Footprints of Regional Science
The Voice of Regional Science

Luigi Fusco Girard
Karima Kourtit
Peter Nijkamp *Editors*

The Future of Liveable Cities

The Regional Science Academy

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Luigi Fusco Girard · Karima Kourtit · Peter Nijkamp
Editors

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Editors
Luigi Fusco Girard
Institute for Research on Innovation and Services for Development (IRISS)—National Research Council (CNR)
Naples, Italy

Karima Kourtit
Faculty of Management
The Open University
Heerlen, The Netherlands

Peter Nijkamp
Faculty of Management
The Open University
Heerlen, The Netherlands

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Contents

Contributors

Mariarosaria Angrisano Department of Economic and Legal Science, Università Telematica Pegaso, Naples, Italy

Martone Assunta Institute for Research On Innovation and Services for Development (IRISS), National Research Council (CNR), Naples, Italy

Alexandru Bănică Department of Geography, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iaşi, Iaşi, Romania

Raphaële Bidault-Waddington LIID Future Lab, Paris, France

Martina Bosone Institute for Research On Innovation and Services for Development (IRISS), National Research Council (CNR), Naples, Italy

Dani Broitman Faculty of Architecture and Town Planning, Technion-Israel Institute of Technology, Haifa, Israel

Francesca Buglione Department of Architecture, University of Naples Federico II, Naples, Italy

Mehmet Güney Celbiş UNU-MERIT and LAET, ENTPE, CNRS, University of Lyon, Lyon, France

Daniel Czamanski The Ruppin Research Center in Real Estate Economics and Appraisal, Haifa, Israel

Tomaz Ponce Dentinho Department of Agricultural Sciences, University of the Azores, Ponta Delgada, Portugal

Pasquale DeToro Department of Architecture, University of Naples Federico II, I-80134 Naples, Italy

Brenno Fonseca University Paris-Saclay, AgroParisTech, INRAE, Paris, France

Rudolf Giffinger Institute of Spatial Planning, Vienna, Austria

Luigi Fusco Girard Institute for Research On Innovation and Services for Development (IRISS), National Research Council (CNR), Naples, Italy

Antonia Gravagnuolo Institute of Heritage Science (ISPC), National Research Council (CNR), Naples, Italy

Christina Kakderi Aristotle University, Thessaloniki, Greece

Nicos Komninos Aristotle University, Thessaloniki, Greece

Karima Kourtit Faculty of Management, The Open University, Heerlen, The Netherlands

Hans Kramar Institute of Spatial Planning, Vienna, Austria

Steffen Lehmann School of Architecture, University of Nevada, Las Vegas, NV, USA

Daniela Mariño Department of Geography, University of Zurich, Zürich, Switzerland

Peter Nijkamp Faculty of Management, The Open University, Heerlen, The Netherlands

Francesca Nocca Department of Architecture, University of Naples Federico II, Naples, Italy

Anestasia Panori Aristotle University, Thessaloniki, Greece

Gabriela Carmen Pascariu Centre for European Studies, Faculty of Law, Alexandru Ioan Cuza University of Iaşi, Iaşi, Romania

Yannis Psycharis Panteion University of Social and Political Sciences, Athens, Greece

Céline Rozenblat Institute of Geography and Sustainability, Faculty of Geoscience and Environment, University of Lausanne, Lausanne, Switzerland

André Torre University Paris-Saclay, AgroParisTech, INRAE, Paris, France

Joanna Williams University College London, London, UK

Pui-Hang Wong UNU-MERIT and Maastricht University, Maastricht, The Netherlands

Luca Zamparini Department of Law, Economics Division, Unlversità del Salento, Lecce, Italy

Challenges for a Liveable Urban World

Luigi Fusco Girard, Karima Kourtit, and Peter Nijkamp

1 Prefatory Remarks

Modern cities are subject to a wide range of external and internal challenges. External challenges comprise inter alia pandemics, war situations, economic recession, migration influx, climate change etc., while internal challenges may refer to unbalanced housing markets, intra-urban poverty and inequality, low accessibility, human health, energy poverty, environmental decay, poor employment conditions etc. City systems are facing a permanent task to cope with many challenges and to develop effective responses, in the spirit of Toynbee's (1946) '*challenge and response*' principle.

For cities and urban areas to survive and to create a promising future under uncertain conditions, it is pertinent to address urgently a range of pressing issues, such as:

- rebranding of cities as the 'natural habitat' for people in the '*New Urban World*' (Kourtit, 2019).
- reinforcement of '*urban culture*' (including '*the urban way of life*') from a human-centred perspective ('*cities4people*' & '*people4cities*').
- enhancement of the *spatial and morphological conditions* that shape human health in cities (e.g. through avoidance of pandemics by proper management of *urban public space*).
- improvement of environmental quality and climatological conditions of agglomerations to face the climate change challenge (*circularity, climate-neutrality, zero-emission*, *green cities* etc.).

L. F. Girard
Institute for Research On Innovation and Services for Development (IRISS), National Research Council (CNR), Naples, Italy
e-mail: luigi.fuscogirard@gmail.com

K. Kourtit (✉) · P. Nijkamp
The Open University, Heerlen, The Netherlands
e-mail: k_kourtit@hotmail.com; karima.kourtit@ou.nl

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- balanced control of negative externalities associated with *mobility patterns* in cities (e.g. *car-free cities, the 15-min city, walkable—and cyclable—cities*).
- coping with *urban poverty*, *inequality and social exclusion* (e.g. favouring equal opportunity and inclusion principles) and favouring *social capital* (including bonding and bridging).
- creation of conditions for a *liveable and loveable city* for residents and visitors ('good city', urban happiness).
- exploitation of the great potential provided by digital technology for urban governance and citizen participation.
- development of an *evolutionary-based resilience perspective on cities* (urbanisation, counter-urbanisation, urban cycles, *'rhythmic' and 'algorithmic' cities*, etc.).
- need for actionable governance strategies and initiatives, taking into account the multi-scalar fabric of urban agglomerations ranging from network cities to city networks (see Neal, 2012)

Cities are nowadays focal points of scientific and planning attention, as they need to successfully address far-reaching—local and global—challenges and responses, while they also need to show socio-economic and political success stories, preferably to be documented from an evidence-based and scientific perspective. Such policy-oriented urban evidence may also find its inspiration in recent important policy documents (such as the New Urban Agenda and the New Leipzig Charter). The city is—and has always been—'*work in progress*'. Its rich history will set the tone for its future. All the time, the city has to re-invent itself, but always in a new jacket (see Bryson et al., 2018). This will also be the main motto of the present publication.

2 Questions Galore

Cities operate in a complex societal arena (Rozenblat & Neal, 2021) and act often as a concentration point of all 'goods' and 'bads' of a society. As a consequence, cities have to face a flood of questions, challenges and problems, as is exemplified in the following rather arbitrary list of science and policy concerns:

- How can agglomeration economies act as effective instruments to cope with negative externalities (e.g. by adopting a circular economy model with a zero or low ecological footprint)?
- Can urban poverty be transformed into a 'community of hope' by means of higher education and advanced technology?
- What are the opportunities for re-building public space in the city into a sustainable and inclusive place for all ('social retro-fitting')?
- Can 'ghettoisation' of modern cities be converted into a promising archipelago of distinct 'urban villages', as seen from the principle of sustainability and inclusiveness?

- How can historical centres of cities, which cannot be remodelled to fit contemporaneous use functions, still be developed as poles of attraction and progress?
- If cities are growing in numbers of inhabitants, how can then a satisfactory balance be found between 2 and 3D architectural morphology?
- Given the ongoing megatrend of climate change and given the vulnerable location of many cities along riverbanks and seashores, do we have creative design principles so as to make these cities climate-resilient?
- If we believe in the '*city4all*' ideal, how can then urban planning provide the means to ensure a equitable balance among different population groups in modern cities?
- Given the multi-faceted functions of a city to provide appropriate amenities for its inhabitants, how can equal access to and equal rights on basic amenities be guaranteed (e.g. in case of migrants' influx)?
- If the city is to be 'the home of man' (Ward, 1976), what does that mean for the ecological, economic, cultural and demographic characteristics of the city?
- When we believe in a multi-dimensional human-oriented profile of urban agglomerations, how do we then ensure equal access to such human rights and advantages for all citizens, with a special attention to vulnerable people (Agenda, 2030, 11th SDG) in support of urban resilience?
- If human settlement structures are always in a state of flux (from 2 to 3D solutions, from high-density centres to low-density suburbs etc.), are we then able to develop solid principles for architecture and planning that satisfy the principles of a '*good city*' (Kevin Lynch, 1960).

It speaks for itself that the above list is very exemplary and can easily be extended with numerous other questions and concerns. But they are all illustrative of the type of challenges faced by modern cities. And they form background material for the scientific contributions included in the present volume on the future of liveable cities. Clearly, the concept of a liveable city is not unambiguous. It may have various meanings and functions, but in general, it refers to attractive and healthy urban living conditions that prompt citizens to remain in an urban area which is also attractive to others. Such conditions may directly or indirectly comply with the quality conditions specified in the New Urban Agenda, as indicated in the next section.

3 Context

Cities and urban agglomerations are no islands in a calm sea. They are subject to sometimes uncontrolled forces which affect their operations and potentials, not only in an economic sense but also in a demographic or technological sense. In addition, they are normally part of a city network and connected to other adjacent or distant cities, thus allowing for social, economic, technological, cultural or ecological interaction. In several parts of the world, cities have a long history and are not the product of careful social planning and coordinated architecture, thus creating a unique identity of cities. As a consequence, many cities demonstrate a high degree of human and social creativity, place-specific and political pluriformity, and rich multi-faceted morphological features stimulating a vibrant urban environment, as is exemplified by European cities.

Cities have in the *New Urban World* (Kourtit, 2019) become escalators of socio-economic, innovative and technological development and of societal and cultural progress. Since the first publication and worldwide adoption of the *New Urban Agenda*[1], it is broadly accepted that ideally urban agglomerations and human settlements: (i) fulfil a critical social and ecological function; (ii) are participatory social organisations and stimulate civic engagement; (iii) favour gender and ethnic equality and stimulate citizens' empowerment; (iv) address the challenges and new opportunities of current and future balanced, inclusive and sustainable economic growth; (v) meet their democratic tasks to achieve sustainable and equitable urban and territorial development; (vi) encourage age- and group-responsive planning and investment for a broad urban development; (vii) are preventive in adopting and implementing disaster risk reduction and management programmes; and (viii) protect, conserve, restore and promote their vulnerable ecosystems (Article 13).

This New Urban Agenda calls for concrete and effective action plans on cities and urban agglomerations all over the world, in order to ensure that human settlements are a '*place4all*' and that citizens can enjoy a liveable and attractive environment which contributes to human well-being. It is of course an important question of how to design and create urban systems that are the '*home of man*' (Barbara Ward, 1976). And there is an equally important intriguing question: '*what is a good city?*' (Kevin Lynch, 1960). Such questions have become of critical importance in policy and science debates on the COVID-19 pandemic, since the very nature of the city—density, size, proximity, agglomeration advantages etc.—was at stake all over the world. There is no doubt that a fundamental re-thinking of city and urbanisation concepts is pertinent.

Views on the 'city of the future' are expressed in many publications. Some studies focus on *city size* or agglomeration size, others on the position of cities in emerging economic-geographical networks, and again others on the functions of cities in the New Urban World. In the New Leipzig Charter (2020), for instance, the following classification of cities is formulated according to their dedicated response to future social, economic and ecological challenges:

- *just city*, in which "the transformative power of cities provides equal opportunities and environmental justice for all, regardless of gender, socioeconomic status, age and origin—leaving no one behind. A just city provides opportunities for everyone to integrate in society."
- *green city,* in which "the transformative power of cities contributes to combatting global warming and to high environmental quality for air, water, soil and land use. The development of high quality urban environments for all includes adequate access to green and recreational spaces."

[1] On October 20, 2016, the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) held in Quito, Ecuador, marked the adoption of the New Urban Agenda, https://habitat3.org/wp-content/uploads/NUA-English.pdf.

- *productive city*, in which "the transformative power of cities is based on a diversified economy which provides jobs while ensuring a sound financial base for sustainable urban development. Cities as attractive, innovative and competitive business locations need a skilled workforce, social, technical and logistical infrastructure as well as affordable and accessible space."

It is clear that the '*future of liveable cities*' which is the theme of the present publication, forms a great challenge for both academic and policy circles. The future of our planet will be mirrored in urban areas. And therefore, intense attention to urban matters is warranted.

4 Aims and Scope

Urban development takes place in a complex and uncertain environment. In the current '*urban century*', the dichotomy between '*urban empires*' driven by economic power objectives (Glaeser et al., 2021) and '*cities4people*' ideals driven by citizens (Kourtit et al., 2022; Wahlstrom et al., 2020) has turned into an important scientific and policy issue that urgently needs new analytical endeavours and effective policy responses. Digital technology in particular has provided several unforeseen opportunities for an actionable citizen-inspired approach to handling the complexity of modern cities. In the '*New Urban World*', residents are not passive actors in the urban space, but active and cognitive inhabitants whose choices, perceptions and behaviours shape contemporaneous and future urban liveability. Liveable cities are healthy and happy places where inhabitants aspire to be and to live; they meet the requirement of a high quality of life in sustainable places. Recently developed ideas like '*climate-neutral*', '*carbon-free*' and '*circular cities*' may—with an active involvement of citizens and stakeholders—contribute to successful achievement of the New Urban Agenda ambitions on liveable places on our urbanised planet.

It should be noted that modern cities function normally in a force field characterised by both rapid progress and dismal decay. Worldwide, in the context of the globally accepted UN Sustainable Development Goals (SDGs) (2015), the New Urban Agenda (2016) is often regarded as a new signpost for a better urban perspective characterised by liveability, inclusiveness and sustainability criteria. In the abovementioned UN policy document, urban agglomerations are regarded as a resource, seedbed and opportunity for inclusive, equitable and sustainable development. Cities may be seen as the 'home of people', with different layers of a 'microcosmic' systemic constellation such as: *individual, oikos, agora* and *polis*. Clearly, the quality of life of citizens in a complex urban area is nowadays threatened by many factors, such as diseconomies of agglomeration (e.g. poor air quality, sub-standard water quality, high population density, lack of community sense and social capital, threats to cultural-historical heritage, etc.). Fortunately, there is a rising tendency nowadays to create or adjust cities that are climate-neutral, car-free, energy-balanced, waste-free, etc., to ensure the foundations for a happy and healthy city.

The recently developed notion of a '*circular city*' (Fusco Girard, 2019, 2020)—and in the same vein a '*climate-neutral urban economy*'—provides the conceptual and actionable policy basis for a 'new generation' of cities characterised by a positive development trajectory that preserves and enhances natural, environmental and cultural capital in the city, optimises digital and human resource yields, and minimises urban systemic risks and threats by wise and effective management of finite physical stocks and material network flows. This ambition calls for a new environmentally benign or climate-neutral organisation of man-environment-biosphere interactions in an urban agglomeration. This is a challenging new urban concept, which is also reflected in fashionable notions such as zero-pollution cities, zero-emission cities, decarbonised cities, green cities or zero-fatality cities. Clearly, the roadmap towards a 'circular city' calls for new forms of effective and accessible knowledge, supported by actionable digital technology. Only then, circular cities—as adaptive complex systems—may safeguard our planet with its increasing population pressure and negative consequences of drastic environmental changes, and may hence favour resilient urban modes of living and working. Clearly, the action agenda of the city of the future is vast.

5 The 'Smart City' as an Actionable Strategy

Given of the significance of urban agglomerations for sustainable and liveable development—in particular, with a view to a circular economy—a new buzzword has in recent years become popular, viz. '*smart*' cities. A smart city (sometimes also called an 'intelligent city') seeks to enhance its performance (from a social, economic, environmental or technological perspective) by introducing and implementing advanced data, knowledge and information principles—mainly by means of ICT or digital technology—in order to support effectively sustainable urban policy and professional city management. A smart city is clearly not a final goal per se, because it is a learning and inclusive place, with a strong engagement of stakeholders, business life and citizens. People actively involved through participation, education, employability and liveability are co-evolutionary and co-creative partners who seek to enhance the long-term performance of cities (the 'XXQ-principle', operationalised through maximisation of urban quality of life; Nijkamp, 2008). Smartness is thus an intermediate objective.

Smart cities are instrumental in achieving liveable cities. In the current '*urban century*', smart cities may act as powerhouses for an equilibrated and cooperative development of cities on our urbanised planet, an opportunity usually based on the locational presence and smart use of urban agglomeration benefits of various kinds (scale advantages, economies of density, proximity and network advantages, etc.). However, such smart or intelligent cities need effective coordination and smart governance based on advanced urban data management, in particular in our 'data-rich' era. Consequently, a cognitive and analytical orientation towards management and decision support systems for future urban well-being is a *sine qua non*. In addition to solid conventional policy-making tools, a smart city needs also modern, interactive and data-rich decision mechanisms—in relation to big data presence—that include and digest relevant indicators (e.g. in the form of urban datacentres, liveability labs, data warehouses and urban dashboards) (Komninos, 2002).

We note here that cities and urban agglomerations are becoming the new cognitive and economic magnets for people and businesses; they accommodate nowadays the main share of economic activity in many countries of the world. They have to cope with many challenges (e.g. mobility, energy, public amenities, urban land use, liveability, climate change, inequality jobs, and housing) which all need actionable, effective and informed policy reactions. Furthermore, a city accommodates a great diversity of interest groups, ethnic groups and stakeholders, with many heterogeneous aspirations and information needs. In this context, urban databases may range from individual to collective aggregation, with different degrees of information accuracy (see Antwi-Afari et al., 2021; Glaeser, 2011; Glaeser et al., 2021; Neal, 2012; Stanley et al., 2017). We note here that there is no systematic data architecture for converting big amounts of (semi-)unstructured information into a systematic and measurable urban data base that is tailor-made for policy-making and operational analytics. The contemporaneous interest in 'big data' (e.g. from base mobile phones, social media devices, sensors in public urban space) presents clearly a new challenge, and also an actionable and promising new opportunity for sustainable and inclusive urban governance. To handle this new challenging option for cities, smart cities need to employ advanced digital expertise on urban dynamics, urban informatics and data analytics, smart urban tools, digital learning capacity and cyber civil participation (Batty, 2013). It goes without saying that particularly in the emerging circular economy framework for modern cities, the stress on appropriate data systems for long-run sustainable urban development policy inspired by civic responsibility and self-organising capacity is formidable. This will be further elaborated in the next section.

6 Digital Intelligence and Urban Well-Being

We live in the era of industry 4.0 technologies. Digitalisation is a transformative technology trend and provides new opportunities for innovative and high-quality services to society. These services may relate to the urban environment, mobility, energy, housing, retailing or labour market. Of course, there are always issues of privacy protection, which have to be taken seriously. In general however, access to and use of digital technology has created a portfolio of new possibilities for considerable performance and welfare enhancement in all domains of the city (Nijkamp et al., 2022). The ICT sector tends to become gradually a pervasive and system-wide characteristic of the urban world.

The modern 'big data' trend provides researchers and planners with original and broad insights into the basics of a contemporaneous urban society, in particular in regard to: (i) the micro–statistical and evidence-based—foundations of life and public space in the city, (ii) spatial perceptions and behaviours of residents and urban stakeholders, (iii) the development and bottlenecks in urban morphology and land use, (iv) the presence and use of urban amenities and public goods in urban areas, (v) the design, planning and governance challenges of contemporaneous cities, and (vi) the modern data-analytics (for instance, advanced geo-science, 3D methods, visualisation and data mining techniques and learning methods) in modern urban sciences ('the city as a data machine'; Batty, 2013). New urban analytics ('urbanometrics') provides useful tools to both scientific researchers and society at large and will help support the ideal of efficient, sustainable, liveable and inclusive cities in our world.

The revolution in big data analytics runs parallel to the need to enhance the socio-economic functioning and governance of contemporaneous self-organising urban areas that are characterised by a distinct and rich architectural design and historical-cultural heritage, a pluriform patchwork of individual and group priorities and choices, a complex interdependent constellation between economic, technological, health care, knowledge and business stakeholders, and an enormous diversity in internal and external network connectivities. The modern digital time transforms the modern city into a complex 'data container' that should serve the policy needs for a radical transformation towards circular cities that would decisively support the New Urban Agenda. Clearly, big data are not the ultimate lifeboat of a 'troubled' city, but they enable policy-makers to obtain a balanced perspective on the urban future that is in agreement with the foundation stones of the *New Urban World* (Kourtit, 2019). The 'circular city' may consequently become an important vehicle for realising the UN SDGs, including urban circularity plans.

The attainment of the ambitious goals of a liveable city in the future is a task fraught with many hurdles. The challenges to public policy are manifold, for instance: the provision of welfare services, the supply of affordable housing, the building of a safe city, the urban–rural dichotomy, the handling of waste management, the creation of professional health care, the maintenance of cultural and educational facilities, or the management of urban public spaces. An integrated policy in a city would therefore, need appropriate citizen participation or engagement, certainly in a conflicting urban policy environment. In this regard, also principles and opportunities of civic co-creation and co-design might have to be favoured, based on citizens' networks and bonding and bridging principles. In many cases, given the pluriformity of districts in a city, a multi-scalar research and policy approach would be preferable as well. In conclusion, a place-specific urban strategy, with even due attention for neighbourhood potential, would be needed.

Urban policy is in full motion. The effective execution of the strategies advocated in the UN SDG policy and of its subsequent New Urban Agenda means a big challenge for both global and urban governance. The increasingly urgent climate goals add another pressure. Citizens may be regarded as pivotal actors in urban sustainability and liveability initiatives. Clearly, their choices, attitudes and behaviours in relation to local quality of life and urban well-being are critical factors for a successful people-oriented local SDG policy. Given the need for evidence-based urban policy, the development of integrated *social indicator systems* on the well-being of residents and their living environment is pertinent. Promising contributions can be found inter alia in urban quality of life (QoL), liveability, happiness, appreciation and urban well-being or recent city love studies. Illustrations of operational indicator systems are, for instance: neighbourhood sustainability indicators, habitability indicators, satisfaction indicators, feelgood indicators etc. The ultimate goal of 'liveable cities' is of course to contribute to the well-being and happiness of citizens. But such 'dream images' need testable and measurable studies on urban life.

7 The Future of Liveable Cities: Composition of the Volume

Urban liveability policy is not based on a cybernetic control mechanism; it is a multi-dimensional, multi-scalar and multi-actor public activity taking into account the broad composition and functioning of the pluriform urban economy, including polycentric settlement structures, climate-neutral land use constellations and poly-cultural urban neighbourhoods. The development of effective smart city policies is still in its infancy and requires professional skills from the side of urban planners as well as of residents.

The present volume on '*The Future of Liveable Cities*' aims to generate a collection of original and state-of-the art scientific contributions—written by recognised scholars from different parts of the world—on the theme of urban liveability. This book publication is multi-disciplinary in nature, with evidence-based contributions by experts from disciplines like urban planning and architecture, geography, urbanistics, morphology, environmental science, urban economics, demography, political science and so forth. The focus of each individual contribution is on urban well-being, from the perspective of sustainable, environmentally-benign and climate-neutral (or -positive) cities. In particular, original and operational models related to the concept of circular cities or climate-neutral places in the context of a green economy are presented, as the future of liveable cities is dependent on the smart use of its resources (including material resources). Such analytical contributions help trace or explore the contextual conditions (quality of environment, neighbourhood quality, energy transition, climate-neutrality, recycling etc.) as factors that shape the well-being of the '*homo urbanus*'.

The composition of this book on '*The Future of Liveable Cities*' is as follows. The present chapter (Chapter 1) provides an overview of the emerging issues in liveability aspects of cities in various parts of the world. This first chapter offers an entry gate to the chapters in the remaining part of this book, which comprises three systematically organised parts. The first part provides various important conceptual and policy-relevant contributions to a better understanding of urban liveability and its constituents. Next, the second part offers presentations of several studies on quality of life in cities, while this volume is concluded, in part III, with a set of operational contributions on healthy and happy cities as characteristics of urban liveability. The contributions in this volume are therefore, clustered into three parts: (I) spotlights on liveable cities; (II) kaleidoscope views on urban quality of life; (III) healthy and happy cities. These three clusters will now briefly be introduced.

Part I, on '*Spotlights on Liveable Cities*', contains five chapters addressing conditions, drivers and effects of urban liveability, seen from different perspectives. Chapter 2, written by Dani Broitman and Daniel Czamanski, provides a conceptual approach to liveability in cities, followed by Chapter 3, written by Rudolf Giffinger and Hans Kramar, on the measurement of concepts and indicators of liveable cities. Next, Nicos Komninos offers a new contribution to the debate on liveable cities (in Chapter 4), with a particular focus on inclusiveness, carbon neutrality and transport innovations. In a subsequent contribution (Chapter 5) Luca Zamparini addresses the importance of digital technology for mobility in liveable cities, while in a final chapter in Part I (Chapter 6), Antonia Gravagnuolo pays attention to historic dimensions in liveable cities, against the background of circular urban economies.

In Part II of this volume, we address the notion of '*Urban Liveability Planning'* from a broader external kaleidoscopic perspective. The opening chapter in this part (Chapter 7) is written by Steffen Lehmann and zooms in on regreening of cities in a post-carbon era. Social equity aspects of liveability in urban areas are next analysed by Tomaz Dentinho in Chapter 8, followed by an overview of liveability in cities in post-socialist European countries (Chapter 9), written by Gabriela Carmen Pascariu. The final chapter in Part II (Chapter 10) is written by Brenno Fonseca and Andre Torre and addresses the issue of land farming conflicts in larger metropolitan areas.

The final part (Part III) of this book deals with '*Urban Quality of Life Challenges'* assessment, against the emerging importance of health conditions and related happiness situations in bigger cities. In Chapter 11, Joanne Williams introduces the post-COVID issues in relation to a circular recovery of cities in Europe. Her contribution is followed by a study (Chapter 12) by Pasquale Toro, Francesca Nocca and Francesca Buglione on corona impacts on real estate values in cities. Next, Celine Rozenblat provides in Chapter 13 a new study on topics and actors of urban health at various urban scales. Finally, Pui-Hang Wong, Mehmet Guney Celbis, Karima Kourtit and Peter Nijkamp present a study (Chapter 14) on socio-economic well-being in relation to urban liveability.

This volume offers thus a rich panoramic overview of quality-of-life challenges and related studies on urban liveability, seen from different angles. The findings from this book illustrate clearly that urban liveability is a field full of data-analytical and measurement hurdles. Clearly, the recent COVID-19 health crisis has also taught us that further evidence-based research is needed for a sound and promising scientific and policy perspective on future cities.

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Spotlights on Liveable Cities

Liveable Cities: A Conceptual Modeling Approach

Dani Broitman and Daniel Czamanski

1 Introduction

The notion that some places are liveable, and therefore are better suited for human habitation than other places, is at least 2000 years old. In the first century BCE, Marcus Vitruvius Pollio (Vitruvius) stressed that, above all, sites selected for cities should promote health. They should be high on hills and away from marshes. Thinking of the Mediterranean, he suggested that western and southern coastal exposures should be avoided because they are too hot during the summer months and too cold in the winter (Salama, 2007; Vitruvius, 1914). Among the many other desirable attributes, he suggested that buildings in cities should possess strength, utility, and beauty.

The first modern reference to urban livability was by Dutch urban planners some 70 years ago (Kaal, 2011). By means of various indices of livability, they emphasized globally competitive and attractive cities. Since then, livability has become a common concept in strategic urban plans. Planners aim to achieve broad outcomes such as quality of life, people-centered urban design, environmental sustainability, and attractiveness to investors.

Several attempts to formalize a definition of urban livability were performed in the last few years. Initial approaches embedded the concept of livability within the much broader framework of urban sustainability, using urban metabolism models (Newman, 1999). Detailed and elaborated indexes developed later use a plethora of data sources (Liang et al., 2020; Wang et al., 2011). Other approaches focus on the most important components, such as human wellbeing (Okulicz-Kozaryn &

D. Broitman (✉)
Faculty of Architecture and Town Planning, Technion-Israel Institute of Technology, Haifa, Israel
e-mail: danib@technion.ac.il

D. Czamanski
The Ruppin Research Center in Real Estate Economics and Appraisal, Haifa, Israel
e-mail: danny@czamanski.com

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Valente, 2019; Zanella et al., 2015) or environmental impact (Zanella et al., 2015). Sometimes, while using complex indexes, specific aspects, such as the quality of the urban structure are highlighted (Kashef, 2016). Since the concept of livability involves human preferences, the relative weight of objective and subjective evaluations in its assessment is still a contested issue (Okulicz-Kozaryn, 2013). In a review of recent studies concerned with livability McArthur and Robin (2019) find that it is a malleable concept that has been co-opted for various purposes including creativity, entrepreneurship, sustainability, resilience, and freedom. Its place in public discourse was fashioned through a connection of vague rhetoric and various indicators and ranking.

For some years now rankings of cities are published by various organizations. The Economist Intelligence Unit (2021) publishes the annual *Global Liveability Index*. Based on surveys, every city is given a rating for some 30 quantitative and qualitative factors. These include stability, healthcare, culture and environment, education, and infrastructure. The quantitative scores are assigned 5 levels: acceptable, tolerable, uncomfortable, undesirable, or intolerable. The qualitative scores are assigned by a group of experts. The scores are then compiled and weighted to provide a score in the range of 1–100, where 1 is considered *intolerable* and 100 is considered *ideal*. The liveability rating is provided both as an overall score and as a score for each category. To provide points of reference, the score is also given for each category relative to a control city (New York) and an overall position in the ranking of 140 cities.

The measurements are repeated periodically and reflect constant shifts in the rankings of cities. There are various reasons for changes in the scores assigned to cities. This has become particularly apparent following the Covid-19 pandemic that has affected living conditions due to healthcare infrastructure, restrictions, and lockdown policies imposed by governments that affected various healthcare, cultural, and educational categories. The Economist Intelligence Unit introduced new indicators: Stress on healthcare resources, restrictions on local sporting events, restrictions on theater, restrictions on classic and modern music concerts, restrictions on restaurants, bars, coffee shops and nightclubs, and restrictions on educational institutes. The resulting ten most liveable cities for 2021 are presented in Table 1.

Prior to the pandemic, according to The Economist Intelligence Unit, the 2019 most liveable city was Vienna, Austria while Auckland, New Zealand, the top city in 2021, was not even among the top ten cities. A major component that determines livability is the sense that people have concerning the quality of life in various cities and the relocation decisions that they make to enjoy that improved quality of life. Liveable cities are places where people want to live and to which they choose to migrate. Migration decisions are acts of “voting with feet” (Tiebout, 1956). According to Salingaros (2005) different types of urban systems overlap “to build up urban complexity in a living city. This raises the need for using concepts such as coherence, emergence, information, self-organization and adaptivity”. Cities are viewed as self-organizing, dynamic systems that are shaped by the decisions of individuals who are influenced by the urban patterns that emerge from their past decisions.

Table 1 List of the most liveable cities in 2021

City	Location	Rank	Index	Stability	Healthcare	Culture & Environment	Education	Infrastructure
Auckland	New Zealand	1	96.0	95	95.8	97.9	100.0	92.9
Osaka	Japan	2	94.2	100	100.0	83.1	91.7	96.4
Adelaide	Australia	3	94.0	95	100.0	83.8	100.0	96.4
Wellington	New Zealand	4	93.7	95	91.7	95.1	100.0	89.3
Tokyo	Japan	4	93.7	100	100.0	84.0	91.7	92.9
Perth	Australia	6	93.3	95	100.0	78.2	100.0	100.0
Zurich	Switzerland	7	92.8	95	100.0	85.9	83.3	96.4
Geneva	Switzerland	8	92.5	95	100.0	84.5	83.3	96.4
Melbourne	Australia	8	92.5	95	83.3	88.2	100.0	100.0
Brisbane	Australia	10	92.4	95	100.0	85.9	100.0	85.7

Source The economist intelligence unit

In the context of self-organizing systems, there are certain rules of the game that contribute to the promotion of liveable cities. We should expect that there is general agreement about the places that are liveable. In such cases, migrations will cause these places to become extremely populous. Indeed, we can ask at least in the context of each country, why are not all the people living in the most liveable cities? There are various reasons for this not to occur. For example, not all people have the resources to consider alternate places in which to live and work. Some people are resigned to living their entire lives in places that experience low livability. More importantly, it is to be expected that as cities grow many of the factors that made them desirable places to live will become much less liveable. Decreasing returns can cause certain cities to lose their predominance.

Therefore, it is the ever-growing polarization among cities that is one of the main challenges of making future cities liveable. Should we strive to bridge the gap among cities? Should we focus on the gap among population groups within individual cities? Or should we accept disparities among population groups and places in order to make some places liveable. Is the elimination of disparities possible? What policies can contribute to this?

The rest of this chapter includes 4 sections. Section 2 presents an analytical framework for considering how liveability affects the distribution of populations among cities, how the resulting distributions affect liveability, and how various factors affect the resulting dynamic. In Sect. 3 we present a description of the model we use to simulate liveability. In Sect. 4 we present some simulations that illustrate the impact of the changing values of various factors on the liveability rankings of cities. In the last section, we suggest some implications of our approach to liveability.

2 Liveability and Population Distribution—An Analytic Framework

We have been developing the analytic framework to explain urban liveability and its variation over time and space for a number of years (Broitman & Czamanski, 2012a, 2012b, 2015, 2021a, 2021b; Broitman et al., 2020; Buda et al., 2021; Czamanski & Broitman, 2012, 2017, 2018). We conceive cities as self-organizing systems. At their heart is the notion that information concerning the various components of liveability spreads throughout the urban system and that this information, whether precise or distorted, affects perceptions of liveability and decisions about where people wish to live. Ex post quantitative and qualitative measures of liveability reflect decisions already made, whether these were made on the basis of true or distorted information. Perceptions of liveability are inevitably subject to filters that distort the information transmitted to others.

According to conventional economic theory, people possess full information that reflects reality precisely. They are capable to evaluate this information and to act to maximize their own welfare. Stiglitz (1986) proposed that the acquisition of information is costly and therefore the distribution of information among economic agents is not uniform. Some agents have more and better information than other agents. Moreover, the ability of agents to evaluate the information they possess is limited and not uniform. Rationality is bounded.

The new urban models are concerned with the creation of spatial patterns that result from the interaction of heterogenous agents and the reactions of the individual agents to these patterns. In these models, equilibrium is not inevitable, although it is possible. The urban system is viewed as "an ever-changing ecology of beliefs, organizing principles and behaviors" in the context of interdependent networks (Arthur, 2021). By means of these networks, the decisions of each agent are transmitted to all other agents. Whether information reaches all edges depends on whether networks are sparse or whether they are dense. In sparse networks information may not dissipate and reach all agents. In dense networks it spreads and reaches all agents. In the transmission process information passes through various filters. Some are neutral and do not affect the content and others change the content and distort it. Acemoglu et al. (2021) show that social media tend to push information that is in some sense "extreme". Social media tend to limit exposure to diverse perspectives and favor "the formation of groups of like-minded users framing and reinforcing a shared narrative". They become "echo chambers" (Cinelli et al., 2021). Acemoglu et al. (2021) claim that these endogenous echo chambers are the mechanism that virally spreads misinformation.

Noise, in the sense that identical messages received by agents are translated into diverse messages send to other agents, is a basic characteristic of human communication (Kahneman, 2021). Distortions are inevitable and therefore even identical agents may reach diverse decisions. Our early model of endogenous growth (Broitman & Czamanski, 2021a, 2021b; Broitman et al., 2020; Czamanski & Broitman, 2017, 2018) assumed that information spreads uniformly and without distortions to all agents in the urban system. Recently we introduced the possibility that information is subject to distortions and that depending on the locations of agents in the system they react to different information (Broitman & Czamanski, 2021b).

Over time decisions of agents result in aggregate performance patterns that in turn are the basis for new rounds of information passed on to all the agents in the urban system. The reactions of the agents to the information that reaches them lead to new aggregate patterns. Thus, liveability dynamics are subject to both positive and negative feedback. Once a place is viewed as particularly liveable, the news spreads and affects migration decisions which in turn affect various liveability indicators. Only after returns to scale are exhausted and growing population density gives rise to negative externalities will information networks generate negative feedback. Therefore, liveability cannot be thought of by means of snapshots of measures. It needs to be traced over time. For periods of time conditions may lead to long-lasting "increasing liveability".

We propose two key operational measures of liveability. The first is population growth. When people value things that a city offer they will choose to move in. This is the urban hardware. It has its drawbacks: An exaggerated growth creates crowding and pollution problems. The second proxy is the city's software, the innovation, smartness, creativity, etc. that allow good living by providing not only good market products but also public services (culture, government, ecosystem services, diversity, civil rights, etc.) Good software is able to overcome problems caused by heavier and growing hardware. So, a liveable city is one in which both (hardware and software) steadily improve. But this is not always possible. Population growth unaccompanied by enough improvement in the software may start a decline cycle. This cycle can be also long-lasting (less population and stagnant innovation) or can be reverted giving birth to a renewed growth cycle, but this depends on the characteristics of the urban systems (whether there are other "comparable" cities that compete with it allowing an up-and-down oscillation among them in terms of population). The rich variety of results obtained using our endogenous growth model allows us to frame cities' liveability dynamics as belonging to one of the following three conceptual scenarios: Cities with steadily growing liveability, cities with fluctuating liveability, and cities with steadily declining liveability. A short description of the model and the conceptual link between its measurement units and the concept of liveability are described in the following section.

To gain insights concerning the evolution of urban liveability we utilize an agent-based model (ABM) of endogenous growth in a closed urban system. The proxy "population" is represented by the number of workers and the "software" proxy (innovation, products, culture, services, etc.) is represented by the variable market value.

3 A Basic Model of Endogenous Urban Growth

The workhorse behind the endogenous urban growth model is the closed and bidirectional conceptual link between innovation and migration. On the one hand, innovation processes within firms located in certain places generate differential GDP growth and are likely to attract migrants, as creative individuals seek higher incomes through employment in innovative firms. In turn, they contribute to the creation of new products and production processes. This is positive feedback that can continue as long the rate of migration does not exceed the rate of growth in GDP. In other words, the condition for a virtuous cycle is an absolute and steady increase in the GDP per capita. Otherwise, the city's population growth slows down and eventually, its population may start to decline. Thus, the interaction between migration and innovation results in a full life cycle of urban evolution, as shown in Fig. 1.

The implementation of our endogenous urban growth model represents a closed economy comprised of various cities with a fixed population of workers. Both the number of cities and the number of workers are fixed. Each worker lives in one of the cities and works in one of the firms located in the same city. Commuting is considered impractical because of the assumed distances between the cities. Although workers can migrate among firms and cities, firms themselves are spatially attached throughout their entire life cycle.

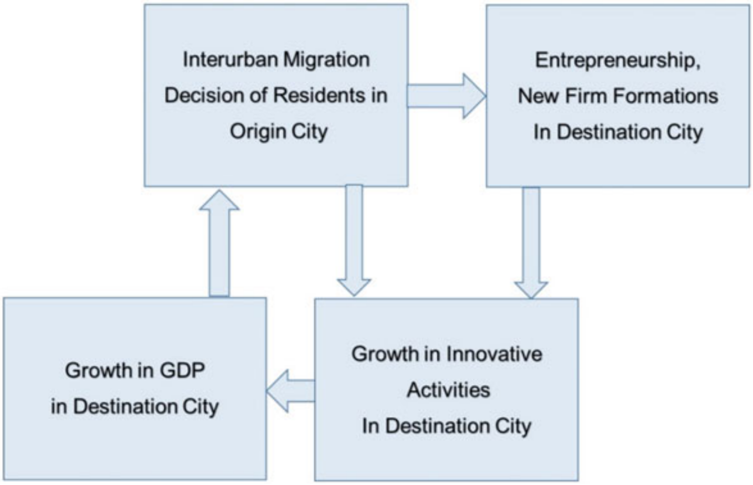

Fig. 1 Full cycle of urban evolution, linking innovation and migration

The migration of workers to other firms (and perhaps also to other cities) is motivated by their search for better conditions (in terms of salaries and quality of life). But these migrant workers may be the source of new ideas that spawn new products and technologies. It is possible also that local workers contribute with innovations of their own. In turn, firms that employ them have the opportunity to adopt and convert these ideas into inventions, if they will and are able to do so. This interaction between workers and firms through the mechanism of innovation is depicted in Fig. 2.

A central feature of the model, closely related to its dynamic qualities, relies on its starting conditions. Initially, workers and firms are equally distributed among the cities. But this egalitarian allocation of resources is only the first step toward a system-wide dynamic reallocation of resources. This is true for workers as physical entities, but also for ideas and innovation. The continuous reallocation of resources

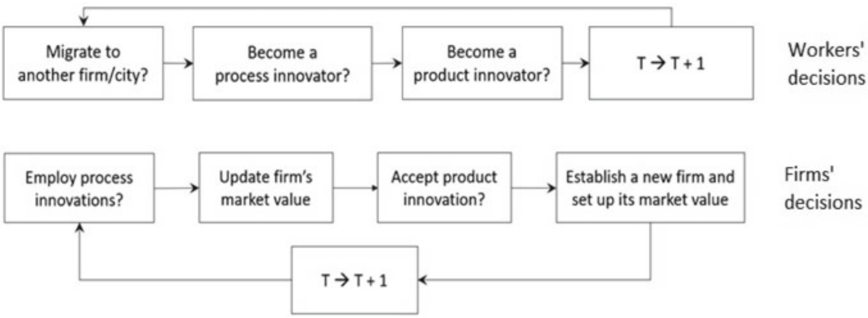

Fig. 2 Decisions of workers and firms in the model

is the foundation on which the rich set of urban dynamics simulated by the model develops.

The full model is described extensively elsewhere (Broitman & Czamanski, 2021a), and therefore here we will describe only the elements that are central to our discussion on liveability. The first element is the population dynamics of each individual city. Since the total number of workers is fixed, migration is always a zero-sum game: The source city loses the migrant while the destination city gains it. This characteristic of the model allows us to focus on cities that are able to continuously attract migrants, those who consistently provide those migrants, and those who are "trapped" in an unstable equilibrium between cycles of growth and decline. The second element is the firm's market value, that is associated with the goods and services that it produces and supplies. During the life cycle of the firm, its market value can increase should it adopt innovative and more efficient production processes. It may happen that some of the firm's workers, suggest innovative new products, fundamentally different from the current firm's portfolio. If the firm is willing to take the risk, it creates a new start-up focused on serving new markets.

