal costs and benefits associated with urbanization, including soil sealing, flood damage and the accessibility of green space, enabling us to explore sustainable urbanization pathways indeed.

The 15’ hub in the global network

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Keywords: social hubs, mobility, logistics

Societal evolutions are changing the urban system as we know it. COVID19 was the catalyst for teleshopping and -working, hence changing origins and destinations of passenger and freight flows (Aloi et al., 2020; Figliozzi and Unnikrishnan, 2021). The on-demand economy with the demand for more personalized logistics and mobility services pose flexibility requirements on transport systems (Beckers et al., 2022). Finally, the popularity of the 15’-city concept in urban planning reflects the need for proximity, social connectivity and car-free environments. These evolutions demand a reorganization is about the re-organization of freight and passenger transport systems considering accessibility, technology and flexibility.

Yet, current transport systems are far from this new organization. In freight, business models for consolidation centers do not work as operators can freely enter all cities without too many restrictions. The lack of legislation prevents throughout testing of automated vehicles while scaling possibilities are currently restricted to university campuses. Finally, although the smart city concept was a popular topic a few year back, true implementations are limited and big players such as google even came back from initiatives. As a result, there is currently no business case nor the necessary structure for an organization that comes close to physical internet, albeit its necessity given the current trends. In mobility, a similar stagnation is visible. Shared mobility is considered an important contributor to the required transition away from the private car while catering to the needs mentioned above. However, Shared mobility still has a considerable low modal share in comparison to the conventional transportation modes. It is particular focused in dense urban areas (Standing et al., 2019) and it still faces new developments which require time to address the barriers for major individual adoption (Butler et al., 2021).

Nonetheless, the physical concentration of transport flows in space creates the potential to respond to many of the requirements associated to the societal evolutions. In freight, pick-up points offer significant economic and environmental benefits compared to home deliveries (Janjevic and Winkenbach, 2020). In mobility, mobility hubs increase the embeddedness of new mobility services in public transport, hence stimulating the shift away from car usage (Coenegrachts et al., 2021). But more so, the concentration of services holds the opportunity to increase accessibility within the ever digitalizing society. By connecting services at the local level with global transport and economics networks, we link agglomeration advantages to network advantages. This is especially relevant given ageing, decline of economic service provisions at the micro level and intensified digital lifestyles.

In this paper, I study the design of these hubs from a transport and economic geography perspective in order to identify how these transport hubs, being the connection between the local and the global, can actually serve as social hubs for the neighborhood. I do this by revisiting traditional geographic

concepts (Geurs and van Wee, 2004; van Meeteren and Poorthuis, 2018). This approach results in the definition of neighbourhood hubs at different urban hierarchies. It shows how new freight and mobility services should be enabled to bolster local accessibility, connecting the 15' city to wider regional and national systems.

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Crowding effect adjustment applied in population prediction

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Keywords: spatial interaction theory, analytical approach, modeling and simulation, population dynamics, socio-economic development

The canton of Valais in Switzerland has been subjected for several years to strong pressures on the socio-economic dynamics of its population. The installation of the Lonza company in Visp attracts a huge mass of new employees who even come from Italy. This raises important questions in terms of land use planning and the use of road and rail infrastructure. To help manage these questions, a socio-economic simulation model has been developed for the canton of Valais in Switzerland (Rojas, 2021). The goal is to simulate and spatialize the evolution of the population over a period of 5 to 10 years. The model is based on hectometric data provided by the Federal Office of Statistics (OFS) in terms of population and employment. This model uses a two-step approach: a forestry approach for population evolution and an agent simulation for spatial interaction. This first model locally produces extreme residuals in the sectors where the semi-hectometric is the densest. The particular topography of the Valais region, enclosed in the steep Alpine mountains, accentuates this hyper-attractive effect. The purpose of this paper is to propose an adjustment of the gravity model initially used by taking topography into consideration and more particularly considering the influence of population density in a region in relation to employability.

Such an approach has been proposed in the work of Allen et al. (1981) for the simulation of a dynamic socio-economic model applied in the context of the central place system theory. An interesting element that emerges from this study is called the “crowding effect” by the authors which is an adjustment of their previous article (Allen et al. 1979). This article tries to implement this “crowding effect” for the population in Valais and take into consideration that population flows (main residence) take into account a negative feedback from population density encouraging individuals, despite the presence of job offers, to move away from centers of attractiveness. The objective is then to show that this approach "smooths" the hyper-attractor phenomenon observed in the central squares identified in large urban centers while restoring a better simulation of the sociospatial dynamics of the population.

It is therefore a question of comparing the initial simulation developed in model 1 and the simulation readjusted in an extension (model 2), including the adjustment of Allen et al. (1981) briefly described above. The comparative analysis of the residues highlights the interest of considering the “repellent” effect described in Allen et al. (1981), limiting the attractor effect of a central place. The analysis of

these different simulations leads to visualize which parameters influence population movements and to what extent population density is linked to the employability of an attracting center and its own topography.

The territory on which the simulation is applied being wide, it was necessary to consider the influence of the distance locally to make the simulations more efficient.

As the objective of adjusting the model for a new finer simulation meets the initial need for a prediction of the population of Valais for strategic decision support, a simple local smoothing of the model is not sufficient. due to the specific topography of this mountainous region. Consideration of the attractive effect of the job offer is also not sufficient to describe population flows motivated by other aspects than living near their place of work. The results of model 2 make it possible to provide more detailed answers.

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The variegated bias of activity spaces derived from mobility data

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Keywords: social media data, mobility, activity spaces, big data

Analyzing functional systems, such as cities and commuter or border regions, is ultimately about the analysis of social interactions or mobility across space. These social interactions are conventionally captured in census, register or survey data through, for example, capturing both home and work locations of residents. However, relying solely on travel-to-work data limits our understanding of functional systems to a relatively narrow perspective and makes it difficult to scale up analysis to cross-regional or cross-country systems. As such, researchers have been eager to capitalize on newer mobility datasets such as GPS logs, social media data, mobile phone operator data, and – more recently – mobile phone application data. These datasets potentially cover a much wider aspect of our daily mobility (and thus functional systems) and high temporal and spatial granularity.

Despite this promise, widespread use of such mobility data for the large-scale analysis of functional systems across countries can be hampered by two specific issues. The first issue revolves around **access** to data. Specifically, accessing raw data is often restricted due to, for example economic, privacy and ethical concerns, and a range of other reasons. Even if this is overcome through the social and economic capital of researchers, specific data providers often operate only in a specific local or national geography. Furthermore, raw mobility data is often not readily usable for functional systems analysis and requires non-trivial computational skills and resources to convert to a derived mobility dataset that is more suitable for such analysis. The second issue relates to potential **bias** in such data. As mobility data is not collected in register or random-sampling frameworks, it is not always clear if and how insights derived from such data can be trusted or even generalized.

This study addresses these two challenges by constructing a large-scale mobility dataset derived from all geotagged social media posts on Twitter between 2012 and 2019 across the contiguous United States. The raw data (~3.8 billion data points) is first filtered by removing inactive and nonhuman users, and subsequently enriched by detecting the most likely home location of each user. The resulting data is aggregated temporally and spatially to a ~500m hexagonal H3 grid. To further safeguard privacy, random perturbations are added to both the location and timestamp, and sensitive locations with few observations that may compromise anonymity are excluded. As a result, we generate an aggregated and de-identified dataset of activity spaces of ~10.3 million users nationwide with a collective ~1.2 billion observations. This publicly shareable dataset enables the fast querying of activity spaces in a specific time period or location, allowing researchers to immediately access

and start an analysis on topics such as spatial inequality in activity spaces in Saint Louis, Missouri; or cross-state mobility on the Eastern Seaboard.

Moreover, the breadth of this dataset also allows an in-depth assessment of potential biases introduced by the selective use of a specific social media platform. By comparing representation of user home locations in this dataset with census statistics, we find that correlation between population statistics at the state and county is fairly good (Pearson's r ~0.98) but this correlation gets notably lower at the granular level of the census tract (Pearson's r ~0.35). More importantly, the uneven representation of residents within such a dataset is not homogeneously distributed. We analyze this through a geographically-weighted regression (GWR) approach where the number of social media users with identified home locations within the mobility dataset is explained through the census population, age, income levels, and racial characteristics of each census tract. It is often assumed that social media users are younger, higher-educated, and whiter than the general population. However, we find that this is not necessarily true for this dataset and is highly context-specific. The strength and direction of the relationship between these variables changes from state to state, from urban to rural and even within cities. This analysis shows that bias is indeed an important issue to take into account. Making these biases transparent opens the road to more widespread use of mobility datasets. For example, users within the dataset can be weighted to account for over- and under-representation; studies can oversample from specific areas of interest; and conclusions on functional systems can be contextualized with knowledge of specific biases present in the input data.

Sensing diversity in Tallinn using mobile phone data

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Keywords: urban vitality, spatial analytics, self-organization, urban patterns, big geo-data

A city is a complex system consisting of myriads of complicated interactions between transport, land use, the environment, and the population at various scales, from the neighbourhood and regional to the global level. Understanding cities entails a combination of uses that should encompass diversity, convenience, interest, and vitality for vibrant urban life. The emergent dynamics of the integrated social-technical and cultural aspects are often unpredictable. These uncertainties leave urban planners often with limited means to tackle urban challenges. However, in the activity landscape, dynamic temporary patterns accommodating diverse activities can often be discovered, which helps to plan for vital cities. Through urban vitality, urban growth and development enhance the territory's functionality and effectiveness and shape these patterns that impact people's connection to the place.

Conceptually, urban vitality refers to a place's relatively high "metabolic rate": flows generate activities, attracting more flows and, again, actors circularly—this emergent and dynamic process results from complex agent interaction, often self-organizing in nature. Agents are attracted to a particular place by the location, similar actors, cluster, or diversity, generating patterns of urban life. This process occurs within the regulatory framework and the feedback received from the pattern. In larger cities, the emerging diversity is typically greater, generating urban patterns required for the intricate distribution of services and wider economic, cultural, and public life opportunities.

Traditional "static" or slow vitality measures (SM) apply non-frequent datasets which stress multiple diversities as a critical factor. Like ecosystems, they form a framework for urban "life forms" to emerge and evolve in time. Here we hypothesize that higher diversity indicates higher urban vitality (and higher self-organization potential) of the area, which planning can support once perceived. Previously, studies on urban vitality were limited by methodological constraints since they often relied on infrequent datasets that only reflected slow evolutionary dynamics. Thus, the resulting understanding of urban vitality was limited to a relatively static view, failing to capture the phenomenon's dynamic and emergent nature. In her renowned work, Jane Jacobs focused on measuring the vibrancy of city life by identifying four key components: mixed-uses, small blocks, aged buildings, and urban density, which highlighted multiple underlying spatio-functional diversities. However, these studies have typically used relatively small and infrequent data sets (separated by years or even decades), focusing mainly on the physical environment providing the arena for human action, not the frequency of human activity per se. Novel forms of data, computing power, and spatial analytics methods enable more frequent scrutiny of people's weekly, daily, or

even hourly dynamics, measuring the spatiotemporal variation, intensity, and heterogeneity of flows. Hence, detecting choreographies of everyday urban life would complement the traditional vitality metrics and improve planning to respond to these patterns in real-time.

This article examined multi-sourced methods to study urban diversity in Tallinn, Estonia. We applied spatial data of physical and socioeconomic components and mobile phone data sourced from the Telia Eesti Telecommunications network to measure the formation of vital activity nodes. The research investigates four aspects. First, we studied what types of spatial configurations the traditional 'static' measures (SM) reveal. Second, we detected the temporal variation of vital places regarding dynamic metrics (DM) applying cell phone data. Third, we observed the correlation of these metrics to see which aspect could anticipate vitality, and finally, we compared the hotspots of SM with DM.

The results indicate a strong correlation between three slow metrics and high mobile phone activity, namely, mixed-use, small blocks, and urban density. The correlation between mixed-aged buildings and activity was not perceived – instead, the result showed high activity around clusters of old buildings, especially in the city's old town. Furthermore, cell phone data provided a more detailed and accurate view of people's daily rhythms and choreographies. They revealed variance in neighbourhoods' temporal identities, particularly highlighting areas with high building density and commercial land use.

Future studies could delve into this local variance, along with the triangulation of vitality using people's subjective experience of vital areas by utilizing ethnography to classify the identities of different neighbourhood areas based on unique sets of metrics, to strengthen their identity through planning policies and fill in any gaps that are inhibiting their vitality. Moreover, the diversity of building age needs scrutiny since our data did not contain information about the affordability of the buildings, which is assumed to be the main factor in generating business diversity and urban vitality.

This study provided insight into the applicability and limitations of the study's methods for generating data-driven scenarios for urban planning. The study highlights the need for complementary approaches that combine big data with traditional methods to measure urban vitality accurately. These findings can help urban planners identify and recognize vital areas and guide their unique self-organizing processes to maintain a vibrant city.

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Understanding functional border regions in Europe through the lens of human mobility: A big data approach

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Keywords: cross-border mobility; functional region; border regions; big data approach; Europe

Mobility and migration are global megatrends as border-crossing mobility has become an important aspect of our society. People interact and cross borders for various reasons, ranging from more permanent migration for work or family to shorter trips for reasons such as tourism, commuting, education or social visits. Furthermore, we increasingly see people whose daily lives are not confined to the fixed territory of one country, such as cross-border commuters and people with multi-local lifestyles between different countries (Carling et al., 2021; Gerber, 2012; Järv et al., 2021). These recurring mobilities crossing country borders for work, shopping, services, and leisure not only affect individuals' social connectedness and integration (e.g. social networks and place attachment) across borders, but also contribute to the (re)production of functional cross-border regions (Pupier, 2020).

However, regardless of its growing importance, relatively little attention has been paid to recurring cross-border practices of (local) people beyond migration and tourism, and how functioning border regions are formed from the perspective of these practices. This is even though cross-border cooperation and governance within the EU is seen as vital to enhance growth and cohesion in border regions. To understand and evaluate how policy and planning (e.g. cross-border development with institutional instruments such as the European Regional Development Fund) enhance cross-border integration within the EU, we need knowledge about how these influence daily lives of (local) people in a border region (Medeiros, 2020).

One reason for this relative dearth of insight into these cross-border practices is that we lack appropriate data sources – register and census data often does not capture the dynamic nature of border mobility, and large-scale surveys are time and resource-consuming and capture only one point-of-time. To obtain information from the perspective of people, we put forward an approach stemming from two conceptual frameworks. First, we consider human mobility to be a tool to understand society as mobility indicates social interactions, which form functional systems such as functional regions (Järv et al., 2022; Poorthuis, 2018; Rodríguez et al., 2022). Second, stemming from the growing literature on big data, we consider inherently transnational sources like social media data to be feasible in revealing mobility of people (Gendronneau et al., 2019; Hawelka et al.,

2014; Poorthuis and Zook, 2017). Thus, it can provide much needed insights into cross-border mobilities and functioning border regions (Aagesen et al., 2022).

The objective of this study is to empirically show the feasibility of our approach in an analysis of all border regions in Europe using geotagged Twitter data from 2013 to 2022. For this we: 1) characterise spatial patterns and temporal rhythms of cross-border mobility by border region, 2) map functioning border regions from human mobility perspective, and 3) evaluate how mobility-based border regions align with the officially delineated border regions of the Interreg programmes, which are one of the most important instruments for cross-border development. In the context of this study, we define a movement as two consecutive tweets located in different countries and with a time difference of less than 9 weeks. With this definition, we obtained ~15 million cross-border movements within Europe.

Preliminary results indicate that we can capture monthly and weekday cross-border mobility rhythms for two distinct groups – people with recurrent mobility behaviour and first-time visitors based on the frequency of mobility crossing a border in a certain border region by Twitter users. This enabled us to reveal two layers that together form a functioning border region: recurrent and habitual mobility practices by more local people and one-time mobility for recreation by visitors. The comparison of functional border regions delineated by cross-border mobility and Interreg programmes shows the spatial concentration of cross-border mobility within an Interreg region as well as overall connectivity beyond an Interreg region. By clustering border regions based on the proportion and seasonal rhythms of the two mobility groups, we found less integrated border regions, more integrated border regions dominated by local mobility, and more integrated border regions dominated by leisure related mobility. We discuss the feasibility of our approach as the proof-ofconcept to capture and characterise functioning border regions for monitoring and evaluating development projects and governance actions of border regions from the perspective of people. Finally, we address future avenues in enhancing this methodology for characterising mobilities as well as mapping functioning regions.