These elements are emphasized because they are central to the main topic discussed in this chapter, the liveability of cities. The "number of workers" living in the city is a proxy for its population, or, more generally speaking, for all urban features that are intimately related to the population dynamics, such as the housing stock, but also for other services (education, health, and infrastructures). This is a measure of the urban "hardware". In contrast, the city's total market value (i.e., the sum of all the market values of firms located in the city) is not related directly to the population, but to the wise utilization of the available resources (whether human resources, creativity, innovation, etc.). The city's total market is a proxy not only for the "private market vibrancy", but also for any feature that affects the quality of living in a city, both in the private and the public realm (the city's "software"). In terms of power law functions of population size with scaling exponents (Bettencourt et al., 2007), the "number of workers" represents all urban characteristics that are linear or sublinear, while the "total market value" represents those urban characteristics that have the potential to be superlinear.

4 One Model, Many Simulations Approaches

One of the most striking and seemingly universal regularities of urban systems is Zipf's law, known also as therank–size rule for cities (Gabaix & Ioannides, 2004). Succinctly, this law suggests that the size of a city in an urban system is inversely proportional to its rank. There is a large literature reporting empirical evidence that supports the existence and validity of the rank-size rule (Gabaix, 1999; Ioannides & Overman, 2003) but controversial issues regarding its interpretation and its proper measurement remain (Arcaute et al., 2015; Arshad & Ashraf, 2018). However, it is important to emphasize that the rank-size distribution of an urban system is an instantaneous realization of prolonged (and at times, even chaotic) dynamics of individual cities (Batty, 2006). In other words, it is a snapshot picture of the status of the system at a specific point in time, reflecting a momentaneous distribution, but not the historic paths of the system's components, the individual cities. Therefore, scaling laws are meaningful only when complemented with a description of the underlying urban life cycles and interactions among them within the system.

The endogenous growth model was used to simulate the effects of different assumptions about intercity migration and innovation mechanisms on the resulting power laws of groups of cities, and individual urban life cycles (Broitman et al., 2020). A rich variety of dynamics and power laws ranges emerged. Two examples are shown in Fig. 3. In addition, there are some general trends regarding the fate of individual cities.

The most obvious implication of the emergence of a power law from an initial state with cities of equal population is an intensive rearrangement of resources: Some cities attract workers (the higher rank cities) while other loose them (the lower rank cities). Evidence of this rearrangement of populations is the spreading out trajectories observable over time both in Chart A and C in Fig. 3. Zooming in and focusing on individual cities in these charts, three archetypes of development can be identified. "Liveable cities" are those that, perhaps after an initial instability period, manage to grow steadily. Despite the increasing burden of a growing population, these cities keep their attractiveness for further newcomers. However, these are very few, and generally only one high-ranked city, a maximum two. On the opposite extreme, there are the "declining cities", that after a period of fluctuations enter a long-lasting

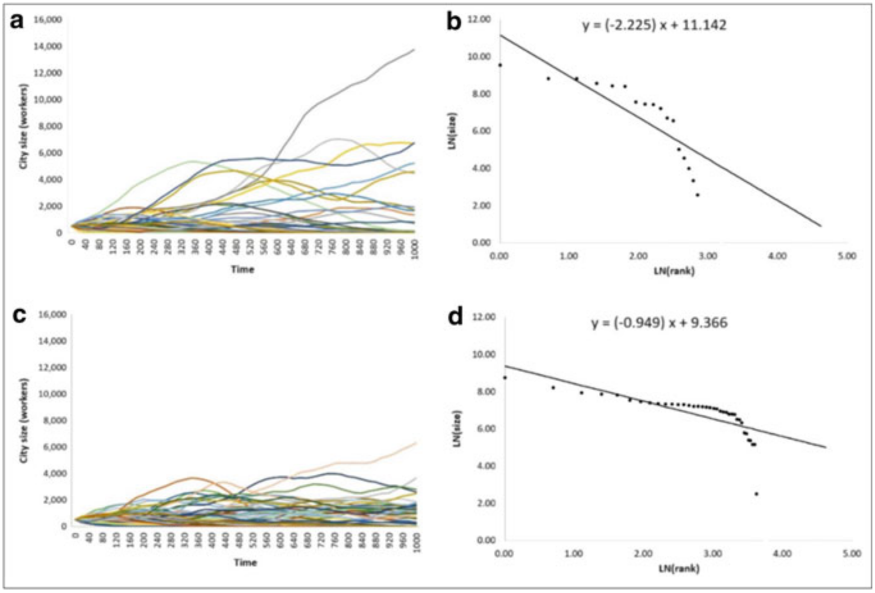

Fig. 3 Examples of urban population dynamics over time (a & c) and their corresponding final rank-sizes (b & d) (adapted from Broitman et al., 2020)

stage of monotonic decrease of population, leading eventually to their disappearance (paths asymptotic with the horizontal axe in charts A and C in Fig. 3. These cities are by definition not liveable, since they are systematically being abandoned by their dwellers, that look for a better (more liveable) future elsewhere. There is a third set of cities whose populations fluctuate during the whole simulation, at times growing and at times declining, but without entering a steady upward or downward path. These places compete with the “liveable cities” and with cities in a similar situation, offering an urban environment good enough to attract a small share of the population at times, or at least, not so bad to provoke a unidirectional stream of people away from them.

But since the previous analysis was focused on the resulting rank-size distributions, the underlying causes behind the liveability of cities were only superficially addressed. In a follow-up study (Broitman & Czamanski, 2021a) the impact of the level of globalization on the resulting urban system was addressed specifically. The assumption was that, in an ideally globalized urban system, innovations are not bounded by geographical location. This means that a new firm created in location X can build on new ideas recently developed in cities Y and Z, quickly creating a new product (and perhaps a new technological branch) in X. This can suddenly upgrade the liveability of X as it becomes a strong attraction force, offering both better-paid jobs and a nicer urban environment. However, the same can happen after a short period of time elsewhere, due to the same global mechanism. The resulting urban world is one in which there are opportunities for each city, but the competition is fierce, and the success is brief. At the opposite extreme, in a “localized” world technologies and innovations are bound to the place in which they were created. This may be because of the need for special infrastructures or specific highly qualified skills that do not exist elsewhere. In this case, if firms in city X manage to develop a new and highly profitable technology, the city will thrive creating a local virtuous cycle. Other cities cannot compete with X on the same ground. Perhaps cities Y and Z may develop their own niches, but they will need to compete for workers with X, successfully or not. But if they fail, they are ultimately doomed to decline. Figure 4 shows an example of the different urban dynamics that emerge from the assumption of several “globalization strengths”.

There is a stark contrast between the seemingly chaotic dynamics in the upper charts (enlarged in the right) and the lower one. On the one hand, globalization causes no city can rest on its own laurels, since preponderance is short-termed. But cities can still decline and even disappear. On the other hand, when globalization is weak, urban life cycles are more clear and less variable in time, but a few winners take the lion’s share, others manage to survive with ups and downs, while the majority of cities decline steadily. But the factors that explain this population dynamics are in the low-right chart of Fig. 4: The distribution of the total market value of the cities in the globalized urban system (dotted line) is far from being even, but the distribution of the not globalized system (black line) is extreme. This means that the few cities that achieve sustainable growth (in this case, only in conditions of weak globalization) are able to maintain it, supported by a comparable market value growth.

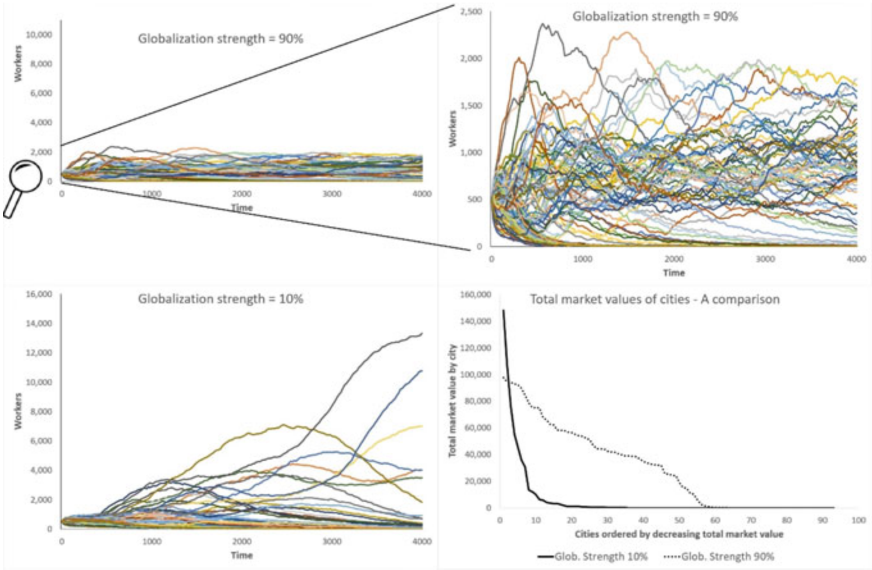

Fig. 4 Urban population dynamics over time assuming high (upper charts), and low (lower right chart) globalization strength. The lower-right chart shows the resulting cities' market values by decreasing size (adapted from Broitman & Czamanski, 2021a)

Following the conclusion of the globalization strength simulations, a further step could be a deeper analysis of the exact meaning of the word "globalization". Since there are several types of globalization (Free trade? Free movement of persons? Lesser restrictions on capital flows?) at the theoretical level it is interesting to assess the impacts of each one of them. But also at the policy level, such analysis can shed light on the effectiveness and chances of local development policies (Broitman & Czamanski, 2021b). Once again, the flexibility of the endogenous urban growth model was harnessed to simulate the behavior of an urban system, this time assessing different development policies. The assessed policies were related to the freedom (or restriction) of the mobility of workers, the capacity to quickly update or create local infrastructures able to support ongoing technological progress, and the expected level of innovation of local inhabitants compared with newcomers. The results were suggestive regarding the type of policies likely to allow the development of lagging cities and had a fruitful interpretation using the lens of entropy theory. However, regarding the liveability of cities, the important conclusion is that, regardless of the specific goals of the model and the used parameters, similar individual development paths emerge, as seen in Fig. 5.

Population and total market value by the city are depicted in Fig. 5 side by side, showing the dynamics of an urban system under two different policy implementations. This time the correlations between both variables are visually more evident. Although there are time lags between the current population of a city and the actual total market values, the general conclusions drafted previously are strengthened.

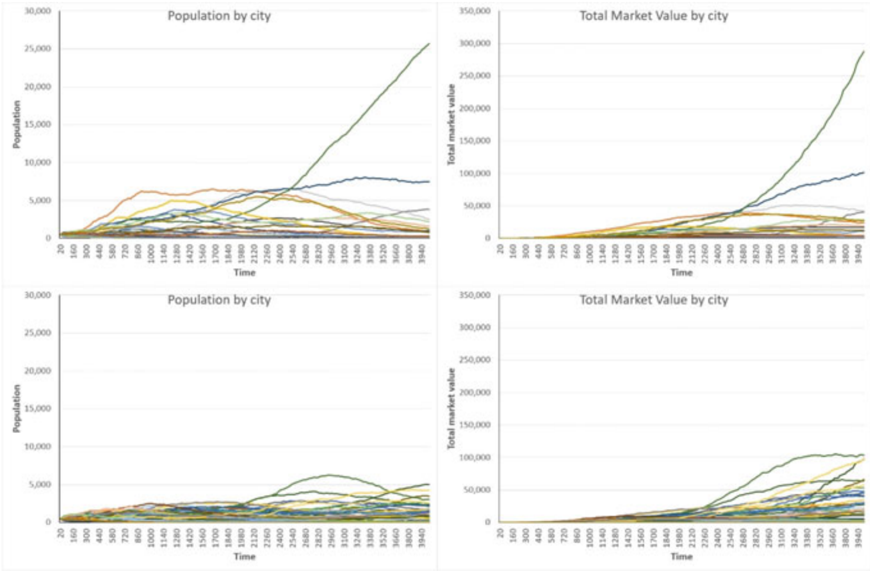

Fig. 5 Population and market value per city dynamics over time simulating different policies (adapted from Broitman & Czamanski, 2021b)

First, a steadily growing market value (at relatively high rates, compared with other cities) is a necessary condition for a steadily growing population. However, this condition is not always sufficient, and it depends on the overall situation of the system. If a single city manages to continue to attract migrants, while increasing at the same time its total market value, it has entered a resilient and sustainable growth path. In that case, the city is likely to be one of the few (perhaps the single one) dominant cities of the whole urban system.

Unfortunately, in a closed urban system as that simulated by our endogenous growth model, the fate of many of the cities that composed the urban system is exactly the opposite. After a period of fluctuations, of both population and the rate of total market value growth, these cities remain trapped in a vicious circle of emigration and stagnating market values. Since the per-capita market value also declines (or in the best case remains stable), the city cannot compete with others that offer better conditions (nevertheless with the predominant cities that become increasingly attractive). It could take long periods of time, but these cities become slowly small towns and finally disappear.

Between both extremes, there are cities that struggle to survive in successive cycles of fast increasing market values, followed by population growth, which causes a decrease in the per-capita market value, increasing migration, and stagnant market values. However, in these cities the recession cycle is not sharp enough to provoke a long-standing decline, having chances to recover and initiate a growth cycle again.

5 Conclusions and the Way Forward

Urban systems are complex entities whose development paths are influenced by a plethora of variables and drivers. Using an endogenous growth model we explored the impact of some of these drivers, on the dynamics of the urban system as a whole and on the fate of individual cities. By means of the model we addressed some of the issues (rank-size, globalization of different types, communication and noise, policies for lagging areas, etc.). The results suggest plausible growth paths for individual cities. Some features of the simulations are particularly important in generating the results. They suggest that there are three main development patterns, that are related to "liveability".

In analyzing the simulations we suggested a hardware/software analogy as two key operational measures of liveability. We suggest that population growth is part of the urban hardware because when people value things that a city offer they will choose to move in. Of course, exaggerated growth can create crowding and pollution problems and reduce the attractiveness of the city. The city's software consists of innovation, smartness, creativity, etc. that contribute to liveability by providing good market products and public services (culture, government, ecosystem services, diversity, civil rights, etc.) Therefore, urban software can overcome problems caused by heavier and growing hardware. So, a liveable city is one in which both (hardware and software) steadily improve. As we discussed above, population growth unaccompanied by enough improvement in the software may start a population decline cycle. The cycle can be long-lasting (less population and stagnant innovation) or can be reverted giving birth to a renewed growth cycle, but this depends on the characteristics of the urban systems.

The rich variety of results obtained using our endogenous growth model allows us to frame the dynamics of urban liveability as belonging to one of the three conceptual scenarios illustrated in Fig. 6: Cities with steadily growing liveability, cities with fluctuating liveability, and cities with steadily declining liveability. The patterns are illustrated in the three left panels. The corresponding right panels suggest the relationship of the hardware and software variables to the resulting patterns. The positions of the circles at time t_0 and t_1 indicate their relative strength of influence.

A similar analogy to the hardware/software suggested in this paper was initially elaborated by Nijkamp (2008) using the XXL and XXQ acronyms applied to cities. More recently, the New Urban Agenda (UN, 2016) motivates the declaration on the expected growth of the "hardware" (urban population) but all the policy recommendations are related to the urban "software" (social function, civic engagement, gender equality, resilience, ecosystem services, etc.).

The overall implication of our analysis is that liveability is a complex phenomenon and that it cannot be understood by means of static tools. Like other urban phenomena it is in a constant state of flux. The contribution of this chapter is a conceptual approach to the main drivers behind cities' liveability: the joint development of the city's "hardware" and the city's "software" in a context of an urban system and its dynamics. Using the results from several applications of our endogenous growth

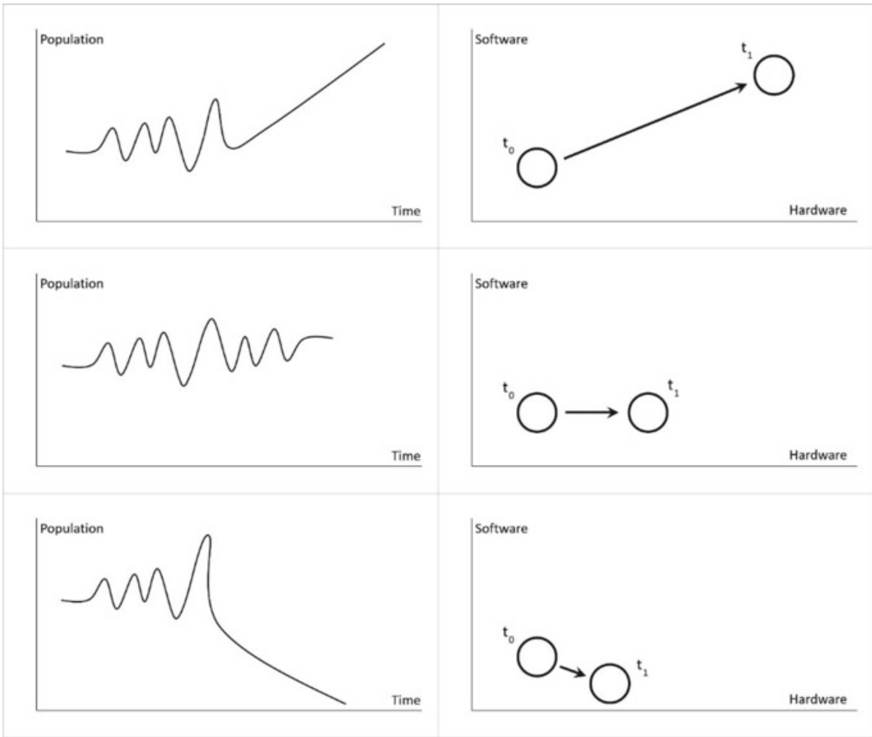

Fig. 6 Conceptual framework using dynamics of the population over time and the hardware/software analogy. Cities with steadily growing liveability (upper charts), cities with fluctuating liveability (middle charts), and cities with steadily declining liveability (lower charts)

model, two simple and comprehensive theoretical principles behind liveable cities are formulated: (1) Liveable cities are characterized by a steady population growth accompanied by a continuous improvement of the overall quality of living of its dwellers. (2) The precondition for a steadily liveable city is a sustainable growth of the city's "software" (products, services, technologies, norms, civic qualities, government, etc.) able to match (at least), the increasing demands of the city's "hardware" (growing population and its related needs).

Although comprehensive concepts like the city's hardware and software can be at first sight too general to allow for a translation into concrete, urban policy-related terms, their strength is precisely their extensiveness. To take a recent and very relevant policy framework as an example, each one of the Sustainable Development Goals (SDG) defined by the "Agenda 2030" (Desa UN, 2016) can be easily classified as "hardware" or "software". SDGs related to the sustainable management of resources, infrastructure, and economic development, when applied to urban areas are part of the city's hardware. While SDGs that deal with education, innovation, and well-being, when applied to cities, belong to the urban software realm. Therefore, the conceptual framework developed in this chapter can serve as theoretical guidelines for urban liveability studies based on hard data, allowing us to discern which components of future indexes are related to the city's hardware and its dynamics. In parallel, which ones are related to the city's software, with its different behavior and characteristics. Understanding the intertwining between both types of variables is the key to the formulation of sound urban policies able to improve the liveability of cities.

To understand liveability and develop empirical and objective measurements, there is a need for dynamic indicators based on fine-grained big data and advanced statistical and machine learning (ML) algorithms such as multiple linear regression, random forest regression, and artificial neural network (ANN). However, these technological tools need always to be guided by a solid theoretical background. The "liveable cities" principles suggested here offer a simple and theoretical framework able to guide future research in this field. From this point of view, it is evident that the study of urban liveability is at its beginning and that there is a long way to go.

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Defining Indicator Systems for Liveable Cities

Rudolf Giffinger and Hans Kramar

1 Introduction

The global process of urbanization has dominated spatial development over the last decades in almost all parts of the world. Urban and metropolitan spaces are increasingly confronted with economic restructuring, growing competition, new urban functions and immigration. These processes have made cities more multifaceted and heterogenous in their economic and social characteristics but also in their socio-spatial patterns of modernization, gentrification, housing and decay. In particular, environmental quality is endangered by increasing emissions, sealed urban areas, densification and the local effects of global climate change. Hence, urban policies especially have to cope with the challenges of sustainable urban development (Sachs, 2015).

Over the last decades, two driving forces have emerged continuously and become crucial for urban development: First, innovations have always been the main driving forces in the evaluation of mankind and have consistently been connected with manifold problems for human societies. In particular, cities have become places of technological and social innovations based on their potential regarding self-organization of urban development (Fagerberg, 2005; Mumford, 1970; Simmie, 2001). For the last decades, Komninos et al. (2018) showed the evolutionary character of technological innovations and identified several innovation circuits having an impact on urban development conditions. Creativity, knowledge production and collective knowledge connected with the use of modern technologies are part of the scientific discourse and have become crucial elements of modern policies (Batty et al., 2012;

R. Giffinger · H. Kramar (✉)
Institute of Spatial Planning, Vienna, Austria
e-mail: hans.kramar@tuwien.ac.at

R. Giffinger
e-mail: rudolf.giffinger@tuwien.ac.at

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Florida, 2002; Giffinger, 2019). These new approaches to investigating technological impacts on urban development were taken up under the "Smart City" label and critically discussed from different perspectives (Nam & Pardo, 2011). Based on technological innovations and the implementation of Smart City concepts, this approach was the starting point for the production of new data and well-structured preparation of existing information making use of new monitoring systems and innovative data retrieval procedures. In this context, different indicator systems were introduced und empirically implemented (Albert & Pandey, 2022; Angelidou, 2014; Batty et al., 2012, 2017; Cocchia, 2014; Giffinger et al., 2010).

Second, climate change has become a dominant issue of public interest and consequently of urban politics over the last decades. The WHO already showed in 2003 that climate change will have an impact on different ecosystems with negative effects on water quality, sufficient precipitate and biodiversity and therefore endanger public health and living quality all over the world in different extent. Due to more recent evidence, the IPCC-report (2021) underpins these ongoing trends driven by the increase of temperature. The specific impacts on urban structures through hurricanes, flooding, heat waves and other natural disasters show the increasing necessity to reduce the impacts of extreme weather events and to adapt to changing conditions. Hence, cities have to tackle different kinds of challenges and need to become places of robustness, adaptation and transformation in order to make them less vulnerable and more resilient. Besides the academic discussion, which tries to establish a comprehensive understanding of resilient development (Davoudi, 2012), policy documents underpin the necessity of resilient urban development (goal 11) in order to reach the Sustainable Development Goals of the UN (UN, 2015). For an adequate assessment and continuous monitoring of resilient development and corresponding policies, a wide range of different types of indicators have been discussed (Figueiredo et al., 2018).

Since indicator systems have become a central part of public discussion on urban policies, the practical implementation brings up a crucial issue: only measurable phenomena can be managed and improved from a systemic perspective. This simple challenge raises a broad variety of tricky questions, which are not always easy to answer: What should be described by indicators? Which types of indicators should be used? How can indicators be defined in order to make them beneficial and trustful? What are specific methodological requirements operationalizing a benchmark approach or a path-orientated approach? These are just some of the challenging questions, which have to be discussed in the context of urban indicator systems in general and especially when dealing with applicable assessment tools for liveable cities. Albert and Pandey (2022, p. 229) conclude in their chapter on "Executing a plan for a community-wide evaluation system", with the basic recommendation that: *"The act of choosing indicators will likely require engagement and collaboration to retrieve and aggregate data, to ensure that the process is viewed as trustworthy, and for many other reasons"*.

Following these recommendations, the paper tries to show and discuss potential ways of defining indicator systems for liveable cities. For that purpose, Sect. 2 addresses the understanding of a liveable city by combining two opposite approaches to urban policies. On the one hand, Smart City policies are directed at the intelligent use of new technologies for sustainable development. On the other hand, resilience-oriented policies address robustness and adaptation in front of potential future impacts. Both approaches are discussed with regard to their most relevant objectives and features and referred to a comprehensive understanding of liveability, which is defined explicitly for the requirements of a suitable assessment tool. The definition provides the general frame for a concept and the beneficial need of a multidimensional indicator system in Sect. 3. In order to elaborate a well-structured approach, four dominant components with corresponding factors enabling a city's liveability are introduced, which are able to reflect and integrate the most important characteristics in the context of smart and resilient urban development. For this purpose, the paper suggests a group of factors with relevant potential dimensions for each of these components, both from the perspective of "smartness" and of "resilience".

Section 4 then gives a brief overview of other indicator systems, to provide important ideas for the content, the type and the implementation of potential indicators as a base for further methodological considerations on an empirical concept of "liveability". Based on these findings two methodologies are proposed for the practical implementation of the assessment: the approach of a static cross-sectional benchmarking of cities is opposed to a path view with time-series consideration of single cities, which allows dynamic monitoring over time, both considering their consequences for the practical elaboration of a proper methodology and their usability for strategic policy advice.

2 Understanding the Concept of "Liveable" Cities

Based on the Brundtland-Report sustainability has become one of the major challenges since the 1980s due to the growing scarceness of resources, increasing emissions and intensifying conflicts between the economy, society and environment (World Commission on Environment and Development, 1987). In particular, cities dominated by urban growth, loss of environmental qualities, economic disparities and social polarization are increasingly challenged to find a more balanced path of development. Since then, the target of becoming a sustainable city has turned out to be the major goal of urban policies until today (Sachs, 2015; UN, 2015). The focus of sustainability is strongly connected with urban development since cities occupy only about 2% of global land, but more than 50% of all people. Even more, 70% of global GDP, 60% of energy consumption and 70% of global greenhouse gases and waste are produced in cities (Habitat III, 2016). Thus, sustainable development is the core agenda of all kinds of cities all over the world, trying to "ensure sustainable and inclusive urban economies by leveraging the agglomeration benefits of well-planned urbanization, including high productivity, competitiveness and innovation […]" (Habitat III, 2016, 2019).

Along with the idea of sustainability, two new global trends gained importance in the prospect of sustainable urban development: Both the concept of “Smart Cities” and the approach of “Urban Resilience” bring new aspects into the scientific and policy discussion. Therefore, the following section tries to introduce the main ideas of these two concepts and to bring them together in a comprehensive understanding of “liveability”.

The basic approach, the goals and the terminology of the “Smart City” concept are strongly discussed in literature. Comparing the intents of different definitions Cocchia (2014) emphasizes that innovation and technology are playing a crucial role in order to improve urban quality of living and concludes that definitions usually depend on the specific academic or societal background (e.g., research, economy, administration, politics). Hence, we assume along with Fagerberg (2005) that the importance of the “Smart City” concept lies in the introduction of new technologies into the urban fabric. This approach is not totally new but in particular, the progress of information and communication technology (ICT) was responsible for focusing on specific technical qualities in different relevant fields of urban development. Based on different understandings and scientific perspectives, the label “Smart City” has increasingly dominated the theoretical and empirical discussion of urban policies over the last years (Angelidou, 2014; Nam & Pardo, 2011).

Innovation can be treated as a stochastic process, which typically takes place in urban areas. Cities have always been a place of progress, both from a cultural, technological and societal perspective (Mumford, 1970; Simmie, 2001). Obviously, their structural and organizational assets seem to provide appropriate conditions for the emergence of innovations and for meeting challenges like competitiveness, socioeconomic restructuring and growth (Lambooy, 2002; Nelson & Winter, 1977). More than ever before, cities offer adequate contexts for technological, social and cultural innovation as they provide a purposive interplay between economy, science and administration, which is described in the “triple helix” (Leydesdorf & Deakin, 2011). Hence, the progress in ICT (in particular the big step to web 2.0) supported the ideas of the “Smart City”-concept, which were built on new technical facilities and their three main characteristics (Bers, 2016; Schaffers et al., 2013):

- collecting information and providing real-time-evidence in recent urban situations
- integrating information from different sources and computing (big) data in descriptive, predictive (optimization of systems) or prescriptive way (interdependencies of systems)
- communicating evidence for decision finding.

Finally, Komninos et al. emphasize the interrelations of innovation cycles and the evolutionary aspect of urban technologies (2018). In general, these new types of information enable two forms of usage. Batty et al. (2017) underpin “There is thus a major distinction between digital technologies being used for the short-term routine management of cities and those for longer-term strategic planning, and this difference is reflected in much of the data, information and knowledge that pertains to the functions that smart city technologies are able to inform” (p. 340).

From an urban policy point of view, however, the definition of indicators needs to consider especially those data (sources), which mainly describe smart urban development but may help to assess the "liveability" of cities in a satisfying way. In accordance with Caragliu's definition (Caragliu et al., 2011), which says that a Smart City is characterized by its ability to use new technologies for strengthening sustainable urban development and by thoughtful management and use of resources, we understand cities as the outcome of a social-technical system. In this understanding, the "Smart City"-approach should consider the implementation of specific technologies in different urban domains, where they are predominantly needed. Such technologies are assumed to provide two positive impacts on liveability: On the one hand, real-time-regulations improve the efficiency of infrastructure systems in terms of energy use or capacities. On the other hand, smart organization of system supply increases the quality and acceptance of provided infrastructure facilities. From that point of view, it is not only the efficiency of infrastructure endowments but also its highly individual and social acceptance, which should be considered in a comprehensive indicator system.

The second approach we refer to is the concept of resilience or "Resilient City", which we introduce as an essential perspective and a relevant precondition for a comprehensive understanding of liveability. Based on the extensive work of the IPCC, which provides detailed evidence on the impacts of climate change, the scientific and political discussion on this challenging issue has increasingly gained importance over the last two decades. Several Reports have convincingly proved that human activities are a decisive driver of emissions and therefore have a detectable impact on climate change (IPCC, 2008, 2014, 2021; NOAA, 2021). Since the late nineteenth-century average temperature has risen more than 1 degree Celsius until 2020 and there is no doubt that this trend will continue dramatically in the near future: Despite the COP 21 agreement of Paris in 2015 and the adoption of the new Sustainable Development Goals ("SDG") in 2016 (which also include the goal of "sustainable, smart and resilient cities") a recent report (IPCC, 2021) emphasizes that previous policies have not succeeded in slowing down or even stopping temperature so far. The IPCC-AR6 report underpins this dramatic evidence in the following words: "*With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels*" (IPCC, 2021, p. 2) In any case, the results of this report leave no doubt that the impacts of climate change will inevitably become stronger with an increasing frequency of heavy natural disasters.

Based on Holling's work (1973) on ecological resilience, the concept of "resilient development" was developed from a systemic point of view and introduced in the scientific discussion of contemporary urbanism (Davoudi, 2012). Recently, the concept of resilient development has strongly focused on two different issues: vulnerability and adaptability. The mitigation of vulnerability and the strengthening of adaptability are both assumed to change the recent path of development due to circular and cumulative interdependencies: The "disaster cycle" demonstrates that vulnerability is negatively interlinked with its capacities for adaptation and vice versa (Galderisi et al., 2010, p. 52). In this systemic view, resilience is understood as a process, which connects the impact and the reaction at a certain moment with the ability to recover and to be prepared for future incidents. This disaster cycle—generally called the adaptive cycle—distinguishes four different phases, in which a system tries to bounce back after an external (often unknown) impact.

From that perspective, the actual impact of climate change depends on the vulnerability of a place or infrastructure system and is therefore determined by relevant conditions and characteristics as robustness, exposure and sensibility. Therefore, local capacities of emergency assistance and prevention are as important for collaborative interventions as the experience and robustness of physical and social systems. Capacities for response and recovery from damage determine the adaptability of a threatened system, which is challenged by external impacts.

Innovative power and learning processes in such situations can actually determine the transformability of a system. Characteristics such as flexibility, redundancy in networks, efficiency, diversity and rapidity have become crucial for the preparedness of a city to cope with a further impact. Evidently, the implementation of the adaptive cycle goes beyond an isolated technical, ecological or evolutionary understanding of systems (Davoudi, 2012). If we understand cities as a spatially concentrated interplay of several systems, a broad social-ecological understanding with a strong focus on people, communities, economies, societies or cultures, which interact across spatial and temporal scales, is needed (Folke, 2016). This understanding is mostly reflected in the definition of Meerow et al. (2016), who say that "… *resilience refers to the ability of an urban [and regional] system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity*" (Galderisi et al., 2010). Hence, the realization of relevant activities in the four phases of the adaptive cycle can be supposed to have a strong impact on the liveability of a city.

Combining the main attributes of the two approaches and referring them to the requirements for empirical implementation, liveability can be defined with regard to the policy concept of a "Smart City" under consideration of the ideas of "Resilience" in the following way: *A liveable city pursues the goal of meeting all relevant challenges with the active involvement of creative, self-aware and participating actors (e.g. residents, businesses, employees). In that way it aims at creating initiatives and realizing projects in a smart and resilient way in order to steer urban development towards sustainability.*

This understanding requires a broad scientific discussion, which is directed at dismantling the most relevant elements of urban liveability. From that point of view, the next chapter tries to shed a light on the most relevant components and factors of sustainable urban development, which are the essence of smart and resilient policies in liveable cities.

3 Components and Factors of "Liveability"

Cities are part of a constant urbanization process on the global level. They are challenged by complex socio-economic, environmental and technological changes (e.g., migration, climate change, technological progress), which have become the main driving factors of urban development. These self-organizing systems have learned to cope with their problems, which are usually embedded in their features, attributes and characteristics and can therefore be defined by economic, socio-cultural and environmental conditions (Camagni, 2009). In this approach, the so-called "territorial capital" is characterized by local resources and territorial factors as tangible and intangible assets, which can either be natural, social or economic features or outcomes of specific policies, which promote complex, multicausal and mutually interlinked processes of transformation.

Over the last decades, the theoretical discussion of urban transformation has started to deal with changing environmental conditions and the emergence of new technologies. According to Olsson, et al. (2004) transformation theory tries to answer the question of how (and to what degree) urban development has shifted to different or new pathways. It is regarded as a process of change, which includes external conditions and internal elements of a system at the same time. In this approach, three distinct phases are distinguished: (1) preparing for change, (2) navigating transition and (3) building resilience to the new trajectory of development. The challenge to steer and to manage urban development effectively requires target-oriented and evidence-based policies, which refer to the robustness, adaptability and transformability of the urban system. These conditions directly influence local resources, capacities and possibilities for action and therefore determine resistance, recovery, response and preparedness of cities against external influences and threats.

Based on these considerations, a purposive concept of liveability indicators on liveability has to meet one main requirement: Sustainable development needs a social-technical understanding of policies (based on the idea of a "Smart City") on the one hand and a social-ecological understanding (based on the concept of "Resilience") on the other, an adequate indicator system has to combine aspects, characteristics and factors from both approaches in a comprehensive and multi-dimensional way. Therefore, in the next step, we will suggest and discuss relevant components of smart and resilient development which then will be described in different dimensions.

Referring the "smart" approach to liveability, the development of cities is determined by a technological, environmental, socio-economic and governing component. Smartness-related policies should foster these 4 components:

- specific mitigation of emissions and corresponding improvements of environmental conditions and living quality.
- adequate improvement of economic and social conditions in terms of economic performance and restructuring, employment as well as through integrating spatial and social allocation.
- new technologies and innovations for the modernization, adaption and expansion of technical infrastructure systems (e.g., transportation networks, power

grids, telecommunication networks) and for the promotion of energy transition in different fields (e. g. transportation, heating, industry, agriculture).
- adequate modernization of governance towards inclusive and transparent public administration and communication (e.g., easily accessible digital administrative procedures, monitoring of planning projects, social media channels).

Hence, from the "Smart city"-perspective the four components should refer to the following list of potential factors and dimensions (see Table 1), which can be implemented by appropriate indicators:

Table 1 Factors and dimensions of smart urban development

Socio-economic component	Environmental component	Technological component	Governing component
Economic performance and image Economic performance, employment, headquarters, knowledge-intensive sectors and branches	**Environmental conditions** Densities, housing and (re-) construction, recreation areas, green corridors	**Transport infrastructure** Mobility system, road and rail networks, public transport, e-mobility, transport of goods, accessibility	**Institutional conditions** Political decision systems, the efficiency of administration and legal system, political stability
Socio-economic structures Qualification, poverty & wealth conditions, life-long learning	**Resource management** Water supply, waste disposal, sewage disposal	**Energy infrastructure** Energy production, power grids, energy storage, energy sources	**Policy implementation** Strategic planning, city marketing, financing and funding, transparency, monitoring and evaluation of goals
Innovation R&D, level of education, technology hubs, entrepreneurship, industry 4.0, creativity	**Emissions** Greenhouse gases, pollutants, noise, health conditions	**ICT infrastructure** Broadband supply, mobile networks, digital twins	**Innovative governance** e-government, urban labs, participation, public networks and co-operations
		Building structure Thermal quality & renovation, state of repair, heating/cooling systems	

According to our understanding, the development of resilient cities is also determined by a technological, environmental, socioeconomic and governing component. Resilience-related policies should therefore push ahead with these 4 components:

- transformation and development of economic, social and built urban systems, infrastructures and monitoring tools to improve their flexibility, robustness and resistance.
- flexible adaptation of ecological systems to be prepared for changing climate, wind, water and soil conditions.
- innovative improvements of physical (infra-)structures, which are prepared to resist external shocks and to recover from negative impacts and have the capacity to adapt to new conditions.
- adequate conditions and initiatives in public administration and governance, which can improve the organizational capacities for adaptation and transformation.

Consequently, the four components should relate to the following list of potential factors and dimensions (see Table 2), which have to be implemented by appropriate indicators:

To sum up, these 4 components of smart and resilient urban development are considering a wide range of factors and dimensions. Considering this illustrative overview, which tries to combine and contrast various aspects of both approaches, some peculiarities become obvious:

- Referring to the adaptive cycle, resilient urban development depends on a city's robustness against external impacts, its adaptive capacity to changing conditions and its transformative power, when climate change provokes unknown future impacts or inevitable new conditions (Galderisi et al., 2012). Hence, the effects of climate change may occur on the urban level both in a continuous or a disruptive way. The interrelations between resistance, recovery and preparedness against future impacts, however, require an evolutionary understanding of socioeconomic, environmental, technological and governing conditions. The same is true for smart urban development: Technological innovations may occur in a disruptive way, but a smart way of decision-finding, implementation and planning needs an evolutionary understanding of the four components from a social-ecological and social-technical perspective (Giffinger, 2019; Komninos et al., 2018).
- In both perspectives some factors or dimensions are similar or equal. Presumably those dimensions can be regarded as key performance dimensions of urban liveability as a combination of "smart" and "resilient" aspects.
- Both perspectives consider urban development in an evolutionary and capitalizing understanding, in which a certain performance is regarded as the outcome of positive or negative accumulation processes. Referring to a city's path of development, a concept of indicators for liveable cities should therefore include dimensions that reflect current performances and dynamic processes.

Table 2 Factors and dimensions of resilient urban development

Socio-economic component	Environmental component	Technological component	Governing component
Robust urban conditions Vulnerable groups, urban qualities, risk assessment, repair and recovery measures	**Robust environmental conditions** Temperature and heat, groundwater, natural disasters, green investments	**Robust technical infrastructure** Capacities, resistance, regional extension, modernization and training, infrastructure investments	**Emergency assistance and prevention** Local and regional capacity building, cooperation and boards, monitoring, emergency and prevention plans
Socio-economic adaptation capacity Circle economy, risk assessment, civil engagement, strategic projects, re-design of urban structures, adaptation research	**Environmental adaptive capacity** Biodiversity, re-design of mobility and green infrastructure, green investments, nature-based solutions	**Technical adaptation capacity** Redundancy in infrastructure systems, R&D, adaptation initiatives and strategies	**Governing adaptation capacity** Regional collaboration, monitoring, budgeting, investment plans and subsidies, awareness building activities
Socio-economic transformation capacity Re-design of social infrastructures, education and awareness, strategic planning, life-long learning, socio-economic transition studies	**Environmental transformation capacity** R&D initiatives, open green innovations, nature-based solutions, environmental transition studies	**Technical transformation capacity** Open innovation strategies, strategic planning and projects, transition studies on flexibility	**Governing transformation capacity** Urban and regional strategic planning, innovative communication approaches, monitoring, funding

Considering these similarities and contradictions, it can be recapitulated that an inclusive understanding of liveability cannot be restricted to one of these two perspectives, but has to relate to both concepts. Therefore, an indicator system, which is able to cover the liveability of a city in a comprehensive way, has to include both smartness- and resilience-related policies, represented in related factors and dimensions and implemented in appropriate, applicable and feasible indicators.

4 Basic Requirements for Indicators on Liveability

As postulated in the last chapter, the factors and dimensions of each component have to be transformed into suitable indicators, which can be implemented by available data. From a policy-related point of view indicators should provide a place-based picture of liveability, referring to the cultural impacts of local urban experiences and traditions, value systems and conditions of development (Friedman 2010). This way of tackling the question is taken up. in the four components of smart and resilient development of cities. Discussing the implementation of such an indicator system Albert and Pandey (2022, p.226) recommend focusing on two specific questions. First, it has to be clarified, how those dimensions can be measured by which type of indicators, and, secondly, there should be a clear answer to the question, of who should decide on the exact selection and definition of indicators. In this chapter, we approach both requirements and try to find proper answers and decisions for our area of concern.

4.1 Required Types of Indicators

The discussion of potential ways to evaluate political measures and strategies has a long tradition in policy-related literature. In a comparative study Figueiredo et al. (2018) distinguish between four main types of indicators, which are directed at the assessment of actual policies:

- input indicators measuring resources spent on policies.
- output indicators measure what policies produce by using certain inputs.
- outcome or result indicators measuring what general results are achieved.
- process indicators measuring if and how actions have taken place.

Since our discussion of urban policies is related to the concepts of smart and resilient development, we will concentrate on two of these four types: first, we refer to the so-called "outcome or result indicators", which describe dimensions of respective factors in terms of performance, quality or acceptance based on revealed behaviour or observed perception. Secondly, we address "process indicators", which reflect projects, investments, collaborative initiatives or policy efforts within certain time periods. Using these two types, we try to follow the idea that smartness and resilience cannot be understood as a final goal but as a continuous and accumulative process, which is directed at meeting the challenges of transformation (Olsen et al., 2004) induced by new technologies and planning approaches (Giffinger, 2019; Komninos et al., 2018). In that way, we try to answer the following questions:

- Which types of indicators are required for the empirical description of urban liveability with a special focus on smart and resilient development?
- Which kinds of information and data sources are needed?