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Capturing built environment effects on human behaviour using catchment area analysis

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Keywords: morphometrics, spatial structure, street network analysis

Research describing and classifying the spatial structures of cities in relation to their built environments is often motivated by the notion that built environments impact human behaviour. Although the notion might be intuitive to understand, the rationale behind the notion often remains implicit and assumed. Making this rationale explicit can help us understand how and to what extent human behaviour is indeed affected by the built environment.

In this paper, we present a novel methodology to capture intra-city spatial structures in a way that reflects their impact on human behaviour. We do this by calculating and describing maximal catchment areas (CA) for every building in our case study of Singapore. CAs consist of polygons which represent areas of the city accessible to people from a particular location within a distance or time-based threshold. For example, this can be used to find areas that an average adult would be able to access in a 5-minute walk: about 420m at a speed of 1.4m/s. For each building, we derived CA polygons at different distance thresholds ranging from 250m to 1500m, along the street network. At each distance threshold, we derive three metrics from these polygons to describe their characteristics, namely the shape, size, and direction of skew. Shape is described in comparison to a unit circle of equal area, i.e., a compactness measure (Maceachren, 1985; Angel, Parent and Civco, 2010). This results in a number between zero and one where being closer to one indicates greater similarity to a circle. Similarity between a CA polygon and a circle is indicative of the uniformity of accessibility in different directions from the associated building. Size is described as the area of the polygon. Size is indicative of relative accessibility patterns regardless of directions from the associated building. Finally, the direction of skew is used to understand if the specific arrangements of the built environment encourage travel behaviour in specific directions. This is calculated as the shift between the position of the building associated with the polygon and the centroid of the polygon. These shapes together provide an understanding of how the specific arrangements of built environment elements in the vicinity (as defined by the distance-based threshold) of each building may impact human behaviours.

We conduct a preliminary investigation to explain the relationship between the built environment (as captured in these three metrics) and human behaviour, proxied through the density of social activities and the characteristics of activity spaces derived from social media data. Regression analyses

indicate that the densities of activities increase as associated catchment areas become larger and more similar to a unit circle. An intermediate distance threshold of 750m appears to have the greatest explanatory power (pseudo-R2 = 0.476) when the shape of the CA is considered while the maximal distance threshold of 1500m appears to be most informative (pseudo-R2 = 0.547) when explaining activity densities in relation to CA areas. The CA metrics used here capture more of the built environment-human behaviour relationship than other morphology metrics that rely on geometric measurements of built environment elements (Berghauser Pont et al., 2019).

Visualizing these metrics reveal underlying patterns that are an outcome of the relative arrangements of built environment elements. The CA methodology used here is specifically designed to capture the effects of these relative arrangements as is likely to be experienced by people. The methodology is quite robust against operational challenges like edge and boundary definition effects (Gil, 2017). Although, at present, we formulate our descriptions only in relation to buildings in our study area, the method can be extended to all built environment elements including open spaces. The minimal data requirements, i.e., just the street network, means that the method can be applied to most contexts around the world. Because the CA methodology seems to capture the potential relationship between built environment and human behaviour, the approach can be useful for urban-geographical researchers interested in examining the effect of the built environment on socio-economic processes like economic productivity, environmental sustainability, and segregation.

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Road network distances and detours in European cities: the effect of internal urban structures

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Keywords: road network, detours, urban form, urban scaling

The road network infrastructure is an important aspect of urban form and its variations across space and city size are not well understood. It is too often ignored in transport research while it is a fundamental constraint to individual travel and to urbanisation patterns.

The present study is part of a larger endeavour to formally and empirically establish the relationship between urban form and road network characteristics. It is more specifically aimed at determining how the ratio of road network distances to Euclidean distances (the physical detour) varies in Europe, and whether it is influenced by agglomeration and spatial expansion. Our "detour" is to represent the physical structure of the road network, hence the form of the city in normal conditions, rather than the excess travel due to peak hour congestion for example.

We study the detour in two spatial configurations: first the radial detour, i.e. the accessibility to the main centre of activities of each city, and second the non-radial detour for trips in all directions between defined internal urban subcentres. This non-radial detour is meant to address the limitation of the monocentric assumption and considers the often-polycentric organisation of the largest cities.

We also find out whether the relationship is homogeneous within cities, i.e. whether the infrastructure in the core differs from the suburbs. Pragmatically, zooming in also resolves the problem of a consistent delineation of cities across cases and size ranges, which we know is a recurrent problem for landuse and transport interactions appraisal (Thomas et al., 2018) or in the urban scaling literature (e.g. Louf and Barthelemy, 2014; Cottineau et al., 2017). Our solution consists in analysing detours for a series of urban extents while controlling for population size, using the scaling of homothetic urban profiles identified by Lemoy and Caruso (2020, 2021).

Road network distances were computed for 301 European Larger Urban Zones (LUZ) (Copernicus, EEA, 2006). Our radial detour metrics are based on empirical distance measurements between populated places and the main centre of the region. The considered trips are the fastest paths computed using the Google Maps Algorithm and result in 303,000 distances. For non-radial detours, we identify clusters of high population density as origins and destinations of trips, following the methods developed by Riguelle et al. (2007). It relies on LISA (Anselin, 1995) and relates to the local spatial context and does not require exogenously defined density thresholds, which could also

depend on size. In cities that had at least 2 clusters, we simulated trips between all pairwise combinations, resulting in about 20,000 non-radial road network distances.

As a result, we clearly establish the linear relationship between the network distance and the Euclidean distance to the centre. The average radial detour is 1.343, which is close, but above the expected detour we would see if urban regions were entirely covered by Manhattan networks.

We show that urban cores bear more radial detours on average than entire functional urban regions. We discovered a small but significant scaling with population size: at the urban region scale, increasing city size seem to imply a dis-economy of scale, especially when other significant geographical factors (latitude, longitude, elevation change, proximity to coast) are controlled for. Most importantly however, we have shown that the scaling depends largely, in intensity and direction, upon cities' spatial definition. When cities' central part only is considered, the disadvantage of large cities becomes an advantage: core areas of larger cities have smaller radial detours.

Then, the non-radial physical detours were found to be larger and more variable. The relation between the radial and the non-radial detours is positive, with a proportionality of 1.124. On average for all cities, we find a non-radial detour of 1.516, which is 13.72% larger than radial ones. Radial detours can thus be seen as minimal detours. It is surprising to find non-radial detours to be higher because polycentricity is in essence a reorganisation of cities that should counteract the negative effect of monocentricity when cities grow. As polycentricity does not lead to reduced detours across subcentres, our result suggests that subcentres rather act as many monocentric structures, smaller in size, within the city.

We find little significant factors explaining the variation of non-radial physical detours across Europe: only the latitude and the distance to the sea remain significant, leaving much of the unexplained to local network or urbanisation particularities. Importantly however, we find that population size is no longer a significant effect even when other factors are controlled for. It is an important finding suggesting that, if there is a scaling for road networks, it is only for radial trips. Urban growth generates a problem of accessibility to the core, not a general accessibility problem. When a city becomes larger, polycentricity comes as a rescue by bringing new subcentralities, rather than facilitating any trip across the city.

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Investigating Geographic Patterns in Covid-19 Using Bayesian Model Averaging

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Keywords: Covid-19, Bayesian, Spatial Statistics

Bayesian model averaging (BMA) (Hinne *et al*, 2020) is a method of statistical modelling that allows a number of candidate models to be evaluated and estimates of their respective probabilities of being the 'true' model to be assessed. These probabilities are useful in their own right – as one can use these to evaluate the relative plausibility of each model, given their ability to predict a data set. This can be used, for example, as a Bayesian equivalent of a hypothesis test, where a null and alternative model can be compared.

However, the flexibility of this approach goes beyond this. While a 'classical' hypothesis test is confined to two models, one of which is nested within the other (for example one model having a specific coefficient set to zero, whilst the alternative allowing any value), this approach allows models to be non-nested (for example a dependent variable having distinct probability distributions in competing models). It also allows for more than two models to be considered at a time. However, the utility of the approach – and indeed the reason for its name – is that having assigned relative probabilities to each model, it is then possible to use these probabilities to obtain an estimate making use of *all* of the models. This is particularly useful when there is reasonable evidence in favour of more than one model. Typical workflows (such as leave-one-out cross validation) end with the selection of a single 'best' model, possibly discarding several models that perform relatively well. However, model averaging often provides a better predictor than any of the individual models considered alone, making use of information from many models.

The above outlines the general principle of BMA, but here we focus on the fact that it can be a powerful tool for spatial data analytics. Some examples of its use include comparing (and averaging|) spatial regression models using different spatial weight matrices; Spatially varying

coefficient regression models where different parameters have fixed or spatially varying coefficents in each model and count-based regression models where different distribution functions are used for the response variable (For example, Poisson vs. Zero Inflated Poisson vs. Negative Binomial).

The last of these examples is considered here – by investigating numbers of cases of Covid-19 reported in the Republic of Ireland in the early days of the recent pandemic, in March 2020. A number of possibilities could tentatively explain geographical patterns in the number of cases observed. The simplest is that the counts have a Poisson distribution (suggesting cases occur independently). An alternative is a zero-inflated Poisson model (suggesting that in some cases no symptoms are exhibited, or for other reasons cases go unreported). Another alternative is that counts

have a negative binomial distribution (suggesting that some clustering in cases may occur – for example several cases in the same household). In addition, the parameters in each of these models could exhibit heterogeneity.

In this study each of these models are considered given the covid data, and their likelihoods are considered. It is also worth noting that the estimation of these posterior probabilities requires some consideration. Here the approach known as *Bridge Sampling* (Meng and Schilling, 2002) is used. It is seen that although some models have very poor evidence, others have similar (good) performance, and predictions can be made via model averaging, as well as inferences about the levels of unreported cases.

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Morphological Regionalisation of French Cities – A methodology for street-based analysis of urban form

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Keywords: Urban Morphometrics, Streetscape, Urban Fabric, Multiple Fabric Assessment, France

Cities are the overlay of morpho-functional patterns evolving in time and space. When exploring urban space, city users are exposed to a diversity of cityscapes alternating vernacular centres, modernist developments, sprawling suburbia and very specific exurbs. The diverse forms of the urban fabric influence the functioning of cities, human perception, practices and uses, and pose different challenges for the urban technological and environmental transitions. This diversity must be recognized and accounted for to understand the city and to conceive place-specific interventions on it. A challenge for urban geographers is thus to identify the contemporary morphotypes, i.e. specific patterns of the urban fabric, organising buildings, streets, plots and site features, that are recurrent within today's cities, and to regionalize vast metropolitan areas on the basis of these morphotypes.

Since the second after-war, urban morphology and its different schools, has produced considerable knowledge of traditional morphotypes and their constitutive elements. The Italian school (Caniggia and Maffei 1979) highlighted the contribution of building types and their historical evolution to the formation of the urban fabric. The French school (Castex et al. 1980), studied the role of plot patterns. The British school (Conzen 1960) set out the most ambitious goal of regionalising urban space in terms of observable forms of the urban fabric (Larkham and Morton 2011). However, the identification and characterization of the urban fabric, as well as the regionalization of cities, remained challenging tasks. They relied on expert-driven and labour-intensive qualitative and manual measurements, which had limitations in terms of reproducibility and scalability. Consequently, comparative studies across different urban regions were hindered. Additionally, morphological research primarily concentrated on historical central areas, overlooking the forms of peripheral and suburban growth prevalent in contemporary urbanization.

Lately, increasing availability of geospatial fine-grained data, greater computational power, and developments in spatial analysis, paved the way to a data-driven stream of urban morphology, referred to as urban morphometrics (Araldi and Fusco 2019; Bobkova et al., 2019; Dibble et al., 2019; Fleishmann et al. 2022; Gil et al., 2012; Oliveira and Medeiros 2016). Urban morphometrics, stimulated by the dialogue with traditional urban morphology, proposes innovative data-driven computer-aided protocols for the spatial analysis of urban form in general, and the urban fabric in particular, producing new insight on the internal morphological structure of cities. This presentation will focus on Multiple Fabric Assessment (MFA, Araldi and Fusco 2019). MFA is a computer-aided

urban morphometric protocol for morphological regionalization: it mainly differs from other protocols by using a street-based perspective, thus allowing a multiscale description of the built environment as observed from the public space of the street. The perceptive-based framework underlying MFA allows for the convergence of urban typo-morphology with streetscape analysis (Harvey et Aultman-Hall 2015) within a coherent analysis protocol. The pedestrian-based modelling approach proves essential in light of the renewed interest in the issues of perception, use, and design of public spaces. What is most specific to MFA and of particular interest to theoretical and quantitative geographers is its integration of geostatistically significant spatial patterns, along with machine learning methodologies, for the identification and characterization of morphotypes.

MFA has been applied to various urban areas in different sociocultural contexts and geographical scales (Fusco and Araldi 2017, Perez et al. 2019, Guyot et al. 2020, Fusco et al. 2021). Based on these experiences, MFA has undergone further development and upscaling to analyse and compare larger study areas. The presentation focuses on recent methodological advancements in MFA, which were needed to implement it on the largest French metropolitan areas. Advancements include: improved streetscape morphometrics; development of a building typology for the entire country prior to morphotype detection through MFA (Araldi et al. 2023); use of Gaussian mixture models to identify different values for each morphometric feature; creation of a new Bayesian clustering algorithm called INBIAC (Iterative Naive Bayesian Inference Agglomerative Clustering) to generate numerous clustering models; selection of the best clustering models based on log-likelihood; use of a hierarchical clustering algorithm to combine the best models and create a nested taxonomy of morphotypes for each study area; final hierarchical clustering of place-specific morphotypes using the original streetscape morphometrics to obtain a general nested taxonomy of morphotypes across all study areas.

The improved protocol opens the way to a multiscale comparative analysis of contemporary urban forms in France. It has been implemented over the eight largest metropolitan areas of France (Paris, Lyon, Marseille-Aix-en-Provence, Lille-Roubaix-Tourcoing, the French Riviera, Bordeaux, Toulouse, and Nantes) obtaining both place-specific morphotypes and a general taxonomy of the urban fabric in French metropolitan areas. The eight study areas could thus be regionalised using both their specific morphotypes and knowledge of their position within a common taxonomy. Common spatial structures emerge from regionalisation, as well as a few specificities linked both to site constraints and to the different spatial extent of morphotypes. These results are a first contribution to a national atlas of morphologically regionalized metropolitan areas.

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Are poor children schooled in low quality environments? The case of French-speaking Belgian schools.

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Keywords: school, air pollution, greenness, socio-economic status

The living environment plays a critical role in overall well-being, particularly during childhood. The positive impact of green spaces on health has been widely demonstrated (Lee and Maheswaran, 2011; Tzoulas et al., 2007) as well as the detrimental effects of air pollution (Landrigan *et al.*, 2018). Moreover, compelling evidence indicates that exposure to nature during childhood contributes to improve cognitive development and mental health (Engemann et al., 2019; Vanaken and Danckaerts, 2018). Children are also highly susceptible to pollution-related diseases (Landrigan et al., 2018). At the same time, socio-environmental inequalities present significant challenges within our societies. The most vulnerable population groups are often exposed to environments with limited green spaces (Schüle et al., 2019) and higher pollution levels (Fairburn et al., 2019). Furthermore, the undesirable and cumulative environmental exposures that children from low socio-economic backgrounds experience at home are also present in schools (Bolte et al., 2010).

In this study, we explored the association between the socio-economic status of the pupils and the school environment in the Fédération Wallonie-Bruxelles, which encompasses French-speaking schools in Brussels and Wallonia, Belgium. We specifically investigated the levels of greenness and air pollution around the school establishments. Our main hypothesis was that children from low socio-economic backgrounds are more likely to attend schools located in environments with low levels of greenness and high levels of air pollution. Additionally, we investigated potential variations in this relationship across various settings. We considered different types of areas, including rural, urban, and high-density areas (Eurostat, 2018). We also examined potential differences in this association across specialized education programs and different educational levels: kindergarten, primary, and secondary levels. Lastly, we investigated variations among different educational networks : in Belgium, subsidised education is either organised by the public authorities or by associations. By examining these factors, we aimed to obtain a comprehensive understanding of how socio-economic status is related to the school environment across diverse contexts and educational settings.

To assess the socio-economic level, we used a socio-economic index (SEI) developed by the Fédération Wallonie-Bruxelles. This composite index classifies school establishments based on seven indicators measuring the socio-economic status of their population. These indicators include income, education levels, employment activities, unemployment rates, activity rates, and social assistance recipients. A small value of the index indicates less privileged socio-economic status (FWB, 2021). We described the school environment for various buffer sizes, incorporating land

cover data at a 2m spatial resolution (Radoux et al., 2023), as well as high-resolution models of air pollution levels. Pollution was NO2, PM2.5, PM10, and black carbon (IRCELINE, 2023).

The study revealed a significant relationship between the mean SEI and both school greenness and pollution levels. Concerning pollution, we discovered a correlation between the mean SEI and the annual mean of black carbon (BC) pollution across all schools ($r = -0.39$, $p < 0.001$). Schools with lower SEI scores exhibited higher levels of pollution in their immediate surroundings. One explanation for this strong association is that, on average, wealthier schools tend to be situated in rural areas, whereas less affluent schools are more prevalent in densely urbanized zones. The correlation between BC and mean SEI becomes negligible when considering only rural schools ($r = 0.08$, $p = 0.005$), but remains albeit attenuated when focusing on schools in dense urban clusters ($r = -0.15$, $p < 0.001$). However, when specifically examining secondary schools located in dense urban clusters, we observed a significant and even strong correlation ($r = -0.31$, $p < 0.001$). Similar associations were found for other atmospheric pollutants. Additionally, our findings indicated that schools with lower SEI scores tended to have fewer green spaces in their surroundings. This association remained statistically significant even when considering different typologies of urban environments.

Addressing the importance of socio-environmental inequalities, it is crucial for authorities to prioritize and allocate resources to establish fair environments in schools. By focusing on enhancing the school environment, authorities can actively contribute to mitigating these inequalities. Creating and maintaining green spaces within school premises can provide students with direct exposure to nature, resulting in improved mental well-being, reduced stress levels, and enhanced concentration during academic tasks (Dadvand *et al.*, 2015). This effort can help narrow the gap in opportunities and experiences among diverse socio-economic groups, ensuring that every student has access to a healthy and supportive learning environment.

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A bivariate multifractal analysis approach to understanding the dynamics of socio-spatial segregation

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Keywords: socio-spatial segregation, multifractal analysis, wavelet leaders, spatial information theory

Introduction

Although the study of fractal and multifractal properties is now an established approach to the statistical analysis of urban data, the joint multifractal characterization of multivariate spatial signals remains unexplored. The latter is critical to understanding complex multiscale relationships in cities, e.g., for socio-spatial segregation processes, where the evolution of behavior across geographical scales has traditionally played a pivotal role (Massey et al., 1996, Reardon et al., 2002, Barros et al., 2018). In this context, the proposed approach, which uses wavelet leaders (Leonarduzzi et al., 2016) for the multifractal analysis (Muzy et al., 1993, Jaffard et al., 2019) of irregular point processes (Lengyel et al., 2022), estimates self-similarity and intermittency exponents, as well as self-similar and multifractal cross-correlation by combining classical multifractal and geographical analysis methods. This can be done at different spatial resolutions, from the continuous screening of the urban environment at the neighborhood level to a comparative analysis of cities and regions (Lengyel et al., 2023). Our results show that the bivariate multifractal analysis may yield more robust estimations than classical two-group segregation measures that typically compare local measures to a fixed global average or operate statically at a single scale (Massey et al., 1996, Reardon et al., 2008, Peach, 2009, Barros et al., 2018). In contrast, the wavelet technique can identify localized differences in signal behavior, allowing dynamic cross-comparisons regardless of the chosen global boundary. Additionally, multifractal analysis can also distinguish between interaction patterns and, for example, delineate the more "perturbed" areas where socioeconomic mechanisms characterized by very different levels of intermittency (the measure of deviations from self-similar fragmentation) coincide. In summary, multifractal analysis is a new extension of evenness/clustering measures that provides additional information on the interrelationships among local socio-spatial dynamics.

Local multifractal analysis and classical segregation measures

Samples from the French census database (INSEE, 2023), available on a *200*-meter grid, are used as case studies to illustrate the methodology. Estimations are performed at every original data point

within a local environment of arbitrary size L across a set of length scales a; For the univariate analysis, the cumulants of order one ($c1$) and two ($c2 < 0$) are used as representatives of fractality and multifractality. For the bivariate case, we estimate the so-called fractal ($-1<\rho ss<1$) and multifractal ($-1<\rho mf<1$) cross-correlation functions based on definitions provided in (Jaffard et al., 2019). In addition to the bivariate multifractal parameters (ρss and ρmf), classical segregation measures are also calculated (globally and locally using the same length scales a); the "Dissimilarity index" and the Spatial Information Theory's "H-index" (Reardon et al., 2002, Reardon et al., 2008, Barros et al., 2018). Our results show that ρss results converge to the classical "H-index" measures at large spatial scales; However, ρss may be able to reveal more nuanced information and variability over successive length scales a as well as locally over the spatial domain. Further, regarding interaction patterns, the cross-correlation function ρmf implies that the closer the value is to zero, the more decorrelated the local dynamics of the two processes and that mixing can occur in two ways. When $\rho mf > 0$, the phenomena exhibit similar levels of intermittency and, thus, a similar intensity of small-scale, localized bursts. However, when $\rho mf < 0$, one process locally exhibits some degree of intermittency while the other does not, suggesting more uneven structural dependencies.

Results in the Greater Paris region, France

More specifically, two pairs of social and economic data are studied: age (share of persons under 18 and over 65) and income (share of poor households and equivalized disposable income per inhabitant). First, we consider Paris and its surroundings, the so-called Petite-Couronne region, at the local level ($L = 2500$ meters), continuously scanning the whole territory at consecutive length scales a (between 400 and 2400 meters). We find significant differences between these two pairs of processes regarding the segregation location and its local dynamics. For example, while in the case of age, more heterogenous mixing occurs outside the city limits to the northwest of Paris, income segregation is concentrated in the inner-city areas, with more irregular interactions in the eastern districts. It is possible that current socioeconomic and demographic trends are contributing to an increase in small-scale social polarization, particularly in these areas ($\rho mf < 0$), and therefore rapidly necessitate various targeted measures. We conclude with a comparative global analysis of the fifty most populous French metropolitan regions.

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Public Transport Supply - A Spatial and Social Equity Analysis in Recife, Brazil

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Keywords: Spatial planning; Public transport; Accessibility; Equity; 'Need-gaps'

This work concerns the evaluation of transport supply equity based on observed supply data and potential demand using the city of Recife in Brazil as a case study. The methodology includes calculating supply and demand measures for the 94 neighbourhoods in the municipality. The supply is calculated based on the public transport routes and the proportion of the neighbourhoods served by these routes. This estimation considers the frequency and capacity of the vehicles operating on this route. The demand considers indicators of the population's socio-economic features and urban facilities. Overlaying these measures makes it possible to detect spatial gaps (or need gaps), highlighting disadvantages in transportation for some city areas or neighbourhoods and areas where the public transport supply is above the potential demand. A service level indicator for each neighbourhood was also estimated using the supply and the population weight.

As a main result, approximately one-third of the population in Recife is in a high level of the needgaps class. The alternative service level indicator, which reveals the proximity of people to public transport, shows that 72 neighbourhoods (84% of the population) are below the average in terms of public transport service. In this need-gaps analysis, the consistency of the results is striking when it shows that the largest 'supply-demand' disparities are in socioeconomically disadvantaged neighbourhoods, contributing to its continuous disadvantage. This type of quantitative geographical analysis has a solid potential to combine different factors in assessing the 'gaps' in the supply of Public Transport Systems by introducing the social equity perspective.

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Scale effects on medical desert classification, France

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Keywords: medical desert, typology, territorial inequalities, healthcare accessibility

Background

Medical deserts are defined as territorial planning problems with spatial decline and inequalities in the supply of care not correlated with actual and future demographic trends. In France, primary health care has been promoted by the World Health Organization as "the first level of contact of individuals with the national health system"(Rifkin, 2018). In this sense, they refer to the provision of universally accessible care and services to meet most of the health needs of the population. French primary care policy has historically been built around the general practitioner, which introduces a principle of hierarchy in access to care. Nevertheless, a very large number of professionals involved in the field of primary care contribute to promoting a better patient-centered integrated approach to care due to the complementarity of these professions for the diagnosis and treatment of patients alongside the GPs(de Bont *et al.*, 2016).

Previous studies have focused on accessibility to healthcare for one practitioner (Launay *et al.*, 2019) or focused on the selection of methodology more or less complex as building an index (LucasGabrielli and Mangeney, 2019). However, less attention has been paid to providing a realistic focused approach on a panel of professionals to take into account the inter-sectoral capacity in the definition (Gao *et al.*, 2016; Chevillard and Mousquès, 2018). Moreover, no attention has been paid to their geographical variability, related to spatial scale effect. From a policy-making perspective, place-based measures in which the level of accessibility is associated with a place or spatial unit of analysis are generally used to measure spatial accessibility. Boundaries of the areas are units defined by historical and political reasons. They are not designed to promote the multidimensional aspects of accessibility to healthcare (Cebrecos *et al.*, 2018).

Aims

This research aims to highlight the consequences of the choice of spatial scale in a territorial description of medical inequalities. In this paper, we use a multi-scalar approach based on a multidomains and multi-professions definition of medical desert in France.

This study has several objectives: i) to describe the statistical impact on variance, the geographical variability, ii) and to analyze the spatial scale effects on the classification.

Methodology

We focused on France mainland and overseas department and performed our typology at the municipality level and two other supra-municipalities scales used by the public policies in France: EPCI (public inter-municipality cooperation establishments) and "living territories". For each geographical unit, a multidimensional typology has been conducted using a three-step method that consisted in creating scores by dimension as a pre-processing step before performing the traditional combination of Principal Component Analysis and the clustering method (Costello and Osborne, 2005). To this end, three typologies were performed to describe each spatial unit of medical desert according to several dimensions. The first dimension is health care accessibility defined by GPs, nurses and physiotherapists localized potential accessibility indicators for all spatial units based on xSFCA method and distance in minutes to the closest radiologists, laboratory, pharmacist and emergency services. Other dimensions have been included: the dynamic of supply (with the temporal evolution of GPs supply and the part of the upper than 65 years old) and the needs of healthcare professionals (with the median income and the standardized global and premature mortality rates per 100 000 inhabitants calculated). Other illustrative dimensions have been used to describe areas. Statistics and global Moran'I indicators, allow us to present the statistical and geographical variability. The Internal validity indicators (Kappa coefficients and entropy values) and the Sankey diagram allow us to analyse the spatial scale effects change by visualizing using arrows the flow quantity between typologies (Porter *et al.*, 2021).

Findings

Using the French example, this research highlights the consequences of the choice of spatial scale in the objective to describe medical desert using three typologies by an approach multi-professions and multi-domains. Our results show a plurality of situations with some classes that accumulate unfavorable situations in all domains as high rurality, low accessibility to multiple professions, high need and low dynamic of supply and the inverse class, which accumulates favorable ones. In addition, the typologies highlight areas where the level of accessibility of some professionals is more mixed, to which must be added the non-negligible influences of the level of needs and the evolution of the supply of care in these areas, which raises questions. We have demonstrated statistics and geographic disparities between the typologies. The results corroborate the findings that larger spatial units tend to present less variability due to the average effect of the aggregation. Finally, the choice of the spatial unit should be adapted to the availability of the data and the public policies concern.

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Abstracts of Parallel Sessions 6

Spatiotemporal dynamics of housing development: the contribution of spatial analysis methods to the understanding of new housing prices in the Metropolises of Lyon and Toulouse (2005-2019)

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Keywords: spatial analysis, multiscale geographically weighted regression, multilevel modeling, regionalisation, housing development, France

Property markets can be seen as social constructs. In this area, the logic of property pricing is particularly resistant to classical microeconomic analysis (volume of demand does not always reduce price levels, price levels are relatively insensitive to production costs, etc.). In the case of the new housing market, the selling price is determined by the choice of developers. Part of their activity is to set the selling price of their dwellings in order to maximise their margin (Bardet, Coulondre and Shimbo 2020), a calculation that can be compared to a compromise between selling high and selling fast.

The hypothesis underlying this work, inspired by previous qualitative work (Ausello, 2022; Le Brun, 2023), is that the way developers adjust the selling prices of their dwellings to their characteristics is sensitive to the housing market situation and dynamics on the one hand, and to their location on the other. The aim of this paper is to test this hypothesis using spatial analysis methods. It implies being able to objectify, according to the phases of the economic situation, the role played by the geographical context in the price setting rules of housing developers.

This hypothesis is tested on two sites, the metropolises of Toulouse and Lyon, for the period 2005-2019. It is based on private databases produced and made available by the company Adéquation. These databases, which are georeferenced (XY coordinates) and fully disaggregated (1 line = 1 dwelling), provide information on the housing production of private property developers and are considered almost exhaustive (Juillard, 2019). On the basis of these data, we have constructed databases of buildings (1 line = 1 building) marketed by private developers between 2005 and 2019 in the Toulouse and Lyon Metropolises. An initial analysis of these databases makes it possible to divide the period under study into several phases for each location. The periodisation adopted has attempted to associate each phase with coherent trends in terms of sales volumes and price variations.

On this ground, our protocol combines three spatial analysis methodological tools: multiscale geographically weighted regression (MGWR), regionalisation and multilevel modelling. Our method follows the work of Marco Helbich et al. (2014), who proposed an empirical segmentation of real

estate markets for the Austrian case, and that of Thierry Feuillet (2021) on the hybridisation of local and contextual spatial models in health geography.

The protocol is divided into four steps:

[1] We first apply a hedonic price model for each phase of each plot, where the price per square metre of each building is explained by four variables: distance from the centre, whether or not the building is located in a ZAC (urban development zone), the proportion of assisted home sales, and the proportion of studios and 1-bedroom units in each building. We

justify the use of a geographically weighted regression method by measuring the spatial autocorrelation of the residuals of this first (non-spatial) model.

[2] We use an MGWR to provide a continuous exploration of the spatial heterogeneity of the statistical relationship between price and its determinants.

[3] We carry out a regionalisation (SKATER method) on the basis of the coefficients assigned to each building by the MGWR. The relevance of this regionalisation is verified by comparing it with a declarative sub-market segmentation (produced by Adéquation on the basis of discussions with housing developers).

[4] We use multi-level modelling to calculate the proportion of total price variance explained by each submarket segmentation (ICC). The result objectifies the degree of spatial mimicry by developers for each location and phase.

This complex methodological protocol makes it possible to draw theoretically significant conclusions on the spatial and temporal sensitivity of new housing. In the case of Lyon, the weight of the spatial context follows 'pro-cyclical' variations: the variance explained by submarket segmentation is higher in the 'high' phases of the cycles (high volumes, rising prices) than in the low phases. This suggests that during low phases, developers lose confidence in the importance of different local contexts. In the case of Toulouse, the result is the opposite: the variance associated with segmentation is "counter-cyclical". In this configuration, we therefore hypothesise that, when faced with a fall in sales volumes, developers opt for cautious strategies and are more likely than usual to follow the prices offered locally by competing developers. Conversely, periods of recovery or expansion seem to encourage more adventurous pricing strategies. This opportunistic approach may be due to the centrality of tax exemption to property development in Toulouse.

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Comparing serious games and optimization modelling to support decision making: Planning the elementary school network of Marinha Grande

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Keywords: Collaborative Planning, Optimization, Public Facilities, Serious Games

There are solid arguments around a crisis in public participation, not because citizens are not interested in participating, but because of the difficulty of doing it in practice (Legacy, 2017). Planners and other practitioners have a legacy of trying to explore new ways to engage citizens to deliver processes where citizens and stakeholders can participate actively and efficiently (Innes and Booher, 2018). Practitioners can define collaborative planning processes to collect new data, where participants can discuss, learn about the issues at stake, test ideas, and reach compromises regarding a planning solution (Farinosi *et al.*, 2019). But how to implement collaborative planning approaches in practice that are accountable, engaging and deliver effective and usable results?

Despite the prejudice about game usage for serious matters as urban planning (Koens *et al.*, 2020), there are cases where game-based planning delivered more creative and innovative solutions while fostering participation (Goodspeed *et al.*, 2020) and engaging youngsters (Cammaerts *et al.*, 2014). One simple solution is combining game mechanisms and physical pieces with printed maps to deliver these serious planning games (Sousa, 2020; Sousa *et al.*, 2022).

It is recognized that games can be very engaging. However, there are concerns about simulation quality and game-based outcomes for planning approaches (Sousa *et al.*, 2022). To test how to build an analogue serious game that can be compared with validated methods, namely the optimization of public facilities networks, and ultimately provide information for planners, we developed a game to plan the network of elementary schools for the municipality of Marinha Grande (Portugal)

First, we collected data about the resident students and existing schools, modelling the facility location problem in *Xpress* Software to find the minimal cost of building schools and transporting the students to respond to all demands. After this, we created a board game where the game mechanisms (game elements that players use and activate to implement choices and the game system transforms inputs into outputs and feedback) helped participants to solve the same problem. Doctoral students in planning, planning practitioners and city councilors from the Municipality of Marinha Grande played the game.