Trying to answer these two basic questions we refer to different existing indicator systems on smart, resilient and liveable city issues. Connecting our idea of smartness with Caragliu's definition (Caragliu et al., 2011), indicators should describe the actual performance of cities in particular. Therefore, in the context of liveability, urban smartness has to be related to socio-economic, environmental, technological and governing aspects to define specific groups of factors with corresponding dimensions.

The indicators should be designed in a way that they provide place-based evidence on urban performance and assets in accordance with Friedman's expertise (2010) using two different approaches of measuring (Giffinger et al., 2021): On the one hand, they describe the endowment of a city regarding the size, extension and quality of technical and social infrastructures and their capacities, efficiencies or intensities of service. On the other hand, the indicators should reflect the citizens' acceptance and use of infrastructure equipment, facilities and establishments offered, which is often the more challenging task. Nevertheless, the ESC-approach (2007) suggests two different forms of operationalization. The actual utilization can either be described by the registration of revealed preferences (e.g. numbers of visitors or customers) or by explicit assessment of perception and experiences (e.g. satisfaction or contentment of the citizens). For instance, the ESC-approach of 2015 described some aspects of living, mobility or governance conditions on the basis of a representative survey of the European Commission ("Eurobarometer"), which is implemented, evaluated and published for cities with more than one hundred thousand inhabitants. In addition, process indicators should express relevant governing efforts supporting smart and innovative development. Again, such indicators can either be derived from realized initiatives and projects or from structured queries of individual experiences and opinions in random surveys, which allow a more general assessment of subjective perception. Hence, five types of indicators are proposed for the operationalization of the mentioned factors and for the implementation of indicators describing smart development. Such indicators will measure:

- characteristics of infrastructure endowment and its performance through object-related observation of distinct characteristics (type "s1").
- characteristics of endowment expressed by the citizens' acceptance through counting of observed and revealed behaviour (type "s2").
- characteristics of endowment expressed by the citizens' acceptance through assessments based on individual perception and experience (type "s3").
- characteristics of governance through description of relevant initiatives and projects, innovations and corresponding investments (type "s4").
- characteristics of governance through assessment of strategic documents, smart projects and initiatives by stakeholders or citizens (type "s5").

According to our understanding of resilience and to Meerow's definition (Meerow et al., 2011), the indicators should describe the ability of cities to improve their resistance, to start recovery processes and to build up capacities for adaptation and transformation. All these characteristics are major assets of a city's resilience against external impacts and therefore describe the local conditions to meet the challenges of climate change in an effective and sustainable way. Consequently, this description has to provide a comprehensive and holistic picture of all relevant local circumstances, which not only includes recent performances but also future potentials for finding adaptive and transformative paths towards sustainable development. In this context, indicators have to provide place-based evidence on urban conditions, which determine the robustness and adaptive-transformative capacities of a city.

Correspondingly, the comprehensive discussion of Figueiredo et al. (2018) underpins that outcome indicators only describe one part of resilient urban development and thus need to be enhanced by process indicators providing a path-specific picture of smartness- and resilience-related activities.

Since climate change is already taking place nowadays and will presumably affect urban liveability with impacts, which can hardly be forecasted so far, two different aspects have to be considered in the definition of indicators: on the one hand indicators should consider existing experiences regarding the three phases of resilient development, on the other hand, they should also refer to their preparedness for future influences and potential impacts, which are recently unknown or beyond clear predictability. Due to the high uncertainty of future impacts of climate change, the ability of cities to meet new challenges and external threats is strongly determined by the robustness, adaptability and transformability of existing economic, social, technical and institutional systems. If a city already has made experience with certain impacts of climate change, robustness in terms of resistance and recovery are presumably easy to describe by different factors and dimensions of the four endowment components.

Due to the indistinct characteristics of unknown impacts, process indicators concerning the adaptability and transformability of urban systems have gained importance. Referring to local awareness, flexibility, openness and innovation, they should give a clear picture of all activities, which are directed at strengthening resilient development in the four components. For instance, activities improving robustness and resistance could be assessed by the costs, which result from the improvement of emergency assistance, from the enhancement of recovery and prevention or from the development of new monitoring systems and risk assessment tools. Activities related to adaptation and transformation have to represent local capacities and endowments and should therefore be described by indicators, which are related to projects improving climate awareness, developing social infrastructures or exploring adaptability, flexibility and transformability to new conditions. In particular, governance issues can be recorded by actual costs of related projects and adequate planning activities. Again, indicators based on representative surveys on the local or regional level are necessary to give an insight on perceptions, preferences and experiences of stakeholders and citizens.

Based on these requirements and assumptions, we propose five types of indicators for the operationalization of the mentioned factors and the implementation of indicators on resilient development. These indicators will measure:

- endowment-related characteristics and performances of robust and redundant infrastructures and adaptive and transformative capacities on the empirical base of object-related observations (type “r1”).
- acceptance of robust and redundant infrastructures and adaptive and transformative capacities on the empirical base of observed/revealed behaviour (type “r2”).

- qualities of robust and redundant infrastructures, innovative and flexible adaptive and transformative capacities on the empirical base of individual perception and experience (type “r3”).
- performance of governance with regard to robustness and preparedness on the empirical base of adaptive and transformative projects, costs or budgets (type “r4”).
- acceptance of governance with regard to technical and collaborative activities on the empirical base of perception and knowledge of urban stakeholders and citizens (type “r5”).

Combining these two sets of indicators offers the opportunity to assess a city’s liveability in a comprehensive and multi-dimensional way on the empirical base of manifold factors and dimensions in four different components, which refer to two complementary approaches of policy. In that way, the confrontation and fusion of the diverging concepts of smartness and resilience can be seen as an ambitious attempt to provide a comprehensive perspective and a broader understanding of urban liveability. At the same time, the combination of two different types of indicators gives the chance to cover not only outcomes and results of policies, but also to reflect the nature and the course of political and societal processes (see Fig. 1).

These types of indicators need different data sources ensuring valid and reliable information. Predominantly, indicators of type s1 and s2 as well as r1 and r2 are based on statistical sources on the local level. If endowment factors (including the description of performance) are related to a larger urban region, data must be provided on the regional level. For instance, infrastructure systems (such as transport or energy networks) or risk assessment of floods should be assessed not only for the core city but need to consider their main characteristics and conditions also for the surrounding region. Indicators of type s3 and r3 describe relevant endowments and infrastructures in a clearly place-based understanding, as they are based on individual perceptions and experiences of citizens and stakeholders. Therefore, the assessment of corresponding indicators needs representative surveys of relevant urban actors, which are mainly concentrated in the core city but can also be located

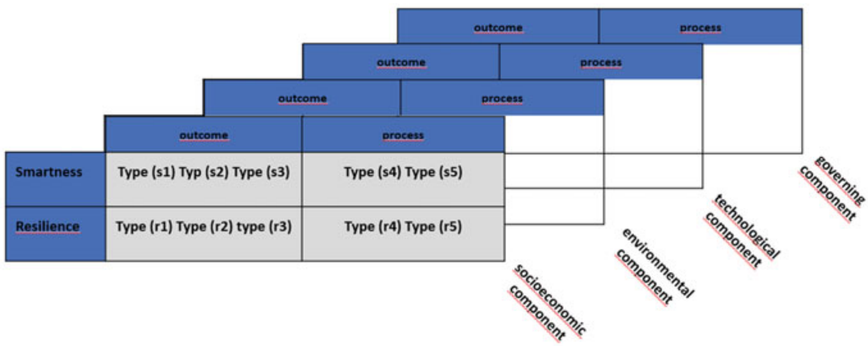

Fig. 1 Types of indicators for liveable cities

in the urban fringe. For instance, the ESC approach (Giffinger & Kramar, 2021) makes use of indicators, which are based on specific surveys on public perception ("Eurobarometer"), executed, evaluated and published by Eurostat.

Type s4 and r4 indicators characterize the characteristics and performances of governance activities related to initiatives, projects and investments, which promote technological innovations or support robustness and preparedness of administrative and institutional systems in front of new challenges. Presumably, such indicators are less defined in quantitative values but more in qualitative descriptions. Type s5 and r5 indicators should express place-based characteristics of strategic documents, smart projects and initiatives with a strong focus on the acceptance of technical and collaborative activities by stakeholders or citizens. The assessment of suitable data should therefore either be based on representative surveys, well-defined stakeholder workshops or a Delphi survey of a large group of relevant urban actors.

4.2 Selection of Indicators

As argued before, an accurate characterization of urban liveability asks for simultaneous consideration of significant criteria of both smart and resilient development in four relevant components. For that purpose, however, it is necessary to develop, define and to implement indicators, which are oriented not only to outcome and performance but also to processes and perception and are therefore able to describe liveability in a multi-dimensional way. In this context, two major questions have to be tackled and (at least partly) answered: Which indicators will finally show the urban profile most accurately? And: Who should contribute to the selection and definition of the most relevant indicators?

As Albert and Pandey (2022) show, a wide range of different sustainability approaches using specific metrics already exists. According to our definition of a liveable city and acknowledging the permanent challenges of pursuing the goals of smart and resilient development, we concentrate our efforts on "outcome" and "process" indicators to support an adequate, goal-oriented and effective policy discussion. Under these premises, two options of an adequate indicator set should be discussed with respect to their usability, practicability and applicability from a methodological point of view. Option A follows a comparative benchmarking approach, which tries to contrast relevant conditions, assets and structures of different cities to a defined point of time. This approach needs the definition of predominantly quantitative indicators, which can be compared across a defined group of cities. In contrast to that, option B considers a path-oriented monitoring approach, which mainly refers to urban dynamics over time and therefore provides evidence on specific transformation processes within a certain city. Since this path of analysis makes it easier to make use of more specific indicators (including qualitative indicators), it can address individual problems, opportunities and threats of a city in a more comprehensive way.

To go into more detail, option A predominantly needs the use of quantitative data sources, which provide reliable and valid information for the operationalization of comparative indicators, which allow a transparent and comprehensible benchmarking of cities. It is quite obvious that the heterogeneity of economic, social, institutional and spatial structures is a big challenge for defining comparable indicators for all cities. Furthermore, the comparability, completeness and integrity of available data is endangered by diverging statistical collection methods in different countries. Nevertheless, due to ambitious research activities in the field of sustainability, a reasonable range of indicators is already available since the 1990s (Gerlein, 2004). Motivated by the definition of Sustainable Development Goals (SDGs) in 2016, institutions like EUROSTAT already offer corresponding indicators in an interactive way (EUROSTAT, 2021), which allows to define, to assess and to compare performance indicators for different cities all over Europe for a more holistic picture of sustainable development. In a similar way, the Global City Indicator Facility GCIF provides a well-established standard set of indicators, which can easily be used for the assessment of urban politics. As a result of the collaboration of UN-Habitat, World Bank OECD and other international institutions, this initiative aims at the definition of an enhanced ISO norm "ISO 37120/2018" (ISO, 2018). The relevance of this approach lies in the idea to integrate the idea of Smart Cities and the concepts of sustainability and resilience as specified in ISO 37122 (ISO, 2019a) and ISO 37123 (ISO, 2019b), which refer to "Sustainable cities and communities" and try to define "indicators for resilient cities" (Naden, 2018).

Referring to the idea of smart urban development, the European Smart City approach, issued first in 2007, has the objective to elaborate specific profiles of comparable European cities. Considering and assessing urban performances in six different domains (economy, mobility, living, environment, people and governance) by means of quantitative data, it provides a practical assessment tool that allows explicit benchmarking of European cities in a transparent and interactive way (Giffinger & Kramar, 2021) The approach is based on a large number of indicators, which have constantly been adapted and updated to changing requirements and different city samples in four versions of release (ESC-1, 2007; ESC-2, 2013; ESC-3, 2014; ESC-4, 2015). Generally speaking, the advantages of this approach mainly refer to the hands-on character of the operationalization in practice: the assessment tool is able to provide a multi-dimensional and holistic overview of strengths and weaknesses of cities in a transparent way. The comparison of data in the six domains considered gives a clear picture of urban performances on different levels of detail, which is the empirical base for a traceable benchmarking of selected cities. In spite of these evident assets, the limits and disadvantages of this approach cannot be denied: the quantitative assessment of smart urban performance is definitely determined by the quality and reliability of available data sources. An increasing number of cities and a growing complexity of indicators is mostly connected with incomplete and insufficient datasets, the use of highly generalized proxies or the switch to higher spatial aggregation levels (e.g. the exploitation of national instead of regional or local data). These procedures are actually necessary to be able to provide an empirical base for a comparative benchmarking of cities, however, they definitely limit the accuracy, significance and explanatory power of the results. Furthermore, most of the indicators used refer to values that measure the outcome and not the process of smart urban development and therefore ignore important details of economic, social, environmental and spatial dynamics.

An interesting approach, which explicitly makes use of the term "liveabiliy" and tries to assess urban performance in all relevant dimensions of the concept, is the "Global Liveability Index", which is regularly issued by the Economist Intelligence Unit. The most recent release of results (Economist Intelligence Unit, 2021) provides evidence of how cities have been affected by the Covid-19 pandemic. This study refers to "stability", "healthcare", "culture & environment", "education" and "Infrastructure", which are scored, evaluated and compared for several cities and metropolises in different continents. The individual ratings of cities in these five categories are done on the empirical base of more than 30 qualitative and quantitative factors, which are combined by means of a simple aggregation procedure. Each of these categories is given a certain weight, which is based on external assessment and strongly determines the total scores and the final index. These assessments are based on the individual judgments of a group of stakeholders, which are referred to as "expert analysts" and "city contributors" (p. 6). Each factor is classified by a qualitative criterium. The underlying quantitative indicators are calculated as ratings based on the relative performance of a number of external data points, which are not explicitly indicated in the report. Hence, this study shows how the assessment of different activities and achievements during the process of transformation can be operationalized, but results remain rather sensitive to the weighting assumptions.

Based on our understanding of liveability we can put these three approaches in a nutshell:

- The "Global City Indicator Facility" (GCIF) elaborated by a group of experts from international institutions enables city benchmarking in some core aspects of smart and resilient development by the explicit use of some relevant indicators. Its main objective is to elaborate a standardized model applicable to all kinds of cities, but it does not explicitly consider liveability in a place-based and path-oriented understanding.
- The holistic picture of the "European Smart City" (ESC)-approach provides evidence-based city profiles, which are qualified for comparative benchmarking. The ESC approach was practically elaborated by urban and regional scientists in collaboration with architects, planners and urban stakeholders (e.g. investment managers and local authorities), whose ideas were integrated into the evaluation method and therefore helped to improve the assessment tool (e.g. selection of indicators, provision of data). Still, the assumption that all factors do have the same weight, remains a limiting aspect of the approach. A critical evaluation of actual urban performances remains an object of further analysis and stakeholders' discussions. Although it provides an applicable and effective instrument for smart outcome-related evidence of cities, it largely ignores the sequence of economic, social, environmental and spatial processes, which would be necessary to deal with urban development from a path perspective.

- The “Global Liveability Index” regularly issued by the Economist Intelligence Unit shows, how the assessment of urban liveability can be operationalized by the quantitative evaluation of a broad range of activities, performances and achievements of a city. The ambitious approach is operationalized through “expert analysts” and “city contributors” of involved cities. However, results remain rather sensitive to the weighting assumption and there is a lack of transparency with regard to the selection of indicators and the specification of data sources. Although the approach tries to refer to the main categories of liveability, it does not include a comprehensive understanding of resilience or smartness in the discussion of urban development and policies.

On the other hand, path-oriented monitoring approaches (as suggested in “option B”) concentrate on the evaluation of the specific situation of a selected city to provide a more detailed description of the actual performance and dynamics there. Consequently, assessment tools dedicated to path analysis require a wide range of both qualitative and quantitative indicators, which allow the presentation and explanation of urban development over a defined period of time. Such indicators need to describe urban liveability not only in terms of outcome but also with regard to dynamic processes in a place-based understanding. A reasonable number of relevant quantitative data, which can be used for the construction of expressive indicators, are regularly delivered by public institutions (e.g. Eurostat or national statistical offices) or by specific data sources produced by the use of smart technologies. According to Batty et al. (2017) both smart measuring and big data production can be useful for the elaboration of significant indicators related to smart and resilient trends. Nevertheless, such a concept should go far beyond smart measuring and monitoring, because a place-based understanding certainly requires specific information, which reflects the acceptance and the actual utilization of infrastructure facilities in particular. Therefore, the preferences of customers, stakeholders or expert groups have to be covered to get a comprehensive picture of the real liveability of a city. The following examples suggest some more specific requirements for the implementation of a path-orientated indicator concept:

As a member of the international acting ARUP enterprise, Bale (2016) elaborates a resilience framework considering the components “Health & Well Being”, “Economy & Society”, “Infrastructure & Environment” and “Leadership & Strategy”, and provides some quantitative and qualitative information for selected metropolises. The qualitative scoring in the form of a Likert-type scale serves as a good example for possible operationalization of indicators of type s3, s4 and s5 as well as sr3, r4 and r5. Quantitative data regarding general aspects of urban performance are taken from international statistical sources. In that way, the study clearly underpins the challenging implications of multi-dimensional city evaluation methods: it becomes obvious that the quality, reliability and significance of urban benchmarking is mainly determined by a well-defined, exhaustive and consistent set of qualitative and quantitative indicators. Experiences from the development of such comparative studies clearly indicate that the definition, selection and operationalization of relevant indicators ask for an intensive collaboration of international and national partners, including administrative bodies, research institutions and local stakeholders.

Figueiredo et al. (2018) emphasize the complexity of resilience, which can be considered as a multicausal, interlinked and place-based process with adaptive cycles and feedback loops. Based on this understanding of resilience, the authors recommend applying quantitative and qualitative indicators with relation to recent challenges and policy objectives. They conclude that it needs proofed scientific evidence on risk assessment with regard to the most urgent challenges, can then be transformed into applicable recommendations for the selection and operationalization of indicators. Thereby, a city's resilience and the related challenges can be described, implemented and evaluated in a place-based way.

Based on our understanding of liveability we can summarize the main aspects of these two approaches in the following way:

- The study of urban resilience by Bale (2016) reflects the social-ecological dimension of urban resilience and uses a profound and well-argued approach, which uses a common understanding of cross-sectional collaboration, which goes beyond the individual situation of a single city. Based on the high competence of this group of scientists and planners, the approach provides valuable evidence on the practical strengths and weaknesses of resilient development, but it neglects a more specific consideration of the social-technical perspective, which is needed for a comprehensive concept of urban liveability.
- In a similar way, Figueiredo et al. (2018)—as an interdisciplinary group—follow a clear social-ecological understanding of resilience. The study provides a well-elaborated set of indicators, which tries to cover place-based and process-oriented aspects of development. Although they acknowledge the importance of surveying and monitoring energy-efficient development in cities, a more precise social-technical understanding and consideration of smart urban development would clearly complement and improve their approach.

5 Discussion and Conclusion: Recommendations for a Comprehensive Indicator Concept of Urban Liveability

Although the speed of worldwide urbanization and the impacts of major global trends increasingly influence urban development, the exact impacts of socio-economic transformation, technological progress or climate change have become more difficult to be assessed or even forecasted. There are good arguments for the assumption that the uncertainty of external influences, challenges and threats will constantly increase in a globalized world. From a systemic point of view, the combination of simultaneous and interconnected trends may produce cumulative effects and feedback loops, which can hardly be predicted by traditional concepts or modelled by existing methods or tools. In this context, it is pretty evident that the complex interaction of different trends seriously threatens the liveability of cities and asks for comprehensive and holistic approaches, which are able to cope with the challenges of urban transformation in planning processes. Over the last decades, the concepts of resilient and smart development have increasingly been considered in the scientific discussion of urban trends, however, without being connected or integrated in a transdisciplinary way. In these separated initiatives, many indicator systems have been elaborated in a beneficial ambition, predominantly following the vision of either sustainability or smartness in urban development without combining them or referring them to each other in a satisfying manner. There are different approaches, which show a more or less well-introduced understanding of smartness or resilience separately. Even the ISO-standardization approach initiated by stakeholders of important international institutions refers to both views without the ambition to integrate them.

In our contribution we discussed both approaches and tried to compare, to oppose and to contrast the concepts and the main characteristics of smart and resilient development. We conclude that a social-technical and social-ecological understanding of urban development needs to fulfill some basic requirements for the definition, implementation and operationalization of a comprehensive indicator set on urban liveability:

- A clear definition of liveability, which includes the main elements, dimensions and criteria of the term is necessary to guarantee a common understanding of all involved partners and to avoid discrepancies and contradictions in the practical assessment.
- The operationalization of such an indicator concept should consider quantitative indicators describing the structures, endowments, outputs and results as basic conditions for future urban development.
- The assessment of urban liveability should also refer to measures, which are able to describe the course and progress of socio-economic processes within a city in a multi-dimensional way.
- The whole evaluation method should be based on a place-based and process-orientated understanding of urban development, which can be expressed by appropriate indices for measurable trends.
- The assessment should not be restricted to the quantity of available facilities, but also include the individual perception and acceptance of infrastructure services and governance, which can be operationalized by exemplary interviews or representative surveys of relevant stakeholders and citizens.
- Since liveability is situated at the intersection of smart and resilient development, all factors and dimensions touching both spheres can be identified as core indicators of urban liveability.

We finally discussed the differences between a static benchmarking of different cities against a dynamic path-oriented evaluation over a longer period of time. Evidently, these opposite and complementary approaches cannot be consulted to answer the same questions or fulfill the same purpose. Therefore, the elaboration of a significant and effective set of indicators has to consider some basic requirements:

- According to the practical application of the assessment tool, there has to be a clear distinction between a comparative benchmarking of different cities and the dynamic monitoring of a single location.
- The main goals of a specific and problem-oriented indicator concept have to be defined by an interdisciplinary team of scientists and stakeholders, who are responsible for the selection, definition and operationalization of indicators.
- The development of the assessment tool needs active participation and involvement of local actors (e.g. citizens, customers, stakeholders, representatives) and institutions (e.g. administration, public bodies) at an early stage.
- The results of the evaluation should be measurable both in terms of observed performances and with regard to revealed preferences, perceptions and experiences.
- The design of an applicable indicator concept should be oriented towards its practical usability in real decision-making processes. In order to simplify and illustrate complex issues, it should provide transparent and traceable results, which can easily be communicated to all groups of actors.

There is no doubt that both options are generally able to deliver results that meet the mentioned requirements to a satisfying degree. In spite of their different characteristics, however, they are qualified for different applications in practice: the benchmarking approach especially allows the discussion of strengths and weaknesses with regard to liveability and therefore can well be applied for evaluating the position in the urban system on a larger territorial scale. On the other hand, it may not offer adequate evidence on specific characteristics or dynamics, because the requirements of comparability and general validity of results impede the assessment of specific topics, which are especially relevant for a certain city. Therefore, specific place-dependencies of indicators might impede the comparability of different cities and make the results less valid. Conversely, path-orientated concepts allow to consider individual challenges and to go into more detail, but they need differentiated and place-based information for different points of time. Acknowledging that urban structures and transformation processes are highly specific and can hardly be generalized for all cities, it becomes obvious that benchmarkings always provide a limited, shortened and constricted picture of urban development. These comparitive approaches are able to illuminate selected parts of complex urban systems, but tend to neglect individual problems, challenges or threats of a certain city. Considering the fact that economic, social and environmental processes do not always follow general rules, but are mainly driven by individual and collective decisions of residents, stakeholders and planners, the implementation of specific indicator sets for each city becomes more attractive, even if this approach reduces the comparability and transferability of results.

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Three Conditions for Liveable Cities: Geographical Inclusion, Carbon Neutrality and Transport Innovation

Nicos Komninos, Christina Kakderi, Anestasia Panori, and Yannis Psycharis

1 Introduction

Liveability of cities has been a permanent concern of city scientists and planners characterized by high levels of fuzziness due to multiple and complex components affecting it. These often refer to the quality of the built environment, as well as the socio-economic and natural conditions, and vary considerably across cities (Southworth, 2016). The conditions of liveable cities are related, among others, to the wealth of cities, well-being, resource security, and carbon neutrality (Hunt et al., 2016). Depending on those conditions and factors that govern liveability, measurement indexes have been proposed, such as the *Global Liveable Cities Index* by Giap et al. (2014), the *Urban Liveability Index* proposed by Higgs et al. (2019), and *Global Liveability Index* by the Economist Intelligence Unit (EIU, 2021).

However, it is difficult to find a common understanding of liveability in cities and the concept is rarely explicitly defined. It is usual to consider that liveable cities are safe, socially cohesive, inclusive, environmentally sustainable, with a variety of affordable housing, good public transport, education, and health amenities, open and green spaces, as well as cultural endowments (Higgs et al., 2019). Environmental conditions and climate change are also placed at the centre of discussions about urban liveability. The UNEP guide Good Practices and Useful Tools for liveable

N. Komninos (✉) · C. Kakderi · A. Panori
Aristotle University, Thessaloniki, Greece

C. Kakderi
e-mail: christina@urenio.org

A. Panori
e-mail: apanori@plandevel.auth.gr

Y. Psycharis
Panteion University of Social and Political Sciences, Athens, Greece
e-mail: psycharis@panteion.gr

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cities focuses almost exclusively on environmental aspects and hazards (World Bank, 2007).

Given this ambiguity, we have chosen to focus this paper on three conditions that are present in most discourses of urban liveability. These are related to geographical inclusion and poverty, carbon neutrality and climate change, and urban transport. Each one of these conditions has a specific contribution to urban liveability. For many years, poverty and inclusion have been considered as the most important factors that shape life in cities, determining what people do for a living, their income level, the distribution of wealth, and well-being. Currently, environmental sustainability and climate change have moved at a pre-eminent position in the overall discussion about cities and sustainability due to the catastrophic collapse that risks associated with them may bring. Mobility and transport play also a decisive role in the way cities are structured and operate, and long-standing urban challenges are related to the way people move in cities, the air pollution, and greenhouse gases emissions from mobility.

We intend to examine these three challenges of urban liveability as a complex system with a high level of interdependencies to overcome a fragmented and silo-based perspective and look at how common solutions can be developed addressing these challenges comprehensively. Also, we examine how current digital technologies and new infrastructure in cities, such as novel means for transportation, smart grid and renewable energy systems, and information and communication technologies, can offer new solutions to those long-standing challenges of urban living.

We start with research questions specific to each condition of urban liveability. First, in the field of geographical inclusion and poverty, we focus on the relationship between residential segregation triggered by different life domains, as well as its relationship with income inequality. We use Athens as our case study to investigate how spatial segregation has changed throughout these various life dimensions and see whether some of them are more significant for shaping geographical inclusion in cities. Moreover, we discuss potential ways in which the post-COVID era will affect the geographical inclusion in cities, in terms of life and working conditions.

Second, in the field of carbon neutrality and carbon–neutral cities, we look into Net-Zero Energy Districts (NZED), city districts in which the annual amount of CO_2 emissions released is balanced by emissions removed from the atmosphere. NZEDs constitute a major component in a new generation of "smart-green cities", which deploy both smart city technologies and renewable energy technologies to promote environmental sustainability, cleaner environments, reduce global warming, and the threats from climate change. We work with a model of transition to NZEDs that allows an understanding of the process and factors influencing the transition of city districts to self-sufficient NZEDs.

Third, in the field of mobility, several questions have arisen about the short-term and the long-term transformations created in urban settings following the Covid-19 pandemic. What kind of policies did cities adopt with regard to urban mobility? What was the impact of new mobility rules and behaviours in cities and how permanent is this impact? What is the role of technology in the new landscape of mobility?

However, besides the particular questions we examine, a common research hypothesis crosses the three domains and drives our research. It is related to commonalities in addressing challenges of geographical inclusion, carbon neutrality, and urban mobility in post-Covid cities. We assume that smart technologies, digital platforms, and data management algorithms allow for optimization and innovation of sector-specific technologies that work in each domain. We can find commonalities in the way digital platforms and algorithms drive optimization and innovation and change human and community behaviours in favour of carbon neutrality, efficient mobility, and geographical inclusion.

2 Geographical Inclusion and Urban Liveability

The existence of a socio-spatial dialectic within urban areas indicates a bidirectional effect between cities and people who live in them (Panori et al., 2017). Treating space as a non-neutral component shows that geographical inclusion can be approached as a spatial manifestation of social relations, with spatial distance following social distance (Gotham, 2003). Spatial segregation, resulting through social categorization of space, may include various factors closely related to living conditions, such as social, economic, educational, and health amenities (Panori, 2017). Therefore, when exploring urban liveability, it is essential to consider the geographical dimension of inclusion in cities, expressed in several cases as residential segregation (Tammaru et al., 2021).

Residential segregation encompasses the spatial dimension, as it refers to the uneven distribution of different socio-economic groups in space within an urban area (van Ham et al., 2020). It includes the housing preferences of high-income groups living in urban areas that very often choose to reside in attractive parts of the city, such as regenerated inner-city neighbourhoods or the suburbs, being highly segregated from lower-income households (Pastak, 2021). This affects not only the residential domain but also broader aspects of everyday life, such as schooling, public space, and leisure activities, all of them closely related to liveability (Boterman et al., 2021). Given that cities can be understood as a collection of sites each of which refers to different life domains, residential segregation can be seen as the outcome of their interaction affecting location choices (Bernelius & Vilkama, 2019).

Literature exploring residential segregation worldwide has shown that European cities indicate lower levels of socio-economic segregation when compared to cities in the US (Tammaru et al. 2015). However, disparities between different socio-economic groups seem to have risen in many cases throughout the last decade, leading to a higher spatial concentration of deprivation in cities (van Ham et al., 2021). This shows that there is a close connection between income inequality and residential segregation, which broadly affects living conditions in cities. On the one hand, inequalities rising through residential segregation can be understood as variations in accessibility and experiences of individuals living in different areas that depend on spatial characteristics (Hedman & van Ham, 2012). On the other hand, residential segregation can be perceived as a spatial expression of income inequality as various neighbourhoods are not accessible to persons with lower income due to increased living expenses, whereas at the same time persons with higher income are not willing to reside in areas with low living standards (Costa & Valk, 2021). Literature suggests that high levels of residential segregation may lead to a significant imbalance of urban liveability, making cities more unequal and less effective in their operations (Musterd, 2020).

Using Athens as a case study, this section investigates how three key dimensions of residential segregation, referring to occupation, education, and living conditions domains, have affected the liveability of the city. The analysis covers the metropolitan area of Athens, including 59 municipalities. It was not possible to explore segregation in lower spatial scales, such as neighbourhoods, due to data availability limitations. A map of the area under investigation is given in Fig. 1.

Table 1 presents the main individual dimensions being used for measuring segregation. In the first case, we choose to use occupation as the main variable for measuring residential segregation levels in Athens following the International Standard Classification of Occupations (ISCO) (ILO 2012). We classify individuals into three broad occupation groups: (i) *top-occup*, including managers and professionals (high-skilled white-collar workers); (ii) *bottom-occup*, including elementary occupations, plant and machine operators and assemblers (low-skilled blue-collar workers); and (iii) *middle-occup*, including all the other occupations (van Ham et al., 2021).

Second, we use the highest level of education attained by each person as the main variable for capturing residential segregation based on education, following

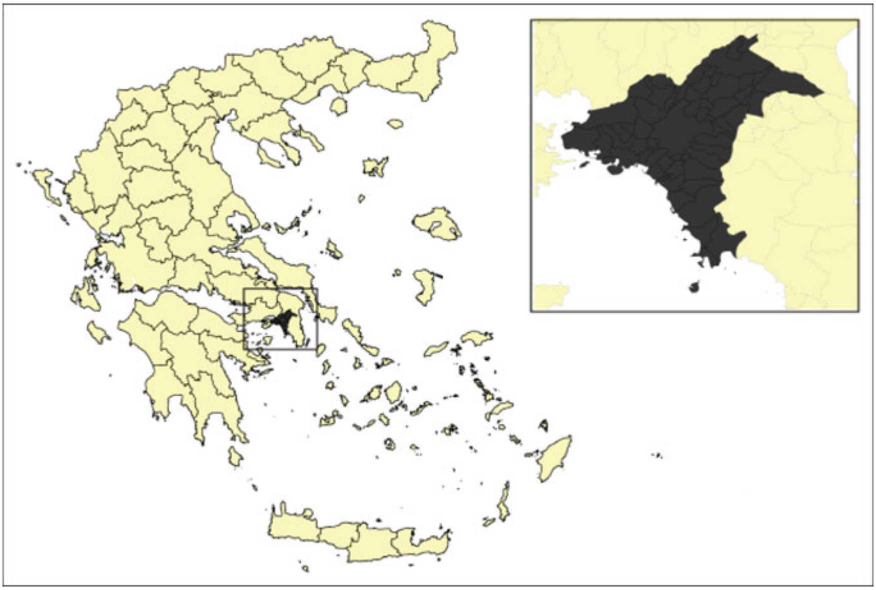

Fig. 1 Map of the metropolitan area of Athens under investigation

Table 1 Main segregation dimensions for calculating dissimilarity indexes for Athens

Residential Segregation Dimensions			
	Occupation	Education	Living conditions
Top	Managers and professionals (high-skilled white-collar workers)	Persons with tertiary education and higher	Persons experiencing not-at-all housing deprivation (0 out of 7)
Middle	All intermediate categories	Persons with secondary education	Persons experiencing medium housing deprivation (1 or 2 out of 7)
Bottom	Elementary occupations, plant and machine operators and assemblers (low-skilled blue-collar workers)	Persons with primary or no education	Persons experiencing increased housing deprivation (3+ out of 7)

the International Standard Classification of Education (ISCED) (UNESCO, 2012). Three groups are created in this case: (i) *top-edu*, including persons with at least tertiary education; (ii) *middle-edu*, including persons with secondary education; and (iii) *bottom-edu*, encompassing all persons that have attained primary education the most.

To measure segregation based on living conditions we have used a set of variables that closely relate to housing and neighbourhood deprivation (Atkinson & Marlier, 2010; Guio et al., 2016). In the first case, household deprivation refers to aspects such as leaking roof, damp walls/floors/foundation, or rot in window frames or floor, lack of bath or shower in dwelling, lack of indoor flushing toilet for the sole use of household, as well as problems with the dwelling for being too dark or not having enough light. In addition to this, we have added a set of variables related to the general neighbourhood conditions, including noise from neighbours or the street, pollution, or other environmental problems and crime, violence or vandalism in the area. All variables have been available through the EUSILC dataset[1] that has been used for the analysis. Based on them we have been able to construct three discrete groups: (i) *top-living* that includes persons living in households with no lack in any of the identified variables; (ii) *middle-living* that refers to persons living in households lacking a maximum 2 out of the 7 identified elements; and (iii) *bottom-living* that refers to persons living in households lacking more than 3 out of the 7 identified elements (Guio et al., 2016).

In terms of empirical analysis, we use the Dissimilarity Index (DI) as our main indicator of residential segregation, following most studies in exploring segregation in Athens. The Dissimilarity Index compares how evenly one population sub-group is spread out geographically compared to another population sub-group and it can be calculated using the following:

[1] https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions

$$DI = \frac{1}{2}\sum_{i=1}^{N}\left|\frac{a_i}{A} - \frac{b_i}{B}\right|$$

where a_i is the population of group A in the i-th area, a municipality in our case; A is the total population of group A in the city of Athens; b_i is the population of group B in the i-th municipality; B is the total population of group B in the city of Athens. The Dissimilarity Index takes values between 0 and 100, indicating the share of a group that needs to relocate towards resulting in a more equal distribution of these groups across space. A value of 0 indicates that there is a common distribution of these two groups across space, whereas 100 shows that the individuals of these groups are located in different municipalities. An increasing (decreasing) trend of the Dissimilarity Index suggests that there is a gradual increase (decrease) in segregation between the groups under investigation.

Figure 2a presents the occupation-related DI evolution throughout the period 2004–2019 for Athens. As we can see, there is an increasing trend in residential segregation for all combinations of DIs, affecting the geographical inclusion of the city. The highest levels of residential segregation based on occupation derive between the top/bottom-occup groups, whereas DIs between middle/bottom-occup groups show much lower values. Second, when approaching residential segregation through education, Fig. 2b shows that there is a diversified pattern between the various groups. Residential segregation between the top/bottom-edu groups presents an increasing trend in all three periods, while this trend is reversed when looking at the DIs describing the relationship between the top/middle and middle/bottom educational groups. This might be caused because persons belonging to the middle-edu group have been effectively integrated in space, both towards areas previously characterized by low or high educational groups, resulting in lower residential segregation levels. Hence, persons with secondary education tend to normalize the geographical distribution of this variable within the city of Athens, boosting inclusion which is considered a liveability factor. Third, Fig. 2c shows that the top/bottom and top/middle DIs related to living conditions indicate increasing evolution patterns. Therefore, we can see that during the period of our analysis, the city of Athens has experienced a gradual rise in residential segregation in terms of living conditions, especially between 2015 and 2019, just after the economic crisis period. On the contrary, the results show that the middle/bottom DIs present a slight decreasing trend in that period, indicating a more efficient geographical distribution of living conditions between those two groups.

We have seen that the spatial outcomes of occupational and educational variations (top/bottom-occup and top/bottom-edu groups) indicate the highest dissimilarity values, compared to spatial variations of living conditions. This suggests that, in the case of Athens, residential segregation underpinning the liveability of the city mostly derives from occupational and educational spatial imbalances. This comes as an outcome of the strong structural changes, such as professionalization, that Athens experienced during the last decades (Maloutas & Botton, 2021; Maloutas & Spyrellis, 2019). Therefore, we can argue that the liveability of cities, which is related to

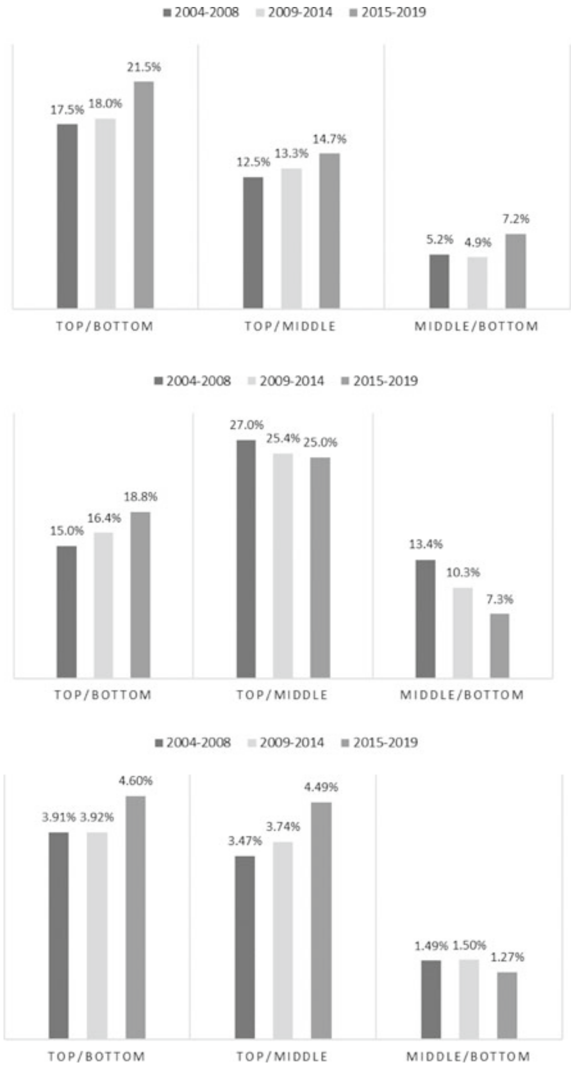

Fig. 2 Evolution of the Dissimilarity Index in the three domains **a** Dissimilarity Index for top/middle/bottom groups in the occupation domain, **b** Dissimilarity Index for top/middle/bottom groups in the education domain, **c** Dissimilarity Index for top/middle/bottom groups in the living conditions domain

geographical inclusion, emerges through structural transformative processes taking place within them.

Disruptive factors affecting the drivers that shape geographical inclusion within a city can be perceived as potential forces that may alter its structural forms affecting liveability and equal access to opportunities. These disruptions may refer to structural changes such as the twin transition, including both digital and green focus elements affecting intra-urban movements and location choices, as well as external shocks, like the recent pandemic crisis.

In the former case, digital transition has considerably accelerated the transformative power of cities, enabling them to leapfrog stages of development by deploying new technologies in their processes (Komninos et al., 2019a; UN-Habitat, 2016). The resulting urban environment is a combination of socio-technological interactions within a city with high complexity and increased digital externalities (Komninos, 2009; Komninos et al., 2021). Thus, digital solutions can be considered as useful tools for confronting societal issues, like poverty alleviation, social inclusion, and geographical distribution of inequality within the urban space, shaping a wide range of new opportunities that arise through a well-planned and participatory urbanization process (Batty, 2019; Komninos, 2014; Panori et al., 2017; Townsend, 2013). In this context, digital tools should mainly be designed to accomplish, or at least enable, critical functions related to data collection, information processing, and communication, towards building strong networks for knowledge sharing within cities (Panori et al., 2021). This is a structural change triggering new forms of externalities within cities that may alter geographical inclusion, and thus, their liveability levels. This is in line with existing literature highlighting causal links between digital tools and urban development (expressed here as urban liveability), that derives through the critical need for information and networks for achieving higher levels of development (Komninos et al., 2019b).

In the latter case, during the last two years, we have experienced significant changes with a strong structural character that have emerged due to the outbreak of the COVID-19 pandemic, covering multiple facets of everyday life and working environments. The post-pandemic world will be different in various ways and major changes are expected in many fields, such as individual and social norms, the use of digital tools for remote working and services, and global mobility (Kakderi et al., 2021). Efforts have been made to assess the impact of COVID-19 on cities and metropolitan regions, indicating the emergence of both short-term and longer-running changes, including transformations of working conditions, changes in city functions, and the creation of new local opportunities for reinvention (Florida et al., 2021; Kakderi et al., 2021).

This has resulted in new approaches that should be considered when exploring the liveable city, also related to the geographical inclusion of cities. In this context, specific attention should be placed on the importance of remote working that will alter existing patterns of residential segregation, as the availability of workers will not be location-focused, but instead, it will be supported by digital tools to bridge geographical distances (Allam & Jones, 2021; Hunter, 2021) Future research on urban liveability should effectively integrate this structural change when exploring the geographical inclusion of cities, as residential segregation dimensions may be largely altered compared to the ones that have been used up until now.

3 Carbon–Neutral City Districts and Quality of the Urban Environment

3.1 Net-Zero Energy Districts

Net-Zero Energy Districts (NZEDs) are an important element in a new generation of smart-green cities moving towards carbon–neutral cities. They are based on smart city systems for energy optimization, use of renewable energy (RE), and nature-based solutions, which combined can zero carbon dioxide emissions. NZEDs are areas, districts, and neighbourhoods of cities where the annual amount of CO_2 removed from the atmosphere is equal to the amount released.

The city is a system of (sub)systems, composed of semi-autonomous systems, such as housing districts, industry, services, and commercial clusters, infrastructure networks, and related activities. Each city subsystem behaves differently towards carbon neutrality, depending on its activities, land uses, energy consumption patterns, and CO_2 emissions. The overall carbon footprint of a city emerges bottom-up from the respective profiles of the systems that compose a city. Therefore, the transition to NZED is a prospect and objective for any urban ecosystem: area-ecosystems (housing, central business districts, port areas, technology campuses or universities), vertical-ecosystems composed of economic activities (processing, food production, education, health, hospitality) and network-ecosystems (transport, energy and other utilities).

The importance of bottom-up cities transition to self-sufficient NZEDs is extremely high because of decentralization and multiplication of initiatives towards carbon–neutral cities. These zero-carbon areas can reduce global warming, contribute to sustainability and cleaner environments, and lower the risks and disasters associated with severe environmental conditions, such as extreme heat, droughts, and floods. The turn to renewable energy that NZEDs bring is especially important for Europe where the dependence on Russian natural gas has led to a major energy crisis in 2021. The European Union 27 currently rely on Russia for almost 38% of their imported natural gas. With plans to close nuclear power in Germany (2022) and Belgium (2025) reliance on natural gas will further increase. The prices of Russian natural gas rose from 3.89 in November 2020 to 28.1 in November 2021. The dependence makes urgent the need for a turn to renewable energy. Moreover, the costs of renewable energy systems continued to fall year on year. The price of solar power has fallen by over 80% since 2010, offering an important advantage for this type of renewable energy, which is quite friendly for city environments.

Net-Zero Energy Districts are a step forward from Net-Zero Energy Buildings. The latter are energy-neutral buildings that give back to the energy grid they drawback (Lin et al., 2020; Panagiotidou & Fuller, 2013); buildings that can produce the same amount of energy they consume all year round (Torcellini et al., 2006). However, moving from the level of building to the level of the city district, the concept has changed as the district is more complex than the building and uses energy not only for residential and office activities but also for public uses, mobility, and various urban infrastructures.

Similar concepts to NZED are also used, such as Positive Energy Districts (JPI Urban Europe) and High Performance Districts (NREL, 2020). Smart city solutions have enriched the NZED concept by using ICTs for energy saving and optimization, enabling energy communities that exchange and share energy over smart grids and digital platforms (Eickhout et al., 2008). To make a city district NZED, smart city solutions work in tandem with renewable energy production and systems for decarbonization (Echeverri, 2018) to achieve objectives for nearly or net-zero energy systems (Wells et al., 2018), carbon neutrality (Hast et al., 2018), and full use of renewable energy (Hansen et al., 2019).

3.2 Towards NZEDs: A Transition Model

To understand the processes, drivers, and limitations of cities transition to carbon neutrality, we designed a model of NZED based on locally produced renewable energy from photovoltaic panels. This type of renewable energy is extremely friendly to cities, as PV panels can be easily mounted on buildings or deployed in open/unbuilt spaces with limited environmental impact. The model can identify the demographic, economic, climate, and technological conditions and thresholds that allow for a city district to turn into a self-sufficient NZED, by deploying smart city solutions, smart grids, digital platforms, consuming energy produced by PV panels deployed in the district, and removing any CO_2 residue by nature-based solutions.

The model is composed of four building blocks related to: (a) demographics and spatial characteristics of the city district, (b) energy consumption and CO_2 emissions from activities and land uses in the district, (c) measures for transition to NZED and actions for carbon neutrality, and (d) the calculation of balance between energy consumption and renewable energy production, and carbon dioxide balance between CO_2 released and CO_2 removed in the district, thus zeroing total emissions (Fig. 3).

3.2.1 Block A: District

The first Block A of the transition to the NZED model refers to the social and spatial features of the city district. It includes variables in five domains: population and density, land use, city grid, building code, and mobility patterns. The five categories of land use included are: (1) housing, (2) social care amenities, (3) local retail and services, (4) road and open parking, and (5) green areas, parks, and plazas. In the next versions of the model, industrial activities can be added allowing a universal application of the model in any city district. These variables define the energy needs and energy consumption in the district, as well as the potential for local renewable energy production through the deployment of PV panels.

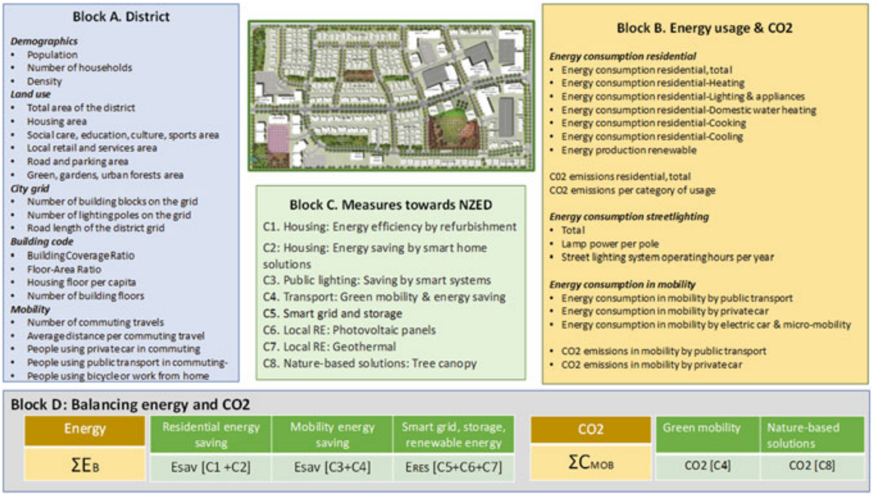

Fig. 3 Building blocks of the NZED model

3.2.2 Block B: Energy Consumption and CO_2 Released

Block B of the model refers to energy consumption and corresponding carbon dioxide emissions from the activities and land uses in the district. Three important types of energy consumption are considered that are common in housing districts, related to residential energy, mobility, and energy for public street lighting.

Residential energy consumption depends on the country's climate condition, the wealth as measured by GDP per capita, and the behaviour patterns of energy usage. An important part of energy usage is made at home in the residential sector, which in the EU represented 26.3% of final energy consumption (2019).

Energy consumption in street lighting depends on the lamps used and the operating hours of the lighting system, which changes with the location and corresponding night length. Calculators of the length of days and nights each month of the year allow for estimating the yearly operating hours of a street lighting system and the energy consumed.

Energy consumption in mobility depends on transport infrastructure and means of commuting by public transport, cars, bikes, the spatial distribution of housing and work areas and resulting commuting distances, as well as the commuting, travels per capita during the year. We use statistical data to compute the travel pattern and resulting energy consumption. To calculate CO_2 emissions, we use the Greenhouse Calculator of the US Environmental Protection Agency that carbon dioxide emissions from travel commuting distances per type of transport means.

3.2.3 Block C: Transition Measures to NZED

This Block of the model is the most important due to measures and actions for decarbonization to be applied in the city district. The literature on NZEDs allows identifying various measures towards carbon–neutral cities from which we have selected 8 types of measures related to smart city technologies, building refurbishment, local renewable energy, and nature-based solutions. These are the following:

- C1. Housing: Energy saving by building refurbishment
- C2. Housing: Energy saving by smart city solutions
- C3. Public lighting: Energy saving by smart city lighting
- C4. Transport: Green mobility and energy saving
- C5. Smart grid and storage
- C6. Local RE: Photovoltaic panels
- C7. Local RE: Heat pumps and geothermal heat pumps
- C8. Nature-based solutions: Tree canopy and CO_2 offset.

Implementing these measures in a city district we can turn most energy consumption to electricity, optimize energy usage by saving systems, use the maximum of local renewable energy, and offset any remaining CO_2 emissions by nature-based solutions, leading the city district into a net-zero state.

3.2.4 Block D: Balancing Energy and CO_2 in the NZED

In block D, we document the transition to NZED by computing the energy balance and the CO_2 balance. In a carbon–neutral state, both balances are positive in favour of renewable energy and CO_2 absorption.

D1. Energy balance: Energy balance is equal to total energy consumption after optimization by smart city systems minus renewable energy produced locally ($ED\mathrm{i}-E\mathrm{RE}i$). To calculate this balance, we take one by one the measures for transition to NZED (C1–C7) and compute the saving of energy due to smart city systems and the renewable energy generated from PV panels. In a positive energy balance, the total energy consumption minus energy saving should be lower to energy generated by PV panels.

D2. Carbon balance: In carbon balance, the total CO_2 emissions should be less of CO_2 removed from the atmosphere by nature-based solutions. Any remaining fossil-fuel usage in residential energy consumption and mobility will produce carbon dioxide which should be removed by nature-based solutions. In a net-zero state, the capacity for CO_2 absorption defines a ceiling for nay fossil energy usage.

The overall NZED transition model can be described by using the following equations:

$$\sum E - \sum E_S < E_{RE} \tag{1}$$

$$C_{\mathrm{MPC}} < CO_{2a}, \tag{2}$$

where $\sum E$ refers to the total energy consumption in housing (ER), street lighting (ESL), mobility (EM) including private cars (EMPC), public transport (EMPT), and electromobility (EMEV); $\sum E_S$ refers to energy savings from heating (EH-S), lighting and appliances (ELA-S), smart city lighting (ESL-S), and energy usage in electric mobility (EEV); and E_{RE} refers to the energy generated by PV panels. Where C_{MPC} refers to the CO_2 emissions from mobility by private car; and CO_{2a} to the capacity of CO_2 absorption by tree canopy in the district.

3.3 Simulation and Results

The NZED transition model we described can be applied to any city district, anywhere in the world. However, the transition scenarios to NZED are countless, depending on combinations of variables of Block A and B, and the measures applied from block C. To understand how city districts evolve towards carbon–neutral districts we have assessed several scenarios. We started from a baseline scenario upon which we calculate the energy and carbon balance for different cities. Then, we change key variables and recalculate energy and CO_2 balances.

The baseline scenario describes a usual district of pure housing. Block A variables reflect a district of 5,000 inhabitants, gross density 100 inhabitants/Ha, housing area 50% of the total area, road area 20% of the total, and green, gardens, urban forests area 30% of the total, road width 8 m, Building Coverage Ratio 40%, and Floor-Area Ratio is 0.8. In Block B, we compute energy consumption and carbon emissions using EU statistics, and country data provided by *Our World in Data.* In Block C, all transition measures (C1–C8) are used, and the corresponding energy saving, renewable energy production, and CO_2 absorption are calculated.

We have assessed the feasibility of NZED transition of city districts described by the baseline scenario at three geographic locations and climate conditions, in cities of northern Europe (Helsinki, Stockholm), central Europe (Frankfurt, Munich, Vienna), and southern Europe (Athens, Rome, Madrid) and examined the feasibility of transition to NZED.

The model shows that NZEDs using smart grids, digital sharing platforms, and energy saving solutions, in combination with local production of renewable energy by PV panels, and nature-based solutions are feasible in Athens only, where the model shows a surplus of 6.18 GWh of renewable energy. In Frankfurt and Helsinki, self-sufficient NZEDs are not feasible and there is an annual gap of 15.03 and 24.56 GWh of renewable energy. The outcomes are similar for other cities of southern, central, and northern Europe, such as Rome, Madrid, Munich, Vienna, and Stockholm. In Europe, there is a positive renewable energy balance in southern European cities, while an important renewable energy gap is observed in cities of central and northern

Europe. But, the simulations we have tested reveal three critical thresholds towards carbon–neutral city districts.

First, *population density* is important as it increases the total energy consumption and vice-versa. By decreasing the gross density in the Frankfurt scenario from 100 to 56 in/ha and in Helsinki from 100 to 43 in/ha, both scenarios show positive energy balances, and NZEDs become feasible. It seems that gross population density at the level of 100 in/ha or net density of 200 in/ha is an upper limit for transition to NZED, given all other conditions remain the same. Second, *electric mobility* is an important threshold as it defines the level of fossil fuels used in mobility and the resulting CO_2 emissions. These emissions should be balanced by CO_2 absorption from the tree canopy. However, in a city district, the available space for tree planting is limited, close to 25–30% of the district area. Therefore, the CO_2 absorption capacity is also limited. If only electricity is used in residential energy, the CO_2 absorption capacity defines the level of fossil fuels used in mobility. The model shows a low percentage of commuting with non-electric cars at the level of 15% of the active population. Third, *solar panel technology* is important as it defines the amount of solar irradiation that is converted to electricity. The power conversion efficiency (PCE) of solar panels has been steadily increasing over the last 20 years (Tang et al., 2017; Xu et al., 2016). In the NZED transition model, we applied a PCE at the level of 20%. However, already panel with much higher conversion efficiency are available. At a PCE at the level of 40%, self-sufficient NZEDs will be feasible in central and northern Europe, enabling the widespread transition to NZEDs based on solar panels throughout Europe.

3.4 NZED, Decision Making and Quality of Urban Environment

The transition model to NZED we used reveals the drivers and barriers towards carbon neutrality and self-sufficient net-zero city districts. Cities are composed of many different districts, functional districts, such as the Central Business District, commercial districts, industrial districts, waterfront, housing districts, neighbourhoods, etc., and administrative districts (e.g. precinct, arrondissement) which divide a city into several administrative departments. The model can be applied to both functional and administrative district. However, per type of district the mix of activities and land uses change and the variables of the model must be adapted.

The most important barrier comes from the use of fossil fuels in mobility. For a long period, when more than 15% of the district's residents continue using fossil fuel in commuting, the district will function as a "near-zero" rather than a "net-zero" energy district without balancing the carbon dioxide emissions. Eventually, it will take a decade or more to reach a level of 85% carbon-free mobility. Also developing a tree canopy at the level of 25–30% of the district surface will take a decade to develop its CO_2 absorption capacity. A transition to NZEDs will take a decade or more to be completed, while universal feasibility throughout Europe demands significant technological progress in solar energy technology. A ten-year horizon for a widespread transition to NZEDs is very near future.

NZEDs offer multiple advantages in the quality of life offered in cities. There are economic advantages due to energy saving costs and depreciation period of equipment, after which PV panels continue producing energy without extremely limited cost. There are social advantages due to working of the city district as an energy community with energy sharing over a common platform and higher solidarity in the district. There are environmental advantages as the district ceases to release carbon dioxide into the atmosphere, while a higher percentage of public and private spaces is given to green and tree areas. Most importantly, the district contributes to climate change by its means.

The transition measures depend on behaviours, capabilities, and forms of intelligence of three types of agents: (1) humans, in decisions for energy investment and saving, generation of renewable energy, adopting a prosumer culture, (2) collectives, in setting rules for the district planning and operation, and (3) machines in data analytics, automation, and real-time optimization. Simulations we have tried reveal how behaviours and capabilities at those three levels are interrelated and how connected intelligence is needed for the transition to NZED (Komninos & Kakderi, 2019; Komninos & Panori, 2019; Komninos et al., 2019a, 2019b, 2021a, 2021b).

Behaviour change and capability development at these three levels are necessary for creating self-sufficient NZEDs. The model shows that the higher impact comes from human behaviour in favour of an energy prosumer culture and electromobility. Also high is the impact of community behaviour change in favour of energy communities, energy exchange, and sharing, which work as enablers for more effective human behaviour also. But in the end, the effectiveness of the system depends on the integration of human actions, community settings, and machine capabilities.

4 Post Covid Urban Mobility Transformations for More Liveable Cities

Transport has a significant effect on well-being and constitutes a major condition for liveability of cities. Liveability generally refers to people's ability to access opportunities that improve their quality of life (Appleyard et al., 2014) and in the context of transport it is related to the idea that transport systems should provide safe, attractive, and enjoyable environments both in terms of mobility and in terms of using the urban space (Anciaes & Jones, 2020). Many cities around the world have tried to adopt this idea in their mobility plans by promoting transport options that ensure equal access of opportunities and promote healthy lifestyles through active travel choices and high-quality urban realm.

Rapid urbanization poses significant challenges to the orchestration of the complex urban mobility ecosystem, comprised by urban authorities, private operators, and individual users; while increased motorization leads to congestion, pollution and reduces sustainability in cities. The recent health crisis only added to the existing problems since social distancing in public transport was impractical (if not impossible) while reverting to the use of cars as a safer alternative deteriorates the problems of pollution and congestion (Basu & Ferreira, 2021; Tirachini & Cats, 2020).

Despite these challenges, the Covid-19 pandemic created an opportunity to change the paradigm of urban mobility and transform the urban setting into a more safe, walkable and socially equitable space. Mobility was profoundly affected by the restrictive measures taken by governments and city authorities all over the world, while the lockdown highlighted the significance of a good quality of life, not only in terms of housing and proximity to green spaces and recreational areas but also in terms of sustainable (and healthy) means of mobility. This led to a significant change in mobility modes in favour of walking and cycling: in the first months of 2020 bicycle sales in the UK rose to more than 50%, while in Paris, traffic in the bike lanes was almost 30% higher than usual (Cosnard, 2020; Reid, 2020). Apart from the change of citizens' behaviours towards sustainable mobility solutions, technology also offered plenty of opportunities for more efficient transportation from monitoring, preparedness, optimization of transport infrastructure and service performance to the development of custom-made solutions to specific hygiene-related problems, even though the level of digital transformation of the urban mobility sector in most cases is relatively low (Gutuerez et al., 2020; James et al., 2020).

The problem of transport liveability does not merely depend on transport policy itself but requires collaboration across different policy areas and levels of jurisdiction (spatial planning, education, digitalisation etc.). The disruption caused by the pandemic could serve as a triggering point for policy re-evaluation and mutual coordination towards more inclusive, green, and smart transport systems.

In a recent study (Kakderi et al., 2021), we collected 60 different urban mobility policy responses to the COVID-19 crisis adopted by 86 cities of different size and characteristics across the world. These are initial responses since they have been collected during the first eight months of the pandemic. Our source of data was platforms and repositories of international organizations such as: (i) COVID Mobility Works,[2] an independent platform dedicated to collecting, synthesizing, and sharing mobility initiatives during the COVID-19 pandemic, (ii) Cities for Global Health,[3] a COVID-19-related initiatives' repository launched by Metropolis and the Euro-Latin-American Alliance of Cooperation among Cities (AL-LAs) and (iii) the OECD library of city policy responses to COVID-19 (OECD, 2020).

The aim of this analysis was to create an extensive catalogue of different initiatives and policy measures (even though many are common between cities) adopted either by the municipality itself or by the local service (mobility) provider and which

[2] https://www.covidmobilityworks.org/.

[3] https://www.citiesforglobalhealth.org/.

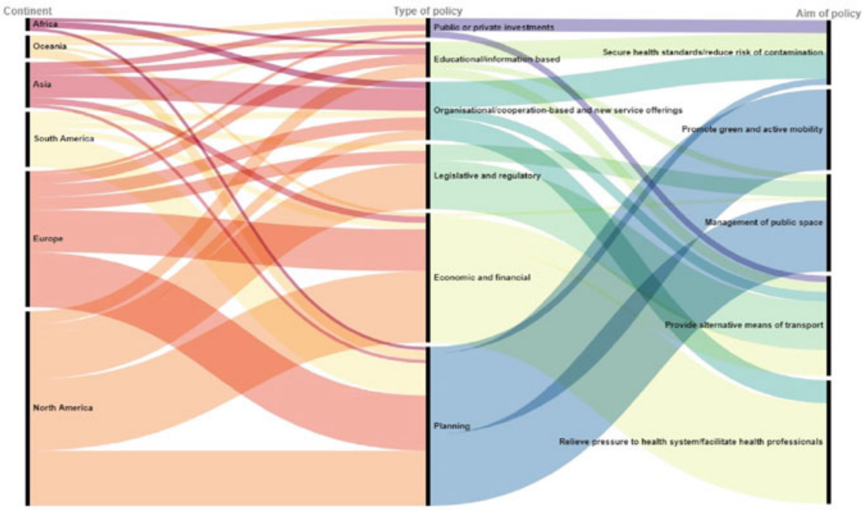

Fig. 4 Location, type, and aim of city policy responses in relation to urban mobility during the first eight months of 2020 (*Source* Kakderi et al., 2021)

directly affected urban mobility. Although many of the policy responses and emerging practices were of a temporary nature, they reflect the responsiveness and flexibility of the urban transport ecosystem in each area against the health crisis and, also, provide an indication of the direction of action, either enhancing or deteriorating city liveability.

Figure 4 presents an overview of the responses collected after being analyzed in terms of geographical location of the city, the type, and the aim of each policy response.

We classified all policy responses into the following types of instruments.

4.1 Planning, Including Land Use, Urban Planning, and Zoning

The spatial planning responses included changes in the land use, considering patterns of flows and the relationship between the spatial structure of cities and emergent mobility patterns/behaviour. Spatial planning as a mitigation strategy against the pandemic related more to the promotion of individual active mobility with measures such as the pedestrianization of streets, the creation of jogging lanes, the development of pop-up (temporary) cycleways, and the extension of the bike lane network and of sidewalks (although in many cases for the benefit of restaurants and businesses) (Kakderi et al., 2021b). A striking example is that of Paris through the RER Velo, a cycle infrastructure project which looks to provide nine segregated routes linking

30 districts of Paris (Nikitas et al., 2021). Other measures, such as the adaptation of school drop-off and pick-up areas and the expansion of transit areas, aimed at securing social distancing.

4.2 Economic and Financial

These include revenue-generating instruments, subsidies, licences, user benefits, cost reductions, and redistributions such as free access or reduced fees in the use of mobility services and related infrastructure, of micro-mobility, or of other means of mobility (taxis, public transit, toll fees), and they were primarily targeted to medical professionals and essential workers (free access of unlimited rides). Financial responses could also include bike donations (Amsterdam) or financial incentives for bike purchase (Nottingham), both of which could positively affect mobility behaviour in the long term. On the other hand, we found subsidies given to taxi drivers to keep them operating (Chicago).

4.3 Legislative and Regulatory

These include guidelines, rules, limits, and binding requirements (mostly of a temporary character), such as the declaration of bicycle shops as essential businesses during the lockdown (Columbus, San Francisco), the reduction of speed limits and restriction to car access to building blocks of some neighbourhoods, as well as the suspension of parking enforcement policy, a measure widely adopted in North American cities (Los Angeles, New York, Denver, and Mississauga, among others). In this category we also found measures of a somewhat spatial planning character, such as the closure of open spaces such as parks, waterfronts, and other leisure-related areas to avoid crowding (New York, Paris, Milan, Thessaloniki). These responses were not included in the "planning" group, since they did not reflect a change in land use, but rather a temporary restriction of access to these sites.

4.4 Organizational and Cooperation-Based Instruments

These include, among others, voluntary commitments, negotiations, networks, improvements/changes in the transport services offerings, adapting to emerging needs, such as the transfer of patients to and from hospitals using buses (Gurugram) or the development of demand-responsive micro-mobility services to help health workers (Abu Dhabi) and/or customers who were experiencing lost fixed-route service (Columbus). Such responses reflect active engagement and a bottom-up organization of mobility providers and stakeholders and create a fertile ground for the emergence of innovative, flexible-routing micro-transit services that require the use of the instant exchange of information, enabling an extra real-time matching of demand and supply on top of in-advance booking, thus extending its accessibility to a wider group of people.

4.5 Educational/information Based

Measures including education and training, information campaigns, capacity building, monitoring, and access to information; targeting both citizens, with the aim to influence behaviour, and mobility stakeholders, aiming to improve capacity building and optimize or increase their mobility services. Examples here included dashboards and open data portals collecting, organizing, and providing mobility and health-related information (Vancouver, Fukuoka), public awareness campaigns to educate transit riders and workers on new safety and preventative measures to reduce community transmission, and even free bike lessons to promote safer alternatives for transport (Newcastle). A more detailed analysis of such measures as well as their direction with regard to the smart growth paradigm is given later in the text.

4.6 Public or Private Investments

These refer mainly to investments in infrastructure; such as the installation of surveillance cameras on trains (Beijing), automated mechanisms on pedestrian crossings that do not require physical touch (Brisbane), and a significant increase in bike and scooter fleets to meet the increasing demand (Rotterdam).

Although most of the city responses analyzed had more than a single challenge to address, most of them focused on relieving the pressure on the health system and facilitating medical professionals, essential workers and COVID-19 patients. Other measures aimed at providing alternative means of transport and promoting green and active mobility and at effectively managing the public space. The management of open spaces can be considered supplementary to the ones promoting green mobility, however, there were cases where they acted in a reverse mode (e.g., restricting the access of pedestrians to open spaces). Finally, we found policy responses aimed at securing health standards in the transport system, to reduce the risk of contamination.

It is difficult to accurately assess the exact level of digital transformation without an in-depth study of the policy measures and the changes made in behaviour, routines, and processes after their implementation. In our study it was quite clear that most measures did not incorporate ICT, and those that did remained at a low level of digital transformation. ICT-based solutions (or at least the ones that included some level of automation) constitute activities performed digitally while the routines that govern these activities remained unchanged. This was the case of Hong Kong (pilot action), where the cleaning and disinfection of train compartments and stations is being performed by robots instead of people, or Beijing, where cameras are used to check compliance with mask wearing. The optimization of routines was observed in very few cases like for example the case of Barcelona app on bus occupancy or the in-app metro reservation system in Beijing. There are however few examples of more complex initiatives, in cities that have already embedded -long before the pandemic- smart systems and services in their operations, like Seoul which tried to use advanced tracing techniques such as geolocalization data, bank-card usage, and video surveillance for contact tracing and to ensure social distancing. The combined intelligence emerging from human–computer interactions reaches the highest possible level of digital transformation where activities may be performed at the digital space, but the routines that govern these activities are replaced by more fit ones, defined within a cyber-physical system of innovation (Komninos et al., 2021). The emergence of intelligence also improves the responsiveness and resilience of the urban transport ecosystem against crises and various challenges and creates liveable urban spaces focusing on the real mobility needs and leveraging innovative solutions.

5 Discussion and Conclusion: Interdependencies in Conditions of Urban Liveability

As we have seen, liveability can be understood as the ability of people to access opportunities that improve their quality of life. In this chapter we argue that inclusion, sustainability and resilience are essential ingredients affecting urban liveability. To better understand their impact on everyday life, we choose to use geographical segregation, environment and mobility as their urban manifestations.

First, urban inclusion is explored through residential segregation to approach liveability as an equal access to opportunities across space. The findings suggest that the uneven distribution of different socio-economic groups in space within an urban area encompasses not only housing preferences of high-income groups living in attractive parts of the city, but also structural variations rising through labour market and educational variations, that affect living conditions and broader aspects of everyday life, such as social, economic, educational and health amenities, all of them closely related to liveability. Therefore, the patterns of geographical segregation rising in the urban space can be perceived as a key condition for urban liveability, which can be affected by disruptions due to structural changes, such as the twin transition, and external shocks, similar to the recent pandemic crisis, changing the social formation of space.

Second, urban environment expressed through the net-zero energy districts can be used to assess the condition of sustainability on urban liveability. NZEDs provide multiple advantages in the quality of the urban life, including economic advantages due to energy saving costs, social advantages due to solidarity aspects rising within a city via energy communities, as well as environmental advantages contributing to climate change actions. Evidence suggests that the effectiveness of the NZEDs, as a factor for urban sustainability, depends on and enables the effective integration of individual actors, communities and cyber-physical systems. This constitutes quality of the urban environment as a key condition for the liveability of cities.

Third, urban mobility through its strong connection with the resilience of cities is an additional condition that should be investigated within this liveability framework. Policies related to mobility have proven to be efficient towards promoting green and active mobility, as well as managing the public space. This is of utmost importance for relieving the pressure on the health system during the recent pandemic crisis. Policy instruments empowering economic, regulatory, collaborative and educational aspects of mobility applications have indicated a positive impact on urban resilience in relation to the COVID-19 outbreak. To this end, liveability can derive as an outcome of changes emerging in mobility behaviour, routines, and processes.

Interdependences between these three identified conditions of urban liveability can also emerge. More specifically, a geographically inclusive city in terms of equal access to opportunities and living conditions, may act as a trigger for the development of energy communities through trust and a balancing factor of mobility processes. At the same time, a better-quality urban environment through the application of NZEDs offers essential conditions for building a trustworthy urban ecosystem characterized by solidarity, inclusion, and carbon–neutral-oriented attitudes towards consumption and mobility. Moreover, a city with an increased resilience deriving by mobility-related innovations that could be used as responses to external shocks, may be able to sustain its inclusiveness and environmental-friendly attitude, even during difficult times.

In all cases, disruptive innovations introduced through digital transition are key elements that should not be ignored when investigating the interdependencies rising between these three conditions: geographical inclusion, environment, and mobility. Digital elements have significantly accelerated the transformative power of cities, enabling them to achieve higher levels of liveability by deploying new technologies in their internal systems. Therefore, the stemming urban environment, as well as its liveability conditions are a mixture of socio-technological interactions within a city with high complexity and increased digital interactions. These shape a wide range of new opportunities for urban liveability that could be further extended by well-designed participatory process encompassing citizens, communities, and digital elements.

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ICT Solutions for Smart Urban Mobility: A Review

Luca Zamparini

1 Introduction

Mobility is one of the main features that characterize a smart city according to all theoretical and empirical works that have dealt with this issue in the last decades (see, among others, Allam & Sharifi, 2022; Ben-Elia & Zhen, 2018; Escobar et al., 2021). It can represent one of the key drivers of competitiveness and of smart development of cities. These would in turn lead to a remarkable enhancement of the degree of affection to cities by residents and to more liveable urban areas, as many of the case studies presented in the chapter will show. On the other hand, an inefficient and ineffective management of urban mobility can determine relevant problems and drawbacks in all the dimensions that interact in the development of cities (environment, economy, people, living and governance).

The main principles that should guide smart mobility initiatives can be summarized in: (a) location efficiency; (b) reliable mobility; (c) health and safety; (d) environmental stewardship; (e) social equity; and (f) quest for a robust and competitive economy. In the context of urban areas, this should be related to both the efficiency of local transport systems and the connectivity with national and international transport systems. In order to reach these goals, it is necessary to pursue infrastructural and immaterial investments. Among the latter, a momentous driver of smart urban mobility is definitely represented by Information and Communication Technologies (ICTs). ICT tools allow private transport users to have information about flows and speed in determined sections of the urban transport network and to have advice about the best possible route. ICT may also be helpful to foster a wide adoption of transport means sharing among citizens. The importance of data for smart mobility has also been emphasized by Mahrez et al. (2021). They have stated that large amount of data can be obtained from various possible sources, e.g. the Internet of Things and the

L. Zamparini (✉)
Department of Law, Economics Division, Unlversità del Salento, Lecce, Italy
e-mail: luca.zamparini@unlsalento.it

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online social media. They can be the starting element of a value chain that considers four important steps. The first one is the validation of the raw data by a private firm or by a public dedicated authority. The second step sees the passage from data to information when the former are aggregated and contextualized in a structured way to make them meaningful. The third step is the accumulation of knowledge via an understandable format of data. The last step is the creation of products and services that generate an added value on the basis of the available data. The use of ICT tools is particularly relevant in order to tackle the issues represented by increasing economic societal and environmental pressure to reduce energy consumption, emissions and pollution, and by the need to enhance accessibility of transport systems through more efficient and cost-effective options and to improve the degree of safety and security.

A report by the EU Commission (2012) has listed the possible dimensions in which ICTs can strategically be used to facilitate more efficient mobility patterns towards an overall smart development of cities: (a) new trends and policy changes in urban environments; (b) accessibility of transport systems; (c) improved safety and security of the users of urban transport networks; (d) reduced energy consumption, greenhouse gas emissions and air and noise pollution; (e) improved efficiency and cost-effectiveness of the transportation of persons and of goods; (f) enhancement of the attractiveness and quality of the urban environment. To fulfil the above-mentioned objectives of smart mobility, several aspects of urban mobility can benefit of ICTs. Some of them are related to public management of transport while others attain the private dimension. The local public dimension of smart mobility management can be related either to the provision of urban network management protocols (as in the case of the management of speed by network users), or to the establishment of fixed (e.g., access to limited traffic zones) and responsive systems (e.g. dynamic lanes). The private dimension of ICT for smart urban mobility can attain virtual mobility services (e.g., teleworking, teleshopping, telecommuting), travel planning options (e.g., multimodal travel planners), the use of social networks and of crowd-sourcing systems (e.g., Waze) to optimize the economic, time and space dimensions of mobility.

Based on the above-mentioned considerations, the present chapter aims at presenting a review of the initiatives that have linked ICT with urban mobility in a series of countries in the various regions of the world. The next section will present a methodological review of ICT and smart urban mobility. The ensuing sections will discuss the proposed case studies. The last section will be comparative in nature, and it will highlight the similarities and differences among the considered case studies. It will also propose some possible future perspectives on ICT and smart urban mobility.

2 Methodological Review of ICT and Smart Urban Mobility

Allam and Sharifi (2022) have highlighted that since 2011 more than 3,000 articles have dealt with the issue of smart urban mobility, especially in Asia, Europe and North America. According to the literature, smart urban mobility is a key factor for the development of the smart city concept. Despite the plethora of different definitions, it can be stated that smart mobility requires the use of ICT tools to improve the quality of urban transport, especially in terms of sustainability, security and safety. On the empirical side, it has been shown that transportation is one of the most frequent objectives (75% of the considered projects in Asia, 60% of surveyed projects in the United States of America and in Brazil, 52% of project in Europe) of smart city projects (Crainic et al., 2019). Specifically, many projects adopt ICT tools to optimize the flow of traffic and operations in congested areas with the aim to convert them into "sustainable districts". Another important goal is represented by the increase of security and safety of passenger and freight transport. In the latter context, ICTs are used for the efficient management of city logistics, especially for the management of the last mile problem in urban areas. One such example is represented by the Italian URBeLOG initiative which aims at developing processes, applications and services for the efficient management of logistics (De Marco et al., 2017).

A review of the relevance of ICT solutions for transport demand has been conducted by Gossling (2018). The study considers that there has been a momentous improvement of availability of transport-related information, mainly through smartphone apps in the last two decades. These have attained, among others, the possibility to have a clear picture of the possible multimodal transport options to move from an origin to a destination, in terms of times and of costs.

A multidisciplinary literature review by Legaspi et al. (2020) has identified technology, policy, community and environment as the main elements that should interact to accomplish a smart urban transportation system. The technologies for smart mobility range from intelligent transport systems to deep learning, big data and Internet of things. These new technologies can clearly influence the choices of citizens about mobility (van Wee et al., 2013) by intercepting personal motivations, by raising new attitudes and by providing new stimuli. Vecchio and Tricarico (2019) have proposed a taxonomy of the possible forms of information that may influence smart mobility choices. They first consider objective information, divided in fixed elements (i.e., the spatial, the temporal and the monetary dimensions) and in variable elements (i.e., temporary conditions of infrastructures and mobility services that may require the need to opt for a different alternative with respect to the one that characterizes the normal conditions). They also analyze the subjective dimension that refers to the information that is voluntarily given by those who choose a specific mobility option. An important element that is cited in the research dealing with technology is constituted by the drawbacks determined by innovation, such as the increase in private transport use and congestion and the concerns related to security.

It should also be taken into account that the relevance of technological enhancements is mainly determined by the degree and spread of their adoption. Consequently, the role of policies and of community acceptance of such innovations are of paramount importance (De Liso & Zamparini, 2022).

A review by Kachniewska (2020) has analyzed the opportunities and threats that are related to the implementation of smart mobility options on the basis of the various factors that play an important role. The first series of factors is connected to the socio-cultural dimension. It implies the improvement of mobility solutions, of safety and of the quality of life, and the social interest as opportunities. On the other hand, the fear of a change in the transport solutions (low willingness to use public transport means), the shortage of skilled staff and the low confidence in efficient transport solutions are the possible threats. The second series of factors attain the technological dimension which lists ICT development and growing acceptance of modern mobility solutions as opportunities and low profitability and scalability of technical and technological enhancements as threats. The third dimension is represented by the environmental realm. The reduction of pollution and of all the other general negative externalities constitutes the related opportunity. The environmental risk connected to the introduction of unknown solutions, the higher energy consumption and the production of harmful waste are the possible threats. The fourth series of factors are the economic ones. The opportunities are represented by the reduction of costs and the increase in economic efficiency due to the implementation of ICT solutions for urban transport. The threats are linked to the magnitude of investments to improve the infrastructures needed for the optimal use of these solutions and the possible low implementation rates. Lastly, the political factors generate opportunities in terms of development of a coherent strategy for the implementation of smart mobility initiatives and the possibility to take advantage of higher amounts of financing. The threats pertain to the low incentives to launch activities without large know-how contribution, the lack of regulations allowing a quick implementation of new technology solutions and of dedicated administrative personnel for the identification of financing and implementation opportunities.

This section has proposed a methodological review of smart mobility and ICT solutions. The following ones will present case studies related to Africa, Asia, Europe, North America and South America.

3 ICT and Urban Mobility in Africa

The three case studies related to the African continent are related to South Africa, Senegal and Cape Verde. Daz and Emuze (2014) have proposed an analysis of the smart city perspectives in Bloemfontein (South Africa). In their consideration of smart mobility, they used nine indicators. Among them, they included the availability of modern ICT infrastructure and tools. These may determine beneficial effects in the mobility sector but also a more robust economic and social development of the city through social inclusion of residents and equitable urban growth. In this context, ICT and smart mobility represent a necessary requirement to achieve wider smartness objectives.

The relationships between ICT and smart mobility in Dakar (Senegal) have been considered by Mboup (2017). He has discussed the important issue of planning for the development of smart mobility. In this context, Dakar did not have a complete mapping of its transit network. Another problem was constituted by the high costs of ICT apps and devices and the consequent lack of its widespread diffusion. The commitment of local and national authorities represents an important prerequisite in this respect. This should lead to overcome the scarce integration of ICT with the transport sector. The liberalization of ICT seems particularly important jointly with the removal of entry barriers to the market to foster competition also in terms of investments in human skills and physical infrastructures. In a subsequent paper, Mboup (2019) has stated that in most sub-Saharan African cities there is a limited choice in terms of mobility for most people (especially with respect to commuting). The only available options are minibuses or on foot. This is due to the lack of efficient and infrastructures and to poor public management that leads to the informal private micro-companies. In this context, ICT may be one of the key drivers for the development of efficient public buses for rapid transit systems that may allow to serve a large part of the population that cannot afford to own a private car. The effects would be beneficial for the entire economic systems, especially in terms of a higher number of working hours and of improved productivity.

Monteiro Tavares and Szpytko (2017) has discussed the use of ICT for reliable transport control on the basis of a case study related to Praia City in Cape Verde, an archipelago in the Atlantic Ocean close to the West Coast of Africa. The small dimension of the town jointly with rapid growth and increased urbanization has generated a variety of social, economic, technical and organizational problems. The considered solution entails the adoption of an architecture for a cyber city and of a virtual communication platform. The proposed steps to reach this objective would be the creation of a centralized public transport management system using ICT tools. The latter may be useful to connect the central management unit to all the hotspots of the city, such as hospitals, police stations and fire brigades.

4 ICT and Urban Mobility in Asia

An assessment of the relationships between ICT and smart urban mobility in India has been made by Patel and Joshi (2017) who have considered the city of Ahmedabad. Based on the experiences in other cities in the world, the municipality of Ahmedabad has launched a mobile app that allows citizens to pose complaints on various issues related to the management of the city itself. It has emerged that the problems related to smart urban mobility are fourfold. First, the general traffic management of the city is considered poor or not satisfactory by 66% of the involved citizens. Moreover, 57% of the sampled population consider that the bus rapid transit system is not an asset for the city given that it has raised the traffic congestion of the area. Seventy-three per cent of the sample considers that a major problem is represented by the lack of a consistent system of parking zones, as the existing ones are normally full or unavailable. On the other hand, 69% of the sample would be ready to pay for parking if it were available. To manage the above-mentioned problems and the other ones related to the various aspects of a smart city, an ICT model has been proposed. A computerized management system should be deployed to monitor traffic in the various neighbourhoods of the city and to forecast traffic jams in order to handle them in advance. The participation of citizens would be required to detect illegal parking and transit episodes and to post them through mobile apps. Lastly, ICT would also be very useful to manage an efficient system of parking, especially in the zones that are more prone to inappropriate parking on roads, leading to congestion problems.

A paper by Milani Medeiros et al. (2018) has discussed how ICT may be important to optimize the mobility behaviour in the case of informal transport activities by considering the peculiar ojek (motorbike taxi) system in Jakarta (Indonesia) as a case study. This city is characterized by high levels of individual motorization, consequent to a lack of integration in terms of schedule, multimodal transport hubs and integration in passenger fares in the public transport. The introduction of ICT tools among end users gave a thrust to the use of the ojek option. This was due to the fact that the previous fare system was very uncertain and, in some cases, unfair given that it was bargained for every single ride. The results of the study have shown that the introduction of ICT has created a dual market between conventional ojek alternatives and smartphone apps-based ones. Moreover, ICTs have played an important role with respect to income, average trip distance and distribution over the territory of drivers. With respect to demand, they have positively influenced the perception of safety and the satisfaction of users. In general, this mode of transport represents an alternative to the bus rapid transit system and the suburban rail. However, the results in terms of general management of mobility and of congestion appear to be mixed.