Game mechanisms, like tile placement and tableau building, helped the users to solve the problem presented by the game. They were implemented by allocating pieces representing students from the map (where students reside) to tables recording school capacity, allowing players to define strategies and calculate the costs of building/closing schools and the transport costs in tangible ways. Using track mechanisms helped to simplify the calculation of these costs. The map was designed as a hexagonal grid, and game mechanisms (connecting) aimed at supporting the decision-making process of players.

The experiment revealed that understanding board game design elements have an important impact in designing games as tools for collaborative planning processes. And comparing it to a widely used and validated optimization approach allows us to assess the quality of the solutions. In the experiment, the optimization model considered only the different costs, while the board game allowed players the freedom to account for other elements associated with the social, cultural, and environmental dimensions of school locations. These dimensions can be difficult to access by traditional decision support methods. The experiment showed that board game players can collaborate and reach solutions that are comparable with the ones obtained through optimization, but they can choose decision criteria other than monetary costs. In cases where the board game players decided to consider social and cultural dimensions, the solution costs increased between 4 to 30%.

The experiment highlighted the potential of game-based approaches, and in particular the use of board games, considering that participants characterised the experience as enjoyable and useful to deal with the problem at hand and establish a collaborative planning and decision-making process.

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Where do people live in urban areas? A radial and scaling analysis of population density over European cities

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Keywords: radial analysis, urban scaling laws, population density

1. Introduction

In urban geography, scaling laws are typically used to reveal how socio-economic or environmental outcomes evolve in a system of cities. Great regularities have been found between several urban attributes (GDP, length of road, number of patents, etc.) and city population, following a power-law relationship (Bettencourt *et al.*, 2007; Shalizi, 2011). However, Batty and Ferguson (2011) argued that conclusions from scaling laws can be subject to uncertainties, as in the literature authors have found fairly different allometric coefficients for the most basic allometry of area versus population (mainly because no coherent and homogeneous definition of cities exist). This invites us to better considerate the internal structure of cities, rather than just looking at aggregated values. In a recent paper, Lemoy and Caruso (2020) demonstrate in Europe that there is an homothetic scaling behaviour for the population density profiles (i.e., how population density evolve with respect to distance to the city center). Here, we further investigate the shape of the curves, and focus on how population is distributed within European cities.

2. Materials and methods

a. Population estimates

Increasing efforts have been made these last years to provide open-access gridded population datasets (Leyk *et al.*, 2019). For instance, the GHS-POP dataset records population estimates with a spatial resolution of 100m. The asset of this dataset lies in its simple approach (proportional allocation of population to built-up areas), but rather large errors have been found in low and middleincome countries (Freire *et al.*, 2016; Kuffer *et al.*, 2022). Because different methodologies are applied to produce population estimates, we repeat the analysis with different gridded datasets.

b. Methods

A radial analysis is performed on hundreds of European cities with more than 50,000 inhabitants. For this purpose, we define the city center as the location of the city hall, and compute the population density within rings of fixed width around the city center. Radial profiles appear to be close to exponential, in agreement with the findings of Clark (1951). Thus, we do both a linear fit of the logarithm and a non-linear fit of the raw value, following (respectively) the equations

$\log(\rho_N(r))$~$\log(a_N)$ - r/l_N and $p_N(r)$~$a_N e^{-r/l_N}$, with $\rho_N(r)$ the population density at distance r from the city center, a_N the population density in the center and l_N the characteristic distance of exponential decrease. Finally, we fit the estimated distances l_N against total population N (linear fit of their logarithms) to have a better understanding of population distribution within cities given their size.

3. Results

We find out that non-linear fits seem more relevant (better goodness of fit). As expected, there is a power-law relationship connecting l_N (the distance at which the model estimates that $a_n e^{-1}$ inhabitants/km² is reached, i.e. the population is $e^1 \approx 2.7$ times lower than in the center) and total population N, underlying that population density decays in a predictive way. It is strong evidence that urban forms are similar irrespective of their size, but some cities appear compact (dense), while others are rather sprawled (sparse). Our results provide an effective comparison of urban forms across European cities, but they also raise the question of the most adequate urban form for a sustainable city. Further analyses are required to explain the observed forms of cities (national effect, coastal and polycentric cities, etc.).

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Combining equity and efficiency: the p-median problem with coverage constraint. An application to public service design

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Keywords: optimal location, p-median, coverage constraint, territorial partition, public service

In spatial planning, models for the optimal location of a resource have long existed (ReVelle and Swain, 1970, Béguin et al., 1982, 1989). It consists of locating *j* facilities (schools, shops, etc.) with a capacity *Cj* according to a demand (the population located in points *Pi*). There are two main logics for this optimal location (Béguin, 1989):

- efficiency, which consists in finding the locations of the *j* facilities that minimise the sum of the distances *Dij* that users located in *Pi* have to travel to reach the facility *j* closest to their home.

-equity or coverage maximisation, which consists of finding the locations of the *j* facilities that maximise the total demand (Sum of *Pi*) within a given distance threshold from a facility *j* (e.g. 15 minutes).

We can also add a third equity logic, which consists in minimising the situation of the worst user. However this logic is rarely used in practice.

Practical solutions to these optimal location problems exist in commercial software (e.g. Network Analyst ©ESRI). However, despite their widespread use, these methods remain inadequate for solving particular concrete optimal location problems. Indeed, in planning practice, optimal locations are rarely based on a single "pure" logic (equity *vs*. efficiency), but rather on mixed logics that integrate spatial coverage constraints, in particular those linked to territorial partitions. For example, if a set of schools is to be located between municipalities with very different populations, it is unlikely that the decision-maker will follow the logic of efficiency entirely, which could lead to no schools being located in the least populated areas, which would be politically difficult to accept (Taulelle, 2012). Conversely, it is equally unlikely that the decision-maker will follow the pure logic of maximising coverage, which could lead to over-equipping sparsely populated areas. In practice, therefore, he will mix these logics, most often finding the solution based on efficiency (economic logic) and tempering it with equity (political logic) by locating facilities, if possible, in all spatial units of a given hierarchical level (e.g. municipalities). The problem is that this approach remains

very empirical. The relocations to insure spatial coverage are carried out "by hand", according to the knowledge of the field, and therefore they remain very questionable.

In this context, in the same vein of the works of Josselin and Ciligot Travain (2013) and SaezAguado and Trandafir (2016), we propose an optimal location method that combines efficiency and a spatial units coverage constraint and apply it to the problem of the location of public services in the South region of France (5 million inhabitants). According to this method, the locations chosen for the facilities must satisfy a double constraint: all spatial units of a level L (e.g. communes) must be served and, at the same time, the sum of the distances *Dij* between users and services must be minimised. If the number of facilities is less than the number of spatial units, the best coverage possible is seeking.

For the resolution, we use the p-median model to which we add a spatial unit coverage constraint (in the same way as Saez and Trandafir did for distance coverage). In practice, we use operational research methods (Kose and Karabay, 2016), which allow us to find exact solutions as long as the instances are limited (here max 1000 points of demand and potential locations for facilities, a division into 1000 spatial units and 700 facilities to be located). Heuristics are being developed to handle larger instances.

In this article, we vary the number of facilities (37 maternities, 478 primary schools, 681 post offices), we use different territorial divisions (municipalities, townships, districts, intermunicipalities) and different logics of optimal location (efficiency, equity through coverage distance constraint, and our mixed method : efficiency combined with a spatial unit coverage constraint), and we measure what is gained or lost in terms of distances travelled by users (*Dij*) by introducing a coverage constraint linked to spatial unit coverage compared to a logic of pure efficiency.

The results put into perspective the debates on the location of public services and more particularly the supposed 'territorial abandon' by the state (Taulelle, 2012, Godoye, 2022).

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Quantifying ambiguity in urban definitions: a spatiallyexplicit sensitivity analysis of the "Degree of Urbanisation"

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In recent years, there has been a renewed interest in both academic and policy circles in defining and delineating urban agglomerations. The suite of delineation methods is increasingly diverse: various modelling techniques exist, relying on different density proxies such as those captured by light intensities, population estimates or built environment characteristics. Virtually all methods involve setting rules and deciding on thresholds, such as the minimum population required to be designated as a 'city'. However, there are no agreed-upon ways on deciding what are the 'best' values for such rules and thresholds, as it is difficult to come up with general conceptual justifications that have universal validity. As a result, thresholds and related implementation rules are intrinsically arbitrary and are at the root of considerable variability that is theoretically unaccounted for in the resultant urban delineations. It is crucial for policymakers and urban practitioners to be aware of sources of variability and their potential implications, for example when interpreting statistics on 'cities'.

We propose to conceptualise and subsequently operationalise this issue as *ambiguity*: the uncertainty that stems from several possible representations of the same urban concept. Ambiguity is inherent to the complex nature of defining urban agglomerations and manifests itself in three different ways. It arises because definitions rely on different epistemological positions on the essence of 'the urban', it emerges from the choice of the proxy around which an urban definition is constructed, and it is induced by specific threshold values and implementation rules. Here, we specifically focus on the third type of ambiguity.

Scholars generally employ sensitivity analyses to tackle ambiguity emerging out of arbitrary rules. Although valuable for assessing the robustness of the proposed urban delineations, sensitivity analyses lack insight into the spatial dimensions of ambiguity and fail to reveal how the effects of arbitrary rules are geographically distributed. To enhance transparency, we propose a conceptual framework to assess ambiguity in a spatially-explicit manner. The framework consists of three

different steps and is developed in a generic way, so it can be applied to any definition of urban agglomerations (including cities, urban areas, metropolitan regions etc.). The first step involves identifying the parameters of variation for a given definition, which include for example threshold values and contiguity criteria. In the second step, a set of alternative operationalisations is constructed by simultaneously varying these parameters. Finally, ambiguity is quantified as the inconsistency in the classification of a particular location across the set of alternative operationalisations.

To illustrate the potential of the framework, we apply it to one of the most employed urban definitions: the "Degree of Urbanisation" proposed by Dijkstra et al. (2021, p. 103312). The definition distinguishes cities, towns, and rural areas in a globally consistent manner by imposing minimum population density and size thresholds on a population grid. The application of our proposed framework reveals that ambiguity is not equally distributed in space: the definition is most sensitive in regions with dispersed urban development, for example in highly sprawled North American cities and the peri-urban region around Cairo. Apart from the influence of population density gradients on ambiguity, we also find that seemingly minor technical implementation rules can generate substantial spatially unequal ambiguity patterns. For example, changing the way in which contiguity of grid cells is defined influences the classification of cities more so in some regions (e.g., the Ganges River Basin) than in others. The contiguity rule, which is a practical consequence of working with squared grid cells rather than an inherent aspect of urban agglomerations, is consequently an important source of ambiguity in the "Degree of Urbanisation" and its impact is unequally distributed in space. Overall, the ambiguity framework allows for a spatially-explicit sensitivity analysis of all parameters of variation and provides a valuable tool for policymakers to make ambiguity tangible.

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Digital or local? Impacts of online shopping and teleworking on urban expansion: a theoretical spatial simulation

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Recent trends in online shopping have been intensified by the Covid-19 outbreak, with consumers moving from local shops and malls to internet-based orders. Even local shopping habits by excellence, such as groceries, have been impacted by these trends, with supermarkets offering delivery of goods to the doorstep. The rise of personalised shopping experiences and mobileoptimised websites and apps for instance, together with advancements in logistics infrastructure, suggest that these are long-term trends, more related to changing attitudes and behaviours (Wieland, 2023). These trends alone already have a long-lasting impact on urban spaces, causing a downward pressure on demand for traditional centrally located retail floor-space, as already indicated by rising vacancies (Orr et al., 2023); as well as a surge in alternative spaces that support this new economy, such as the concept of 'dark kitchens' (Souza et al., 2022), warehouses and suburban logistic spaces. Nonetheless, these concerning trends are also coupled with changes in the working culture (Barrero et al., 2021). It is evident that the pandemic has also accelerated previously existing trends of teleworking, further decreasing demand for central offices and urban dwellings. However, these are shifts that can act both ways, and the long-run general equilibrium effects are not yet clear. For instance, this urban flight can make central areas attractive again due to a downward pressure on rental and property prices (Florida et al., 2021). This can attract a certain parcel of the population back to central areas; a phenomenon that is not new and, sometimes, is also coupled with a change in character of traditional neighbourhoods which is often referred to as 'gentrification' (Glaeser et al., 2023). On top of it all, recent concerns of environmental sustainability have led to a rise in the tendency of promoting local economies (the 'buy local' movement), that can challenge these changes (Winfree and Watson, 2021). The interaction of all these forces remains uncertain: it challenges the standard trade-off between housing and commuting costs, which commands the distribution of the population along the distance to the main job centres. Moreover, it questions the local push-pull factors that command clustering and subcentre formation, to where people make short-distance trips. It is vital to understand how these changes may impact locations of

people and service-shops, their derived trips, and whether government reactions can improve sustainability and welfare.

This paper is the first in a series that builds up an agent-based model with microeconomic foundations, simulating the interaction between households and firms to contribute to discussions about the future of consumption, retail spaces, and urban form, with a focus on societal welfare and macro-patterns emerging from these interactions. The model encapsulates various factors such as online-shopping behaviour, preferences for buying local, importing costs, commuting and shopping trips, frequency of teleworking, a simplified rental market, and increasing returns to scale for firms.

The environment proposed comprises a two-dimensional landscape with discrete locations. At its heart lies a Central Business District (CBD), which offers employment for households. This setting follows the traditional monocentric city model conceptualised by Alonso (1964) and further explored in recent literature (Ahlfeldt, 2011; Delloye et al., 2018; Mossay et al., 2020). Households consume a uniform product sold by retail firms (shops), with an alternative consumption behaviour that consists on importing the products by themselves. Firms import the products to the landscape, and sell them for a profit to households. Households maximise utility, consisting of housing consumption and the uniform product consumption, while firms maximise profits.

Comprehensive analytical examinations investigate the anticipated outcomes of the model, via a simplified one-dimensional representation (linear city). With that, we explore the different bid-rent curves generated by the two possible consumption behaviours (importing vs. consuming locally) and how different land-use patterns might emerge depending on the relative prices between the two. For instance, we explore how high import costs offsets the financial benefit of a lower unitary price upon importing, benefiting local consumption that then prevails throughout the landscape.

Preliminary results suggest that differences in relative prices between importing and consuming locally, for households, might directly impact the viability of shops in the city centre. The main mechanism for that to happen is expected to be higher rents, analysed in this paper via the bid-rent theory. Different choices in the parameter space have also suggested discontinuities in the urban fabric depending on behaviour intensity: both housing consumption and, by consequence, density, are affected by how households decide to consume. Finally, changes in frequencies of visits to the city centre may also affect the outcome landscape of the simulation, highlighting how cities can respond to external shocks in working habits.

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Livelihood Dynamics in South African Peri-urban Areas: The Plight of Women in Ga-Mothapo, Limpopo Province

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Keywords: Livelihood, sustainability, peri-urban, vulnerabilities, livelihood strategies, shocks

The rapid expansion of peri-urban areas has lead to women being exposed to increased livelihood challenges as a result of marginalisation, inequality and limited access to resources. Despite policies and laws in place to improve the livelihoods and plight of women, very little has been achieved for women living in peri-urban areas. As a result, women in peri-urban areas tend to engage in informal livelihood activities that are not sustainable. This study therefore aimed to investigate the sustainability of the livelihood strategies adopted by women in Ga-Mothapo, Limpopo, South Africa by exploring: i) the different livelihood strategies adopted by women in Ga-Mothapo; ii) the impact of shocks to livelihood sustainability; and iii) the vulnerabilities experienced by women living in this peri-urban environment.

This study is informed by the Sustainable Livelihood Framework (SLF) as a research approach to livelihood analysis. The SLF is applied to analyse various aspects of livelihoods, including shocks and vulnerabilities, to determine its sustainability. The data was collected through a survey questionnaire administered to 150 participants in Ga-Mothapo The questionnaire data was then analysed using the SPSS Software. A focus group discussion with 10 women from the study area followed the survey to develop a more nuanced understanding of the experiences of women regarding their own livelihoods. To provide context to the participant's status quo, policies and programmes that influence their livelihoods were also considered.

The preliminary findings of this study reveal that women living in Ga-Mothapo tend to adopt unsustainable livelihood strategies as a result of the challenges they face with accessing financial support, land and employment. The respondents identified lack of formal employment opportunities and inaccessibility of land for agricultural practice as the main vulnerabilities influencing their livelihoods. Most respondents identified Covid-19 as a major livelihood shock. Future research will further explore the livelihood strategies, vulnerabilities and shocks to contribute to the development of livelihood trajectories in an attempt to promote sustainable livelihoods for women living in periurban areas.