Chong et al. (2022) have proposed a clear analysis of the issues confronting mobility in Southeast Asia and of the role that ICTs can play in these respects. They state that there is a lack of data and knowledge sharing in terms of urban mobility. This hampers the diffusion of experience, ideas and know-how among cities and among countries. To overcome this problem, ASEAN member states established in 2018 the ASCN (ASEAN Smart City Network) which should serve as a tool to collaborate towards smart and sustainable development of cities. However, the first years of operation have been marked by the scarce political will to establish regulatory and operational strategies and norms. Another issue is represented by the weak governance that generates the inefficient financing of technology and ICT-based projects for smart mobility. The proposed solutions are constituted by the enhancement of collaboration at the urban scale using open data, living labs and urban analytics centres. Moreover, the role of citizens for the creation of new solutions should be emphasized. There is also the need to gain a standardized framework to obtain interoperability of data and to create integrated urban mobility systems. Investments in digital solutions would allow cities to create innovation through data exchange and through a renewed emphasis on the needs of the users of the mobility system. Liability and accountability should characterize the above-mentioned data governance and sharing. Lastly, investments should be made on digital literacy and ICT skills both for the general public and for the administrative bodies.

An evaluation of the ICT benefits for enhancing walkability in a city has been discussed by Yang and Lam (2021). Walkability ICT is constituted by a series of devices that are integrated in order to make walking enjoyable, convenient, safe and confident. These tools allow users to determine personalized routing, they may show hotspots and points of interest. Differently from traditional applications aimed at sporting activities, the newer ones are aimed at leisure activities which do not necessarily tend to the optimization of timing and routing. The experiment conducted by Yang and Lam in Hong Kong allowed them to obtain some quantitative results about the walkability improvements determined by the adoption of ICTs. It has emerged that the habit of downloading priced apps and the interest to visit hotspots and points of interest are statistically significant and they may constitute the main drivers of the diffusion of ICTs among citizens. In this context, the advertising of these tools and of their potential may also be important for the enhancement of the competitiveness of cities as tourist destinations.

5 ICT and Urban Mobility in Europe

Tafidis et al. (2017) have proposed a comparative study that has considered three areas in Portugal, Spain and Romania (Bucharest) and two different ICT applications; urban congestion charging systems and the eco-routing navigation system. The first measure has emerged as a relevant measure to reduce congestion in city centres and to finance infrastructure building and maintenance (Grisolia et al., 2015). Specifically, the eco-routing system requires an active inclusion of the citizens as it is vital that each car contain an in-vehicle information system that allows to receive continually updated traffic information. The eco-routing system assesses the various alternatives and proposes the optimal solution in terms of minimization of fuel use and emissions. The results obtained in the study have shown that such applications can determine positive effects in terms of both cost reductions and abatement of carbon dioxide emissions. However, it would also be important to ascertain the effects that would be obtained through the combination of different measures in the same city.

In the context of the implementation of smart mobility projects, Kachniewska (2020) has proposed a methodology (Steep analysis) that considers five categories of factors that may influence the success or failure of such projects (see Sect. 2 for details); (a) political factors (e.g., laws and regulations, attitudes of administrative bodies, privatization processes); (b) economic factors (e.g., inflation rate, unemployment rate, GDP, market size); (c) socio-cultural factors (e.g., lifestyles, education levels, demographic growth, values); (d) technological factors (e.g., patents, impact of new technologies, technology levels in the various industries, scientific discoveries); and (e) natural environment (e.g., pollution, climate change, environmental protection, recycling, renewable energies). Such factors were then tested by two informed panels and the discussions generated several interesting considerations: (a) the need to involve the citizens in the ICT for mobility decisions and strategies adopted at the local level; (b) the degree of success or failure of these policies also depends on the pace of their implementation. The faster and more efficient, the better; (c) the need to develop new data sources and intelligent infrastructures to facilitate data generation, acquisition, exchange and analysis; and (d) a decentralized approach to innovation appears to be the most appropriate one. The consequent theoretical model has then tested by considering several Polish cities. It has emerged that there is a heterogeneity between the largest cities and the small/medium ones in terms of financing and technological competence. Moreover, urban sprawl, depopulation and ageing society determine low efficiency and efficacy of ICT solutions in the latter, jointly with a relative lack of public and private initiatives. Lastly, the research stated that a smart mobility cannot be reached simply by computerizing its various stages; communication processes and citizens' involvement also play a momentous role.

6 ICT and Urban Mobility in North America

In the case of the United States of America, and of New York in particular, Mostofi (2021) has considered the relationships between ICT-based mobility services and sustainable mobility behaviours. The specific ICT tools that were taken into account in the research are the advanced traveller information systems and the ride-sourcing services. The formers provide the possibility to access to real time information about the accessibility of the available transport modes and about the optimal route to reach a determined destination. The latter matches the mobility requirements of demand with the nearest drivers through dedicated algorithms and GPS mapping. The results of the analysis confirm that, even in a city as New York that is characterized by a higher modal share of public transport with respect to most other US cities, the use of advanced traveller information systems increases the use of sustainable transport options (specifically, rail, bicycles, bus and shuttles). On the other hand, the results about the use of ride-sourcing services are mixed as it emerges that the most replaced transport option is public bus transport; especially, as expected, by the lower income brackets of the considered sample. Consequently, it is envisaged that a specific tax should be imposed on the use of ridesharing for short distances. The revenues of such tax may then be used to improve the conditions of bike lanes and of pedestrian paths to foster soft mobility. Lastly, part of the revenues may also be allotted to economic incentives for the citizens who opt for multimodal trips and use ridesharing jointly with public transport or city-bikes. A similar experiment has been conducted in Juarez City (Mexico) where an Android application has been developed to allow citizens to ascertain all possible public transportation routes (Holguin et al., 2019). A shortcoming of the proposed application is that, in its first instance, it was unfriendly for the users. Moreover, given that some public transportation routes were not present, the algorithm was not optimal, as in some cases the proposed solutions were inefficient. Such issues were then treated in the following versions of the application.

7 ICT and Urban Mobility in South America

Mercado et al. (2014) have proposed a description of the use of ICT by the public transport company in Barranquilla (Colombia). The demand for public transport is characterized by a strong daily and yearly seasonality. Such variations of demand are also influenced by the weather conditions. Periods of strong rains determine a sharp decrease in demand and congestion, due also to the low quality of parts of the road network. In such context, the use of ICT may be very beneficial for the management of both standard and peculiar situations. There are five main ICT tools that are considered in this project: (a) sensors in vehicles; (b) road and routes information systems; (c) digital control tools for the average time to move from an origin to a destination; (d) GPS tracking of vehicles; and (e) digital controls in the vehicles. Two important elements that are emphasized by the research are the importance of public acceptance of the new technologies and the role of training for both the employees of the public transport company and the general public. Both elements would lead to an efficient implementation of the new solutions and to an effective reduction of transit times, congestion and overall negative externalities of transport.

The implementation of smart mobility option in Curitiba, a Brazilian city that jointly with Bogotà in Colombia has been at the forefront of the introduction of the Bus Rapid Transit system thanks to dedicated lanes has been described by Scriptore et al. (2021). Such city was then marked by a large increase of the motorization rate and lack of continuous investments in the public transport system. Both elements have led to congestion and crowding of public transport. The city has also important problems in terms of safety, especially for the citizens opting for cycling as their main transport means. In order to solve these issues, the ICT tools may play an important role in various respects. They may indicate the best times to use determined routes. They may also be implemented to manage congestion periods and areas in an efficient way. Moreover, they may allow users of the system to check public transport options, to gain traffic information and to make reservations for their trips. Lastly, ICTs may foster the choice of shared mobility options that would determine higher sustainability of mobility.

Suarez Lopez et al. (2019) have discussed the use of a mobile application (called Arequipa Smart Mobility) in Arequipa (Peru) to gain a large number of tracking data on the mobility of university students. The choice of this cohort of residents was justified by the fact that it is a relevant component of the overall population of the city that normally mobilizes daily for study and leisure reasons. The analysis of their mobility was important to gain awareness on their choices in terms of routes and transport modes. Moreover, the experiment allowed to ascertain what are the urban spaces that have the highest presence of university students and what is the degree of accessibility of the various neighbourhoods of the city. These data were then used to plan the supply of public transport services and the enhancement of the spatial quality of the most attended areas.

8 Concluding Remarks and Future Directions of ICT and Smart Urban Mobility

The previous sections have provided an analysis of several case studies related to ICT and to smart urban mobility in a sample of cities in various continents. Several considerations can be made, based on the discussions emerging from these case studies. Firstly, it must be considered that any ICT solution has to take into account the transport systems and infrastructures on which it will be deployed. Coherently, some opportunities in peculiar cities cannot be used as such in other, different, contexts. Secondly, the efficiency and effectiveness of ICTs require the willingness to adopt them by the population (Yeh, 2017; Zia et al., 2016). In some cases, it is necessary to provide opportunities of training in order to maximize the potential of the new solutions. Moreover, ICTs and smart mobility normally determine an enhancement of sustainability, safety and security of the transport systems (Cohen-Blankshtein & Rotem-Mindali, 2016). However, there is also the risk that such technologies may imply negative side effects and economic and social externalities (e.g., see the case studies related To Jakarta in Sect. 4 and to New York City and Juarez City in Sect. 6). It is then necessary to carefully consider the context in which such solutions will be adopted. Lastly, efficient ICT solutions should be useful not only in regular conditions but also to counter the negative effects of peculiar events, like unexpected rains and floods (e.g., see the case study related to Barranquilla in Sect. 7). This is particularly relevant in the case of developing countries, whose cities are in some neighbourhoods characterized by poor infrastructures and transport systems. The cities in such countries would be those who need more stringently the adoption of ICTs for the optimization of their urban mobility.

Some authors have provided discussions over the possible future developments of ICTs for smart urban mobility. Several theories and considerations can be mentioned. Ceder (2021) has proposed a list of the possible future technologies that include: (a) Machine-to-Machine (M2M) global platforms; (b) networked computer control systems; (c) real time traffic information system connected to driver services in vehicles; (d) Software-as-a-Service, (SaaS)-based platforms; (e) real time machine learning technologies; (f) human–computer interaction technologies; (g) social, online ridesharing communities; (h) sensors and machine vision technology for automated driving technology; and (i) advanced wireless sensor technologies and software for Vehicle-to-Everything (V2X) environments to support intelligent transportation services. However, for the efficient implementation of such new technologies, an important role will be played by effective public policies, also in the context of post-Covid19 urban development (Kakderi et al., 2021). The decarbonization and the environmental sustainability of transport options will play an ever-increasing role in the development of such policies (Aresenio et al., 2018; Kobashi et al., 2020) jointly with the consideration of an ageing population in most countries of the world (Battarra et al., 2018). For all these issues, ICTs may play a prominent role given their potential to make urban mobility more efficient for all age cohorts of residents, to optimize (minimize) the required travel distances to move from origin to destination, and to influence the option of environmentally friendly transport options in the context of a Mobility as a Service transport system; as many of the case studies in the preceding sections have shown.

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Adapting Historic Cities Towards the Circular Economy: Technologies and Materials for Circular Adaptive Reuse of Historic Buildings

Mariarosaria Angrisano, Martina Bosone, Martone Assunta, and Antonia Gravagnuolo

1 Introduction

In recent years, there has been a growing international governmental focus on the emergencies of climate change and biodiversity, in relation to the objectives of the Paris Agreement (UNFCCC, 2015), in the declared interests of health, well-being and prosperity of all. The agreement's goals are to limit global warming to well below 2 degrees Celsius (°C) and to reduce carbon dioxide (CO2) emissions. There is a strict relationship between climate change and the city. The activities that take place in an urban context substantially contribute to climate change. In fact, a large amount of resources is consumed in cities with negative external effects in terms of pollutants and climate-altering emissions (Fusco Girard & Nocca, 2019).

In this scenario, the construction sector is considered one of the fields that contributes more to environmental depletion and climate change due to the continuous use of materials, energy and manufacturing technologies. Governments are striving to find new sustainability solutions and strategies both for the construction of new buildings and for the redevelopment/reuse of existing ones, including historic

M. Angrisano
Department of Economic and Legal Science, Università Telematica Pegaso, Naples, Italy
e-mail: mariarosaria.angrisano@unipegaso.it

M. Bosone · M. Assunta
Institute for Research On Innovation and Services for Development (IRISS), National Research Council (CNR), Naples, Italy
e-mail: m.bosone@iriss.cnr.it

M. Assunta
e-mail: a.martone@iriss.cnr.it

A. Gravagnuolo (✉)
Institute of Heritage Science (ISPC), National Research Council (CNR), Naples, Italy
e-mail: antonia.gravagnuolo@cnr.it

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buildings. In this regard, it is important to underline that existing building stock in Europe represents 80–90% of all buildings that will exist in 2050 (European Commission, 2019b), while buildings are responsible for 40% of the energy consumed in Europe (European Commission, 2020b). Buildings account for 36% of global greenhouse gas emissions (mainly from construction, emissions during use, renovation and demolition) and 40% of the EU's energy consumption (Energy Efficiency in Buildings 2020). However, currently 75% of buildings in the EU are not energy efficient, mainly due to the fact that they were built before the current requirements were enacted (European Commission, 2020c). Since the signing of the Paris Agreement in 2015, CO2 emissions from the buildings and construction sector have peaked in recent years, before declining to 2007 levels in 2020 (United Nations Environment Programme, 2021). This decline was mainly due to the COVID-19 pandemic, while long-term transformative progress in decarbonising the sector remains limited. In 2020, building energy demand accounted for 37% of global energy-related carbon dioxide (CO2) emissions (IEA, 2021b). In the same year, CO2 emissions in the sector reached a level not seen since 2007, falling by around 10% from around 9.6 gigatons in 2019 to around 8.7 gigatons in 2020, as a result of changing building-related energy use patterns, while the average annual growth rate of buildings and construction globally fell by 4% from 2019 levels. Undoubtedly, one of the main reasons for this reduction was the COVID-19 pandemic.

The building and construction sector plays a key role in the post-global pandemic recovery and climate change challenges and requires countries to make an effort in improving and complementing their NDCs with specifications on building efficiency and low-carbon building materials. So far, few countries are revising their building or energy codes to incorporate links to adaptation and resilience. New building codes should be specified accordingly, while interventions needed to reduce the climate impact of existing buildings should be combined with investment in adaptation and resilience measures. For many years, governments have been adopting and issuing different measures to face the problems related to the built environment sector. In 2015, 90 countries took measures to reduce building-related emissions or improve energy efficiency in their Nationally Determined Contributions (NDCs) under the Paris Agreement. In 2020, 136 countries mentioned reducing emissions from buildings in their NDCs and more than 80 countries have developed energy codes for buildings (United Nations Environment Programme, 2021).

To achieve the goals of the Paris Agreement, the Marrakech Partnership for Global Climate Action Human Settlements Pathway of the United Nations Framework Convention on Climate Change, co-led by GlobalABC and also adopted by the #BuildingToCOP26 coalition, set the following goal: "By 2030, the built environment should halve its emissions, whereby 100 per cent of new buildings should be net zero carbon in operation, with widespread energy efficiency retrofits of existing assets well underway, and embodied carbon reduced by at least 40 per cent, with leading projects achieving at least 50 per cent embodied carbon reduction. By 2050 at the latest, all new and existing assets must be zero-carbon throughout their life cycle, including operational and embedded emissions" (World Business Council for Sustainable Development, 2021). GlobalABC's Global Buildings and Construction

Roadmap (GlobalABC et al., 2020) and regional roadmaps for Asia, Africa and Latin America set out the path to implement policies and technologies to support the 2030 target, including a focus on materials and the issue of embedded carbon reduction.

The "European Green Deal" (2020) launched by the European Union is an action plan promoting the efficient use of resources through the circular economy model (European Commission, 2015; Hossain & Ng, 2018), capable of restoring biodiversity and reducing pollution. It is a "new growth strategy" that aims to transform the European Union into a modern, resource-efficient society, with the goal of reducing greenhouse gas emissions by 2050 (www.europarl.europa.eu). The Commission, with this document, recommends revising the regulations on construction products and improving their sustainability in the perspective of the circular economy, promoting their reuse and recycling. The design of buildings should be ideally also supported by digital systems, with the support of appropriate assessment tools such as the Level(s) framework of indicators to evaluate the environmental impacts of each project.

Cultural heritage buildings can be thus suitable for energy retrofit and recovery, if appropriate materials and technologies are employed to preserve their cultural attributes and values. The recovery and regeneration of abandoned and underused heritage buildings can be an effective strategy for the implementation of the circular economy in cities and regions. The Horizon 2020 project interpreted the adaptive reuse of cultural heritage within a circular economy perspective, linking cultural and ecological values (see Horizon 2020 CLIC framework, Deliverable D2.7, www.clicproject.eu). In terms of policy action, the CLIC framework of circular adaptive reuse of cultural heritage should contribute to the European Union's Green Deal and the climate challenge of the New European Bauhaus (European Commission, 2019b, European Commission, 2020). The interpretation of sustainable adaptive reuse as circularity strategy implies the adoption of an integrated perspective for the elaboration of nature-driven solutions capable of contributing to the regeneration of ecosystem services, continuously and dynamically reshaping the circular city/territorial ecosystem. The implementation of territorial ecosystems of circular cities starts from the reuse of disused heritage assets for their transformation into "integrated productive environments": creative places as "condensation nuclei of development" (Zeleny, 2021). In this way, cultural heritage adaptive reuse can become capable of transforming a dead site into a living system (Fusco Girard, 2021).

This contribution aims to identify strategies and tools for historic buildings renovation and energy retrofit to reach climate targets in the perspective of a more circular and sustainable building stock. A review of recent literature was developed to explore innovative materials and technologies that can be employed for energy retrofit of historic heritage buildings, including the analysis of exemplary case studies, taking into consideration the needed balance between cultural values conservation and climate change-related objectives.

The following sections focus on setting the state of the art of knowledge in the field of sustainable and circular adaptive reuse of cultural heritage, including particularly materials and technologies for energy retrofit, and indicators and tools for evaluation of building performance in historical settings. Case studies were selected to explore whether and how innovative materials and technologies are currently used to achieve higher energy performances in historic buildings, maintaining their cultural values. The analysis of exemplary practices, based on the information officially available from published sources, led to the development of an abacus of suitable materials and technologies for historic buildings' circular adaptive reuse and renovation. Finally, overall recommendations are proposed to enhance policies on historic buildings retrofit regulations.

1.1 Circular Economy for Buildings Higher Energy Performance

Since long, the European Commission has aimed to push forward the demands of the transition to the circular economy model for the built environment (European Commission, 2015). However, national and local policies in Europe are not yet sufficiently consolidated to meet both the carbon neutrality and the circularity objectives related to building energy performance. From a circular perspective, buildings are considered "material banks" (Gravagnuolo et al., 2020) in which an attempt is made to reverse the ecological footprint (Shady Attia, 2018b) by increasing the carrying capacity of the building through maximum efficiency in the management of combined resources and maximum generation of renewable resources. As argued by Cambier et al. (2020), although the EU has charted a direction (European Commission, 2015) for the adoption of the circular economy model, it is evident that the rather complex landscape of the circular economy continues to create confusion and misalignment between building designers and advising engineers, slowing down the tools' adoption in practice and leading to significant differences across continents and even between EU Member States (Hossain & Ng, 2018) with respect to the strategies adopted in various sectors, including the construction sector.

But rather than being concerned with giving order and coherence to the vast number of definitions formulated over time, as also underlined by the European Commission's Communication on Resource Efficiency Opportunities in the Building Sector (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on Resource Efficiency Opportunities in the Building Sector 2014), the most urgent need is to identify a common EU approach to the assessment of the environmental performance of buildings. In fact, Velten et al. (2021) have pointed out that the long-term goals and pathways of the Paris Agreement, resulting in a much stronger focus on the transformative nature of the changes needed to address the climate crisis, have also highlighted the importance of identifying assessment and monitoring methods and tools able to capture both the complexity of the progressive transformation and the impacts on the all linked sectors (Saadé et al., 2022), to inform policy-making in a timely and sufficiently detailed fashion. Furthermore, Saadé et al. (2022) affirmed that the adoption of a systemic perspective for the assessment of impacts helps to orient choices based on the understanding of the mutual influence between the different elements of the building and also between this and the context. Adopting clear and shared assessment tools would also facilitate the dialogue between the different actors involved in the choices concerning the building sector (architects, engineering firms, contractors, developers, public authorities, etc.) allowing to identify and limit the environmental impact of buildings from the beginning of the design phase. Energy efficiency in buildings is an area where investment continues to increase, reaching more than $180 billion in 2020, up from $129 billion (in 2020 dollars) in 2015 (United Nations Environment Programme, 2021). However, the largest contribution to this figure comes from a small number of European countries, considering that by 2030 it is predicted that 82% of the world's population will still live in countries with no or only voluntary building energy codes (United Nations Environment Programme, 2021).

The European Commission has adopted recommendations/guidelines for the adoption and implementation of the circular economy model for more energy-efficient buildings. The Circular Economy emphasises the adoption of a life cycle approach to stress the opportunity of reducing the consumption and waste of materials and energy through the use of innovative solutions and technologies able to circularise flows closing material loops. In 2020, the European Commission launched the New European Bauhaus to make operational the aims of the "European Green Deal" linked to the upgrade and renovation of the built environment to reach climate-related targets. The New European Bauhaus is a transversal project aimed to improve quality of life without losing sight of green and digital innovations. A "new sustainable and circular movement" is advocated to make "green" the built environment, through the use of renewable energy, the use of bio-materials, the reuse of waste materials, the protection and conservation of biodiversity. The aim is to create a "new design movement", which uses not only new technologies, but also "beauty" and inclusion, as tools to enhance cities' liveability (European Commission, 2019b). The guidelines of the new European Bauhaus clearly state the objective of creating products and services that carry the EU Ecolabel and are capable of meeting high environmental standards throughout their life cycle. In this regard, the criteria for awarding the EU Ecolabel to products for roofing, coatings based on wood, cork and bamboo, paints and varnishes, textiles, furniture, and other construction materials were established. In addition, great value is placed on vegetation, which is seen as an element that will help mitigate heat in cities and mitigate the effects of natural disasters. The implementation of the "biodiversity strategy" and the widespread deployment of nature-based solutions will contribute to the new European Bauhaus, as nature-inspired design is among the most efficient, sustainable and aesthetically sound strategies for liveable and healthy cities. Moreover, the New European Bauhaus initiative recognises that cultural heritage and historical monuments can contribute to sustainability (beautiful, inclusive, and sustainable), as well as to the green transition, through the energy retrofitting of the historic buildings (European Commission, 2020).

After the publication of the New European Bauhaus document, the European Commission launched the new research programmes (Horizon Europe 2021–2027) focussed on renovation/reuse of cultural heritage in a sustainable and circular way. Each research programme has to be pursuing specific objectives in line with those of the European Green Deal developing methods to maintain, preserve and restore monuments and artefacts through new sustainable and circular materials and technologies. It is recommended to promote research on the quality of conservation, in order to foster a more sustainable and green maintenance and restoration of cultural heritage, guaranteeing higher quality standards in conservation and restoration of Europe's cultural heritage (https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en).

As part of the European Green Deal (European Commission, 2019b, European Commission, 2020b), the recent Renovation Wave policy (European Commission, 2020) identifies very concrete measures in terms of regulation, financing, skills, technological innovation for materials and services, cross-sectoral dialogue and shared design based on three areas: decarbonisation of heating and cooling systems, combating poverty and energy inefficiency and renovation of public buildings. In the Renovation Wave strategy, the European Commission adopted the principle of "life cycle thinking and circularity" to make buildings "less carbon intensive throughout their life cycle" (European Commission, 2020). The life cycle approach is in line with the principles of the circular economy, which aim to reduce the consumption and waste of materials and energy by extending the life cycle of products and services as much as possible through the use of innovative solutions and technologies, capable of circularising flows and reintegrating waste as an input for new production processes (Ellen MacArthur Foundation, 2015). Thus, this strategy places the issue of energy efficiency of the European building stock at the centre of a more complex system of issues related to it and also to the fulfilment of social objectives linked to the creation of new jobs, and to improve the quality of life, health and well-being of residents. In 2016, Arup, Frener and Reifer, BAM Construction and The Built Environment Trust developed a circular pilot project to demonstrate how a prototype of Circular Building can be applied, to explore how the construction industry can work towards zero waste, applying the circular economy thinking to the built environment. The Circular Buildings were designed for all the elements to be disassembled and reused. Furthermore, through the support of digital technologies, each building component was scheduled and linked to information allowing it to be reused. This proposed system aimed at using all the collected data in a Building Information Model to obtain a virtual "Materials Database". In another recent urban exhibit, Arup and Futur2K designed, in a co-creative process and, with the involvement of other experts, the first two prototypes of the modular circular building system, using renewable and recyclable materials such as timber, cork and recycled tiles made from construction waste. As explained also in the publication "Circular Business Models for the Built Environment" (Arup et al, 2016) adopting a systemic perspective across the whole life cycle of assets, using new technologies and applying advance design approaches, additional value could be created, also providing benefits at financial, social and environmental level.

In April 2022, the European Commission established a plan to cut its greenhouse gas emissions by 60% by the end of the decade, and more importantly, to offset the rest of its emissions through carbon removal (European Commission, 2022). The plan emphasises cutting emissions from transport and office buildings, focussing on the transition to more sustainable modes of travel. About buildings, the proposal is to use them less (halving the number of buildings the European Commission manages in Brussels from 50 to 25 by 2030) and better (using space more flexibly, with dynamic collaborative workspaces and increased teleworking), while also changing the energy mix of buildings, reinvesting the money saved in building energy efficiency and climate neutrality. In the buildings themselves, on-site energy production will be developed using photovoltaic solar panels and solar water heating. With these measures, the European Commission declared it should be able to reduce the overall greenhouse gas emissions of its buildings by 60%, their final energy consumption by 14% and energy consumption for heating and cooling by 18% by the end of the decade. Moreover, with the Energy Performance of Buildings Directive 2010/31/EU or "EPBD" (Energy Performance of Buildings Directive) and the Energy Efficiency Directive 2012/27/EU or "EED" (Energy Efficiency Directive, which complemented the EPBD), the European Union established a legislative framework to improve the energy performance of buildings, with the aim of improving the energy efficiency of the building stock, contributing to its decarbonisation by 2050, facilitating the conditions for the creation of a stable environment for investment decisions and providing more information to support and guide the choices of consumers and businesses to save energy and money. The EPBD already set minimum requirements for the energy performance of new buildings and for existing buildings undergoing major renovation. It also obliged Member States to adopt long-term renovation strategies, leaving them free to decide how and when to carry out renovations.

1.2 Embodied Carbon in Buildings

According to the policy goals set at European level, it is clear that the use of innovative materials and technologies plays a key role in the implementation of the circular building model for both new construction and reuse of existing buildings, many of which are heritage buildings located in historic urban areas and therefore protected by Laws on conservation of cultural values. Adopting the Circular Economy model can contribute to the achievement of fewer consumption of material resources and more environmental benefits in each phase of the construction and adaptive reuse process.

Since the introduction of the European Energy Performance of Buildings Directive (EPBD), the requirements of building codes have evolved to near-zero and net zero energy buildings (Shady Attia, 2018a; Belussi et al., 2019). Several studies have attempted to associate energy neutrality targets with building materials, however, very few countries have addressed carbon emissions in the EPBD prior to the use phase (Tallini & Cedola, 2018). Considering construction materials, a relevant issue is related to the "embodied carbon" to be valorised for the construction and restoration of existing buildings.

Embodied carbon is the CO2 emission associated with construction materials and processes during the entire life cycle of a building and includes CO2 emitted during the production of construction materials, their transport for distribution and construction site, and construction activities (Pasanen et al., 2018). Considering the amount of carbon stored in building materials involves assessing their performance throughout their life cycle, including two types of emissions, as defined by EN 15,978 "Sustainability of construction works—Assessment of environmental performance of buildings—Calculation method" and life cycle thinking (Chau et al., 2015; Heiskanen, 2002; Ingrao et al., 2018; Pombo et al., 2019): operational emissions (i.e. those arising from the built environment during the use of buildings) and embodied emissions (i.e. emissions produced during the construction of buildings). Pasanen et al. (2018) highlight the contribution of buildings in generating long-term emissions due to the embodied carbon in the materials used. Thus, while reducing fossil energy use and increasing renewable energy, embedded carbon has nevertheless increased (Pasanen et al., 2018). Therefore, the importance of embodied emissions is set to increase dramatically as more buildings are constructed and renovated to higher energy efficiency standards. For this reason, the importance of embedded/ embodied emissions is set to increase dramatically as more buildings are constructed and renovated to higher energy efficiency standards.

Until recently, carbon embodied in buildings has only been addressed at European level by voluntary measures. Various provisions have been put in place across Europe by cities, regions and countries in the form of certification schemes, regulations, standards and guidelines. However, the European policy landscape is set to change. In its Renovation Wave strategy, the European Commission has adopted the principle of "life cycle thinking and circularity" to make buildings "less carbon intensive throughout their life cycle" (European Commission, 2020).

The ongoing review of key policy and legislative documents—such as the Energy Performance of Buildings Directive, the Energy Efficiency Directive and the Construction Products Regulation—is likely to start integrating life cycle carbon into the policy framework. Particularly, the "embodied energy" of materials and technological solutions should be addressed to include all potential externalities of the adaptive reuse and retrofit process within the overall performance assessment. In this perspective, the European Standard EN 16,883:2017 provides guidelines for sustainably improving the energy performance of historic buildings, e.g. historically, architecturally or culturally valuable buildings, while respecting their heritage significance (European Commission, 2017b). It acknowledges the importance of assessing the whole life cycle of a building by stating that "historic buildings should be sustained by respecting the existing materials and construction, discouraging the removal or replacement of materials /…/ which require reinvestment of resources and energy with additional carbon emissions" (European Commission, 2017a). While a common EU policy on life cycle carbon is still being developed, Denmark, the Netherlands and France have introduced CO2 limits for a large proportion of new buildings (Attia et al., 2021), while Finland and Sweden plan to do so. Germany, as well as the UK and Switzerland, non-EU members, have life cycle assessment requirements for some public buildings; Belgium is planning similar requirements. The International

Energy Agency's Sustainable Recovery report stressed that programmes to support the building and construction sector are a proven response to economic crises as they are able to respond to countries' expressed needs for housing and the need to boost economic activity and the renovation of existing buildings (IEA, 2021a).

1.3 Tools and Indicators for Historic Building Circularity

The interest for environmental assessment tools is growing as their importance in concretely facing climate change towards the achievement of sustainability and circularity goals in the building construction sector. In this time several researches were developed about this research area (Cole, 2004; Cooper, 1999; Crawley & Aho, 1999), focussing on their comparison (Forsberg & von Malmborg, 2004; Todd et al., 2001) and categorisation. International projects were developed in the field (BEQUEST "Building Environmental Quality for Sustainability through Time" (BEQUEST), CRISP "A European Thematic Network on Construction and City Related Sustainability Indicators" (CRISP, 2004), IEA Annex 31 "Energy related Environmental Impact of Buildings" (IEA Annex 31 2001), and PRESCO "European Thematic Network on Practical Recommendations for Sustainable Construction" (Peuportier et al., 2004). The ATHENA Institute (Trusty 2000) and the IEA Annex 31 (2001) introduced the two main well-known classification systems for the environmental assessment tools. According to the first, the tools are classified in three levels, while the second provided a classification considering five classes. Since these assessment tools are based on very specific data concerning technical aspects and building performance, it is assumed that, especially in this case, they seem to be more appropriate for monitoring processes that occur and existing situations, due to the type of data required for their proper functioning. However, a number of studies (e.g. Buyle et al., 2019) confirms that they are often also used as predictive tools, for the development of different scenarios on the basis of which appropriate intervention strategies can be identified.

Different organisations have developed, proposed and applied various definitions, targets and key performance indicators (KPIs) of (nearly) zero energy buildings (Belussi et al., 2019; D'Agostino, 2015; Hermelink et al., 2013; Kurnitski et al., 2012; Moghaddasi et al., 2021; Pless & Torcellini, 2010; Torcellini et al., 2006). According to Andresen (2018), the most consistent definition proposed for zero energy buildings was made by Sartori et al. (2012) who propose a methodology to elaborate Net ZEB definitions in a systematic, comprehensive and consistent way through specific criteria. Starting from this systemic perspective, Velten et al. (2021) proposed a framework consisting of eleven "net zero elements" ranging from the emission sectors ("Zero carbon energy", "Sustainable agri-food system and land-use", "Net zero industrial transformation", "Emission-free buildings", "Moving without emissions", "Carbon dioxide removal") to the cultural, governmental and economic structures linked to them ("Net zero transition finance", "Enabling technologies", "Lifestyle changes", "Just transition to climate neutrality", "Climate Neutral Governance").

Although some studies confirm that the concept and definition of a circular building are still under-researched and under-developed (Cambier et al., 2020; Saadé et al., 2022), several authors have tried to develop metrics to assess circularity practices in the building sector. As stated by Saadé et al. (2022), the existing literature, although growing exponentially, still addresses separately the issue of measuring the circularity of buildings and that of assessing the environmental performance of buildings or urban projects in their life cycle. Therefore, future studies should be oriented towards an integration of these two aspects in order to bridge the existing gap.

Some authors, e.g. Walzberg et al. (2021), suggest that future research should be directed towards integrating existing methods while improving circularity metrics. The increasing focus on zero-emission buildings based on life cycle (Ala-juusela et al., 2021; Andresen, 2018; Liu & Leng, 2021; Twum-Duah et al., 2019; Velten et al., 2021; William et al., 2021) is due to the fact that several studies have shown that for passive and near-zero energy houses, the energy demand during the operational phase is reduced by using more insulation and generally more materials for technical systems, thus increasing the importance of embodied energy. In fact, embedded energy can account for 20–50% of a building's life cycle energy use (Cabeza et al., 2014; Chau et al., 2015), reducing embodied GHG emissions by up to 61% (European Environment Agency, 2020). By moving towards full ZEBs, embodied energy could increase even more than total life cycle energy use.

In recent years, the use of Life Cycle Assessment as a coherent and relevant tool embracing this systemic vision has become increasingly established (Corbett, 2015; Fregonara et al., 2017; Haupt et al., 2017; Scheepens et al., 2016; Smol et al., 2017), but especially applicable at both the materials and building scales.

There are different tools to "measure" the environmental performance of buildings, like LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), WELL Building Standard, Living Building Challenge and so many others. The common purpose of all these certifications is to certify that buildings have satisfied specified green construction standards, such as energy efficiency, water efficiency and CO2 emissions reductions.

Furthermore, the European Commission has launched in 2017 the Level(s) assessment tool with the aim to provide a common tool to evaluate the building's performance (European Commission, 2017). It is the only officially acknowledged evaluation method for the circular economy in Europe. It tries to assess new construction's performance from the standpoint of the circular economy. It only makes reference to the construction industry and offers a set of metrics for assessing the environmental performance of industrial, commercial and residential buildings while taking into account every stage of their life cycles. The Level(s) framework is built on six macro-objectives that are related to the following three thematic areas: health and comfort, cost, value and risk; environmental performances of the life cycle. Level(s) encourages operators to implement both the Life Cycle Assessment (LCA) and the Life Cycle Cost Assessment (LCCA) or the assessment of life cycle costs (Nocca & Angrisano, 2022). This tool does not provide a specific operational method for assessing the environmental impacts of heritage reuse. In this regard, there are some studies of Nocca et al., (2021, 2022) which proposed a system of indicators to be integrated into the Level(s) tool. Specifically, Nocca et al. (2021) identified three new thematic areas to be added to those identified by the European Commission (environmental performances of life cycle; health and comfort; cost, value and risk): social value; intrinsic value; state of conservation (and related use value) (Nocca et al., 2021). In a subsequent study by Nocca and Angrisano (2022), these indicators were further enriched with additional indicators deduced from Green Building Council (GBC) certification for historic buildings (GBC, 2019) and from Heritage Impact Assessment (ICOMOS, 2011).

Despite this, scholars (Giorgi et al., 2017; Haupt et al., 2017) show that specific circular indicators are more widely used than LCA in the literature on circularity metrics, probably because it often continues to be considered limited (Franklin-Johnson et al., 2016) and too challenging due to the need of a large amount of data (Elia et al., 2017). Already in 2011, OVAM (Public Waste Agency of Flanders) launched the TOTEM project (Tool to Optimise the Total Environmental impact of Materials online), later introduced in 2018 in most EU Member States, which was the first step to quantify carbon emissions for building construction materials. The TOTEM tool was developed on the basis of the current European standards specific to construction products and buildings (EN15804 + A2, EN 15,978, EN 15,643 and TR 15,941) and the more general ISO 14040 standards for the application of life cycle analysis. This tool was developed as a response to a more general need to provide a scientifically valid and objectively verifiable basis for the assessment of the environmental impacts generated both by the individual components of a building and by buildings as a whole. A study carried out during 2015–2017 by DG ENV and DG GROW (with the technical support of DG JRC-IPTS) proposes indicators that can be used at project level to measure the performance of EU office and residential buildings, considering three macro-objectives for the "Life cycle environmental performance" (Greenhouse gas emissions from building life cycle energy use, Resource efficient material life cycles and Efficient use of water resources) and three macro-objectives for "Quality, performance and value" (Healthy and comfortable spaces, Resilience to climate change and Optimised life cycle cost and value).

Angrisano et al. (2019) conducted a literature review about life cycle assessment as a tool to support circular economy innovation in the built environment sector identifying five cluster sectors (categories) in which the LCA was useful: development, consumption, production, emission and sustainability assessment. In particular, this study highlighted the importance of considering LCA not only as an ex-post evaluation, but also as an ex-ante evaluation tool (Buyle et al., 2019), which can be accompanied by multicriteria evaluation processes, because of the involvement of different actors in the design/reuse of a building. Ex-ante LCA has the potential to guide research efforts towards maximising the final environmental performance and to influence technology development starting from the beginning. Furthermore, ex-ante evaluation can help decision-makers in determining new functions and uses of historic buildings. This evaluation tool has the potential to consider the potential negative environmental impacts before implementing a specific intervention and take decisions to mitigate them (Helming et al., 2012).

Giordano et al. (2021) used the Embodied Energy (EE) and the Embodied Carbon (EC) as indicators for the development of a calculation tool named EURECA for assessing the environmental impact of the building over its life cycle, while Twum-Duah et al. (2019) have focussed on reviewing and developing four existing load indicators for zero energy buildings: self-consumption, self-production, load shedding probability and coverage rate indicators. Some systematic literature reviews propose taxonomies of circularity indicators integrated in a life cycle perspective. Elia et al. (2017) analysed the ability of 16 environmental assessment methodologies (including LCA) to assess the circularity of a system at the micro-scale, as defined by (European Environment Agency, 2016). Saidani et al. (2019) identified a set of 55 indicators measuring circularity of which 18 are based on a life cycle perspective. Parchomenko et al. (2019) classified 63 indicators, indicator systems and assessment tools that measure circularity performance by organising them into a simplified scheme based on 24 elements identified to characterise circularity metrics. The classification proposed by Corona et al. (2019), on the other hand, relied on the distinction between measuring circularity and evaluating the effects of circularity as a criterion for the analysis of 19 metrics and evaluation methods.

The Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015) developed the Material Circularity Indicator (MCI) developed at product and company scale and then adapted it to measure the circularity of constructions. More and more reviews focussed on circularity indicators have been recently developed (Geng et al., 2009; Ghisellini et al., 2016; Iacovidou et al., 2017; Parchomenko et al., 2019; Saidani et al., 2019; Su et al., 2013). Starting from an in-depth analysis of 76 literature sources on how indicators are currently used in cultural heritage research and practice as impact assessment tools, Bosone et al. (2021) proposed a comprehensive evaluation framework (Circular Cultural Heritage Adaptive Reuse impacts assessment framework), performing a classification of the selected and analysed sources and indicators and defining 40 criteria resulted from different rounds of discussion conducted with an interdisciplinary group of experts. Particularly, from this study some criteria are considered most adequate to achieve efficient results in terms of (nearly) zero energy buildings such as energy efficiency (self-generation of energy sources for the operational phase through renewables, also reducing energy consumption needs through heritage-compatible technologies), freshwater efficiency (self-generation of water resources for the operational phase through water capture, filtering and reuse systems), nature-based solutions (regeneration of natural resources through nature-based solutions aimed to enhance air quality, freshwater quality, green surfaces), soil recovery (remediation of polluted soils and brownfields, land recovery through reuse interventions), construction and demolition wastes (avoided construction and demolition wastes through the adaptive reuse intervention), materials extraction (avoided raw materials extraction through the adaptive reuse intervention). These criteria were further detailed in specific indicators in the Deliverable D2.4 “Database of indicators and data in pilot cities” (available on www.clicproject.eu), in which a set of 62 quantitative and qualitative indicators divided into 11 indicators categories was built according to three main critical drivers identified as basis of the conceptual model of adaptive reuse of cultural heritage in the perspective of the circular economy: the regenerative capacity, the generative capacity and the symbiotic capacity (see: CLIC Framework). Specifically, in the regenerative capacity, the indicator category "Natural Capital Regeneration" is referred to circular solutions and is defined through 12 indicators for each of which the assessment method is specified: energy generated on site through renewable sources, energy performance level upgrade, carbon emissions per sqm indoor area, de-impermeabilization of soils, heat island effect reduction, reduction of freshwater consumption, rainwater recovered, reduction of raw materials consumption, use of regional resources, green surfaces, nature-based solutions, environmental remediation. From these, Foster and Kreinin (2020) performed a literature review showing the alignment between circular economy goals and adaptive reuse of heritage assets in a life cycle perspective.

A relevant aspect is the compatibility of materials and technologies considering the cultural landscape. The UNESCO Recommendation on the Historic Urban Landscape (UNESCO, 2011) highlights the need of addressing historic buildings reuse and recovery within a larger landscape perspective, taking into account the visual and perceptual impacts of reuse projects. Thus, cultural-aesthetic and functional aspects should be addressed together in the adaptive reuse design project.

1.4 The Horizon 2020 Project CLIC

In the European Horizon 2020 project "CLIC—Circular models Leveraging Investments in Cultural heritage adaptive reuse", innovations and innovative technologies become the necessary integration for successful impacts in the environmental, social and economic perspective, contributing also to the improvement of the building self-sustainability, thus minimising the external financial support. In particular, the CLIC project highlighted the role of energy technologies and innovative materials first of all in the adaptive reuse of abandoned/underused cultural heritage. The CLIC project stressed the value of cultural heritage/landscape in the circular city model in terms of connections between traditional and new technologies, interpreting the innovation as a factor able to improve the building metabolism, reducing entropy and multiplying benefits.