Dynamic reading and delineation of urban areas – Applying cellular phone data in the case of Tallinn, Estonia

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Keywords: Cellular phone data, Urban area definitions, Urban dynamics, Complexity

Cities are complex networked systems consisting of intertwined structure of activities and flows, in a state of constant flux. The patterns of activity change by day, week and years creating an ever-changing entity. Over time their configurations evolve through restructuring the urban tissue in a continuous trans-scalar process.

Official urban area definitions produce one reading of urbanity. They are mostly national, and yield figures: urban population percentage, urbanisation rate, urban population density and alike. First, as national definitions, they produce widely varying outcomes, as our prior study proves (Vanhatalo and Partanen, 2022). Secondly, as they are very often based on population, i.e. on static residency, and consequently ignore the dynamics of different activities of cities, these readings can produce a flawed image of urbanity. Therefore, it is necessary to explore the impact of utilising novel methods for more appropriate reading that captures dynamics of urbanity.

Here we applied cellular phone data in spatial analyses to observe temporal activity patterns within the city of Tallinn, Estonia. We scrutinized changes in these on daily, weekly, monthly, and yearly basis, by utilising a cellular dataset from two different years, three different months and four different days. On basis of the cellular data four activity classes were established. Further, we compared these spatiotemporal images to the urban areas by six different national definitions. In addition to the cellular data, other conventional datasets, such as population and buildings, were used.

Results indicate that regarding activity level, certain spatial patterns could be recognized for each time frame. The results confirmed for example that certain residential and workplace areas follow the expected cycle of work-leisure cycle, but at the same time also unexpected patterns were revealed, as certain areas differed from this cycle. When comparing the geography of the high-activity areas to the delineation of the national definition, it could be detected that they differ significantly. However, some of the national definitions appeared to outline the overall activity landscape quite well. This study improves the understanding of dynamic nature of the urbanity applicable in urban planning, research, and governance.

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Segmenting mobility hubs users with traffic flows

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Keywords: mobility hubs, commuting patterns, transport policy

Remote work has enabled people to live further away from their workplaces, increasing the flow of commuters coming to the city from sub- and peri-urban areas (Caldarola and Sorrell, 2022). Lowdensity residential areas present a challenge to guarantee adequate transport coverage. As a result, residents of sub- and peri-urban areas rely on private vehicles to reach their workplaces. A higher number of people commuting from outside cities adds more pressure on the intra-city traffic flows. Mobility hubs tailored to the needs of the residents living in sub- and peri-urban areas could help to alleviate intra-city traffic. However, persuading residents to choose shared mobility available in hubs instead of their private car requires policymakers to tailor nudging strategies based on their individuals social and economic backgrounds. Likewise, it requires looking at the spatial characteristics of the infrastructure available in their residential area. Similarly, finding effective hub locations must consider both the demand and infrastructure available.

This study aims to define segments of commuters living in Antwerp's peri- and urban areas who could become mobility hub users. The study uses demographic information and origin-destination (OD) flows from commuters to identify (i) private vehicle drivers living in the vicinity of infrastructure that could facilitate modal shift (ii) places of interest to develop the peri- and urban mobility hubs network.

The authors employ shared mobility data, i.e., shared cars and bikes, and a yearly survey to companies with more than 100 employees on commuting conducted by the municipality of Antwerp to create OD flows and build maps with highly transited routes. This allows for segmentation of the drivers based on mobility and demographic patterns. The survey provides insights about employee characteristics such as genre, household location, salary, type of job, and telework availability. An exploratory spatial data analysis is conducted to identify commuting patterns. In these patterns, we search for groups of commuters that have the potential to improve the sustainability of their trips through the use or expansion of the mobility hub network. The identification of these profiles could support policymakers to create nudging strategies based on actual living and built environment conditions, i.e., public transport stops and cycling lanes available. Moreover, we use the findings to improve the network of mobility hubs based on the urban form and facilitate inter- and intra-urban commuting flows.

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Transport accessibility and regional performance: a spatial analysis for Europe

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Keywords: Transport accessibility, Regional performance, European Union

For years the European Commission invested in transport infrastructure, based on the belief that new levels of accessibility can attract more people and businesses, thus improving regional development (European Commission, 2020). Nevertheless, a direct relationship between transport infrastructure investment and regional development is not always observed in practice (Elburz et al., 2017), leading to growing concerns that additional transport infrastructure investments may not have sizeable effects on regional development (Rodríguez-Pose and Ketterer, 2020). Several authors claimed that regional characteristics may constrain the extent of transport infrastructure impact (Sloboda and Yao, 2008; Crescenzi and Giua, 2020). The identification of regions where transport infrastructure investment may bring more economic added value and social surplus has a preponderant importance on the efficient allocation of public funds. This research proposes a two-phase approach to make that identification. Firstly, the region's efficiency in transforming inputs (e.g., capital stock per employee) onto outputs (e.g., GDP per capita), is evaluated using Data Envelopment Analysis (DEA). Afterwards, the spatial relationship between regional performance and transport accessibility (air, rail, and road) is assessed based on the Local Bivariate Moran Index. The approach is demonstrated in a case study of 186 European NUTS 2 regions, located in 19 countries, encompassing Central Europe and Southern Europe. The main goal of this work is to answer the following two questions: (1) Is there a significant relationship between transport accessibility and regional performance in the case study regions? (2) If so, in what regions can it be found, and of what kind is that relationship?

Concerning the first question, results show that not all the regions have a significant relationship between transport accessibility and regional performance. For the road mode, the relationship between regional performance and road accessibility is statistically significant for 53% of the regions, whereas for the rail mode, the figure drops to 49%. For air accessibility, the percentage of significant regions drops further down to 41%. Concerning the second question, the Moran significance of the relationship is mostly of the high-high type, i.e., regions with high neighbouring accessibility have high regional performance, more specifically: road 63%, rail 55%, air 53%. In these regions, improving transport accessibility in the neighboring regions may further boost regional performance. Regions also exist with Moran significance of the low-low type, i.e., low accessibility

and neighbouring low regional performance. For these regions, public investment policies should combine socioeconomic investment rather than going all-in on transport investment. Finally, a small subset of regions had high performance and neighbouring low transport accessibility, making them the prime candidates to benefit from investments in the transport infrastructure. The opposite also happens, i.e., low performance and neighbouring high transport accessibility, for which transport investment is not likely to lead to performance improvement. Socioeconomic investment is suggested instead for this purpose.

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Commuting Patterns in the Netherlands: a Display of Polycentric Structures in Complex Networks

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Keywords: complexity, urban, networks, netherlands, randstad, DBSCAN, polycentricity

The concept of polycentric social and economic systems is a vital representation of a highly effective system. From the neoclassical economics point of view, the competition between economically equal-powered centres leads to better and faster development of regional economic systems. The Netherlands is a chrestomathic and a classical example of such a system with its widely known urban agglomeration called Randstad as a four-piece urban agglomeration.

However, the structure of Randstad is not floating in a vacuum. It's surrounded by vast suburbs and other cities important for regional parity. Also, Randstad is being reshaped with urban growth processes as the spatial patterns of daily trips change. These processes differentiate the polycentricity in two different aspects. The first is named the morphological polycentricity. This term stands for relative homogeneity of internal characteristics of nodes in a polycentric system (for this study — the municipalities as the socio-geographical units, involved in interactions with the others). The other aspect is functional polycentricity, which refers to the homogeneity of interactional patterns. Both interactions and importance of a system in a whole geographical system can be quantified via commuting of people.

In this study, we examine spatial and temporal changes in the polycentric structure of the Netherlands as a whole throughout the 2004—2017 period. The data is a set of mobility survey results — Mobiliteitsonderzoek Nederland (MON), Onderzoek Verplaatsingen in Nederland (OViN) — which are held in the Netherlands annually. These datasets provide us with information about short-term travelling in the country, such as workers commuting, shop trips etc. Reshaping this data into a set of correspondence matrices and then to graph representation with the nodes as Netherlands municipalities and edges as interaction intensiveness between each pair, we defined morphological and functional network characteristics as follows.

The morphological characteristic of a node in a system is a random walk betweenness centrality measure, as it reflects both topological characteristics and weights taking into account a degree of transit through the node. So, the morphological polycentricity is the homogeneity of centrality measures.

As for the measurement of functional polycentricity, we've decided to use functional regionalisation of networks through percolation regions modelling. This way of modelling the regions shows hierarchical regions structure in networks. Proposed by H. Rozenfeld and D. Rybski and further

developed by E. Arcaute and M. Batty, this method was used primarily without deploying to a conceptual framework of non-network nature.

It has a significant advantage in performance and spatial interpretability of results compared to conventional algorithms. We've implemented this modelling using DBSCAN clustering with different noise filters. Using this, we've differentiated the hierarchical regions' cores by their sustainability, or the number of clustering iterations before they are included into the top-level cluster. The functional polycentricity is the region's core sustainability homogeneity in this case.

Results of polycentricity evaluation in morphological aspects are somewhat predictable. The four main municipalities of the Randstad (Amsterdam, Hague, Rotterdam and Utrecht) are stable in the top-tier of municipalities centrality measures through all the yearly timeframes 2004—2017. Although the distribution itself is stable in both spatial and temporal ways, there are still changes in order of municipalities in the rank-size distribution. Except for the tail for the distribution, the lower the rank in this distribution the more changes of municipalities in each rank. The mentioned tail, however, is low in changes — these are the municipalities of Frisian Islands. Moreover, the centrality is highly correlated with socio-economic measures of place prosperity (functional diversity, for instance), so these conclusions can be correspondent to regional statistics.

From a functional perspective, however, the Netherlands is not a polycentric country. In terms of hierarchical regions core sustainability, it has one dominant centre — Amsterdam, and this disparity between the Amsterdam-related region and the rest of the country grows. All the municipalities included in the Randstad agglomeration are highly connected to each other and as the strength of the interaction grows, it becomes almost impossible to delineate the separate cores in this de-facto united city. However, some of the peripheral centres have relatively high sustainability because of geographical distance to the Randstad. These are Groningen, Leeuwarden, Maastricht, Tilburg.

The strength of connections between municipalities volatiles greatly but with no significant spatial pattern. This refers to the idea of a complex system itself, as its self-regulatory ability reshapes and balances the weights of connections. It's the reaction to multiple socio-economic changes in the Netherlands such as the rapid growth of population and functional diversity in Flevoland province.

Methodologically, random walk betweenness centrality showed satisfactory results in the quantification of morphological characteristics. The regions modelling through percolation and DBSCAN still needs validation on a territory with completely different inhabitation patterns, different population density and longer distances between municipalities in extremum.

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Potential impacts of autonomous, electric, and shared vehicles on sustainable urban mobility

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Keywords: sustainable urban mobility, electric vehicles, autonomous vehicles, shared vehicles, mobility 4.0

One of the challenges of implementing sustainable urban mobility is the constant development of new technologies. The evolution of these technologies is in line with the development of the industry. In the case of mobility, the so-called “Mobility 4.0” is a concept driven by technological innovations such as the Internet of Things (IoT), artificial intelligence (AI), automation, and electrification, among others. In theory, these technologies enable an efficient integration of different modes of transportation, creating more sustainable, safe, and customized mobility solutions, such as on-demand services, smart public transportation networks, electric vehicles, shared mobility, and autonomous vehicles (as detailed by McKinsey and Bloomberg, 2016). However, even considering the expected benefits of these technologies, their potential impacts on urban mobility are still unknown. The aim of our study was to assess the potential impacts of the three selected technologies on sustainable urban mobility. Our method involved three steps. The first one was the creation of a framework to summarize the concept of sustainable urban mobility through meaningful descriptions of its key domains (i.e., Accessibility, Environmental aspects, Social aspects, Political aspects, Transport infrastructure, Non-motorized modes, Integrated planning, Urban circulation and traffic, and Urban public transport) and related themes (in our case, two for each domain). Next, we conducted a literature review to identify impacts reported on actual applications or prospective studies involving these domains. Finally, we applied an online survey to decision-makers, planners, and scholars potentially involved with sustainable urban mobility to identify the characteristics of the anticipated impacts. In summary, the questionnaire was designed to identify if the impacts of the three technologies on the 18 themes describing sustainable urban mobility would be Very positive, Positive, Neutral, Negative, or Very negative. We also asked about individual characteristics (sex, age, education, etc.), professional experience (workplace and time), and the respondent's level of knowledge regarding the three technologies.

We focus here on the 194 valid responses to the online survey. Regarding the impacts associated with autonomous and electric vehicles, we observed a concentration of “Neutral” responses (up to 73%). For autonomous vehicles, however, exceptions were observed in the theme "*Laws and regulations for people with special needs*" (with 38% of “Very positive” responses), which is related to the domain Accessibility. Themes with predominant “Positive” responses were: "*Availability*,

diversification, and quality of public transport" (part of the domain Urban public transport, with 40% "Positive" responses), "*Traffic flow and circulation*" (part of the domain Urban circulation and traffic, with 39% "Positive" responses) and "*Integration of actions and policies for urban mobility*" (part of the domain political aspects, with 38% "Positive" responses). The evaluation of the theme "*Traffic accidents*" must also be highlighted because the choices were distributed with similar proportions among the alternatives "Very positive, Positive, Neutral, and Negative" (with 26%, 25%, 21%, and 21%, respectively). This was the only theme with such a balance in the responses, which suggests that the potential impacts of that technology on traffic accidents are still difficult to assess.

In the case of electric vehicles, the "Very positive" responses were concentrated on the domain Environmental Aspects, with 57% of the responses for the theme "*Control of impacts on the environment*" and 40% for the theme "*Natural resources*". In addition, the two themes with a predominance of "Positive" responses are parts of the domain Political aspects: "*Integration of actions and policies for urban mobility*" received 41% of the choices, whereas "*Fundraising and management*" received 39%.

In the case of shared vehicles, the responses were concentrated on the alternatives "Positive" or "Very Positive". This outcome is similar to what we found in the literature review when looking at actual applications. The theme "*Traffic accidents*" was again a highlight, not only because it was the only theme with the predominance of "Neutral" responses (in this case, 49%) but also because it received 12% of "Negative" evaluations.

Based on the results, it is not yet possible to draw definitive conclusions regarding the future impacts of the studied technologies. However, the aspects that called the attention of the experts as either positive or negative must be considered when trying to maximize the positive impacts (and/or reduce the negative ones) of the technologies investigated.

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Abstracts of Parallel Sessions 7

Urban agglomeration as a network of consumers' purchase locations: e-commerce case study of Moscow

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Keywords: e-commerce, network, customers, deficit, functions, urban, agglomeration, structure, complexity

Urban agglomerations are often represented as a complex network of some sort of interactions. Usually, these interactions are primarily connected with transportation in a physical form. Commuter trips, public transportation connectivity, urban footprint — these are most common sources for unveiling the spatial structure of urban locations. However, as the progress of digitalization marches on every sphere of society lifestyle, the physical representation of the settlements' connections can often be non-representative. General digitalization trend which was sped up by the recent pandemic showed that the online connections are as important as the physical ones. The e-commerce industry was not an exclusion. Online shopping has already become a vital part of human lives. In some countries, like China or Russia, almost 40% of people have used the e-commerce services at least once within a timespan of the year, as per Data Insight yearly report.

In this study we are trying to exploit e-commerce data to delineate and dive deep into the spatial structure of a monocentric urban agglomeration of Moscow. Although, this is a pretty plain polygon to examine the capabilities of online purchases data, this territory is well-examined by various urban geographers and therefore was an object of various empirical studies. This allows us to validate the results and to enrich the exploration.

For the study we use the aggregated and non-personified data from one of the leading Russian marketplaces containing the information on quantity of created orders and the locational properties of the orders such as the locations of the warehouses, the delivery outlets as well as the location of the person at the moment of the purchase. This dataset allows us to examine the connectivity between the location in various way although we focus primarily on the relations between the location of the customer at the moment of the purchase and the delivery location and the relation between delivery and warehouse locations. These two relations have the capability to explain both the commuting patterns and the territories in deficit of some or various goods. The first one unveils the suitability for receiving the packages while the person is at his working location while he's at home. The second one is strongly connected with the functional capabilities of the centre-periphery relations where centres are more functionally complete and are provided with a variety of goods when the peripheries are not able to self-sufficiently provide themselves with the goods, as per the Christaller's theory of central places. We combine both relations into one metric to include both the functional deficit and the commuting patterns into the process of unveiling the spatial structure.

The results of the study have proved the validity of the e-commerce data for the spatial structure examination. The spatial structure and the agglomeration delineation and delimitation could be interpreted in both centre-periphery paradigm and the complex networks terms as the purchases from the current location of the customer tend to be located delivery-wise close to the workplaces. On the contrary, the delivery locations tend to be in a strong deficit of the goods in need.

Simulation of home spatial distributions based on workplace

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Keywords: simulation, homes location, commuting

The implementation of mobility plans requires to consider employees commuting, that is to say home-to-work travel. However, the availability of data on these trips is limited due to the General Data Protection Regulation (GDPR). To solve this problem, we wish to simulate the locations of home-to-work travels using available data such as (i) the SIRENE database which lists companies on a given French territory, (ii) home-to-work flows from population census, and (iii) INSEE's gridded population data (200 meters per side).

The objective of this study is to simulate the home spatial distribution of the people employed in companies listed in the SIRENE database, taking into account the distance to the workplace and the density of households in the territory. To achieve this objective, we developed a method in several steps.

The first step consists in calculating a flow-distance distribution law based on home-to-work flow data. This law defines distance classes based on flow size. Then, we locate a selected company on a single point which becomes the center of our simulation. Using the flow-distance distribution law, we determine the center of each distance class, and a distance probability function is used to create individuals around the company. To distribute these individuals, we draw concentric circles with radii equal to the value of the center of each class, and we use trigonometry, cutting each circle into a defined number of angles (Gelfand and Saul, 2001). We apply statistical noise by adding a jittering function to both the final point location and the angles (Slocum *et al.*, 2008). This yields a first distribution of the locations of employees' homes, relative to the distance of the workplace.

The second step consists in considering the population density, specifically the household density, to locate homes more plausibly. To do so, we introduce variability from each of the generated random points. We then calculate buffer zones in which the points could be located, based on the distance from the company. These buffer zones are based on the interquartile variation of each of the distance law classes, and by extension, the related circles of the random points. Once these buffer zones are fixed, we cross them with the density of households in the territory to obtain a new probability of drawing: generated points are more numerous or closer to denser zones than less dense areas. To do

so, we generate the centroids of the population grid and calculate the weighted barycenter of each square contained in the buffer zones, in order to place a new point that represents the simulated location of employees' homes (Pumain and Saint-Julien, 2010).

The results of this method make it possible to simulate a realistic likely distribution of the location of employees' homes according to distance and population density. We obtain points distributed around the location of the company, depending on the local territorial characteristics.

These results can be used to implement mobility plans, including employees commuting. The data obtained can help to understand employees' commuting and propose more efficient mobility solutions.

Furthermore, this simulation method can be adapted to different geographical contexts. Indeed, it uses home-to-work flow and population density data that are available in many French, and maybe European territories. Moreover, by extending this study to all the companies in a region, it becomes possible to analyse all home-to-work mobility flows, providing a generalizable approach for reorganizing mobility.

However, it is important to notice methodological limitations. Firstly, it is based on aggregated home-to-work flow data, which do not take into account the specificities of each individual and each company. Additionally, this method does not include the socio-economic variables of employees, which may impact their choice of home location.

Despite these limits, the simulation method presented in this study offers an innovative approach to simulate the distribution of the location of employees' homes in companies, considering population density. It can be used to implement more efficient mobility plans and can be adapted to different geographical contexts.

In conclusion, this study shows that it is possible to simulate the distribution of the location of employees' homes in SIRENE-based companies by considering the distance to the workplace as well as population density. This method offers an innovative approach to grasp the commuting patterns of employees and to propose more effective mobility solutions. It is important to note that this simulation method can be adapted for different geographical contexts. The output can help to gain a deeper understanding of the commuting patterns of employees and to propose more effective mobility solutions, especially for companies or clusters of companies.

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Evaluating the accessibility of territories, a multi-scale fractal approach to proximity

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Keywords: Proximity-based accessibility, Urban system, Fractal geometry

Recently, evaluating the accessibility of cities and territories to facilities and amenities represent a major challenge to meet the objectives of sustainable urban development. Although issues related to accessibility are epistemologically old, they are regularly undergoing a renewal of their operations through academic approaches as new theoretical concepts and planning models. In particular, the study is about the "15-Minute City" or "city of short distances" (Büttner et al. 2022), which measures the performance of access to amenities on a local scale, with the aim of strengthening active modes such as walking. The diversity of approaches and methods, available in the literature, employed to assess proximity-based accessibility necessitates taking into consideration the effects of urban scales, distances and service types in the evaluation rules.

This study presents an innovative methodology to (i) assess the accessibility to reach amenities and services and (ii) identify potential areas for future development of a territory that promote the accessibility by proximity.

The first part of the methodology uses a classic approach in the literature to assess and qualify the accessibility of neighbourhoods to the opportunities of a territory with the use of geospatial data and route calculation algorithms. To this end, different types of amenities (education, health, retail, commercial and shopping centres, as well as leisure areas and green spaces) and a number of proximity access distances corresponding to these categories of opportunities, according to different modes of transport, were selected. This approach takes into account the distances, times, urban scales and the types of transport modes with a focus on active ones. The methodology that considers various transport modes such as public transports, the use of private vehicles as well as active modes, with the help of the capabilities of the *r5r* software (Pereira et al., 2021).

As part of this research, the Marne-la-Vallée area located in the eastern region of Paris, France, was chosen to apply the methodology. The study area is a "new city" developed since the 1960s according to a discontinuous linear urban growth of the form of a Transit-Oriented Development (TOD) structure located around the stations of Regional Express Railway line. Since the development planning policies of this territory are founded on accessibility and also since the study area is on newly developed region, it is important to investigate its outcomes in terms of

accessibility. This first approach provides a robust measure of overall accessibility, taking into account physical distance, travel times, and ease of access to amenities and services. It is thus possible to develop a typology that qualifies the level of accessibility performance of neighbourhoods to the various amenities.

After this first diagnostic phase, the second part of the methodology focuses on identifying areas suitable for future development of the territory on the basis of its urban framework reflecting the accessibility. Using demographic and cartographic data of buildings, amenities, services and reserved areas, as well as transport networks, the different polarities (urban centres) of the study area are organised in the form of an iterative function system, using the *Fractalopolis* software (Bonin et al., 2020). Based on fractal geometry to construct a multi-scale urban framework, the system identifies locations that may experience increased demand for new infrastructure and amenities in the future (Yamu and Frankhauser, 2015). Taking into account both the current accessibility to different types of amenities, the importance of each pole in the urban organisation of the territory and future growth projections, the methodology offers a global perspective on areas suitable for urban development, particularly services and housing.

By combining these two steps, the proposed methodology provides policymakers and urban planners with a multi-scale decision-making tool to assess accessibility and identify the most appropriate areas for the future development of the territory. The information generated by this methodology can thus help promote balanced and sustainable development in urban and regional areas, ensuring that facilities and services are accessible to all residents with a degree of proximity that limits car use and favours active modes. The methodology has the potential for broader applications beyond the specific case study area. By adapting the geospatial and analytical frameworks to different regions and incorporating relevant data, the methodology can be customized to fit diverse contexts. This flexibility enhances its usability and applicability in various urban planning and development scenarios.

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Exploring the Proximity Concept for Enhancing Regional Connection. The Case Study of the Sardinia Island (Italy)

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Keywords: Proximity approach, 15-Minute City, Sardinia Island, Regional Planning, Regional Polarities

In recent years, numerous cities across the globe have adopted the proximity concept as an urban planning approach for enhancing the quality of urban life (Zhang et al., 2023; Ferrer-Ortiz et al., 2022, Yamu et al., 2022). This concept aims to design cities so that all essential services, conveniences, and social activities are in physical relationship with each other, close in space in terms of distance to travel and in terms of time to arrive. Besides the availability of basic services this approach focuses on the conditions that enhance the possibility and the capability of people to use them and actively participate in public life. This not only reduces the reliance on private car, but also promotes social cohesion, health, and well-being by enhancing the city's liveability and quality of life. Furthermore, this concept aligns perfectly with current sustainable urban mobility policies, which promote low-impact means of transport that are accessible to all citizens, thereby contributing to climate change mitigation and the development of resilient cities (Moreno et al., 2021; Pozoukidou et al., 2021; Allam et al., 2022; Song et al., 2022).

However, the proximity approach is typically debated in terms of single neighbourhoods or districts, and its potential in regional planning has attracted less attention in both research and practice. Regional expansion of this concept requires to consider the interrelationships and interdependencies between various urban polarities and, consequently, a group of cities or urban centres linked by economic and social connections, thereby forming a network of interdependent and complementary communities. This approach on a regional scale generates "regional polarities" and effective regional planning, which could be a successful way of addressing contemporary sustainability challenges and enhancing the liveability and quality of life throughout the entire region.

For our purposes, the authors take into consideration various recent urban planning models centred on the proximity approach. Among them, the territorial model included in the Spanish and Basque urban agenda is considered for its methodological comprehensiveness. In this model urban and rural areas are considered as “entities” operating in a complementary and fractal way, according to the principles of Ecosystem Urbanism of Salvador Rueda. The territorial model proposes that urban systems – and their functional areas – are compact in their morphology, complex in their

organization, metabolically efficient and socially cohesive (Rueda, 2019). The delimitation of functional areas depends on very different variables, including metabolic ones, and requires variable geometries for efficient management (*ibid.*). According to this model, the traditional mobility system which generated suburbs is redefined to identify a network of nodes connected by sustainable modes of transport and smart infrastructures.

The implementation of the proximity approach to the regional scale presents challenges and issues. First, it encourages the economic growth of even the poorest areas, rather than concentrating it in a central city. Second, it decreases the need for long-distance travel, which can have substantial environmental and social costs. It promotes social equity and community resilience by creating a more cohesive and interconnected urban environment.

Political will and coordination between various jurisdictions and levels of government is one of the greatest obstacles. It could also require substantial investments in public transit and transportation infrastructure, as well as modifications to zoning and land use regulations.

Based on these assumptions, the authors attempt to make a theoretical contribution to the potential application of the proximity approach on a regional scale by identifying parameters and factors that can satisfy the needs of highly vulnerable regions that cannot achieve a high level of (economic, social, and environmental) development due to geographical constraints. To accomplish this, the authors focus on a case study of Sardinia (Italy). The study of Sardinia from the perspective of territory/proof of this theory is emblematic for a number of reasons. In the first instance, it is an island, and by definition, an island is a territory with precise boundaries and limits. Second, its morphological, geographical, political, and social characteristics have, over time, resulted in an island with significant geographical disparities, not only in the urban area - between the coastal and inland areas- but also in the administrative and political context.

In conclusion, starting from some disparities, that are structural of the Sardinian context:

(i) the demographic evolution, concentrated near the coast and in the main Sardinian municipality, Cagliari, causing serious dysfunctions in the local economy, particularly for inland areas (Crenos, 2020; Svimez Report, 2019; Cocco et al., 2016)

(ii) fragile territorial balances associated with the survival of the island's internal centres (Desogus, 2016; Garau et al., 2019; National strategy for internal areas, 2019; Urban area strategy, 2018; Territorial Planning, 2020) and (iii) administrative governance (Regulations on European Structural and Investment Funds, 2015),

the regionalisation of the proximity approach can facilitate the regional development process by establishing and enhancing physical ties (infrastructure, shared services) that generate social and economic ties.

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Proximity or opportunity? Spatial and market determinants of private individuals buy-to-let investment flows

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Keywords: Multiple property ownership, rental investment, register data, spatial interaction models, adaptive zoning

The literature on investment in housing has argued for an increasing liquidity of real estate investment in a context of financialisation (Beswick et al., 2016; Fernandez and Aalbers, 2016; Fields, 2019; Özogul and Tasan-Kok, 2020). From a spatial point of view, this means the rise of long distance investment (Ho, 2020; Taşan-Kok et al., 2021). However, most of the studies dealing with this issue focus on very specific types of investors such as large corporate landlords or private individuals at the top of the wealth distribution (Alstadsæter et al., 2022; Ho, 2020). Recent research on private individuals investing in housing tend to show that they do not follow such logic. They tend to be 'home-biased', meaning that they invest locally or regionally (Hochstenbach, 2023; Levy, 2021). An in-depth analysis of investment behaviour of this category of investors is all the more important given their importance in housing markets of several counties such as France, the Netherlands and the UK and given the revival of private landlordism observed in OECD countries (Ronald and Kadi, 2018).

This paper contributes to the debate on the liquidity of real estate investment by looking at the spatial dimension of individuals and households' investment in rental housing. In order to go beyond mapping and descriptive statistics, we develop a modelling approach allowing for a better understanding of the respective role space and market characteristics in determining investment flows in rental housing. We use spatial interaction modelling to analyse the role of different factors as well as to highlight preferential flows of investment within and between cities. We pay special attention to territorial heterogeneity by focusing on households living in – and investing from – three cities with very different local market characteristics and positions in the French urban system: Paris region (the capital city), Lyon (a regional centre), and Avignon (a medium-sized city).

In order to perform this analysis, we created a dataset by integrating and enriching microdata from tax registers and real estate transaction deeds covering a population of 8.2 million individual owners. Focusing of owner-occupiers from the three cities, we tracked 223,095 investments in rental housing made by 188,963 different households between 2010 and 2018.

Using this data in a spatial interaction framework led to a methodological issue. The origindestination matrix of rental investment exhibit very sparse flows: few very large flows between some areas and many very small flows. Three solutions are usually applied in this situation : i) aggregating flows into wider zones – thus loosing information on investment in proximity; ii) removing small flows – thus loosing complexity in the data and biasing the estimation; iii) separating short and long distance investment by using two models – thus assuming that they would obey to different logics. To avoid these pitfalls, we adopted an *adaptive zoning* approach (Hagen-Zanker and Jin, 2012). The idea of this approach is to keep high spatial resolution where interaction is strong (for example at short distance or between areas with important size) and to aggregate faraway and less populated places where spatial interaction happen less frequently. Such adaptive zoning strategy is appropriate to represent investors' geographical perception and allows to investigate multiple spatial scales in housing investment from intra-urban investments to inter-urban ones into a single model.

Spatial interaction models using adaptive zoning appear as a good solution for modelling buy-to-let investment happening at several spatial scales, to uncover preferential flows of investment within and between cities and to reveal local specificities. Our models demonstrate that geographical proximity, approached through several variables, is highly determinant in explaining flows of buy-to-let investment from private individuals. Residuals analysis of spatial interaction models also revealed striking facts related to the geography buy-to-let investment:

• There are important variations in local investments depending on the place of residence of investors. Households from certain areas, such as the ones from the centre of Lyon, tend to invest a lot locally, while households from the centre of Paris do not.

• There is a convergence of investments from certain peripheries of the FUAs – especially the rich suburbs – toward the centre of agglomerations.

• Investors from the FUA of Paris are much more inclined to long distance investment.

• Preferential flows from the FUA of Paris target in priority Toulouse and Bordeaux, two large and fast growing cities from in the South West of France, as well as places with high residential amenities such as urban areas of the Mediterranean and the Atlantic coasts.

Regarding market characteristics, we find that the price of housing in the homeowner's market of residence has a negative impact on the magnitude of flows. Moreover, we find that investors tend to invest in upmarket areas and in places that are more expensive that their market of residence. Our results indicate that proximity and security of investment play a more important role than opportunity.

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Time budgets and forms of preindustrial cities: time for empirical studies

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Keywords: travel time budget, urban form, geo-historical data, European cities

Studies of pre-industrial settlement systems contribute to considerations on the ability of our societies to ensure the sustainability of present-day systems over time. The recurrent identification of a higher density of large settlements than of small ones in diverse past settlement systems implies that inhabitants tend to densify their occupation of space rather than to spread it out (Ortman et al, 2014; Lobo et al, 2020). Thus, movement of residents in the context of their daily activities is one of the key explanatory elements of the areas of settlements. This reaffirms the strong relationship between morphology and mobility. Indeed, the constraint of the day duration on individual mobility and the resulting spatial structuring is a long-standing issue: in T. Hägerstrand's reflections about "the indivisibility of the individual" and time geography (Hägerstrand, 1974); the daily frequency of work-related mobility is also central to Y. Zahavi's proposal on invariance of travel time budgets (Zahavi, 1979). More recently, A. Bretagnolle conceptualises the one-hour time-distance as an "anthropological invariant" (Bretagnolle, 2009, p. 12), probably in reference to C. Marchetti (Marchetti, 1994). Her review of the literature on the evolution of intra-urban transport and urban forms since the end of the 19th century shows that geographers and architects have been using the concept of time budgets since the beginning of the 20th century to delimit the spatial extension of cities (Bretagnolle, 2009, pp. 11-47). The old maps representing the intra-urban built-up area and the communication axes, on which are superimposed the isochronous curves delimiting the spaces that can be reached in 60 minutes from the centre, show that this temporal threshold is very significant.