Cities are complex systems that are constantly evolving and represent the place where the majority of the world's population is concentrated (it is expected that by 2050 about 70 per cent of the world's population will live in cities). This is why they are also the most congested places where the most urgent challenges of our time such as climate change, the fight against poverty and inequality are at play. The question of how to "make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2015, 2017) is at the heart of many European documents that individuate in the human-centred approach (European Commission, 2019c, 2020c) the prerequisite for realising a model of cities capable of ensuring the social equity of the transitions envisaged both in the recent European Green Deal

(European Commission, 2019b) and in the definition of "A new industrial strategy for Europe" (European Commission, 2020b), adopting a holistic perspective.

The proposal of a human-centred circular regenerative model requires a paradigm shift in which all economic values coexist and evolve together with ecological and social/human values in a relational perspective, in order to consider "human well-being" (Hannis, 2016) at the core of economic development (Boulding, 2013; Capra, 1989; Costanza et al., 1997; Schumacher, 1973; Sen, 2003; Serageldin, 1999).

Considering urban systems as living organisms (Reflow project 2019), the adaptive reuse of cultural heritage is thus proposed as a strategy to transform dead urban systems into living ones (Fusco Girard, 2021) through the generation and regeneration of values on a multidimensional level. In fact, applying the circular economy model to the regeneration processes of urban systems also includes the consideration of "soft" aspects, which go beyond the "hard" ones specifically related to the environment and the built heritage, and which concern human and social capital. Aiming at the regeneration of these forms of capital, in addition to manufactured capital and environmental capital, (Fusco Girard et al., 2014) enhances the key role of creativity and innovation in the planning, design and management phases of development strategies. The circular regenerative approach thus conceived, on the one hand, succeeds in preserving existing (tangible and intangible) values, helping to regenerate the values of identity and belonging; on the other hand, it produces "new" values in multiple dimensions, the result of adaptation to changing needs over time, projecting them into an evolutionary development perspective fuelled by a synergetic, relational and cooperative culture.

Comparing urban systems to living systems means interpreting their complexity in terms of the impacts produced by the incoming and outgoing flows (i.e. their metabolism) on the processes of spatial transformation and on the socio-cultural dynamics of the people living in such systems. This relational and interconnected vision of the different components that make up a system implies an interpretation of the circular economy as an economy of co-evolution (Kallis & Norgaard, 2010) and relations whose objective is to rebalance flows to simultaneously meet objectives of economic development, environmental protection and improvement of people's quality of life and well-being, thus integrating the challenge of climate change with that of humanisation (United Nations, 2017).

Starting from this perspective, the CLIC project founded its approach on the evolutionary perspective/paradigm (Ayres, 1994; Schumpeter, 1943) paying attention to quantitative/qualitative impacts and quantitative/qualitative metabolism, considering them also in their circular mutual relationship. The adoption of the evolutionary perspective/paradigm is at the basis of the circular paradigm in which the evolution of the economic system is linked to technological innovations, thus stressing the attention to the node of energy and of metabolism. From this point of view, the analysis of building performance means the understanding of its metabolism, namely of the whole system of complex dynamics and flows that characterises both its internal functioning and the way it relates to the context.

2 Methodology

The methodology of this study is based on the review of literature sources and observation of selected case studies related to the renovation and reuse of existing buildings, with particular reference to historic buildings.

Literature sources include both scientific papers retrieved from Scopus/WoS database, and "grey" literature including policy papers and international independent organisations' reports published in the last ten years (2012–2022). Only sources published in English have been considered for this review. Literature sources have been selected according to the main topic addressed, focussing on assessment tools for building energy performance, circular economy in buildings, and indicators for the circular building and circular city. Through the analysis of available literature, key criteria are identified to achieve circular building performances in the renovation of the existing building stock, particularly historic buildings that pose more challenges related to the need of preserving authenticity and integrity. Thus, case studies are identified in which compatible technologies and materials have been used to reach high circularity performances in the renovation process. Based on the results of the case studies analysis, an abacus of technologies and materials for circularity in historic buildings renovation was realised, which could support decision-makers and professionals to achieve circularity goals in the reuse and renovation of historic building stock.

The following section presents the results of the literature review conducted and analyses case studies to identify compatible materials and technologies to achieve circularity in historic building renovation.

3 Materials and Technologies for Historic Buildings Renovation Circularity

Materials represent an important resource for the creation of products and services for society. Their use has followed a linear approach over time. They have always been used to perform specific functions and taken to landfill after their use. Over time, this system has produced significant impacts from an environmental point of view, referring to the pollution of natural ecosystems. The construction sector is one of the largest users of natural resources and is now considering the possibility of using materials that can be reused after the end of their first life cycle.

In this section, the scientific literature of reference has been analysed about the most advanced technologies and materials that are used for projects of reuse/renovation of historic buildings. Therefore, the scientific papers available on the Web of sciences platform have been selected and analysed. The search was done by keywords, i.e. new materials and technologies for the renovation/restoration of cultural heritage. The field of investigation was "materials science". More than 339,590 papers resulted in the Scopus database, which shows the relevance of the topic for the scientific community, however the choice was restricted to more recent papers published between 2018 and 2022 to ensure that the latest technologies and materials tested in recent years are analysed in line with new legislation.

A specific selection of relevant scientific articles was conducted based on those focussed on historic buildings, circular economy in existing buildings and energy retrofit. The results were integrated by "grey" literature consisting in institutional documents and reports. Selected papers were analysed and are briefly discussed in this section. From the review conducted, it emerged that the sustainable and "circular" reuse of historic buildings is mainly related to the issues of energy efficiency, the use of new materials and technologies and the problem of the reconstruction of missing parts of buildings or additions (Table 1).

Researches (Assefa & Ambler, 2017; Baker et al., 2017; Bullen & Love, 2011; Elefante, 2007; Foster, 2020a, 2020b, 2020c; Kubbinga et al., 2017; Munarim & Ghisi, 2016; Thornton, 2011) highlighted the environmental benefits of adaptive reuse of buildings, in terms of significant reductions in energy consumption and related greenhouse gas emissions, due to the implementation of innovative technologies and materials. To address these issues, most of the innovative solutions being proposed by researchers for cultural heritage reuse are related to the use of bio-materials and nanomaterials and the use of new technologies.

One of the most relevant issues in cultural heritage renovation is related to thermal insulation. In this field, researchers and designers try to find the best solutions in line with the principles of sustainability/circularity design. Among the first strategies to improve the thermal conditions of historic buildings, there is the use of new insulation materials. In this regard, Sobotka et al. (2021) state that renovation work for cultural buildings is being carried out so that it can be enjoyed by future generations. Nowadays the construction technology is changed: some construction products have been discontinued and replaced with others of different quality parameters, lower prices, etc. (Sobotka et al., 2021). For example, the use of pre-fabricated materials significantly improves the speed of execution of interventions (example: expanded polystyrene elements—EPS). A number of pre-fabricated materials have the feature

Table 1 Literature review

Topics	Reference
Conventional insulation materials	Assefa and Ambler (2017); Baker et al. (2017); Bullen and Love (2011); Elefante (2007); Foster (2020a, 2020b, 2020c); Kubbinga et al. (2017); Munarim and Ghisi (2016); Thornton (2011); Sobotka et al. (2021)
Bio-materials	Angrisano et al. (2021); Arup (2017); Foster (2020b)
Nano-materials	Tenpierik (2010); Buratti et al. (2016); Zhao et al. (2015); Abdelrady et al. (2021); Lamis Mendes et al. (2021); Ganobjak (2020); www.energy.gov
Technologies	Interreg Central Europe (2018); Murphy et al. (2009); Elabdy (2021); www.innovafvg.it

that they can also be reused (Sobotka et al., 2021). Among pre-fabricated materials, there are ones that are used for the thermal insulation of buildings usually realised with polyurethane, called panels VIP (Vacuum Insulated Panels). Vacuum Insulation Panel (VIP) technique is considered a promising solution for providing high-performance thermal insulation in buildings due to their ultra-low thickness (5–50 mm) and very low thermal conductivity (0.002–0.004 W/(m K)) compared to conventional insulation materials; these values are ten times less than those of conventional insulation materials used in buildings today (Abdelrady et al., 2021). Therefore, Vacuum Insulation Panels (VIPs) are considered by many to be the most suitable material for walls, roofs and floors in new and refurbished buildings where space is limited (Tenpierik, 2010). There are other types of insulation panels made from natural materials (hemp, cork, wood wool fibres, cellulose, etc.). Therefore, the use of natural hemp fibre panels is diffused for roofs and internal walls and on some floors against the ground. Hemp panels are materials characterised by low thermal conductivity, both in hot and cold conditions. They are particularly suitable for very humid environments. Compared to other insulation materials, hemp has the advantage of absorbing moisture and releasing it over time. Its breathable properties counteract the onset of interstitial condensation, creating healthy living environments, free of bacteria, mould and microbes. In addition, hemp fibres are characterised by countless environmental advantages: (1) they produce oxygen and absorb large quantities of CO2 from the atmosphere; (2) they are completely renewable natural fibres; (3) it is a low-energy input crop; (4) it is an environmentally advantageous material, in fact if we consider the CO2 absorbed by the plant during cultivation, its carbon footprint is close to zero (Angrisano et al., 2021). Use of natural materials would trigger a different approach in construction by allowing a number of benefits with respect to traditional materials options by having lower CO2 content, reducing health risks and cost.

Arup is currently investigating the production of building materials from organic waste processing. Intercepting current low value organic waste streams, both from the countryside and our cities, would reveal an opportunity to issues such as organic waste streams, that represent a costly problem in both economic and environmental terms (Arup, 2017). In recent years, Arup developed different protocols about new materials for architecture, like BIQ Hamburg (a new green building in Hamburg), first façade system in the world to cultivate microalgae to generate heat and biomass as renewable energy sources (Arup, 2017). In this project structural glass photo bioreactors are used as external cladding elements and dynamic shading devices (Arup, 2017). The Mushroom Tower is the first example of a structure (designed by Arup) albeit temporary, made by using mushrooms as base materials. In fact, mushroom bricks have been used to create the structure of three towers for an installation for the MoMA in New York City. The mycelium, the base material for the bricks, is a microscopic, fibrous fungus that binds itself to its food source to create a strong, resilient matrix in any shape desired (Arup, 2017). The Bio-Build project explored the use of natural-based composites to create the first worldwide bio-composite system for structural facades. Bio-composites are composed of natural fibres such as flax, hemp and jute and natural resin derived from residual waste from sugar cane and corn harvesting. These are fast-growing plants that regenerate in short cycles (Arup, 2017). Vegetal wastes are non-hazardous, from the treatment of these wastes it is possible to make biological materials for construction. Their use will not lead to an increase in negative impacts on the environment or negative impacts on human health. Today, organic waste is used to make panels for interior and exterior building finishes, furniture (made from natural fibres), insulation materials, etc. In a report by Arup, there are a lot of interesting examples of new construction materials made from organic waste. For example, residual waste from "corn cobs" can be used to make a stiff core for sandwiches. These can be combined with flat boards obtained from other organic waste (Arup, 2017). According to Arup's studies, there are other bio-materials that can be used for the production of insulation panels, such as cellulose, sugarcane, sunflower, peanut, seeds, stalks and leaves, flax, potato, rice, wheat and pineapple. They can be used to produce panels with different shapes and features by adding, where necessary, water, heat, pressure and no additives. Foster states that materials made from biomass processing are much more efficient than materials made from fossil fuels. They are less toxic, biodegradable and have a lower life cycle impact (Foster, 2020b).

Scientists and designers are also experimenting with the use of nanotechnologies to create innovative building materials. Furthermore, for the thermal insulation of the walls, the technique is constantly evolving, to adapt to different needs and situations. For example, the use of nanotechnologies represents nowadays the most advanced technology for the creation of ultra-thin coats. Thermal insulation with nanotechnology materials is recommended when buildings need to be insulated with a thin thermal envelope, or when there are historical constraints. Among nanomaterials, nanogel has come to be considered as one of the most promising nanomaterials to use in energy-efficient buildings (Buratti et al., 2016; Zhao et al., 2015). Nanogels are nanoparticles made up of hydrophilic polymers that are physically or chemically cross-linked (Abdelrady et al., 2021). In a study of Abdelrady et al. (2021), it reads that nanogel is highly porous and lightweight, with very low thermal conductivity, it also has good optical transparency and high acoustic insulation. Nanogel is currently in use throughout the building insulation market for filling between double-glazed (DG) windows, multiwall polycarbonate panels or methyl methacrylate panels. It can be used for facades, skylights, roofs and walls. For Lamis Mendes et al. (2021), instead the best solution to enhance thermal conditions inside historic buildings is tied to the use of aerogels, the most promising thermal insulation materials in recent decades. Nowadays, the incorporation of aerogels into various matrices to replace more conventional materials is growing, because it is a very light substance, with a slid consistency similar to a gel composed of 98% air and 2% amorphous silicon, which is the main component of glass (Lamis Mendes et al., 2021). In appearance it is a solid foam, which among many properties such as withstanding high temperatures, also boasts that of being an excellent insulator. It is an insulating material that can be used as panels, blankets, cement, mortars, concrete, glazing systems, solar collector covers, among others (Lamis Mendes et al., 2021). Ganobjak et al. (2020) assert that nanogel physical properties, foremost their low thermal conductivity and their vapour diffusion openness, make aerogel materials well suited for application in historic buildings. Because of the drastically improved thermal envelope, moisture problems due to condensation on cold building elements, which can give rise to mould and bacteria growth, can be avoided (Ganobjak, 2020). This is especially important for historical buildings as the goal is to protect the historical building substance as well as possible (Ganobjak, 2020).

Another important material used for the thermal insulation of buildings is the heat-reflecting insulator. It is characterised by one or more reflective surfaces and is combined with air gaps. The insulation properties are given by the low emissivity of the material. It is a very flexible material (because it is produced in rolls) and inexpensive (www.energy.gov). Also, cool materials are used for wall thermal insulation. They are cladding and finishing materials for roofs, facades and outdoor floors that reflect and disperse a high proportion of solar energy, preventing the heating of urban structures and improving thermo-hygrometric comfort.

With regard to technologies, a recent report of Interreg Central Europe affirmed that the study and use of new systems for mapping and monitoring cultural heritage is becoming prevalent, such as recording methods 3D scanning, electronic tacheometry, digital photogrammetry, drone photography, laser scanning, degree photography, visualisation techniques 3D, GIS, diagnostic methods, thermography, damage inspection, nuclear magnetic resonance, thermal analysis, X-ray computed tomography etc. (Interreg Central Europe, 2018).

The use of Building Information Model (BIM), and Heritage BIM for cultural buildings, nowadays represent the most predominant design method. Murphy et al. (2009) affirm that preservation of historic buildings is a continuous resilient and sustainable ongoing process. For this reason, the integration of HBIM and IOT (Internet of things) tools is capable of supporting this process and simultaneously produces various benefits especially about the visualisation and collection of all data about the buildings (Murphy et al., 2009). Although HBIM shows a great potential in achieving resilience, as it works as a documentation, visualisation, simulation tool, however there is a need for smart tool/software that could be installed in the building to detect any hazards or unsafe actions, then develop reports/mitigation plans to mitigate these clashes automatically, besides ensuring more connection between the building and users/people (Elabdy, 2021).

In the field of historic buildings conservation, also the use of sensors to monitor the internal temperature of buildings and the deterioration of materials is widely used. In this framework, in addition to traditional sensors, the set-up of innovative and effective nano-sensors opens up new interesting applications for cultural heritage conservation (www.innovafvg.it). Sensors for such applications need to have a number of features, such as high sensitivity, non-contact operation, stability and robustness, relatively fast time response and recovery time, while maintaining a very small size, being low cost and with low operating power, which is associated with low power (thermal) dissipation in the area (www.innovafvg.it). The advantage of using nano-sensors lies mainly in their small size, which allows them to be placed close to the interested surface. Their type of operation does not involve electrical interrogation which could be vulnerable to the effects of magnetic interference, and their sensitivity (www.innovafvg.it).

Another solution for energy renovation of historic buildings is the “photovoltaic windows”. These are real windows made of photovoltaic glass that can absorb solar radiation to generate the electricity needed to meet the needs of a housing unit. The visual impact is zero, as a transparent gel containing amorphous silicon is used, which is applied to the surface of the individual pane or inserted into the cavity of an insulating glass unit. Photovoltaic glass can have a transparent, semi-transparent or coloured appearance to fully adapt to the environment in which it will be placed and allow greater architectural integration. Also available is chromogenic glass, a special system capable of modifying optical properties in response to a light, electrical or chemical stimulus from an external environment. They are used extensively in glazing where there is no solar shading. Regarding photovoltaic technologies, photovoltaic panels and roof tiles are often used for the recovery of historic buildings. There are particular photovoltaic tiles that are called “invisible” because they have the colour of terracotta tiles, designed for historical centres to ensure a perfect architectural and aesthetic integration. They are formed by a single body, indivisible, with a very high resistance that hides and protects the photovoltaic cells incorporated within it. In each case, the mitigation of the impact of photovoltaic panels to be installed on historic buildings is possible through a reflection on these elements and a study on the arrangement of the panels so that they do not alter the general lines of the building. In the case of insertion on the roofs these must be arranged with “the same inclination and orientation of the pitch”, with the objective of avoiding volumetric alterations.

Finally, Nature-Based Solutions (NBS) are very often used on flat roofs and external walls of buildings. This technology consists of low-maintenance *sedum*-like vegetation. It involves the planting of essences capable of surviving in situations of extreme drought, with a high capacity for regeneration and self-propagation. This technological finish provides several benefits to buildings, including protection from waterproofing and regulation of the microclimate by lowering air temperature. In addition, a layer of insulation material is applied to green roofs to maximise energy savings.

3.1 Case Studies

In this section, a series of relevant case studies are reported in order to understand which are the most used materials and technologies in already realised projects of renovation of cultural heritage, which can be considered as good practices. Both Italian and European case studies have been analysed. The case studies include those published by the Italian Ministry of Cultural Heritage (MIC), those by GBC Italy, as well as some that emerged from the literature review in the previous section.

Among the cases presented by the MIC, the renovation project of the eighteenth-century Malta Stock Exchange building in Valletta is a good example of the reuse of an abandoned cultural building. The building originally consisted of one large empty space covered by a wooden roof truss structure. On either side of this building, two glass bodies have been built to be used as new offices. These areas are built using an exposed structure of steel columns and lintels with glass partition walls, while open office spaces bridge under the restored wooden truss roof. These spaces are cooled and heated by a hybrid system that allows natural ventilation during the day and at night. A distinction was made between the existing masonry walls and the new structure (Table 2).

The design of the Borghesan house in Padova (Italy) was characterised by a series of objectives that guided all the design choices, i.e.: respect for all the mouldings and façade friezes that so strongly characterised the Art Nouveau building; the restoration of masonry parts attacked by damp; the systematic recovery and reuse of all the original materials and artefacts involved in the intervention, including the large south windows and the original doors; the use of materials from renewable sources; and the systematic implementation of interventions that were as reversible as possible. A perimeter excavation was carried out around the entire house to avoid direct contact between the perimeter walls and the ground. A rainwater collection pipe was inserted in this excavation, and an external crawl space was built to allow air to circulate, allowing the masonry to dry out. On the exterior façades, a thermal insulation system was realised. The sections of the building that had mouldings and friezes were covered internally with a coat made of 6 cm wood fibre panels that contain a functional mineral layer on the inside that guarantees a controlled passage of humidity and allows for the proper diffusion of vapour and capillary water transport. The roof was insulated with a breathable sheathing and a layer of 20 cm wood fibre panels. Furthermore, the ventilation of the roof allows excess moisture to be disposed of. A Controlled Mechanical Ventilation system with heat recovery has been installed (Table 2).

A case of post-war reconstruction (Thirty Years War) instead concerns the mediaeval Castle of Moritzburg in Germany. The former Moritzburg Castle in the city of Halle is an example of Gothic military architecture typical of late fifteenth century Germany. Over time, the building has undergone numerous modifications, but it still retains the original structure of its main architectural elements: the surrounding wall, three of the four round towers at the corners and the central courtyard. It was a very significant renovation intervention, as the parts to be reconstructed were all built in line with the principles of sustainable architecture. For example, the roof was reconstructed using the principle of a ventilated roof, the conical skylights with ventilation flues were inserted and the entire interior was reconsolidated with reused materials (Table 2).

The energy conversion of the building Rue Fauriel in France, on the other hand, has been a significant intervention of insulation of the façade glazing, in fact the southern facade is characterised by the presence of many windows. The roof tiles were preserved and the polycarbonate roof was replaced by energy-efficient double glazing. Internal insulation was then implemented to avoid all thermal bridges, through the use of wood panels inserted in the interior wall, consisting of two layers of 100 mm and 200 mm wood wool. An air gap was created between the existing wall and these new panels to reduce heat transmission inside and outside. These insulation layers are also present in the lower part of the roof, in the form of three layers of insulation. Heating is provided by a geothermal heat pump in two 99 m wells (Table 2).

Table 2 Case studies

Case study	New technologies and materials used	Source
Building of the Malta Stock Exchange	• natural ventilation • Sunscreens applied inside the windows • photovoltaic panels	MIC 2015. Guidelines for the improvement of energy efficiency for cultural heritage
Casa Borghesan in Padova	• insulation of the external and internal envelope • substitution of the fixtures • ventilated roof	MIC 2015. Guidelines for the improvement of energy efficiency for cultural heritage
Castle of Moritzburg in Germany	• ventilated roof • ventilation flues	MIC, 2015. Guidelines for the improvement of energy efficiency for cultural heritage
Rue Fauriel in France	• insulation of the façade glazing • thermal storage system insulation of internal walls • geothermal system • heat pump boiler • natural ventilation	MIC 2015. Guidelines for the improvement of energy efficiency for cultural heritage
Palazzo Mozzi Bardini in Florence	• new aluminium windows with double glazing with protective film for the reduction of ultraviolet radiation • ventilation roof • more efficient lighting system	MIC 2015. Guidelines for the improvement of energy efficiency for cultural heritage
Palazzo Guinelli in Ferrara	• introduction of a glulam structure in the building, covered by a green walkable terrace • natural insulating materials • insertion of an internal coat along the walls of all the floors • heating/cooling system with radiant underfloor heating and cooling panels,	www.gbcitalia.org
Sant' Apollinare in Perugia	• trigeneration plant fed by biomass and biogas coming from the building's wet waste • reuse of rainwater for toilettes	www.gbcitalia.org

(continued)

Table 2 (continued)

Case study	New technologies and materials used	Source
National Museum of Italian Judaism and the Shoah in Ferrara	• management and recovery of drinking water, wastewater and rainwater • use of reused materials for the realization of new architectonic elements • renovation of air conditioned system	www.gbcitalia.org
San Giuseppe of Falegnami in Rome	• Two layers of wood fiber insulation • use of new materials for the reconstruction of new elements	www.gbcitalia.org
HAKA-building boasts Rotterdam	• use of reused materials for the realization of new architectonic elements • use of doors coming from other disused buildings	www.iabr.nl
Venlo project, Rotterdam	• realization of a green passport of all new materials • use of reused materials for the realization of new architectonic elements	www.c2c-centre.com

The project of Palazzo Mozzi Bardini in Florence is significant for the renovation of the plant and structural system and the realisation of a new exhibition section covered by a real solar greenhouse. The existing windows have been replaced with new aluminium windows with double glazing and protective barrier for the reduction of ultraviolet radiations. To mitigate the excessive heat during the summer periods, sunscreens have been inserted. The roof has been totally restored with a double ventilation system. Also, the whole lighting system has been replaced with a much more efficient system (Table 2).

Green Building Council (GBC Italia) promotes the dissemination of the best practices about the reuse of cultural buildings according to the sustainable principles. Moreover, they launched the "green building council protocol" to certify the circularity of historic buildings renovation, that follows the LEED certification principles. GBC Historic Building is the protocol for voluntary certification of the level of environmental sustainability of conservation, rehabilitation and integration of historic buildings in respect and protection of their historical, heritage and cultural value (www.gbcitalia.org). With this protocol, a number of reuse projects of historic buildings have been verified and certified (Table 1). The project for Palazzo Guinelli in Ferrara is one of these. The eco-sustainable project has included the introduction of a glulam structure in the building, covered by a green walkable terrace. Roof was completely disassembled and restored, with the inclusion of an insulating layer. All the insulating materials are natural, of recycled origin and with recyclable properties (Angrisano et al., 2019). The energy requalification project was carried out with the insertion of an internal coat along the walls of all the floors. Instead, the plant engineering project started with the idea of respecting the place and exploiting the peculiarities of the building and its original ventilation ducts (one of the very few cases of a historical air conditioning system in Italy). A heating/cooling system with radiant underfloor heating and cooling panels, laid dry and/or nailed to the floor, has been inserted (Table 2) (www.gbcitalia.org).

A reuse project based instead on a completely concept green is that of Sant'Apollinare in Perugia. The new building is self-sufficient thanks to a trigeneration plant fed by biomass (vegetable oil from the thistle, oleaginous biomass from the surrounding countryside) and biogas coming from the building's wet waste (Angrisano et al., 2019). Furthermore, the building's manholes are connected to a rainwater collection tank, which is used for flushing toilets (Table 2) (www.gbcitalia.org).

The project of the National Museum of Italian Judaism and the Shoah in Ferrara had as its first objective to ensure the recycling of water, considered as a valuable asset. The designers have developed an efficient system for the management and recovery of drinking water, wastewater and rainwater. All the plant components and all the energy systems of the building have been optimised in order to achieve an overall energy performance based on all energy consumption with an improvement of 25% compared to the reference building. Particular attention was given to thermal and visual comfort by increasing the possibility of personalised use by users in common and private rooms. All waste from the construction site has been recovered, achieving a reuse rate of over 97%. In addition, in order to ensure a high quality of indoor air, the building has been air conditioned with primary air system and fan coils, with the air changes provided for the healthiness of the environments (www.gbcitalia.org).

The church of San Giuseppe of Falegnami in Rome is another very significant example of renovation. It is the first case of a religious building that has adhered to the GBC verification system. In 2018, part of the roof collapsed causing the wooden golden caisson and marble floor. Once the safety work was completed, the actual restoration site was started, which immediately had as its objective to ensure the sustainability of the work, applying and sometimes exceeding the minimum environmental criteria required by current legislation (www.gbcitalia.org). Two layers of wood fibre insulation with different densities were installed over the double planking of the roof. This intervention has contributed to the maintenance of the microclimate necessary for the conservation of the wooden structures. The construction waste has been recovered for the consolidation and reconstruction of the walls. Where necessary, the use of new materials has been chosen on the basis of their environmental impact throughout the production cycle (Table 2).

About some case studies which emerged from the literature review, the most significant are those of "HAKA-building boasts" and "Venlo project" in Rotterdam. The first one is very innovative. It was an old factory converted into offices with an auditorium, a meeting room, kitchen spaces and an exhibition area. All interior spaces were created with materials from demolished buildings and other reused materials. For example, the coloured walls were built with 8000 kg of old clothes, while the doors were made of recycled materials from other buildings. **Venlo** project is an old school which has been converted. The innovative idea is to realise green material passports were made. Here too, all the materials used came from the demolition of other buildings. The residual products were then transformed into new products and materials such as an acoustic wall made of old doors and the use of recycled fabrics for the soft fabric finish (www.c2c-centre.com) (Table 2).

In the case studies analysed, an improvement in energy performance and a reduction in water consumption were reported, also thanks to the use of water reuse and storage systems that were already in place because they were fundamental to the management economy of the historic building at its origins. Furthermore, for all the case studies analysed, the solutions and materials chosen were approved by the Italian Cultural Heritage Superintendency and the competent authorities of the European cities.

Moreover, to better cover the objectives of the Paris Agreement related to the climate change, considering that "75% of buildings in the EU are not energy efficient""(European Commision, 2020c), the most suitable materials and technologies able to reduce the negative environmental impacts are those related to bio-building, i.e. natural and recycled materials, realised by locally sourced resources, and the use of renewable energy. It is necessary to perform a careful design in buildings construction, ensuring the well-being and comfort of people without placing an excessive burden on the environment.

In the next paragraph, an abacus of innovative materials and technologies most used for the reuse of cultural buildings was proposed, which comes out from the analysis of the literature and case studies examined.

3.2 Abacus of Innovative Materials and Technologies for the Reuse of Cultural Buildings

From the analysis of the reference literature and case studies, an abacus of materials and technologies that are currently used in projects for the reuse of the historic built heritage has been identified. These materials and technologies have been already used in relevant retrofit and reuse projects of historic buildings and approved by heritage authorities, therefore they can be considered compatible with historic buildings conservation (Table 3).

The use of nanomaterials appears to be the most studied and applied solution by designers today for the reuse of cultural heritage. But, throughout their entire life cycle, the production of nanomaterials has a number of negative effects on the environment (extraction, production and disposal). They are specifically created using a variety of techniques, including physical, chemical, and biological processes. The first two procedures are the ones that take a lot of energy and result in a variety of

Table 3 Abacus of innovative materials and technologies for the reuse of historic buildings

Materials for thermal insulation
VIP (Vacuum Insulated Panels)
Bio-based materials (hemp, cork, wood wool fibres, cellulose, sugarcane, sunflower, peanut, seeds, stalks and leaves, flax, potato, rice, wheat, pineapple)
Aerogel
Nano plasters
Heat-reflecting insulator
Cool materials
Technologies for higher energy performance in historic buildings
Nature-Based Solutions (NBS) (principally green roofs and facades)
Photovoltaic windows
Photovoltaic panels and roof tiles
New triple and double-glazed windows
Sunscreens
Natural ventilation
Ventilated roof
Heat pump boiler
New systems for air conditioned
Glulam structure
Green walkable terrace
Radiant floor
Solar panels for hot water
Trigeneration system plant fed by biomass and biogas
Rainwater recovery system
Wall covering with recycled clothing
Use of doors from disused buildings
New system for mapping, monitoring and designing high energy performance of historic buildings
Nano-sensors
Electronic tacheometry
Digital photogrammetry
Drone photography
Laser scanning
Degree photography
Visualisation techniques 3D
GIS

(continued)

Table 3 (continued)

Diagnostic methods
Damage inspection
Nuclear magnetic resonance
Thermography
X-ray computed tomography
Thermal analysis
BIM-HBIM

environmental contaminants as well as a huge number of harmful byproducts. For these reasons, the use of bio-materials represents the most satisfactory solution.

4 Discussion and Conclusions

This contribution aimed at identifying compatible materials and technologies for the circular adaptive reuse of historic buildings, ensuring high energy performance levels, reduction of emissions and wastes in the perspective of the circular economy. Based on case studies analysis, an abacus of compatible materials and technologies is provided. However, it should be noted that to ensure high energy performances within the whole life cycle of buildings, technologies and materials, a more comprehensive "life cycle" approach should be implemented in the analysis of energy performances and GHG emissions for the reuse of historic buildings. Particularly, the "embodied energy" of materials and technological solutions should be addressed to include all potential externalities of the adaptive reuse and retrofit process within the overall performance assessment.

Clearly, in the field of historic buildings renovation and reuse, there is no "one-size-fits-all" solution, as all historic buildings and sites are different and have unique features, however the results of this analysis can be useful to support designers and decision-makers towards higher energy performance of historic buildings, to reach climate and emissions targets at national and global level.

Furthermore, it is also necessary to consider that any building work to be carried out on historic buildings is governed by the cultural heritage code (also called the Urbani code) Legislative Decree 22-1-2004, no. 42. In this legislation there are all the admissible interventions on cultural heritage. In particular, in Presidential Decree No. 31 of 13 February 2017, there are listed all the sustainable and "green intervention" on cultural heritage (photovoltaic panels, micro wind generators, technological installations, interventions on facades, etc.).

Materials and methods for the conservation and restoration of cultural heritage can often be energy consuming, not environmentally friendly or even harmful for the health of operators and curators. Moreover, many of these materials and methods prove to be neither durable nor sustainable, often leading to repetitive and costly restoration of artefacts, monuments and heritage sites. In this context, proposals under this theme should provide solutions and explore ways for quality conservation and restoration in a green and sustainable way. Designers should develop effective and sustainable strategies that are feasible, easy to use, accessible, and safe for practitioners and artefacts to ensure long-term preservation and physical access to cultural heritage resources. Monitoring the condition of artefacts, monuments and sites with technological solutions should also be considered. Materials and methods proposed for remedial or preventive conservation and restoration should be green, durable and sustainable. In addition, the elaboration of traditional methods and materials, as well as digital and cutting-edge technologies, should be developed or further exploited as needed.

The effort to achieve a socio-ecological transition (Sabato et al., 2021) depends on collective responsibility and intergenerational and international solidarity. The current climate crisis can be seen as an opportunity for innovators and investors, companies and cities, as well as consumers, families and individuals to enjoy the benefits of a more sustainable environment, which succeeds in preserving ecosystem balances, protecting existing natural capital, improving the quality of life by reducing pollution, increasing green spaces, cleaner air, cooler and greener cities. Improving these aspects means taking significant steps to address climate change, starting with converting our cities into places of health and well-being, and therefore into places where people want to live and work. There is a need to readapt and reuse the built environment, combining energy efficiency to achieve almost zero-carbon buildings and at the same time the need to preserve and regenerate the healthiness, identity and beauty of cities, to increase the attractiveness of European cities as places where sustainable development dynamics can be truly implemented through the creation of new jobs, technological experimentation and social innovation. This study showed how appropriate materials and technologies for the reuse of cultural buildings are key to ensure the balance between cultural and environmental values preservation.

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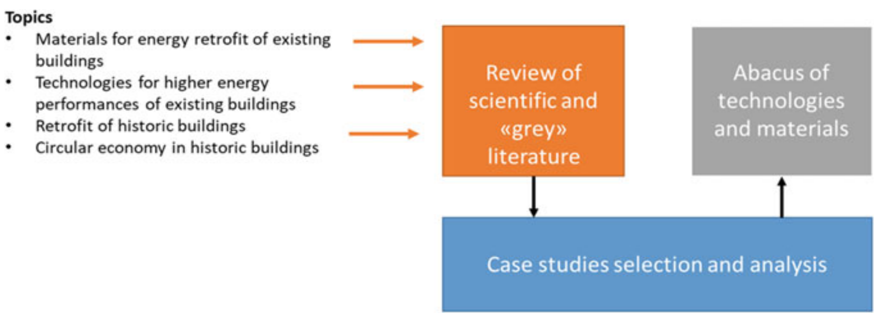

Fig. 1 Methodology of this study

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Urban Liveability Planning

Green Liveable Urban Futures: The Integration of Nature-Based Solutions into Planning as a Strategy for Regreening the Post-oil City

Steffen Lehmann

1 Introduction

Cities are centres of consumption: 75% of our natural resources are consumed in and by cities, while cities are responsible for 50% of the world's waste and emit approximately 60–80% of global greenhouse gases. Moreover, by 2030, metropolises must solve the challenge of accommodating more residents, offering a higher quality of life, and buffering the consequences of climate change. This is a considerable list of challenges. At the same time, urban ecosystems are increasingly under stress, as they must withstand more frequent and longer dry periods, with increasing heat, air pollution and water shortages (IPCC, 2018).

Over recent years, the quality of life in many cities has continued to decline. The reasons for this decline include air pollution, urban heat, ever-increasing traffic—mostly private cars—and housing that has become unaffordable. Therefore, we must plan ahead better, including for the further increase of urban populations and green spaces, so that we do not lose the liveability of our cities that we currently enjoy.

Cities need to change the way they grow. As many of the fast-growing cities expand, they end up building over floodplains, forests and wetlands that could absorb rising waters during a storm and urban flooding, or hold reservoirs of water during a drought (Gates, 2021). Forests and wetlands store and regulate water, prevent floods and provide fresh water. Restoring ecosystems as a natural defence against climate change (e.g. by planting mangrove forests along coastal cities) has also a significant payoff as it reduces the pressure on urban water utilities.

This chapter has a close look at the numerous health benefits that result from applying the concepts of urban renaturalisiation and regreening the city by weaving nature back into the urban fabric. Vegetation and, in particular, tree planting, green roofs, regreening and rewilding, offer multiple benefits to the urban climate, health

S. Lehmann (✉)
School of Architecture, University of Nevada, Las Vegas, NV, USA
e-mail: Steffen.Lehmann.Cities@gmail.com

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and well-being by contributing to decreased levels of harmful pollutants in the air, reduced ambient temperatures and heat-related mortality.

The term *nature-based solutions* (NBS) refers to the use of nature for addressing environmental, cultural and societal challenges while increasing biodiversity and balancing urban temperatures. According to the IUCN (2019; note: IUCN is the International Union for Conservation of Nature), NBS are "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". The solutions can include green roofs, green walls and sustainable drainage systems. Green wall is a term that encompasses all forms of vegetated wall surfaces, whereas green screens consist of steel or plastic mesh on which climber vegetation grows.

Evidence shows that people who live in neighbourhoods with more trees, greenery and easy access to green spaces experience lower levels of stress and mental illness, confirming the concept of *biophilia*—the idea that humans have an innate desire to connect with nature (Kellert, 2011; Rachel & Stephen, 1989; Roger, 1993; Ulrich et al., 1991; Wilson, 1984). Alongside the ecosystem services and biomass that urban vegetation provides, trees and other plants have qualities that cannot be easily quantified in monetary terms, including aesthetics and meeting people's psychological needs to experience nature. Establishing and reinforcing people's connection with nature is widely recognised as critical to their mental and physical health.

Nature is essential for human existence, urban well-being and a good quality of life. Green spaces in cities—big or small—all contribute to health and well-being. However, many cities, including in the United States and in Europe, do not offer fast and easy access for residents to green space and nature within the city. Improving better access to green spaces and extending gardens and parks would offer a large number of advantages, such as NBS integration and ecosystem services (including better water management, enhanced urban flood controls, slowing down the loss of biodiversity, contributing to food security, and even restore damaged ecosystems). Furthermore, it is widely acknowledged that additional green space helps to keep cities cool during heatwaves.

Trees have all kinds of benefits, both aesthetic and environmental. Stopping deforestation and planting trees is by far the cheapest and lowest-tech way to capture carbon dioxide from the atmosphere. A tree can easily absorb over four tons of CO_2 in its lifetime (assumed lifetime of 40 years). Native trees in a tropical climate cause more cooling, because they release a great deal of moisture, which transforms into clouds. There are many services that nature provides if the ecosystem is not damaged: including a capacity to absorb and store carbon, clean polluted water, reduce flood risk, produce abundant food and biomass, and multiply species and enhance biodiversity. Nevertheless, natural landscapes in cities have become limited, degraded and replaced with impermeable hard surfaces, such as roads, paving, parking lots and buildings; and the reversal of this trend is still in its infancy (Xing et al., 2017).

Analysing the distribution and performance of green spaces in different metropolitan areas is of relevance, as it reveals the neighbourhoods with a lack of green space; and these areas should be enhanced first by enabling all categories of green, including: public parks, gardens, playgrounds, constructed wetlands, dog running areas, roof gardens, green walls, rewilding zones and so on. Regreening has become a powerful strategy with which to bring back flora and fauna, including butterflies, insects, birds and wildlife into the urban context. Regreening is not a contradiction to increased urban densities and does not necessarily lead to a low-density, dispersed or car-dependent city model. Higher densities allow for the creation of new green spaces. However, as the discussion of this chapter shows, it is essential that the design of the NBS strategies is fully integrated with other complementary planning interventions and seeks synergies across all sectors, integrating regreening scenarios as part of a whole systems approach.

Hence, the aims of this chapter are to explain the different kinds of actions useful for implementing urban greenery, underlining the innovative contribution of nature-based based solutions to the urban project for regreening cities. The applied methodology includes comparative case study research of the various trends and the effectiveness of various solutions applied.

The chapter recommends the integration of nature-based solutions as a practical strategy in urban design and planning with the aim to strengthen resilience, improve health conditions, slow down the biodiversity decline and reduce the dangerous urban heat island effect. Additional green spaces contribute to keep cities cool during heat-waves and improve the urban microclimate. Of particular interest is the regeneration of neglected parts, such as postindustrial brownfields or economically weak districts, where regreening and rewilding concepts can have their most positive impact. Recovering and restoring streams, salt marshes and woodlands is now a vital part of how cities can adapt to future climate change.

2 Towards a Post-oil City: The Need for Urban Regreening

The *Post-Oil City* is a city that has moved from its previous dependency on fossil fuels as energy source towards being a city that is entirely run on energy from renewable, clean energy sources. This transition from fossil fuels to renewable energy affects the process of urban planning, the mobility systems and other essential infrastructure. Nevertheless, what is the role of nature in the urban context?

Our current disconnect from nature has evolved over the last 300 years with the emergence of science, technical progress, and the subsequent Industrial Revolution. Within a short time, humans have experienced a transition from a life predominantly spent outside towards a vastly different life spent mostly in cities, inside buildings—resulting in a fundamental change in our relationship with nature. For example, more than 80% of the US population currently lives in urban areas, with a substantial proportion being 'estranged from nature' (Office for National Statistics, 2016, 2). Today, we spend over 90% of our lives indoors, in controlled interior environments (ASHRAE, 2010), with an increasing amount of time spent on 'screen time' online.

Over the centuries, humanity has become a force that changes the planet, and this change has become so fundamental that it has finally commenced to affect the earth

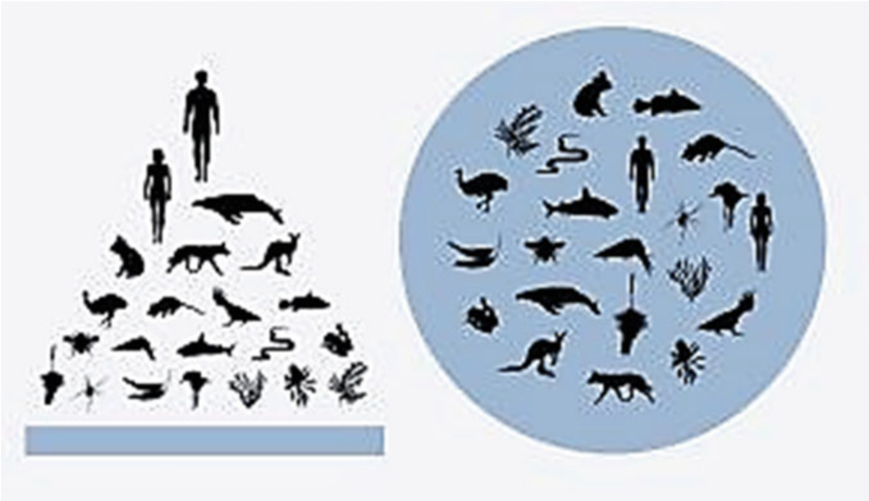

Fig. 1 The two different belief systems, where humanity is either above nature, exploiting it, or part of the same ecosystem (Lehmann, 2008)

system. In 2020, it marked a cross-over year when scientists found that the total weight of all human-made and built objects have for the first time exceeded that of all living things (known as biomass) on our planet. In other words, the combined weight of all buildings, roads, plastic, bricks, concrete and other things humans have made outweighs all animals and plants (BBC 2020) (see Fig. 1).