Beyond the critics of the invariance of time budgets in contemporary daily mobilities (Charron, 2007, pp. 4-33), it turns out that the measuring of it has not been explored empirically and formally for pre-industrial intra-urban areas – with the exception, to our knowledge, of the research carried out by A. Chase on the Mayan city of Caracol in Belize (Chase, 2021). Indeed, the notion of time-budget invariant is mainly used as a theoretical reference in the bibliography on past societies: on the one hand, as one of the elements to define the city as a socio-spatial object (Lobo et al, 2020); on the other hand, to elaborate spatial models. In this case, the use of the concept is varying. It is predominantly invoked to establish spatiotemporal thresholds for accessibility models, elaborated to delimit areas of surrounding landscape of villages (Zhang et al, 2010), the vicinity of cities (Kaše, Heřmánková, Sobotková, 2022), or potential relationships between places, such as ports (Jarriel, 2018).

The strong growth of open access geo-historical sources and data in recent years is gradually transforming research on past city spatial dynamics. It is henceforth possible to empirically test the

invariance of time budgets, notably the one-hour invariance between the centre and the urban margins of pre-industrial cities. A first set of 14 small and medium-sized towns in northern France at the beginning of the 19th century will be presented. Their respective historical trajectories are diverse and they belonged to different micro-regional systems of cities at that time. Data on street networks, on different definitions of urban areas and on ancient city centres (as castles or cathedrals) and contemporary ones (town halls at the beginning of the 19th c.) are mainly based on 1:40,000 French military État-major maps (Gravier 2023). The results of walking accessibility models according to centres, urban areas and different travel speeds are based on methods of spatial analysis along networks (Okabe, Sugihara, 2012). They reveal that the one-hour threshold is far too high to delineate spatial extensions of these cities. This first set of small and medium-sized towns will be enriched by two very large cities: Paris and Ghent. I examine the former on several dates. First in 1380, using data derived from the "Plan restitué de Paris en 1380" originally produced in 1975 by J. Leuridan and J.-A. Mallet and reproduced by C. Brulet (Noizet, Bove, Costa, 2013). Then in 1799 and 1836, based on Verniquet and Jacoubet contemporary plans (GeoHistoricalData, 2019). I study the second for the 14th-15th centuries, based on the revised map of Deventer (Coomans, Hermenault, 2022).

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Mapping Demographic Change: Historical Population Grids for Bulgaria and Turkey Using Geocoded 20th Century Census Records

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Keywords: Population modelling, Geo-History, Spatial Statistics, Urban Patterns

Introduction and Research Aim

This study provides a comprehensive examination of geocoded population data in Turkey and Bulgaria over the twentieth century, utilising four population years, with a specific emphasis on depopulation patterns in the region using a quantitative geographical methodology. Previous research on census data for Turkey is limited and mostly comes in the form of aggregated district or subdistrict level. This paper remedies a gap in the literature and presents a more fine-grained long-term comparative research on the municipal level. Our aim in this ongoing research is to create a reliable, fine-grained population grid for Turkey and Bulgaria that enables analysing population trends further back than presently possible with datasets from the Global Human Settlement Layer (GHSL: 1975- 2020) or WorldPop dataset (2000-2023) (Leyk et al., 2019).

Understanding long-term dynamics of population change is important for a variety of fields ranging from urban planning to environmental research. The datasets generated from this study will contribute to a deeper quantitative understanding of urbanization patterns and rural population development, while also allowing for the development of better models to measure the impact of natural disasters or policy changes on population trends within the study region.

Background

This study is part of an ongoing Proof of Concept project, GeoAI_LULC_Seg, which aims to further enhance the disaggregation of this population data by incorporating historical Land Use Land Cover (LULC) imagery of the region, to create populated density maps for a similar time period. The data utilized in this analysis covers four significant census periods in Turkey during the twentieth century: 1935, 1955, and 1970 to 1990. As part of the UrbanOccupationsOETR ERC-funded research project, conducted between 2017 and 2022, these records were manually geocoded based on archival population censuses.

The project successfully geocoded over 14,000 inhabited locations in West Turkey for the specified census years, as well as plotted approximately 5,000 individual populated places for similar years in

Bulgaria. To acquire and transform the data, tabular data from the Bulgarian National Statistical Institute and Turkish Statistical Institute were utilized. Additionally, the UrbanOccupationsOETR project has also been working on creating a gazetteer for places during the Ottoman Period, with a forthcoming publication on this topic (Kabadayi et al.). The dataset resulting from these efforts has been made available through the project's website: urbanoccupations.ku.edu.tr/public-datasets/.

Methodology

Auxiliary materials such as georeferenced historical maps, archival papers, and other sources were used to trace places (Ma et al., 2021). Tracing locations using such data frequently results in spatial discrepancies owing to flaws in old maps and other archival resources. For example, the location may be represented differently throughout years, resulting in some spatial accuracy conflicts. Therefore, in this study, we used a multi-step procedure that included multiple data processing and geographical analysis techniques to adjust for these conflicts.

To begin, we obtained and geocoded demographic data for both Turkey and Bulgaria, allowing us to translate the data into geospatially meaningful information. A PostgreSQL database was used for collaborative efforts for the manual geocoding. The next stage in our process was turning our populated location data into a 3-dimensional vector array using the Xarray and Geocube Python libraries, which supplied the capability for data reading and transforming the data. Then we used the SciKit GStat library for further spatial analysis. Using these tools, we were able to perform spatial interpolation on the data and adjust the census years when discrepancies were detected. Lastly, 10km population surfaces were created and made accessible as a WebApp using ArcGIS Online.

Findings

Comparative analysis between the two regions shows a very distinct pattern of population development between 1935 and 1990. In our analysis, the created grids cover 282,378 km2 of West Turkey (30 provinces) and 110,993 km2 of Bulgaria. Aggregating the population within this area, we calculate that the Bulgarian population density increases approximately 43% between 1935 and 1990, whereas West Turkey has its population density increase by a significant 263% over the same period. In other words, in 1935, Bulgaria had 54,3 people per km2, which increased to 77,4 persons in 1990. We see 27,6 persons per km2 in West Turkey in 1935, but a substantial rise to 100,8 in 1990. Furthermore, on a more regional level, this study finds significant inequalities in the shared border region, Thrace, which spans Turkey, Bulgaria, and Greece. This region had population increase in Turkey and depopulation in Bulgaria throughout the twentieth century.

In conclusion, this research offers a deeper understanding of population dynamics in Turkey and Bulgaria, contributing valuable insights for geo-economic researchers in this area. By creating the most detailed spatial surface grid currently available for Turkey and Bulgaria, the study paves the way for more informed forecasting models and longer-term trend analyses, particularly regarding long-term depopulation. The practical implications of this research extend to many fields, making it an invaluable resource for researchers and policymakers alike.

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Supervised classification of the French Riviera morphogenesis using a machine learning approach

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Keywords: Urban Fabric, Urban Morphometrics, Machine Learning, Urban Growth, Morphogenesis

This contribution focuses on the analysis of the evolution of urban forms on the French Riviera within the 20th and early 21st centuries. More specifically, it defines evolutionary paths and contextual factors behind them. To this end, a context-specific model is created, allowing for the analysis of contextual variables and determining to what extent they influenced the evolution of urban morphology. The analysis is carried out by breaking down space into urban blocks, within the compact city, and block sections, in more dispersed suburban areas. The contextual variables represent the external morphogenetic factors of site, situation/accessibility, morphological context and historic period. Old cadastral maps and airborne images are the raw input data of our analyses. Five different study areas within the French Riviera are used to identify the evolutionary paths of urban form, to quantify them, as well as their bifurcations and the possible impacts of the external factors. Together, they are representative of the variety of observable forms on the French Riviera and of their past development paths.

In a first phase, components of the urban fabric are pre-processed. In particular, the street network undergoes in-depth processing. The linear street segment data was transformed into network coverage data and planar graphs. The study also used street continuity according to the Morpheo approach (Lagesse, 2015). The street network provides the following elements: accessibility to plots, the key element in the division of block sections and a structural element of the city's development (Hillier, 2002). Plots and buildings are also pre-processed to identify recurrent patterns in a simplified way.

In a second phase, the analysis requires supervised classification of the evolution of the form of the urban fabric. A specific label of evolutionary pathway is assigned to each spatial unit, as in previous research by the authors (Prouin et al. 2022). The expert classification is based on the classical approach of urban morphology (Conzen, 1960; Caniggia and Maffei, 1979), and knowledge of the urban history of the study area (Graff 2013). The main components of urban form are buildings, streets and plots (Marshall, 2005; Lévy, 2005), as well as the site (the orographic and hydrographic

structure of the area). To explain their evolutions, we considered both path dependency (previous morphological states and how they were achieved) and the situation of these different analysis units, namely their value in relation to their urban environment.

In a final phase, the pathways of the morphological structure becomes the target of supervised classification. The machine learning model "Support Vector Classification" is used (Maysam et al. 2012) to predict labeled categories based on non-textual data optimized for a small number of referenced individuals. The model searches for the pathway of the morphological evolution based both on the current morphological status of the spatial units and on a few explanatory variables of site and situation. Therefore, the obtained results have a dual interpretation. Firstly, the identification of the current morphological state, regardless of their morphogenesis, based on the description of the elements of urban form. Secondly, a set of metrics capable retaining the traces of the morphological pathway and capable of identifying it. The goal is to reveal residual morphological structures of a particular morphogenesis.

The analysis shows to which extent a morphological process can be inferred by observable forms and a limited number of contextual variables. By contributing to the analysis of urban forms as contingent manifestations of transitional morphologies (Trisciuoglio et al. 2021), our model opens the way to assessing the evolutionary potential of present-day observable forms. The latter can thus be understood within different possible evolutionary paths, more or less plausible according to the contextual variables, and offer insight into future urban developments.

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40 years of Sprawl in the USA: Scale and Geographic Effects

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Keywords: sprawl, scaling effects, expansion

Urban sprawl has long been a subject of interest since it began in earnest in the United States during post-war urban development. It was originally defined as a car-reliant, low-density development pattern with open space between developments, resulting in scattered or fragmented development with low accessibility. Because of the many negative social and environmental implications of sprawl it has become important to determine whether a city is sprawled or sprawling, given its population or population growth, to adjust planning policies where necessary.

While many sprawl metrics have been suggested based on land use data and applied to case studies or limited sets of similar cities, there is still a need to quantitatively measure sprawl at a point in time and compare levels between a variety of cities, large and small. There is also a need to measure the process of sprawl, by comparing the same cities at different time periods, possibly over several decades.

Our main goal is to understand if and how urban sprawl progressed since its main assumed active period of the 1970s in the US. Here we contribute an analysis of urban sprawl over the last 40 years for 275 metropolitan areas of the conterminous United States. As we focus on the 1976 to 2016 period, we complement the work of Burchfield et al (2006) with the last 2 decades and the same set of cities and complement the more recent work of Zietz and Kirchhain (2022) with the earlier 2 decades and a doubled sample of cities.

In the present contribution, we particularly pay attention to the fragmentation of urbanisation as a key dimension of sprawl, yet we keep density in the picture as a second dimension because it is still one of the main instruments used in planning to combat sprawl. Also, while there is evidence that raw densities are (log-log) related to city size in population terms (Ahlfeldt et al, 2019), net densities, i.e. the ratio of population on the urbanised land (not total land) are much less analysed despite being more directly linked to the density used by planners and being less prone to the problem of delineating metro areas (Openshaw, 1981). Our second goal is therefore to unravel the relationships between the fragmentation of residential land and net densities, across space and time and across the urban hierarchy; that is the size of cities in population terms (Cutsinger et al, 2005; Zietz and Kirchhain, 2022; Lemoy and Caruso, 2020).

To achieve our goals, we first investigate the change in two fragmentation indices, 1) the perimeterto-area ratio of residential development (PA ratio) (Torrens and Alberti, 2000; Ewing, 1997; Galster et al, 2001) , and 2) the percentage of open land found in a square kilometre surrounding each developed residential cell (openness index) (Burchfield et al, 2006; Angel et al, 2010), as well as in 3) the net density (Angel et al, 2010; Hamidi and Ewing, 2014; Boyko and Cooper, 2011; Galster et al, 2001). Second, we explore the relationship of the indices with population size and growth in an unconditional manner and after controlling for socio-economic and physical factors along the factors provided for 1976 by Burchfield et al (2006).

The indices are calculated using land cover data from satellite images and reported as a mean value per Metropolitan Statistical Area (from 1999, as used by Burchfield et al) and then compared to investigate the spatial distribution of sprawl across the MSAs of the conterminous USA. We also rank the cities that are most and least sprawled, and see how these change over the years, as well as between methods. After viewing the spatial distribution of the indices, we use scatter plots to determine the correlation between indices.

Initial findings show that the most sprawled MSAs are found in central/mid-west USA, and that the perimeter/area ratio and the openness indices are highly correlated, while density is not correlated to either. Larger MSAs with higher populations tend to have a lower PA ratio and percentage of open space, thus indicating that these MSAs are less sprawled. There does also appear to be a negative relationship between PA ratio and openness index, with the log of the population, while there is a positive correlation between density and the log of the population. The findings are, however, in the preliminary stages and need further investigation.

Once we have completed the comparison of indices per MSA, we will also recreate a regression run by Burchfield et al, using our indices and their variables, to determine if the same factors are found to have an influence on whether a city will tend towards sprawl or not. We will also add the variable of population to the regression, to determine the influence of city size on the development of sprawl.

With this study we hope to shed some light on how sprawl has changed in the USA over the last 40 years, as well as to determine how the size of a city influences the development, as well as whether different indices yield different results, or if they in fact all measure the same inherent characteristics of sprawl.

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Sustainability Indicators for Tourism Applied to Urban Context in Mozambican Cities

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Keywords: Sustainability of tourism activity; Evaluation indicator systems; Multicriteria analysis; Urban planning

This work develops a system of indicators that can help measure the sustainability of tourism activity in Mozambican cities' urbanisation processes, using the cities of Inhambane and Xai-Xai as a case study. The development of the Sustainability of Tourism Activity Indicators System (SISAT) applied to the urban context results from applying the Delphi technique to define the indicators. The MultiCriteria Decision Analysis (MCDA - Multi-Criteria Decision Analysis) AHP (Analytic Hierarchy Process) methods were tested to quantify the relative weights of the indicators and ELECTRE (ELimination Et Choix Traduisant la REalité or ELimination Et Choice Translating REality) Tri, applied to order the alternatives of the proposed system, through the aggregation of preferences, which allowed classifying the indicators in different scenarios. According to the degree of importance, ease of measurement and applicability to the Mozambican urban context, the SISAT structure comprises 62 core indicators distributed in 34 themes and four dimensions, with the following distribution: environmental dimension (21 indicators), socio-cultural (16 indicators), economic (12 indicators) and governance (13 indicators). Furthermore, with the construction of the set of matrices, through the application of the weighting quantification method and preference aggregation method by A, B and C classes, relative to the high, medium and low-performance indicators, respectively, the relative hierarchy created for the City of Inhambane presents common and also divergent aspects when compared to the results identified in the City of Xai-Xai. These results confirm the importance of adapting the SISAT to local realities.

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Residential Mobility Patterns to and from Gentrifying Neighbourhoods: A Longitudinal Study in the Rotterdam Context

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Keywords: Gentrification, Residential mobility, Longitudinal analysis, Origins and Destinations, Spatial inequality

Over the past decades, European cities have experienced an increase in the share of middle-income households (van Ham et al., 2020), and neighbourhoods have upgraded physically as well as socioeconomically. At a local level this process is recognized as gentrification, briefly defined as: "*the transformation of inner-city working-class and other neighbourhoods to middle-and upper-middleclass residential, recreational, and other uses*" (Smith, 1987, p.462). Although gentrification potentially improves neighbourhood quality while wealthier households move in, this transformation usually leads to the direct or indirect displacement of working-class residents (Marcuse, 1985, p.205).

There has been a significant research interest in understanding the changing residential patterns within gentrifying neighborhoods. Scholars often focus on conceptualizing the "gentrifier" or estimating the extent of direct chain displacement (e.g., Freeman, 2005; Freeman and Braconi, 2004). Something these studies often overlook is the spatial component of gentrification-induced residential moves, specifically, where people move from and where they move to. Studies that do incorporate this spatial component of gentrification-induced residential moves generally find that gentrification is related to population dynamics or inequality at wider spatial scales. For example, Hochstenbach and Musterd (2018) found that gentrification leads to the concentration of poverty in the outskirts of cities, and Loumeau and Russo (2022) estimated that improved transit systems have caused high-income households to move from the core city to secondary cities, triggering gentrification in these areas.

This research aims to locate residential mobility patterns to and from gentrifying neighbourhoods in Rotterdam by identifying origins and destinations of gentrification-related residential moves, subsequently positioning them at different spatial scales in the Dutch context. The case study Rotterdam, the second largest city in the Netherlands, presents an intriguing case for several reasons. Firslty, Rotterdam's local government's actively engages in attracting affluent households, which

stimulates and accelerates the process of gentrification. Secondly, gentrification in Rotterdam is less advanced than other major cities in the Netherlands, limiting housing unafordability issues and immobility as a consequence of gentrification. Lastly, Rotterdam's position as part of the polycentric core of the Netherlands, known as the Randstad, enhances its significance. The high level of connectivity and short distances within the Randstad, as well as throughout the entire country, suggest that residential moves extend beyond the boundaries of the city, highlighting the relevance of exploring the interplay between local and regional mobility dynamics and gentrification.

In order to identify these residential mobility patterns, we apply a longitudinal approach relying on rich administrative data provided by the Central Bureau of Statistics (CSB) of the Netherlands. We trace residential moves to and from Rotterdam for the period 2003 until 2020, specifically highlighting moves related to neighbourhoods identified as gentrifying based on economic, social and demographic criteria. The aim is to map moving patterns at different spatial scales, with locations outside of the city clustered according to their distance to Rotterdam and population density. Subsequently, we examine how moving patterns to and from Rotterdam have evolved, and compare between the different neighbourhood types in Rotterdam. We analyse the effect of gentrification on inter-urban residential moves in the context of the polycentric composition of the Netherlands. The high connectivity between Rotterdam and other major cities of the Netherlands potentially enables households to make a tradeoffs between cities. By taking the interplay between residential mobility at different spatial scales and gentrification into account while relying on rich administrative data, our study aims to provide valuable insights into the complex dynamics of gentrification in Rotterdam and its connection to broader population trends in the Netherlands.

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Exploring driverless demand-responsive transit regional systems: a comparative study of point-to-point and hub-and-spoke designs

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Keywords: Regional transport; Demand-responsive transit; Driverless vehicles; Hub-and-spoke design; Integer optimization model.

Vehicle automation is a rapidly advancing technology. The Society of Automotive Engineers (SAE International, 2021) defines six levels that vary from no driving automation (level zero) to fully driving automation (level five). Level-five vehicles, also known as driverless or automated vehicles, will be able to navigate and operate on roads without any human intervention. There are some concerns regarding the consequences of private-owned driverless vehicles, such as the increase of vehicle kilometers traveled and congestion (Pakusch *et al.*, 2018). However, the expected high costs associated with the purchase of driverless vehicles encourage their shared use (Martínez-Díaz and Soriguera, 2018).

Driverless shared mobility systems can bring alterations on the way people use transport modes. In urban areas, these systems are expected to attract many passengers due to small waiting times and low prices (Bansal et al., 2016). However, passengers from low-demand areas would probably only stop using their private vehicles if these systems operate with low fares (Liu et al., 2017). In these areas, driverless demand-responsive transit (DDRT) systems can represent a new form of flexible and low-cost transit (Winter et al., 2018) able to overcome problems often associated with traditional transit alternatives such as low-frequency services, reduced operating hours, and cost inefficiencies.

The operational costs and fares of DDRT systems (particularly in low-demand areas) can potentially be reduced with the use of a hub-and-spoke (H&S) design. A system with this design would benefit from economies of scale by using hubs to aggregate passengers traveling from different origins to the same destination. This design is commonly applied to reduce the operational costs as well as CO2 emissions of transit networks (Hosapujari & Verma, 2013). The use of a H&S DDRT solution can be viewed as a cheaper alternative to point-to-point (without the use of hubs) services, though there is an absence of literature contributions comparing DDRT systems with these two designs.

In this paper, point-to-point and H&S DDRT regional systems are compared from the perspectives of the system's operator and of its passengers. For this purpose, a methodology was developed to assess the operation of the DDRT systems in a low-demand region. A real-world setting (Coimbra region, central Portugal) is used as an application to compare the operation of different DDRT system configurations, specifically point-to-point and H&S. The point-to-point configuration serves all passengers using direct links connecting trip origins and destinations, while the H&S one associates

each passenger with a route that can include an intermediate stop at a hub location (hub route). A hub route is composed of one collection link connecting the trip origin to a hub, and one distribution link connecting the hub to the trip destination.

The proposed methodology relies on optimization models. For the H&S configurations, a hub location model is used to determine the optimal hub locations, passenger movements, and vehicle movements that maximize the profitability of the DDRT system. For point-to-point configurations, the passenger and vehicle movements are obtained by minimizing the number of vehicles applied to serve the demand. Key performance indicators are estimated to summarize the experience of both operator and passengers.

The methodology was applied to four different scenarios varying in terms of design (point-to-point and H&S), vehicles used (car and van), and operation of direct and collection links (solo-riding and ride-pooling). The scenarios were tested through a sensitivity analysis by using different demand levels, periods of the day, number of hubs, and unserved demand penalties. Results indicate that a H&S design increases the profits involved in the operation of a DDRT regional system. This increase was significant for solo-riding scenarios but minor in the ride-pooling ones. Ride-pooling H&S scenarios make it less likely for the optimal (profit maximizing) routes to use a hub. This is also reflected in the hub locations. Hubs in the ride-pooling H&S scenarios are more spread across the region while hubs in the solo-riding one are concentrated around the most populated municipalities. In terms of passenger experience, the use of hub routes enables a fare reduction but also leads to increases in travel times and distances.

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Studying city-wide speed limits for balancing pedestrian safety and travel times: the case of Tallinn

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Keywords: Simulation, complexity, road safety, travel time, urban planning

Globally, pedestrian-car accidents result in almost half a million fatalities each year, emphasizing the urgent need to enhance road safety for human mobility. Extensive studies examining the relationship between car speed and accident fatality have consistently demonstrated that a significant reduction in car speed leads to a considerable decrease in both the fatality rate and the frequency of accidents themselves.

While decreasing the overall speed limit within cities may appear a simple and straightforward solution to mitigate car-pedestrian fatalities, it is necessary to consider the potential drawbacks. One of the primary implications is that it inevitably increases travel time in the city overall. This, in turn, leads to many undesirable consequences from heightened fuel consumption and amplified noise levels to elevated CO2 emissions, delayed emergency response services, escalated driver stress levels, and increased passenger time pressure. Regrettably, these consequences not only jeopardize the well-being of individuals but also pose a threat to the environment. Therefore, addressing the challenge of reducing pedestrian-car accident fatalities calls for a careful balance between enhancing road safety and minimizing the negative impacts associated with increased travel time. Finding innovative approaches that effectively enhance safety without unduly compromising other critical factors is crucial for promoting both human well-being and environmental sustainability.

Here we argue that we need to find a balance between simultaneously prioritizing safety and minimizing travel time within urban areas. However, devising simple solutions for the intricate interplay of safety, speed, and travel time poses a significant challenge due to the inherent complexity of the urban system. Hence, employing a microsimulation model capable of replicating emergent phenomena and uncovering potential non-linear dynamics within the system becomes essential. Numerous simulation models exist that primarily focus on estimating fatalities and injuries on roads or within specific network structures. However, they often overlook considerations related to traffic congestion, travel time, and particularly the explicit non-linearity of the system. Consequently, it was necessary to develop a simulation model specifically designed to address these aspects. By harnessing a tailored simulation model, we were able to comprehensively capture the intricacies of the system, including its complex dynamics, intertwined variables, and emergent behaviors. This empowers us to gain insights into the intricate relationships between safety, speed,

and travel time, thereby paving the way for more informed decision-making and the development of effective strategies to enhance both safety and efficiency in urban transportation networks.

We introduced a safety score that characterizes the potential severity of accidents within each road segment based on the corresponding speed limit. Our investigation focused on the city of Tallinn as a case study. By thoroughly examining the map of the city street network, we computed this safety score at the city-wide level. To gain further insights, we developed a simulation model using MATSim, which allowed us to observe how changes in speed limits affected travel times. We explored over 2000 different combinations of speed limits in Tallinn and generated corresponding maps for each configuration. Through this extensive analysis, we calculated the overall city safety score as well as the cumulative travel time.

Our study revealed some counterintuitive findings, highlighting the presence of non-linear patterns in the safety score resulting from gradual reductions in speed limits. Surprisingly, higher speed limits (and subsequently saved travel time) revealed a correlation with higher safety scores, while lower speed limits showed the opposite trend. Consequently, we identified certain combinations of speed limits that fostered higher safety scores while minimizing travel time and alleviating congestion. Our research demonstrates the value of employing such a model to comprehend the often unforeseen consequences of altering speed limit policies within a complex urban setting. By accounting for our desired conditions, this model allows for the estimation of a dynamic equilibrium between safety and travel time throughout the city. Ultimately, this knowledge facilitates informed decision-making and the development of effective strategies to strike an optimal balance between safety and efficiency in urban transportation systems.

The effect of sidewalk paving materials in the comfort and safety of walking: a case study in Braga, Portugal

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Keywords: Sidewalks, Pedestrian pavements, Paving materials, Walking, Walkable cities

Sustainable mobility aims a modal shift towards more sustainable forms of mobility to minimize the harmful impacts associated to the intensive use of cars. The promotion of active travel, namely for short daily urban commutes, can help in decarbonizing transportation. As almost every trip begins and ends with walking, pedestrian infrastructure is a crucial component of any sustainable transportation system. Sidewalks are a critical pedestrian infrastructure and can be defined as an uninterrupted facility parallel to a carriageway to conduct pedestrian traffic and related activities. The general characteristics and condition of sidewalks determine the extent to which walking is a comfortable and safe mode of transport (Fonseca et al., 2022). Wide, well-maintained, and clean sidewalks have been reported as enabling comfortable and safe walking experiences. The paving materials used on sidewalks can affect pedestrians' comfort and safety significantly. Slippery materials, uneven surfaces, cracks, depressions, and flooded sidewalks are very hazardous to pedestrians and may lead to accidents, falls and limit the mobility of seniors and disabled people. However, many cities still lack information about the characteristics of their sidewalks' paving materials (Hosseini et al., 2022). And surprisingly, the influence of sidewalk paving materials in walking remains a under-researched topic.

This article summarizes the preliminary conclusions of an innovative study conducted in Braga, Portugal, to understand the effect of sidewalk paving materials and their condition on walking. A pedestrian route between the bus station and the University of Minho (Campus de Gualtar) was selected as a case study. This route connects the city center with the urban fringes, crossing various public facilities, commercial and residential areas, being utilized by many people, including students of the University of Minho. Methodologically, the evaluation includes a mixed approach, combining objective and subjective components. The objective component involved the evaluation of the

following five indicators: roughness, friction, texture, thermal comfort, and reflectance of the paving materials used on sidewalks. The general characteristics of the sidewalks were collected through a street audit to identify the paving materials and their condition. The performance of the five indicators was evaluated *in situ* at seven specific locations. The presence of irregularities can be caused by several factors, such as broken, raised, or cracked surfaces. This indicator was measured by using a 3-meter ruler. In addition, the roughness of the entire route was measured through an accelerometer installed in a baby stroller. Friction is a fundamental parameter since a paving surface with adequate friction minimizes the risk of falls due to slipping. This indicator was evaluated through the British pendulum method. The texture is related to surface roughness, which influences drainage, surface deformation, anti-slipping and friction. The texture was evaluated through the Mean Profile Depth (MPD) method. Thermal comfort determines the level of comfort of pedestrians at the street level. This indicator was measured with a thermal camera and surface temperature sensor. Finally, reflectance shows the fraction of light a paving material reflects, which influences the pedestrian thermal and visual comfort. This indicator was measured with an albedometer. The subjective component was based on a face-toface questionnaire addressed to pedestrians walking on the selected route. The questionnaire aimed to understand the pedestrians' perceptions about the paving materials used on sidewalks. The questionnaire includes a Likert scale through which respondents were invited to evaluate the influence of having paving materials providing a regular surface and appropriate friction, texture, thermal comfort, and reflectance on walking.

Various different paving materials can be found along the route, which include granite cubes, mortar, stone slabs, traditional Portuguese cobblestones, concrete blocks, and concrete hexagons. Some segments are in poor condition, having extremely degraded paving materials. Regarding friction, the paving materials with lower values (moderate risk of slipping) were the traditional Portuguese cobblestones and the stone slabs, while the materials with higher friction were the concrete blocks and concrete hexagons. Most of the irregularities on the route were found in the segments paved with granite cubes, mainly at the beginning of the route (near de bus station). The questionnaire showed that respondents would like to have even sidewalks with paving materials providing an adequate friction, but in general they are not satisified with sidewalks found in the selected route.

In sum, the preliminary results show that sidewalks on the selected route should be improved, as they are significantly damaged, thus interfering with pedestrian comfort and safety. Improving the sidewalk paving materials in this route and extending this work to the entire city should be included in future planning policies in order to make Braga a more pedestrian-friendly city.

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Spatial assessment to identify candidate areas for dynamic street space allocation solutions in the city of Coimbra

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Keywords: Spatial analysis, spatial search, dynamic street space allocation, best locations

In urban areas, space is limited, and a significant portion is dedicated to roads, parking, and other purposes related to transportation. Unfortunately, this space has been unfairly biased towards motorized modes of transport, particularly cars. However, many cities are now shifting their focus towards people-centered planning, aligning with the United Nations' Sustainable Development Goals. Additionally, a significant amount of urban street space remains unused or underutilized. For example, streets and avenues that are congested during peak hours are often empty during off-peak hours. On-street parking is scarce in residential areas overnight but remains idle during the day when residents are away for work. To address this issue, urban planners can consider reallocating the unused street space to accommodate alternative modes of transportation, such as creating bus lanes, or to serve other urban functions, such as markets or promenades, in a fair manner. Some existing approaches, like night time parking or weekend markets held on the streets, already attempt to utilize the space differently. However, these approaches are often localized and fixed, following rigid rules or being temporary solutions like pop-up cycle lanes implemented through tactical urbanism. As a result, they do not effectively respond to changing demands for accessibility or mobility.

This work is part of the broader long-term project Streets4All (https://streets4all.tecnico.ulisboa.pt). Recognizing the growing conflict over limited urban space, the project proposes an Equitable and Dynamic Allocation of Urban Street Space, aiming to simultaneously accommodate the moving needs (transportation) and the staying needs (streets livability). It seeks to develop a complete framework, consisting of: identifying the dynamic space allocation solutions currently available, defining a methodology for selecting the best suitable sites, establishing a design thinking process to propose new urban designs with dynamic solutions, and using simulation methods to test them.

The focus of this work is the second task of the project, which has the objective to define aggregate criteria and guidelines to map the potential areas for dynamic street space allocation in cities. Specifically, aiming to identify potential urban areas for implementing dynamic allocation solutions in the mobility space, such as streets, avenues, and squares. More specifically, we present a procedure that was first applied to the city of Lisbon and subsequently applied to the city of

Coimbra. Hereinafter, we will present the Coimbra case study process. In this case study, we used the same base criteria as used for the Lisbon case study (Valença et al., 2022) to find potential intervention areas: Betweenness, Closeness, Degree, Density, and Diversity. To accomplish this, we defined the main urban area of Coimbra, enclosed by the principal arterial roads, divided it into a square grid, and for each grid cell we determined the values for all considered criteria. The network elements and related data were obtained from Open Street Maps.

The centrality criteria - Betweenness, Closeness, and Degree - analyze the characteristics of the urban street network based on its layout and structure. By measuring topological distances and considering every node in the network with equal importance and access opportunities, we can gain insights into the configuration of the network. The Density and Diversity criteria reflect the impact of land-use on travel behaviors and patterns. To determine Density, we utilize data from the Portuguese Census and calculate the number of people within each grid cell. To evaluate Diversity, we employ the Entropy index. This index is on a scale of 0 to 1, where 0 indicates homogeneous land use with only one type of land use present, and 1 signifies an equal distribution of various land-use types.

These five criteria were processed with each one having an output grid based on meeting certain defined values. These outputs were then overlapped to obtain a final grid presenting all cells that met the five criteria. However, as a consequence of encountering a limited final output in Coimbra, contrasting with the Lisbon case study, some adjustments were made to tune the methodology. For instance, we adapted the population grid (Density) to consider adjacent grid squares, and eliminated all low-value nodes of Betweenness, analyzing them as percentiles instead of absolute values. With these adjustments, we were able to identify two areas for intervention in the final output grid.

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