We face an array of societal and technological challenges, which in the past we have tried to solve in ways that were not always successful, using outdated fossil-fuel-based urbanisation models. This has led to urban sprawl, biodiversity loss, increased inequality, and global human vulnerability. An urbanisation model resulting in urban sprawl is wasteful in terms of land use, energy use and other resources—including wasted time, which would be better spent with family than being stuck in traffic.

2.1 Towns, Sprawl and the Hinterlands

Every city is unique. Cities differ in not only their size, density and the distribution of their green spaces, but also in their climatic, social and cultural contexts, geography, demography, topography, and in the ways in which they are vulnerable to climate change. When it comes to enhancing urban resilience through applying NBS and regreening strategies, what works in one city may not work equally well in another. However, urban regreening projects generally allow for repairing and restoring some of the damage caused to ecosystems while enhancing resilience.

Green spaces and gardens play a particular role in this. Our ancestors built gardens long before they built homes: the emergence of the garden dates back over

400.000 years, when the nomadic hunter-gatherers became gardeners; while the construction of individual dwellings dates back only around 12.000 years. With the rise of agriculture outside the settlements, the garden became also a place of refuge; for example, in Chinese and Arab history, gardens were built for delight and contemplation rather than for food production. Throughout history, 'paradise' has often been depicted as a walled garden and protected place (see Fig. 2). The surrounding wall clearly depicts the boundary between what is protected inside (e.g. plants, cattle), and what is outside of the garden territory.

Long lost is the productive and carefully balanced relationship that once existed between towns, cities and their hinterland (the urban–rural interface). Today, due to the lack of effective urban growth boundaries for most cities, far too many suburbs are being planned and built on greenfield sites that were formerly protected green-belt land. At the same time, sufficient brownfield land for urban infill and regeneration would be available, but is frequently ignored. For example, there are sufficient brownfield sites for accommodating an extra million new homes in England alone, and hence there would be no need to further encroach on precious greenfield land which should be protected for future recreation, biodiversity, forestry, agriculture and food supply (CPRE, 2018; Grinde & Patil, 2009; Lehmann, 2019a, 2019b).

Urban sprawl plagues cities in both developing and industrialised countries. A study by UN-Habitat has shown that since 1990, urban densities worldwide are in

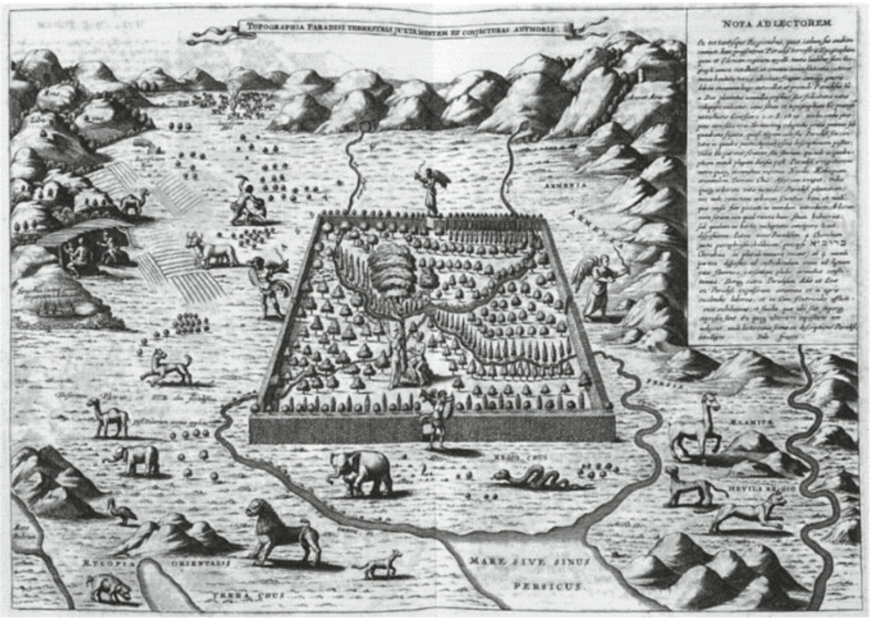

Fig. 2 Engraving by Athanasius Kirchner 'The Terrestrial Paradise' ('Das irdische Paradies'), 1675, Amsterdam. Paradise was originally defined as a walled garden, an earthly place that could protect an ideal state of peace (*Source* courtesy Commons Wikimedia 2021)

slow decline, a result of rampant land consumption (UN-Habitat, 2020). In the United States, for example, land development has quadrupled since 1945, growing at twice the rate of population growth. In addition, research shows that sprawl has a negative social impact, leading to more isolation, loneliness, cases of depression and obesity (Hand et al., 2017; Lehmann, 2017; UN-Habitat, 2020; Woo et al., 2014).

Today, in the United States, more than 60% of the population lives in suburbs of dispersed, car-dependent cities; in Houston, Dallas, Phoenix and Las Vegas, this figure is even closer to 80%. Los Angeles and San Diego in Southern California are classic examples of sprawling metropolises with mile after mile of scattered low-density car-dependent development, suitably called the "100-Mile City" (Sudjic & Sayer, 1993). Urban sprawl means excessive land consumption. In Germany alone, more than 100 square kilometres of greenfield land is sealed every year, built on, or paved over. Consequently, the rainwater can no longer seep away to join the groundwater, often leading to urban flooding after heavy rainfall. The days of heavy rainfall are 85% more common in Europe today than a hundred years ago, and scientists predict that this trend will only continue until 2100.

Twentieth-century urban zoning has made cities more car-dependent and has led to adverse and unequal environmental and economic conditions. Intentional planning with a concern for integrated green spaces has the potential to dissolve longstanding environmental, social and economic inequities.

Planners and architects have long advocated for increased urban density and walkable, compact, mixed-use, transit-oriented development, combined with greening strategies, to improve city residents' life, combat sprawl and mitigate climate change. Green roofs and plants reduce the heat load and clean the air, which allows for smaller air-conditioning plants. More and more green roofs are now designed with native plants and water saving in mind. Greenery has become not just visually but physically inseparable from the manmade; an important step for green and water transitioning from mere decoration in planning to become one of the basic building blocks of contemporary cities.

Transporting food into the city is a major source of environmental pollution, including the cost of gasoline for distribution and waste from packaging. If a city produced only 10% of its food in urban rooftop farms, it would allow 34.000 sqm of land to be returned to forests every day.

Numerous cities worldwide have now set targets of 30% green cover (with Sydney's and Melbourne's target even of 40% green cover by 2050). Well-considered urban greening strategies can address the disparity with socioeconomically disadvantaged communities to help reduce population health inequities. Transforming the practice of planning must lead to the delivery of coherent and robust urban concepts, and not just architectural objects. Combined with strategies for gentle densification, different urban infill scenarios and the integration of NBS, transformation and regeneration will need to be simultaneously dense and green. As numerous projects have shown (e.g. in Singapore, etc.), this is not a contradiction—we can have both: dense and green combined.

2.2 Working Definitions

The following part provides short working definitions of the terms *urban greening, rewilding, urban resilience*, and *urban heat island effect*.

Urban greening refers to the process of establishing the components of green infrastructure and plants within the built environment. It helps to provide viable solutions using the properties of natural ecosystems and the services nature provides. Municipalities are now looking at how urban areas can adapt their landscapes to better manage the increasing heat stress and to build adaptive capacity. Ecosystem services delivered by urban vegetation through healthy street trees, tree-lined avenues, gardens, parks, wetlands, urban forests, green roofs and living walls are now becoming appreciated in planning. Recent modelling studies by researchers at the University of Surrey found that green roofs could result in a reduction in air pollution of up to 30 to 50%.

Rewilding activities are ecological restoration and conservation efforts aimed at protecting natural processes and wilderness areas by restoring an area of land to its natural uncultivated and self-regulated state. It includes the reintroduction of species of wild animals, insects, birds, flora and fauna that have been driven out or exterminated; it increases biodiversity. Passive rewilding aims to reduce human intervention in ecosystems, giving human-cultivated land back to nature. In contrast to highly managed parks or gardens, rewilding initiatives are leaving selected allotted spaces mostly self-regulated.

Urban resilience refers to the ability of cities to maintain human and ecosystem functions simultaneously over the long term, even during a disaster or crisis, and the capacity to deal with sudden change and continue to develop (Alberti & Marzluff, 2004). This *adaptive capacity* refers to a city's ability to cope with and recover quickly from hardship. A resilient city is typically one that is prepared and well equipped to mitigate the multiple effects of climate change, such as heatwaves, urban flooding, energy blackouts and other potential disasters. It has a robust infrastructural system and can transform even a crisis into a positive development (Lehmann, 2018; Meerow et al., 2016; Mitchell & Harris, 2012). Regenerative urbanism means to move from 'doing less harm' to 'restoring the damaged ecosystem'.

The dangerous *Urban Heat Island* (UHI) effect leads to significantly warmer urban areas compared to surrounding suburban or rural areas, and this temperature difference is usually larger at night than during the day. The UHI effect occurs because the dark surfaces (e.g. black asphalt on roads and concrete on building roofs) absorb and store heat during the day and then release it at night. The main cause is the modification of land surfaces and material, for instance, concrete roofs that store and trap solar radiation heat during the day. Urban greenery can help reduce this heat gain and the negative impact on human health (Lehmann, 2015; Sailor, 2014). Green roofs and facades can best counteract it with plants and vegetation, white or light-coloured surfaces (using the albedo effect to reflect solar radiation), and materials that absorb and store less heat.

3 From Howard's Garden Cities, to McHarg's Environmental Manifesto, to Biophilic and Green Urbanism: The Way to Healthy and Resilient Cities

As far back as in the 1722 book *The City Gardener*, the English botanist Thomas Fairchild (1667–1729) noted that 'city residents feel more relaxed and healthy when they can enjoy gardens and greenery' (Fairchild, 1722). From René Descartes (1637) to Thomas Fairchild, Ebenezer Howard, Ian McHarg and Dennis Meadows, there are direct linkages that exist between a rich palette of seminal literature and different schools of thought about the possible role of NBS. Fields, orchards, gardens, meadows and fishponds right alongside their largest and most significant building, the cathedral, traditionally penetrated the great cities of the past. Ebenezer Howard's vision of the garden city movement (published in 1902) proved to be enormously influential in city planning circles throughout the world.

Today, planners aim to bring nature back into the city in all kinds of ways to compensate for the lack of green spaces. From *garden cities* to *biophilic urbanism*, reconnecting cities with nature means enhancing resilience at the urban scale, and a growing recognition of the need for daily contact with nature and green spaces to live happy, productive and meaningful lives.

The concept of *urban metabolism* understands cities as vulnerable living organisms. It analyses the flows of energy, resources, food, people and waste or materials in cities as if the city were a living ecosystem, and provides a framework for the interactions of natural and human systems. Ecologist Arthur George Tansley (1871–1955) expanded the term to encompass the material and energetic streams (Tansley, 1935). Numerous other influential texts by various authors offer further ecological wisdom on the relationship with landscapes and their ecosystems (Carson, 1962; McHarg, 1969; Register, 1987; McDonough & Braungart, 2002; Girardet, 2008; Lehmann, 2010; Perrotti, 2018).

Green spaces in cities—big or small—all contribute to the health and well-being of residents. The seminal publication *Design with Nature* (Ian McHarg, 1969) was the first environmental manifesto to explore green spaces in cities and examine how the ethos of designing with nature has evolved over the twentieth century. With the threat of climate change, species extinction and major resource depletion, McHarg addressed the need for broader coordination, longer-term strategies, and clarity of policy, leadership and action (Steiner et al., 2019). The 1972 report *The Limits to Growth* (Meadows et al., 1972) was immensely important in the way it challenged the common thinking of the time about land consumption, finite resources and the questionable concept of endless growth. Shortly after, it was followed by James Lovelock's pivotal book *Gaia: A New Look at Life on Earth* (1979). The World Cities Report 2020 'The Value of Sustainable Urbanization', published by UN-Habitat (2020), points in the same direction: our models of urbanisation based on GDP growth and increased consumption will need to change, and the integration of NBS will play a key role in this future change.

The concept of *biophilia* was first introduced by psychologist Erich Fromm in 1964 and then popularised in 1984 by biologist Edward O. Wilson, who studied the lack of connection with nature in urban life. The guiding principle is quite simple: connect people with nature to improve their well-being and quality of life. Wilson suggests that humans possess an innate tendency to seek connections with nature and other forms of life (Kellert, 2011). As already predicted by Rachel Carson in *Silent Spring* in 1962, we are now in the process of redefining our relationship with nature and realising how our health depends upon it. This growing understanding is not about giving up technology but rather about developing the most advanced NBS technologies to date, for instance, through the biological revolution, digital fabrication and nanotechnology. We have to use that rich and available knowledge to find innovative and improved solutions for cities, employing ideas of biomimicry—innovation inspired by natural systems (Benyus, 2002; Lehmann, 2019b; Neves & Francke, 2012).

Biophilic urbanism uses the calming and cooling effect of nature as a tool in planning. It is about new ways to combine density with greenery to enhance urban resilience. The strategy is to have more urban greenery and higher densities at the same time, as dense and green do not have to be a contradiction: it is about increasing density while at the same time increasing the amount of accessible green space, and integrating urban greenery in new ways, including urban food production and farming on roofs of large buildings. Thus, increasing urban density must result in more green spaces and the integration of vegetation into the urban fabric.

In the book 'The Principles of Green Urbanism' (2010), I offer a conceptual framework for the integration of NBS and for regreening cities. Cities are not obvious places to reconnect with the natural environment. Cronon (1995) asserted that urban inhabitants have created a wholly artificial view of what nature and wilderness are, based on ideas of open space and grandeur that rarely correspond to the lived reality of the people who inhabit mostly suburbia. The view of nature as a pristine and uninhabited space makes it difficult to see nature on a smaller, less imposing scale and to appreciate, for instance, that a tree in a back garden can equate to a tree growing in a forest—that the two trees are identical despite their different settings. In our minds, the forest tree somehow has a greater perceived natural value (Cronon, 1995).

There are four key strategies:

- Halting building on greenfield sites, establishing a strict and effective urban growth boundary.
- Renaturing the city so that the landscape and greenery is allowed back into the city: instead of the city eating into precious landscape, it is the reverse: green fingers can extend into the city.
- Applying NBS, including planting urban forests, which has been shown to be beneficial (e.g. in Melbourne, Australia; see Fig. 3), as it keeps cities cooler during heatwaves and sequesters CO_2 emissions; including green roofs, living walls and constructed wetlands.
- Redesigning streets, restricting cars, planting trees, and allowing for permeable surfaces.

Fig. 3 An urban forest in Melbourne, Australia, helps to keep the city cooler during heatwaves and binds dust from traffic. Melbourne has formally embraced an Urban Forest Strategy with the aim to increase tree canopy cover from 22 per cent to 40 per cent by 2040 (*Source* Courtesy City of Melbourne 2012)

4 Excessive Heatwaves and Fast-warming Cities: the Causes for the Urban Heat Island Effect

The term urban heat island (UHI) is used to describe an urban area that is warmer than the rural areas that surround it; local-scale temperature increases will accompany future population growth, putting more people in danger from the negative health effects of extreme heat. Those particularly vulnerable to heat-related health problems include young children, older adults, outdoor workers and low-income populations.

The main causes of the UHI effect are urban development, the loss of green space, and building materials that absorb heat (rather than reflect it). Heat-trapping materials cause a rise in ambient temperature, and this additional heat can bring a number of other harmful consequences. Impermeable surfaces that stretch across cities, such as black asphalt and rooftops, absorb the heat. Light-coloured and permeable materials can successfully reflect heat and remain cool, taking advantage of the albedo effect. Increased air pollution is also a symptom of the UHI effect leading to breathing problems owing to fine particulate matter, and accelerates the formation of ground-level ozone. Rising temperatures can also harm water quality, as minor temperature changes have frequently a devastating impact on aquatic life. When warmer water drains into sewers, it subsequently flows into natural bodies of water, upsetting natural ecosystems and accelerating the growth of bacteria.

The recent IPCC report and numerous other research studies confirm that more plants, trees, vegetation and greenery in the city will reduce the heat load and the UHI effect, as large-leaf trees bind the dust, clean the air and reduce the amount of required air-conditioning (Bowler et al., 2010; Doick et al., 2014; IPCC, 2018; Pauleit et al., 2005; Schwarz et al., 2015; Sharifi et al., 2021). Therefore, many cities have abandoned the outdated twentieth-century concept of infinite urban growth, searching for new ways to enable more compact inner-city living on a smaller area of land per capita. There is now a revival of the nineteenth-century pre-automobile, compact, six-storey European city model (a model that can be found in the blocks of Berlin, Paris, Milan, Barcelona, Athens, Stockholm, besides numerous other cities), as it has shown to be the most energy efficient and resourceful of all models (Lehmann, 2019a). It creates a reasonable population density (at around 40 + dwellings per acre / 80 + dwellings per hectare) and does not waste valuable land. It does not generate unnecessary traffic or waste energy, but offers

- quiet green courtyards, which allow for natural cross-ventilation,
- a diversity of public spaces, squares and streets as places for regreening, and
- five to six-storey mixed-use urban blocks that share walls and circulation.

The compact walkable European city model is the most sustainable way of urbanisation, as it results in the lowest use of land and resources.

Large parking lots store excessive heat and are significant UHIs. Studio NAB has developed a conceptual proposal of how a typical big-box parking lot could be reimagined as an urban farm; with some space for charging electric cars from onsite solar panels (see Fig. 4). Urban communities have not typically been associated with food production, which is associated mainly with rural spaces. Greenhouses and fruit trees grow produce that can be supplied directly to the neighbouring store. In this proposal, some parking spaces remain, where the asphalt has been replaced by green space that can help sequester CO_2 and absorb rainwater. Through significant technological advances (e.g. robotic farming using hydroponics), urban agriculture could possibly meet up to 10% of the entire food demand of urban communities and make meaningful contributions to food security and public health.

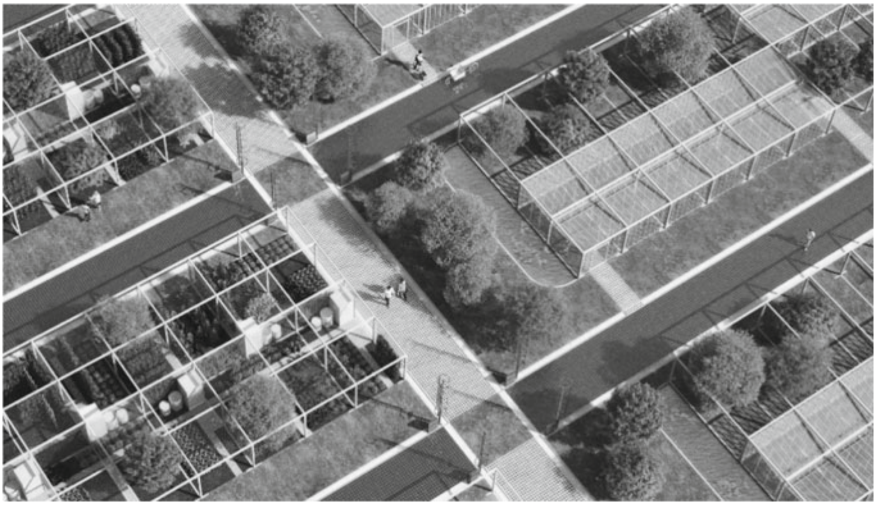

Fig. 4 The conceptual proposal Car Parks 2.0 transforms large carpark lots into a productive field for urban farming; by French design firm Studio NAB 2019 (*Source* Courtesy Studio NAB)

5 Integrating NBS into Planning: the Positive Impact on Land, Water, Air Quality, Urban Heat, Biodiversity, and on Health and Well-being

With an ageing population, single-person households have become more common in most countries over the last twenty years; in Frankfurt for example, over 50% of households are already single-person households. There is much research supporting that regular contact with nature has many benefits for health and well-being, and easy access to public parkland can reduce loneliness and inequities in well-being. Astell-Burt and Feng (2021) found that reducing loneliness has many potentially positive impacts on health. Their research shows that there is a direct association between urban green space availability within 1.6 km/1 mile distance from home (a commonly used "walkable" distance in urban planning) for the incidence of loneliness. Green space and parkland allow for social gatherings and chance encounters with neighbours, reducing loneliness. Adults in neighbourhoods where at least 30% of nearby land was parks, reserves and woodlands had 26% lower odds of becoming lonely compared to citizens in areas with less than 10% green space. For people living on their own in areas with 30% or more green space the odds of becoming lonely halved (Astell-Burt & Feng, 2021). This means that people's odds of loneliness could fall by up to half if cities hit 30% green space targets.

Scientists are now closely examining all relevant issues for the integration of NBS, such as impacts on land, water, air, urban heat, biodiversity, recreation, and health and well-being. NBS can generate considerable improvements in the transformation and revitalisation of cities, and are simultaneously addressing environmental and societal challenges while increasing biodiversity. In addition, NBS help to keep cities cool, reduce the heat load, bind dust, and manage stormwater, runoff, and deliver positive impacts from ecosystem services. Researchers are working to identify the most impactful principles for the integration of NBS at the planning level (e.g. using sustainable drainage systems and bio-filtration swales) and looking at new forms of urban greenery in the expansion of existing green spaces (Santamouris & Osmond, 2020; Wong & Yu, 2005).

A definition of NBS offered by the European Commission states,

> NBS solutions are 'inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience (…) and bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. (EU Commission,)

Thus, NBS provide practical, sustainable, cost-effective and adaptive alternatives for various urban planning objectives, taking steps towards a more competitive, resource-efficient and greener economy (often termed *green growth*). It can also help to enhance rather than deplete natural capital: green roofs and living walls can act as carbon sinks (Rizvi et al., 2015; Shanahan et al., 2015).

Rewilding is an effective passive NBS strategy that is not technology dependent and addresses the climate crisis with a minimal number of resources. A return to the wild for selected underused urban areas can be a powerful way to reintroduce lost biodiversity back and bring communities into closer connection with nature. Rewilding gardens can create 'green lungs' and even improve local economies through nature-based tourism.

Rewilding areas in cities has become a powerful NBS strategy and biodiversity blooms in cities where manicured green spaces were allowed to proliferate as native grasses, shrubs and wildflowers attracting more animals that are diverse, with a diverse flora and fauna, over time. When self-regulating meadows replace maintenance-heavy monoculture, these rewilding zones also become more drought resistant and sequester more CO_2. It is a shift away from a centuries-long tradition of managing public green space and the use of pesticides. Rewilding initiatives can focus on smaller areas within existing parks. Early urban rewilding initiatives were the Mauerpark in Berlin-Kreuzberg and the High Line in New York City, once-abandoned railway lines that went wild over decades before being adapted into blossoming public parks. The German city of Dessau bought up unused properties and brownfield sites to create a 120-hectare continuous green zone that returned to nature; the grounds of existing housing estates became part of the rewilding project, improving the lives of the residents.

Dutch architects MVRDV designed a contemporary garden town on an artificial peninsula for the 2022 World Horticultural Expo in Almere, a patchwork of different types on green spaces that will allow citizens to live in direct contact with nature (see Fig. 5). Such urban design concepts incorporate and reintroduce greenery and biodiversity into the urban built environment, subsequently leading to new models of urbanisation. However, it is essential that the design of NBS is fully integrated

Fig. 5 A new garden district as a 45 ha (110 acres) extension of Almere: located on an artificial peninsula for the 2022 World Horticultural Expo. A patchwork of different types on green spaces will allow citizens to live in direct contact with nature. The new district that will produce food and energy, clean its own water, recycle waste and hold a great biodiversity (*Source* courtesy MVRDV 2012)

with other complementary planning interventions. The inclusion of trees, shrubs and other plant matter into urban spaces and onto roofs is of paramount importance in helping to keep cities cool, mitigating the effects of buildings and pavements which increase heat absorption and heat storage (Hawken & Lovins, 1999; Watts, 2018).

Similarly, the collection and storage of rainwater in constructed wetlands and the protection of mangrove forests along coastlines employ NBS to achieve several objectives, including disaster-risk reduction and minimising species extinction. Urban flood control is regulated in a natural way, with mangroves alleviating the impact of wind and waves on coastal settlements while also capturing CO_2. Additionally, a mangrove forest provides safe nurseries for marine life and helps control coastal erosion resulting from a rise in sea levels, mitigating potentially harmful effects on the environment and on human health and society (Kabisch et al., 2016; Lennon & Scott, 2014; Maes & Jacobs, 2017; Rich, 2018; World Forum on Natural Capital, 2018).

5.1 Bringing Nature Back into the City: The Case for Tree Planting to Keep Cities Cool

This part aims to explain the different kinds of actions useful for implementing urban greenery and regreening.

As most of our cities keep growing and warming, the scale of the issue is significant. For example, in 2021, cities in the European Union were home to more than 70% of Europe's population, and this figure is expected to increase to over 80% by the middle of the century. This translates to 36 million new urban citizens in Europe by 2050 alone, who will need a basic supply of housing, employment, healthcare and access to a diversity of green spaces (EU Commission, 2020).

The International Energy Agency estimated in 2018 that—with increasing urban heat—air-conditioning would be one of the biggest drivers of electricity demand worldwide over the next 30 years, which has significant implications for carbon emissions unless our urbanisation model changes and cooling systems become more efficient. Global demand for cooling is projected to overtake heating demand for the first time in 2070 (IEA, 2018).

As climate change brings higher temperatures and unpredictable downpours, cities are expecting a new kind of resilience from their urban green spaces. To this aim, there are numerous tree-planting programs on the way. In the European Union, three billion new trees will be planted by 2030, many in and around cities, as part of the EU's *Biodiversity Strategy for 2030: Bringing Back Nature* (EU Commission, 2019). Ambitious greening projects are also on the way in several megacities, including New York, which planted a million trees between 2007 and 2015. London hopes to green more than half the city by 2050 to make it the world's first 'national park city'; while Paris has recently created four inner-city urban forests.

With more and more people living in urban areas, the need to create and enhance green spaces around and within cities has never been greater. Some large cities have far too little green space within their urban areas, struggling with urban flooding (e.g. Bangkok and Jakarta). After heavy rain, stormwater cannot drain, and there are no green spaces to slow down, store and reduce the water runoff. The 'Sponge City' concept stores water during heavy rainfall, so that parks become water reservoirs and biotopes in which many animal and plant species can coexist. It seems there is no shortage of innovative projects worldwide that recognise the significance of inner-city green spaces.

Severe heatwaves will become more common and more frequent. Cities with extremely hot days and many residents who cannot afford air-conditioning will need to create cooling parks and gardens with tree cover where people can go to escape the heat. An enormous number of studies have been published on the potential impact of additional urban vegetation on urban temperature, thermal comfort, pollution reduction and health. For example, Wright (2011) and Johns (2019) wrote about the resistance and barriers to green infrastructure. Lennon (2014) and Mell (2017) assessed the future of green infrastructure and the policy gaps that remain in the current planning legislation; while Roe and Mell (2013) evaluated the monetary value that green infrastructure can add. While usually lacking a scientific quantification, most of the studies conclude that increasing urban greenery offers numerous benefits. While planting trees in urban spaces is an effective and efficient way to adapt to climate change, it is not a holistic solution (Akbari et al., 2001; Santamouris & Osmond, 2020). Furthermore, trees are not always seen by all as a benefit, as they are in a constant struggle for water and space.

To reap the benefits of urban treescapes, it is vital that trees are seen as more than merely an aesthetic addition. Trees regulate the urban microclimate, and their cooling effect through shading buildings is significant: trees can cool buildings by up to 5 C. This cooling effect is a valuable tool that can be used to address both heat stress and cooling costs. Beyond using trees as a geo-engineering fix, urban ecologists point out that more trees in cities could also change people's perspectives on urban living and give them a greater understanding of how to value nature in general. Nevertheless, the right tree selection is needed for each place—planting monoculture plantations typically creates forests that are of low biodiversity value and with little CO_2 carbon storage capacity. Instead, we should focus on restoring the natural woodland ecosystem in all of its natural biodiversity.

Adding green roofs and plants to the tops and sides of buildings provides significant ways in which to improve the urban microclimate, and wet roofs that temporarily store water can help to cool buildings naturally through evaporative cooling. One square metre of green roof binds up to 10 g of fine dust per year and absorbs 375 g of CO_2. In addition, green roofs reduce surface temperature and heat losses from buildings (Santamouris & Osmond, 2020).

There are now plans for urban landscape restoration and rewilding projects worldwide, with the aim to create leafy, resilient and healthy places in cities. Berlin's former inner-city airport Tempelhof has been renatured, offering an efficient carbon sink (see Fig. 6). The city of Brisbane transformed a disused inner-city golf course into a 64-hectare public green space replete with revegetated forests, native bushland, restored water holes, constructed wetland and a lake. It is not as simple as the more trees one has in an urban space, the better the air quality. Some trees are markedly more effective at filtering pollutants from the air than others. For effective renaturing, it is important to explore which tree species is doing the best job. Conifers offer highly effective particulate matter (PM) reduction because they are an evergreen species. It also depends on canopy size, leaf size and leaf structure. So, what kind of greenery should be prioritised? There is plenty of research that confirms the undeniable correlation between additional tree cover and a temperature drop during the peak day period and at night, and an improvement in air quality. More research and knowledge are still needed through scientific quantification of which tree species are most effective in improving air quality, and which are the more heat-tolerant species.

Usually, trees need 20 to 25 years to mature, which can make the appropriate sizing of tree cover for new planting difficult. Additionally, some species are markedly more effective in filtering and removing pollutants from the air than are others (Heal et al., 2012). The filtering activity depends mostly on the canopy size, leaf size and leaf structure. Generally, bigger tree canopies trap more particles, and larger leaves can trap more pollutants than can small ones. Trees with rough, hairy leaf surfaces and

Fig. 6 The Tempelhofer Feld is a new public recreational area on the former inner-city airport in Berlin. The airport closed in 2008 and its enormous 386-hectare open space, the former airfield, was turned into a public park (opening in 2010), offering cycling, skating and jogging trails, urban gardening sections and a large rewilding area (*Source* courtesy of Berlin Senate)

large leaves act as the best filters: silver birch, silver maple and conifers such as pine trees are highly effective. Trees with a dense, large canopy and evergreen species are the most effective pollutant trappers, while yew hedges make good roadside additions to reduce pollution. Some trees are effective in filtering atmospheric pollutants such as sulphur dioxide through their leaves. Nanoparticles and fine dust (e.g. from diesel engines, factories and construction sites) can be inhaled and enter the human respiratory system, causing several illnesses.

Urban greenery requires valuable drinking water, especially in the hot summer months, and native plants generally need less irrigation and are more drought resistant. In the city, where every tree and every bush must compete for space and water, forget the decorative green of the maintenance-intensive parks, golf courses and manicured lawns—urban greenery must become part of the basic city infrastructure so that it has a robust lobby and thus has space and budget. Given the serious spatial limitations in cities, green walls, green screens and vegetated roofs are effective in narrow street canyons where there is little room to plant trees or hedges. In Mexico City, most of the local pollution is attributed to the excessive use of private cars. Mexico City has planted ‘green columns’ alongside highways and underneath flyovers and turned pillars into green walls that reduce the fine dust and pollutants for residents along the inner-city freeways. Since 2016, more than 1,000 concrete columns have been turned into vertical greenery, which captures fine pollutant particles and reduces pollutant concentration in street canyons (see Fig. 7).

Fig. 7 Mexico City has planted "green pillars" underneath their freeways as green walls that reduce the fine dust and pollutants for residents along the inner-city freeways, the Periférico highway, which rings the central city. There is no space to plant trees (*Source* photo by the author 2020)

6 Conclusion: Liveability and Ecological Design Means Regreening Cities

As climate change intensifies, cities are on the front line, suffering from heatwaves and increased flooding. Urbanisation models play a significant part in this. Even former U.S. President, Barack Obama is on the record speaking out against urban sprawl, when he called on architects, planners and policymakers to tackle sprawl and to "create liveable density. It is not gigantic towers or single family homes; we can and must do better. Humane density" (Obama at the AIA National Conference in Chicago, June 2022).

The chapter underlines the innovative contribution of nature-based based solutions to the urban project for regreening cities. To stop global warming and avoid the worst effects of climate change, humans need to stop adding greenhouse gases to the atmosphere. To achieve this, every city will need to change its ways how people get around from place to place, how energy is generated, stored and transmitted, and how buildings and public spaces keep us warm and cool. To achieve this, entrepreneur Bill Gates has outlined "a plan of technological innovation and research that will upscale R&D in clean energy projects, match R&D with the greatest needs, work with industry from the beginning, put a price on carbon, and build the infrastructure that will get new technologies to market" (Gates, 2021, 202). It is one of several promising initiatives.

Strategic planning of vibrant mixed-use quarters requires appropriate population densities and should provide at least 25 square metres of green space per capita (UN-Habitat recommendation). Regreening is not a contradiction to increased densities; green has always been part of our cities, and it needs to be reintroduced without leading to lower density. More density can also mean more green.

Access to public parks and green spaces in less than 10 min by foot from home plays a vital role. The neighbourhoods of the future will have to offer new forms and pockets of green spaces fully integrated in the existing urban fabric, including concepts that go beyond roof gardens, green walls and planted atria. Healthy green corridors in cities will offer multifunctional zones to optimise the design integration of NBS at all scales. Strategic and integrated development, which concentrates on energy and water management, green infrastructure, NBS, and the urban microclimate, is likely to take a leading role in the design of post-oil cities.

Trees provide cities with substantial potential for carbon capture. Urban vegetation represents one of the most considered urban heat mitigation measures for cities and strengthens urban resilience and disaster preparedness in case of heatwaves or flooding. Additional tree planting and rewilding initiatives can considerably decrease the levels of heat-related illness and the maximum temperatures of UHIs, while improving air quality and runoff-water management. With new record summer temperatures, cities should be regreened at record speed. In the green city of the future, all flat roofs of buildings will need to be roof gardens and water reservoirs for plants.

Picture a cleaner, quieter and self-sufficient city where opportunity is not dependent on the location, and everything is walkable, where the transformation towards a Post-Oil City has resulted in a local booming economy specialising in sustainable practices and NBS.

Significant benefits that are expected from urban greenery and regreening projects include enhanced resilience, health and well-being by contributing to decreased ambient temperatures, lower heat-related mortality and levels of harmful pollutants in the air. Pockets of green spaces will serve multi-purposes, as areas for recreation, for mitigating the warming urban microclimate and for trapping pollutants.

Cities are inevitably a part of the natural world and we see urban planners becoming more sensitive to incorporating nature into their designs. In this context, nature-based solutions can generate significant benefits for citizens and municipalities, improve urban health and well-being and offer an opportunity to effectively deploy nature in helping to resolve major societal challenges—such as climate change, social inclusion, food security and disaster-risk reduction. However, as the discussion of this chapter shows, it is essential that the design of NBS is fully integrated with other complementary planning interventions and seeks synergies across all sectors.

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The Impact of Spatially Egalitarian Functional Urban Areas: The Case of Lisbon Metropolitan Region

Tomaz Ponce Dentinho

1 Introduction

The form of Functional Urban Areas (FUA) varies from country to country (OECD/European Commission, 2020). Similar environmental, technological and socioeconomic features can lead to differences on urban landscapes across borders because institutional rules change from country to country.[1] This is notorious when political borders are crossed from Portugal to Spain, from Spain to France and then to Italy, Germany, England, Switzerland or the Benelux. Certainly, there are changes from urban to rural areas, from the Mediterranean habitats to the Atlantic or Continental ones along latitudes, latitudes and altitudes. Nevertheless, the strong feeling of border crossing seems to reveal a clear dependence of the urban form on institutional rules rather than on differences in environmental, technological and socioeconomic features.

On the other hand, over time the various expansions of Functional Urban Areas create the idea that technological and socioeconomic contexts play a major role in the evolution of the urban tissue. However, the revitalization of central quarters of growing Functional Urban Areas, old urban forms generated more liveable habitats for human interaction rising the question of whether more advanced technological and socioeconomic urban zones, somehow associated with the ideas of Smart Cities (Caragliu et al., 2011) and New Towns (Wang et al., 2014), lead necessarily to creative

[1] We use the framework of the work of George Chadwick (1978) in his book "A Systems View of Planning. Towards a Theory of the Urban and Regional Planning Process" where the author proposes a conceptual urban system involving environmental, technological (adapted spaces), socioeconomic and institutional subsystems.

T. P. Dentinho (✉)
Department of Agricultural Sciences, University of the Azores, Ponta Delgada, Portugal
e-mail: tomas.lc.dentinho@uac.pt

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urban forms for human interaction. Actually, old places become renewed and vivified with minor changes in the regulation policy (Malyshev, 2002).

Even the argument that technological evolution of mobility led to different creative urban forms is not completely accurate when we witness the adjustment of motor vehicles to old urban tissues, associated with parking and traffic regulations and physical restrictions, and the creation of underground motorways and railways, after decades of their imposed disaggregation of older urban forms when motorways and railways were imposed on the surface or urban centres (Broere, 2016). It seems that people and places reveal their aptitude for sustainable and creative interaction even after being disturbed by different waves of technological, socioeconomic and institutional changes nurtured often by ideological, fashionable, unsustainable and non-competitive urban forms and policies, that do not attract entrepreneurs (Cuthbert, 2006), do not follow adequate planning procedures (Punter, 2007) namely related to urban density.

The problem is when politicians introduce the idea of egalitarian tariffs for public transport tariffs across all Functional Urban Areas with peripheral areas paying the same as central ones. The result is, on the one hand, the justification for a public monopolistic provider of transport to accommodate cross subsidization of the transportation costs, usually associated with more strikes[2] and, on the other hand, the increase of land prices in peripheral areas associated with urban sprawl.[3] Poor people in the periphery will be even poorer because they will move more far away from the centre of the Functional Urban Area, stimulated by social housing programs built on low cost and low accessibility peripheral land. The Functional Urban Area will tend to become less competitive not only because of urban sprawl but also because the transport monopoly will tend to be less innovative and more dependent on powerful strikes. According to (Della-Porta et al., 2019), there are both negative and positive aspects between competitive mechanisms and coordination mechanisms.

Regarding pricing and subsidy policies, (Hörcher & Tirachini, 2021) argue that more research would be needed on optimal prices and subsidies to overcome the ideologies of "zero subsidy" and "zero fare". We try to add to that research effort by looking at the trade-offs between transport tariffs and house prices knowing that, despite fare schemes not being the most efficient method of addressing inequity, and despite fare schemes alone not capturing the complete description of residents outcomes, fare scheme changes do have distributional effects. Actually, geographical features and transport costs have significant effects on housing prices (De Bruyne & Van Hove, 2013) and, depending on the structural features of urban areas, house prices have a strong effect in labour and housing markets and in social profile of urban areas (Musterd, 2020).

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[2] Uniform tariffs require cross subsidization and a coordinator public entity that is constrained by the monopolistic power perceived by the labour unions.

[3] Metro and railways promote suburbanization around stations and terminals and since railway transportation have high fixed costs some degree of equalization of tariffs make sense. The problem arises if road public transportation is included because there are more stations and it is easy to go further in the urban sprawl, until the border where average cost equals the average benefit.

The aim of this chapter is to analyse the negative and positive impacts of the establishment of egalitarian public transport in Lisbon Metropolitan Area in 2019,[4] first, using an urban spatial interaction model with endogenous land use values simulated for the establishment of egalitarian tariffs of public transportation that, as hypothesized, will increase land prices in the periphery generating urban sprawl: Second, using data on evolution of housing prices from 2019 to 2022 to analyse where those prices grew more along the Functional Urban Area of Lisbon and testing if they grew more in the areas of the periphery more accessible by public transports. Lisbon has with 2,8 million, 18 municipalities, 9 in the north of the Tagus Estuary and 9 in the South, connected by two bridges.

Beyond this introduction, we review the literature on places liveability (Point 2), present and provide intuitions of the impact of egalitarian transport policies in the Lisbon Metropolitan Region (Point 3), formulate and estimate a model with land use to understand the systemic interactions between the cost of travel and housing prices in the Functional Urban Area of Lisbon (Point 4) and propose conclusions and recommendations (Point 5).

2 Place Liveability

Figure 1 indicates the conceptual locus of Smart, New and Liveable Cities. The frame is the virtuous circle of sustainable development and the sustainable development goals with one half circle of production from financing, investment, capital, productivity and income, and another half circle of wellbeing with redistribution, consumption of private and public goods and free amenities and with wellbeing. Dated, partial and relatively failed policies have a place on the scheme: basic needs, subsidies on the financing of projects, allocation of public goods, capital revealed over time, rent redistribution and protectionism had their defenders and chances; and the same happens with the trendy ideas of Smart, New and Liveable Cities (Southworth, 2016).

Based on the framework of Sustainable Development Goals systematized in Fig. 1 the approach adopted in this chapter assumes that there is an association between "Liveable cities" that create Good Health and Well-being (Goal 2) based on Sustainable Cities and Communities (Goal 11). Furthermore, this depends on Climate Action

[4] The "Navegante Metropolitano" pass, established since April 2019, will allow you to use all regular public passenger transport services in all 18 municipalities in the Lisbon metropolitan area. It will have a price of 40 euros and a monthly validity, that is, from the first to the last day of the month for which it was purchased. Those who choose the "Navegante Metropolitano" can go, for example, from Setúbal to Mafra, using any public passenger transport service operator with a single pass. https://www.aml.pt/index.php?cMILID=SUS5C743299BA9B1&cMILL=3&mIID=SUS5C743261A63E4&mIN=sobre&mILA=&cMILID1=SUS5787A25518AED&mIID1=3&mIN1=Mobilidade%20e%20transportes&cMILID2=SUS5C7431770397C&mIID2=SUS5C743115D5991&mIN2=novos%20passes&cMILID3=SUS5C743299BA9B1&mIID3=SUS5C743261A63E4&mIN3=sobre.

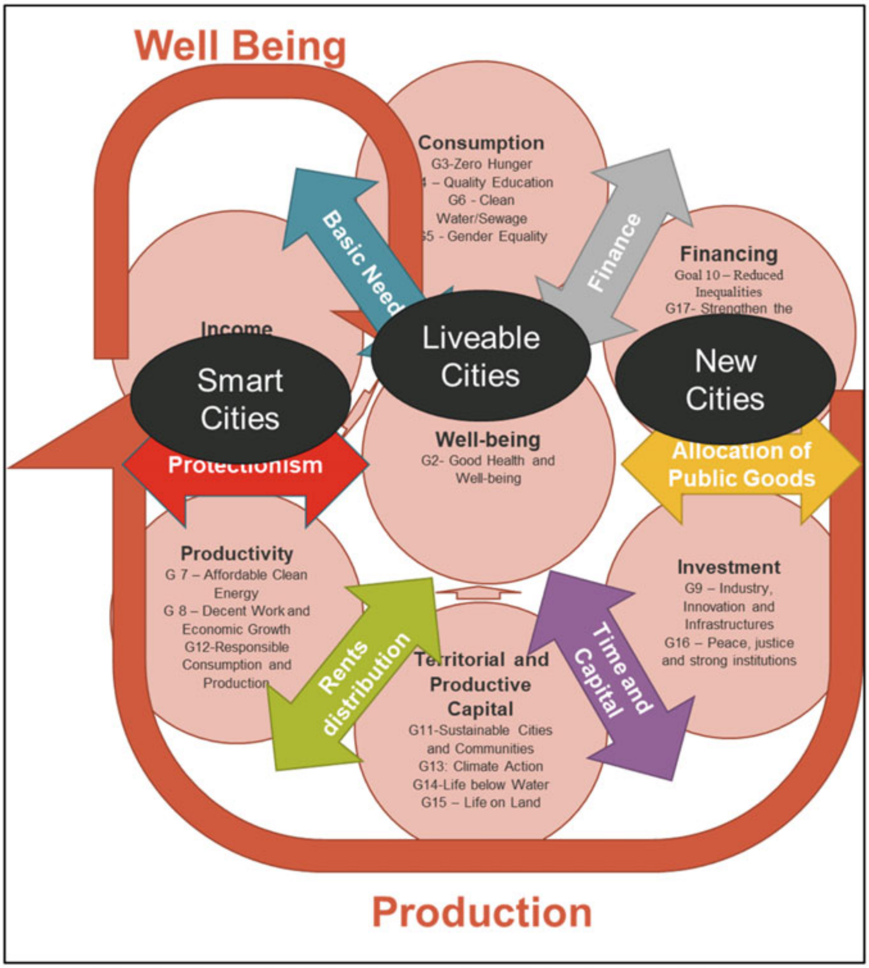

Fig. 1 The conceptual locus of smart, new and liveable cities (*Source* Author)

(Goal 13); Life below Water (Goal 14) and Life on Land (Goal 15) and specially with the promotion of Peace, Justice and Strong Institutions (Goal 16).

This is different from the idea of Smart Cities that invest in Affordable Clean Energy (Goal 7); promote Responsible Consumption and Production (Goal 12) to reach Decent Work and Economic Growth (Goal 8), attempt to Reduced Inequalities (Goal 10) to achieve (Goal 1 - No Poverty).

Different as well from the concept of New Cities that Strengthen the Means of Implementation and Revitalize the Global Partnership for Sustainable Development (Goal 17) and promote Industry, Innovation and Infrastructures (Goal 9) to generate—Peace, Justice and Strong Institutions (Goal 16).

Urban designers have the unique background to deal with the experiential features of cities. Worldwide unprecedented urban growth strains the quality of life on many dimensions of the cities—walkability of streets, sociability of public spaces, access to recreation and nature, the lengths of the journey to work and shopping, urban noise, safety, health and much more.

There are many sectoral aspects and a large set of potential indicators or evidence-informed targets needed in urban, transport and infrastructure policies designed to create healthy and liveable cities and to create benchmark policy measures to facilitate internal and external evaluation. Consistent standards enable not only to compare liveability between cities but also to assess the evolution of each city regarding these indicators (Chen, 2021; Lowe et al., 2020).

Moreover, there are sectorial policies targeted to sustainability and liveability. On urban logistics (Taniguchi, 2014), on food consumption (Elshater, 2020), on health associated to public transports (Khomenko et al., 2020), on green areas (Banzhaf et al., 2020), on drainage schemes (Maher, 2020), on urban forms and pollution (Nieuwenhuijsen, 2021), on technology to empower citizens (Sarkar, 2020), on urban contexts of identity (Oktay, 2020), on affordable housing in developing countries (Paşalar et al., 2020).

The problem is not on the dreams or the tools to promote those dreams, but on the set of assumptions taken for granted regarding the effectiveness of the proposed tools. The assumption that jobs and people would fill new cities, the assumption that technology conditional would increase cities' smartness and competitivity or that the provision of amenities will promote wellbeing. The same supply-driven ideas are implicit in the focus of basic needs, subsidies and allocation of public goods, assuming that the process of their provision is neutral (Ostrom & Ostrom, 1977), that time reveals the complementarities capital neglecting space (Hicks, 1973), that land rents are neutral and that the protectionism of inward-looking cities does not impact their relative performance.

The purpose of this chapter is not to destroy these wonderful ideas and associated policies, usually designed to capture big public spending, but to promote those dreams through the soft policy of institutional rules (Knight, 1992) in its different components (Dayneko & Dayneko, 2017): property rights, finance entities, legislation, urban planning, professional support, implementation and law enforcement of legal documents; training and education institutions; and informal institutions that facilitate cooperation and establish the norms of behaviour. The chapter specifically looks at property rights on transportation and land use to see how they can promote smart and liveable cities, old and new. What is evident is that institutional rules do have a role in urban form while being influenced by it (North, 1990).

Edella Schlager and Elinor Ostrom (1992) talk about suitable property rights. Property rights do have a role in the promotion of liveable places subject to intrinsic constraints. Property Rights are promoted by city managers, claimed by people's places and lived by visitors, users and proprietors.

Paul Samuelson (1954) tells us that the optimal provision of public goods occurs when the sum of the marginal wiliness to pay for a specific provision of public good equals the marginal costs of its provision. Being so the provision of public infrastructures along space should follow the Camarelistic Principle (Oliveira, 2021) according to which each 100 m of urban infrastructure should be paid by the users of that infrastructure. On the other hand, William Alonso (1964, 2005) reiterated by many others (see Duranton & Puga, 2015), proves that due to physical limitation of space the land rent decreases from the city centre to the periphery and therefore the value that can be collected by the promoters of linear urban infrastructures, potentially creating social and spatial segregation (Pumain, 2022).

The problem is when an egalitarian and expansive perspective of city development adopts the perspective that the size of the city should be defined when the average cost equals the average benefit (Simões-Lopes & Pontes, 2010), leading to a tragic of urban sprawl (Dentinho, 2011). That is what undermines the policy of equal prices for urban public transportation established in Lisbon in 2019 which effects are studied in the following point.[5]

There are a few studies that show the relation between urban centrality and house prices indicated (Qiao et al., 2016) and reviewed by (Ibraeva et al., 2020). Nevertheless, the study of the impact of the sudden uniformization of public transport tariffs seems to be a novelty.

3 Spatial Interaction Model to Assess the Impact of Egalitarian Transport Policies in the Lisbon Metropolitan Area

The Spatial Interaction Model with Land Use (Silveira & Dentinho, 2018) adapted to assess the impact of egalitarian transport policies in the Lisbon Metropolitan Area (Fig. 2) departs from the location of the Basic Population (that depends directly on the basic employment, and it is directly estimated by active population data per activity) and separates it from public and private transport users (k). Then distributes employment/transport users according to the residence—services shopping matrix $[B_k]$ and allocates residences following the employment—residence commuting matrix $[A_k]$ per transport user.

The Choice of Transportation is estimated by relating the logarithm of the weight of private car to logarithm of average time of public transportation from each municipality (Fig. 3).

Then the Spatial Interaction Model for the Lisbon Metropolitan Area, shown in Fig. 3, has seven main equations. Equation (1) relates the Population per municipality and per mode of transportation $[P_k]$ with the basic population per municipality and mode of transportation $[E_{kb}]$, the residence—services shopping matrix $[B_k]$ and the

[5] https://www.aml.pt/index.php?cMILID=SUS57DBFCB3A844B&cMILL=3&mIID=SUS57DBF9CE6D7CE&mIN=Tarif%E1rios%20e%20Passes&mILA=&cMILID1=SUS5787A25518AED&mIID1=3&mIN1=Mobilidade%20e%20transportes&cMILID2=SUS57DBFB5F23B12&mIID2=SUS57DBF8D8D52C5&mIN2=Transportes%20e%20tarifas&cMILID3=SUS57DBFCB3A844B&mIID3=SUS57DBF9CE6D7CE&mIN3=Tarif%E1rios%20e%20Passes.

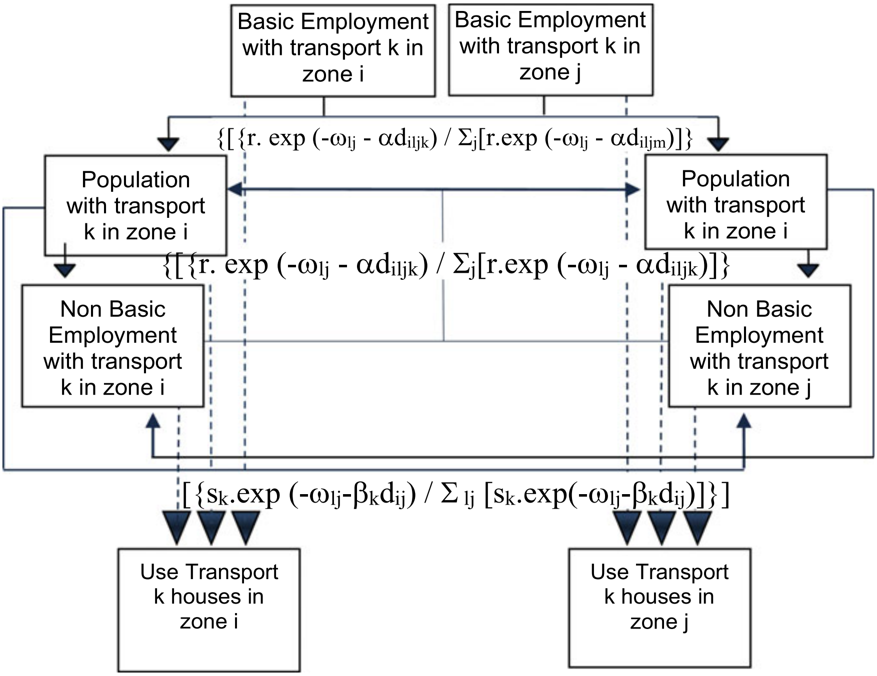

Fig. 2 Spatial interaction model with land use

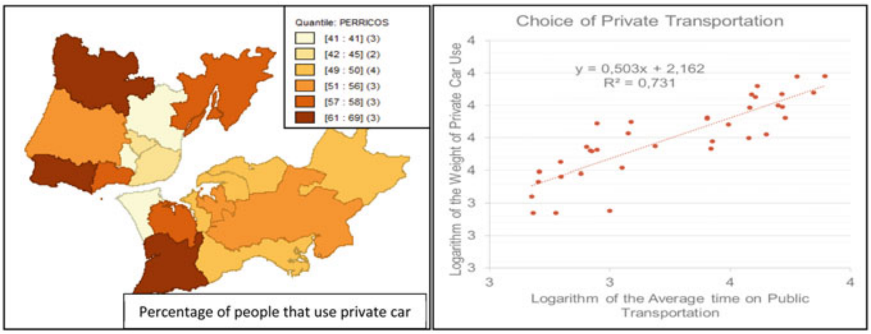

Fig. 3 Choice of private transportation (*Source* PORDATA 2019)

employment—residence commuting matrix $[A_k]$

$$[P_k] = \{I_M - [B_k][A_k]\}^{-1}[P_{kb}] \tag{1}$$

With Eq. (2) it is possible to derive the distribution of the employment per municipality by and mode of transportation by multiplying the population per municipality and mode of transportation $[P_k]$ by the residence—services shopping matrix $[B_k]$

$$[E_k] = [P_k][B_k] \tag{2}$$

Equation (3) explains that the coefficients of matrix $[B_k]$ depends on the inverse of the service rate (s), on the attrition function of the residence—services shopping movements ($e^{-\beta_k d_{kij}}$), on the capacity per municipality (V_j) and on the correction of the capacity per municipality (W_j).

$$\left[B_{kji}\right] = \frac{s.V_{ik}/W_{ik}.e^{-\beta_k d_{kij}}}{\sum_{i=1}^{m} s.V_{ik}/W_{ik}.e^{-\beta_k d_{kij}}} \tag{3}$$

Equation (4) explains that the coefficients of matrix $[A_k]$ depends on the inverse of the activity rate (r), on the attrition function of the employment-residence commuting movements ($e^{-\alpha_k d_{kij}}$), on the capacity per municipality (V_j) and on the correction of the capacity per municipality (W_j).

$$[A_{kij}] = \frac{r.V_{jk}/W_{jk}.e^{-\alpha_k d_{kij}}}{\sum_{j=1}^{m} r.V_{jk}/W_{jk}.e^{-\alpha_k d_{kij}}} \tag{4}$$

Equation (5) computes the footprint of the available space per municipality (Ai) of residents ($a_{\mathrm{hk}}.P_{ik}$) and employees ($a_{kf}E_{ki}$) where we assume that space for private car users is different from public transportation users.

$$Aik \geq a_{\mathrm{kh}}.P_{ki} + a_{kf}.E_{ki} \tag{5}$$

Equation (6) explains the adjustment of the correction of the capacity per municipality in each iteration ($Wi(t+1)$) that depends on the correction capacity of the former iteration ($Wi(t)$) and in the correction by the indicator of the use ($a_{\mathrm{kh}}.P_{ki} + a_{kf}.E_{ki}$) of the available capacity (Aik).

$$Wik(t+1) = Wi(t)\{a_{\mathrm{kh}}.P_{ki} + a_{kf}.E_{ki})/Aik\} \tag{6}$$

Finally, the bid rent per municipality is a function of the capacity per municipality and type of transport user (V_{jk}) and on the correction of the capacity per municipality and type of transport user (W_{jk}).

$$\omega_{ik} = -\left(ln\frac{1}{(\frac{V_{ik}}{W_{ik}})}\right) \tag{7}$$

After estimating the basic population and employment based on location quotients above 1 we estimated the service rate (s = 0,48) and the Inverse of the activity rate (r = 1,68). Then using the choice of private transportation estimates of Fig. 3, we pick up in Google Earth the commuting times by car (Annex 1, Table A1) and by bus

Table 1 Average commuting and shopping times and attrition parameters

	Average Time	Attrition Parameter
Commuting with car	18	$\alpha_c = 0{,}112{,}364$
Commuting with bus	38	$\alpha_b = 0{,}02{,}506$
Shopping with car	9	$\beta_c = 0{,}583{,}256$
Shopping with bus	13	$\beta_b = 0{,}351{,}844$

(Annex 1, Table A2) and determined the Basic Population and Employment by type of mobility (Annex 1, Table A3). Afterwards, we could structure the equations model (1) to (7) in excel and, using the solver, calibrate the attrition parameters to secure that the average commuting and shopping distances equal the average estimated commuting and shopping distances (Table 1).

The calibration of the bid rents (ω_{ik}) for spaces of car users and bus users was done in three interactions presented in Fig. 4 beginning all of them by the unity.

For this essay, we do not disaggregate the model by type of house and therefore we cannot relate the estimated bid rents for car and bus users by type of house. Nevertheless, we can relate those two bid rents sets with the price of houses for each municipality in Table 2. Clearly there is a relation between the bid rents and house prices but with a premium for the south sea front municipalities of Lisbon, Oeiras, Cascais and Sesimbra.

Finally, we can use the estimated model to simulate the impact on house prices of egalitarian policies of equal transport prices for all metropolitan areas (Fig. 5). The

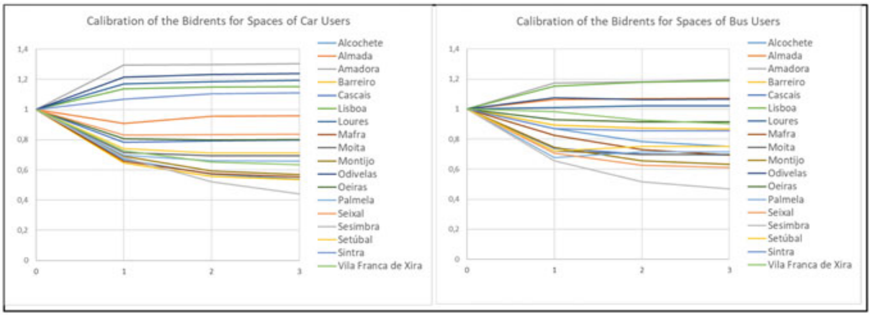

Fig. 4 Calibration of the Bid rents for spaces of car users and bus users

Table 2 Relations of the bid rents with House Prices for car and bus users

Car Users	Coefficient	Stat t	P value	Bus Users	Coefficient	Stat t	P value
Constant	871,4	9,34	0,0000	Constant	689,6	6,430	0,000
Bid Rent	415,0	3,90	0,0014	Bid Rent	619,5	5,057	0,000
Sea Front	446,5	6,52	0,0000	Sea Front	453,7	7,670	0,000
R	F	Sig		R	F	Sig	

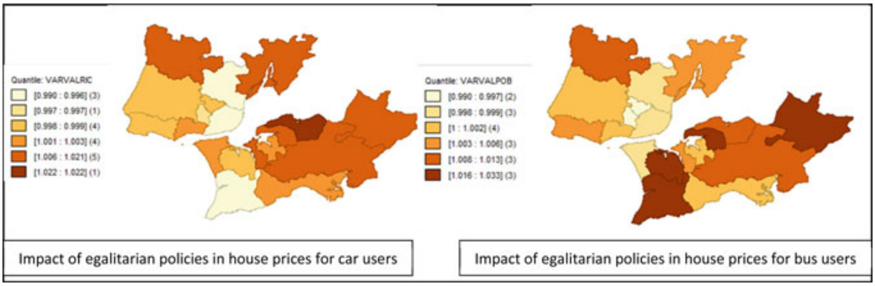

Fig. 5 Impact of egalitarian policies in house prices for car and bus users

model reveals that more peripheral municipalities have higher increases in house prices even more if they depend more on public transportation. In the next point we test these simulation results with real data from 2019 to 2022.

4 The Tragedy of Spatially Egalitarian Social Passes for the Metropolitan Area of Lisbon

The announcement made by the journal in March 2019 was "The inhabitants of the 18 municipalities of Greater Lisbon will be able to travel monthly for a maximum amount of 40 euros. Here is an example of the savings: a Fertagus pass between Setúbal and Lisbon, including Metro and Carris, costs 1933.8 euros per year (161.15 euros per month)".[6] The hypothesis to be tested are:

Hypothesis 1: The establishment of egalitarian tariffs of public transportation will increase land prices in the periphery.

Hypothesis 2: The creation of public monopolistic provider of transport to accommodate cross subsidization of the egalitarian tariffs of public transportation is associated with more strikes.

Hypothesis 3: The establishment of egalitarian tariffs of public transportation will reinforce urban sprawl.

1) *The establishment of egalitarian tariffs of public transportation will increase land prices in the periphery.*
   Figure 6 shows the evolution of the median house prices per square metre in Lisbon Metropolitan Area (INE, 2023). There is an overall increase in the medium house prices in the Lisbon Metropolitan Area.

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[6] https://jornaleconomico.pt/noticias/18-cidades-por-40-euros-novos-passes-da-grande-lisboa-entram-amanha-em-vigor-427983.

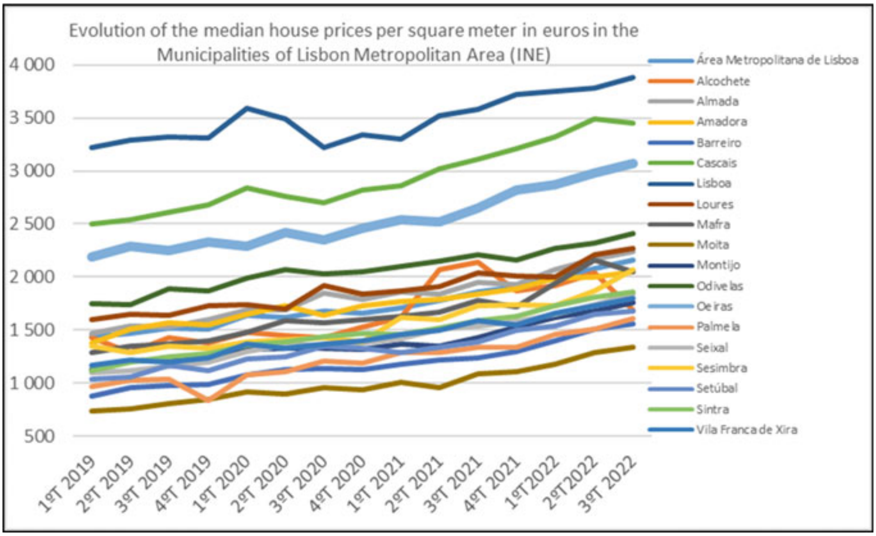

Fig. 6 Evolution of the median house prices per square metre in Lisbon Metropolitan Area (INE)

Nevertheless, looking at the Relation between the Median House Prices Growth from 2019 to 2022 per municipality to the Median House Prices Growth of the Lisbon Metropolitan Area (Fig. 7) the pattern is clear.

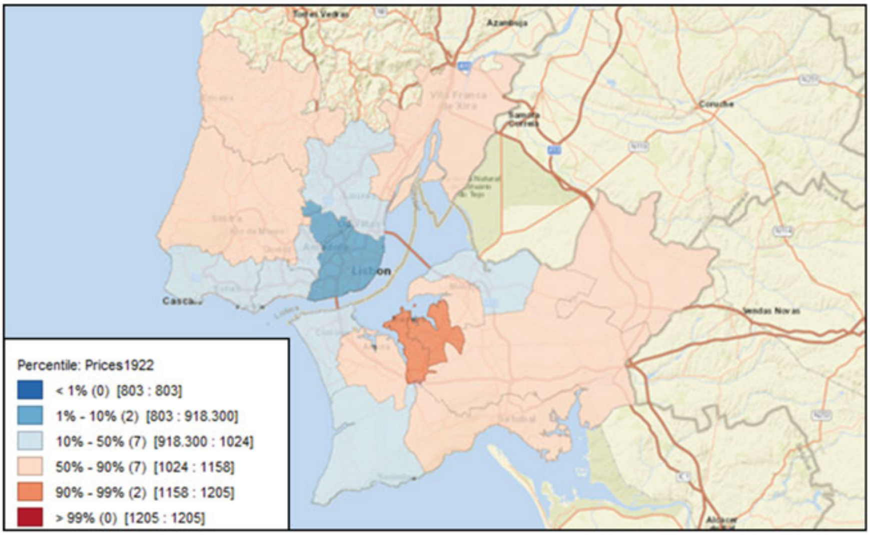

Fig. 7 House price index (base 2019) for each municipality in 2022 divided by the house price index (base 2019) of the Lisbon Metropolitan Area (INE) (*Source* Author)

The median house prices in the more peripheral municipalities of Barreiro and Moita—because they have to cross by ferry—grew more 15,8 % than the growth in the Medium House Prices of the Lisbon Metropolitan Area (dark orange in Fig. 7).

In the peripheric municipalities of Sintra, Mafra, Vila Franca de Xira, Montijo, Palmela, Setúbal and Seixal (light orange in Fig. 7), the medium house prices grew more than 2,4% than the growth in the Medium House Prices of the Lisbon Metropolitan Area (light orange in Fig. 7).

The median house prices in the relatively central municipalities Cascais, Oeiras, Amadora, Loures, Almada and Sesimbra—that combine the proximity of the sea with the accessibility to Lisbon—the medium house prices grew at the same path of the Medium House Prices of the Lisbon Metropolitan Area (light blue in Fig. 7).

Finally, the Medium House Prices of Lisbon and Odivelas grew less 19,7% than the growth in the Medium House Prices of the Lisbon Metropolitan Area (dark blue in Fig. 7).

Furthermore, by multiplying the relative increase in the House Prices per Municipality (Fig. 7) by the median value of the houses per municipality, then by the annual interest (5%) and, finally, dividing by 12 months, we get an indicator of the changes in the opportunity costs of the houses per municipality (Fig. 8). Interestingly, the municipalities that benefit relatively more from the egalitarian tariffs expressed by the reduction of the opportunity costs of their houses are the richer municipalities of Lisboa and Cascais.

Summing up not only we confirmed the hypothesis that "The establishment of egalitarian tariffs of public transportation will increase land prices in the

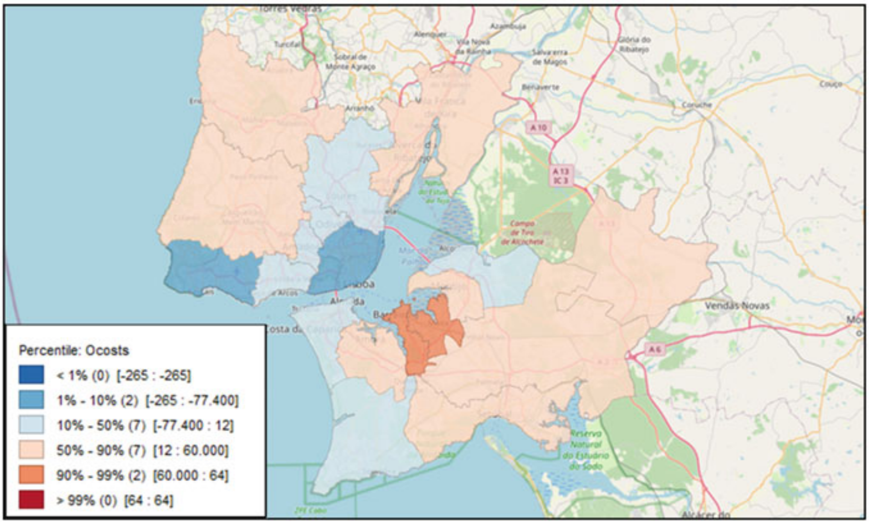

Fig. 8 Changes in the opportunity costs of the houses per month (*Source* Author)

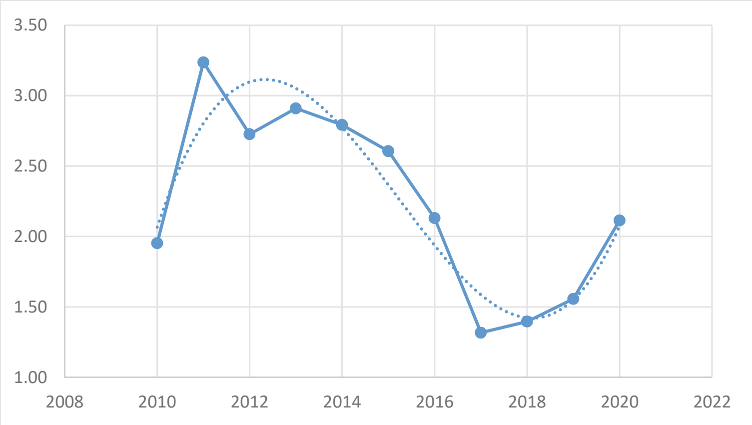

Fig. 9 Evolution of strikes on transports, storage and communication relative to the strikes for all sectors (PORDATA) (*Source* Author)

periphery" but also we estimate that the municipalities that benefit relatively more from the measure are the richer municipalities of Lisboa and Cascais whereas the poor ones have an extra opportunity cost per house that overcomes the egalitarian tariff of 40 euros.

2) *The creation of public monopolistic provider of transport to accommodate cross subsidization of the transportation costs is usually associated with more strikes.*

   Data available on strikes per sector published by PORDATA (Fig. 9) (https://www.pordata.pt/db/portugal/ambiente+de+consulta/tabela) does not discriminate strikes per region. Nevertheless, it is interesting to perceive that strikes in transportation and storage grew 8,3% from 2018 to 2020 whereas the total strikes decreased 28,5% from 2018 to 2020. Associated with this, the ratio between the index of strikes for Transport, Storage and Transportation with the index of Total Strikes increased from 1,32 in 2018 to 2,11 in 2020.

   This is not enough to prove the hypothesis that "The creation of public monopolistic provider of transport to accommodate cross subsidization of the transportation costs is usually associated with more strikes", but it is a good indication for further analysis.

3) *The establishment of egalitarian tariffs of public transportation will reinforce urban sprawl.*

   Data on changes in the stock of housing is only available for 2011 and 2021 (INE). Figure 8 presents the municipalities that increased above and below the change in the Lisbon Metropolitan Area. There is urban sprawl with higher increases of the housing stock in the peripheral municipalities of Mafra, Seixal, Montijo and Palmela, but also in Oeiras.

   Comparing with Fig. 10, with the exception of Oeiras, where house prices increase less than the average of the Metropolitan Area from 2019 to 2021, and Moita and Barreiro, where house prices increase more than the average of

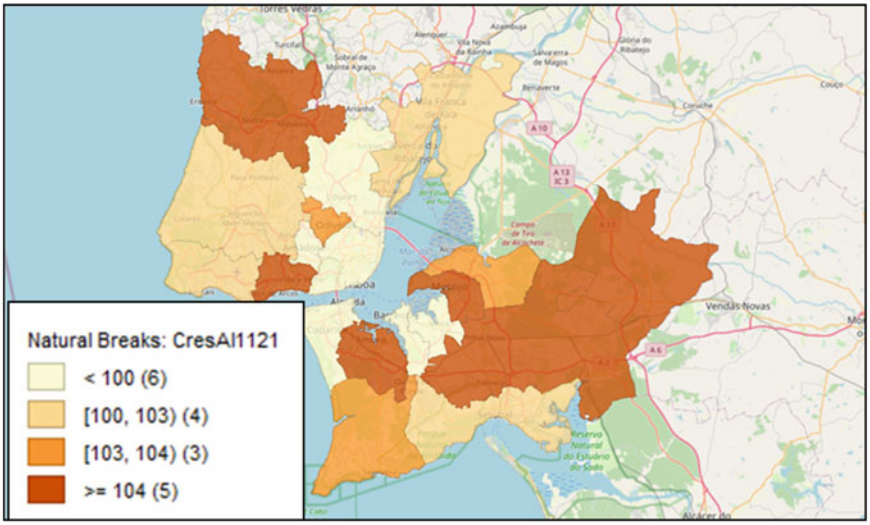

Fig. 10 Change in housing stock from 2011 to 2021 (PORDATA) (*Source* Author)

the Metropolitan Area from 2019 to 2021, the municipalities that show higher growth in the stock of houses for the longer term of 2011–2021 are also the ones that registered higher increases in house prices, associated with the policy of equalizing transport tariffs, reinforcing the pressure for urban sprawl and increasing cost or the Metropolitan Area.

Summing up there is an indication of the confirmation of Hypothesis 3: The establishment of egalitarian tariffs of public transportation that will reinforce urban sprawl.

5 Conclusions

The argument of the chapter was that Liveable cities depend on environmental, technological and socioeconomic assets but mainly on the institutional allocation of property rights that allow their mobilization by and for citizens. One of the main property rights of citizens is to have access to jobs and shops with reduced transport and residence costs. Access to jobs relates to the Sustainable Development Goals of Decent Work and Economic Growth (G8), Reduced Inequalities (G10) and achieve (G1 - No Poverty). Access to Shops relates to Responsible Consumption and Production (G12), Good Health and Well-being (G2). Finally, urban accessibility and avoiding urban sprawl have to do with Sustainable Cities and Communities (G11); Climate Action (G13), the protection of good soil relates with Life on Land (G15) and reduced transport costs with Affordable Clean Energy (G7).

The problem arises when politicians try to promote one objective, in this case equal access within the metropolitan area, without taking into account the intrinsically systemic nature of the various sustainable development goals.

As hypothesized the uniform transport costs in Lisbon Metropolitan Area would lead to increased house prices in the periphery, to reduced competition in transportations, to urban sprawl and to an increased cost of the urban area. The spatial interaction urban model presented in Point 3 sustains that there is an higher increase in real estate prices in the periphery when compared with house price increases in the centre. And that is confirmed by the reality that reveals that house prices are rising more in the periphery, strikes in the transport sector are becoming more frequent and that there are clear signs of reinforced urban sprawl and related urban costs.

Actually, using a spatial interaction model with space use calibrated for the metropolitan region of Lisbon and based on real recent data it becomes evident that the uniformization of public transport tariffs will increase the house prices in the periphery and promote urban sprawl. In the ned poor people will lose the apparent benefit because it would become more expensive to rent the house they need and those houses will be more far away.

To conclude on the idea of Liveable Cities, we should have them but based on elementary principles that trendy policies of New, Smart and Dream Cities tend to forget. The Samuelson (1954) Principle that marginal costs of public goods should be equal to marginal benefits both changing across space. The Chadwick (1978) Principle of the Systemic View of the Environmental, nowadays, advises us to look at Sustainable Development Goals systemically. The Alonso (1964) Principle that space is a constraint and a capability.

Annex 1: Data

Table A1 Commuting times by car between municipalities of Lisbon Metropolitan Area

Time by Car	Alcochete	Almada	Amadora	Barreiro	Cascais	Lisboa	Loures	Mafra	Moita	Montijo	Odivelas	Oeiras	Palmela	Seixal	Sesimbra	Setúbal	Sintra	Franca de
Alcochete	8	35	32	33	55	37	30	46	20	16	30	48	30	31	49	30	45	38
Almada	35	10	21	32	34	19	26	42	26	36	24	28	29	19	37	31	31	39
Amadora	32	21	6	42	30	20	16	32	32	33	11	22	39	29	46	41	20	31
Barreiro	33	32	42	10	57	41	43	59	20	32	43	49	29	24	41	31	52	54
Cascais	55	34	30	57	11	35	36	44	51	55	34	26	54	44	62	56	22	51
Lisboa	37	19	20	41	35	10	25	41	36	37	22	27	39	29	46	40	29	35
Loures	30	26	16	43	36	25	6	23	29	30	11	28	38	34	52	38	24	24
Mafra	46	42	32	59	44	41	23	12	45	46	26	41	55	50	68	54	26	39
Moita	20	26	32	20	51	36	29	45	10	19	31	44	21	20	38	26	46	42
Montijo	16	36	33	32	55	37	30	46	19	8	33	51	32	30	47	31	48	44
Odivelas	30	24	11	43	34	22	11	26	31	33	6	25	38	31	49	37	22	27
Oeiras	48	28	22	49	26	27	28	41	44	51	25	11	47	37	55	49	26	44
Palmela	30	29	39	29	54	39	38	55	21	32	38	47	8	26	39	15	50	49
Seixal	31	19	29	24	44	29	34	50	20	30	31	37	26	10	35	29	40	48
Sesimbra	49	37	46	41	62	46	52	68	38	47	49	55	39	35	18	36	59	66
Setúbal	30	31	41	31	56	40	38	54	26	31	37	49	15	29	36	8	54	49
Sintra	45	31	20	52	22	29	24	26	46	48	22	26	50	40	59	54	10	39
a Franca de X	38	39	31	54	51	35	24	39	42	44	27	44	49	48	66	49	39	12

Source Google Maps

Table A2 Commuting times by bus between municipalities of Lisbon Metropolitan Area

Time by Bus	Alcochete	Almada	Amadora	Barreiro	Cascais	Lisboa	Loures	Mafra	Moita	Montijo	Odivelas	Oeiras	Palmela	Seixal	Sesimbra	Setúbal	Sintra	Franca de
Alcochete	16	71	65	67	111	75	61	93	40	32	61	97	61	63	99	61	91	77
Almada	71	17	34	88	104	36	52	85	66	73	44	66	36	35	75	41	62	56
Amadora	65	34	14	85	71	27	32	65	124	67	29	72	74	69	61	75	27	63
Barreiro	67	88	85	6	94	34	87	119	11	65	74	97	26	90	83	30	94	74
Cascais	111	104	71	94	8	54	73	89	170	111	70	16	140	139	83	145	97	101
Lisboa	75	36	27	34	54	14	50	83	76	75	30	33	91	85	93	95	65	45
Loures	61	52	32	87	73	50	11	46	58	61	22	56	77	69	105	77	48	48
Mafra	93	85	65	119	89	83	46	23	91	93	52	83	111	101	137	109	52	79
Moita	40	66	124	11	170	76	58	91	6	38	112	89	14	78	77	18	118	128
Montijo	32	73	67	65	111	75	61	93	38	16	67	103	65	61	95	63	97	89
Odivelas	61	44	29	74	70	30	22	52	112	67	11	62	84	90	99	89	66	66
Oeiras	97	66	72	97	16	33	56	83	89	103	62	8	141	125	111	81	85	78
Palmela	61	36	74	26	140	91	77	111	14	65	84	141	2	62	79	4	92	105
Seixal	63	35	69	90	139	85	69	101	78	61	90	125	62	18	71	65	99	99
Sesimbra	99	75	61	83	83	93	105	137	77	95	99	111	79	71	31	73	119	133
Setúbal	61	41	75	30	145	95	77	109	18	63	89	81	4	65	73	2	97	110
Sintra	91	62	27	94	97	65	48	52	118	97	66	85	92	99	119	97	14	65
Vila Franca de	77	56	63	74	101	45	48	79	128	89	66	78	105	99	133	110	65	23

Source Google Maps

Table A3 Data on basic population and employment by type of mobility

	Alcochete	Almada	Amadora	Barreiro	Cascais	Lisboa	Loures	Mafra	Moita	Montijo	Odivelas	Oeiras	Palmela	Seixal	Sesimbra	Setúbal	Sintra	Franca de
Basic Employment in the Residence	2105	18631	19238	8106	23476	57919	23459	9260	7063	5767	15211	19804	6942	17971	5660	13115	45636	16909
Population associated to Basic Employment	3528	31223	32242	13585	39344	97067	39315	15519	11836	9664	25493	33190	11634	30118	9486	21980	76483	28339
Average time of transportation	36	30	31	36	49	31	30	44	38	37	33	41	37	41	47	36	40	42
Proportion of the Population that Use Car	0,49	0,41	0,41	0,49	0,69	0,42	0,41	0,61	0,53	0,50	0,45	0,57	0,51	0,57	0,65	0,50	0,56	0,58
Population associated to Basic Employment by car	1732	12653	13287	6645	27118	40292	15925	9442	6268	4872	11362	18838	5915	17155	6210	10895	42730	16349
Population associated to Basic Employment by bus	1796	18571	18955	6940	12226	56775	23390	6077	5569	4792	14131	14352	5719	12964	3276	11085	33753	11990
Space for Car Users	6905	135464	157500	31650	193261	525073	156760	44304	40037	22122	130698	127844	33606	119786	19052	65412	372099	67958
Space for Bus Users	5449	126088	159730	50302	86155	767482	181203	19845	39810	22023	107905	107984	58356	64276	11747	115421	243335	37667

Source INE, author

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Challenges in Building More Liveable Cities in Post-socialist European Countries: From "*Cities4all*" to "*Cities4everyone*"

Alexandru Bănică and Gabriela Carmen Pascariu

1 Introduction

In the post-second global war period, the urban development in the former socialist bloc of Eastern and Central European countries did not follow a fundamentally different macroeconomic and functional dynamic from that of Western Europe countries (Enyedi, 1992; Sailer-Fliege, 1999). In both cases, Eastern and Western, urbanisation relates to the industrialisation processes promoted through growth policies following the same evolution stages: urbanisation, suburbanisation, desurbanisation and re-urbanisation (Berg et al., 1982), though on different social models: market economy versus centrally planned economy, with specific institutional systems. Nevertheless, capital cities became the core of both systems' main administrative, social and economic functions. Central authorities intensified urbanisation by developing a dense network of small and medium cities. The growth of cities was achieved mainly through rural-urban migration, agglomeration and industrial clustering (Musil, 1993), generated by free markets in the capitalist system, through centralised planning in the socialist system, respectively. As growth poles, cities have played a key role not only in balanced territorial development but mainly in ensuring economic dynamics, promoting innovation and technological progress, human capital development and in increasing welfare. Moreover, both systems witnessed specific social segregation and subordination of environmental and social

A. Bănică (✉)
Department of Geography, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iaşi, Iaşi, Romania
e-mail: alexandru.banica@uaic.ro

G. C. Pascariu
Centre for European Studies, Faculty of Law, Alexandru Ioan Cuza University of Iaşi, Iaşi, Romania
e-mail: gcpas@uaic.ro

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issues to economic objectives specific to the so-called "30 glorious years" (Fourastié, 1979).

However, at the end of the 1980s, the urbanisation level in Central and Eastern Europe was lower (63% in Central Europe and 55% in South-Eastern Europe) compared to that in Western Europe (80%) (Tosics, 2005). Moreover, the particularities that resulted from one economic model and institutional system or the other generated significant structural differences (economic, social, spatial, governance) between the two and seriously influenced the post-socialist cities' dynamic and capacity to transform within the post-1990 evolutionary context.

In a transition process subject to European policies' implementation, on the one hand, and to the adoption of the open market economy system, on the other (which was most often uncontrolled and only fragmentarily included in the urban development strategies and policies, and which proved rather reactive than proactive), CEE cities had to adapt to two fundamental changes: of the economic system and the institutional system. The defining axes of post-socialist transformations were: economic restructuring, labour market transformation and migration, spatial reorganisation, housing market transformation, institutional and social transformation and environmental changes. However, we acknowledge that the heterogeneity of post-communist cities is rather high and the differences between them must be considered (Hirt, 2013). Nevertheless, all Central and Eastern Europe cities depend on economic, spatial, environmental, cultural and institutional conditions which defined their development in the socialist period and which generated a particular "path dependency" (Tosics, 2005), in the sense that the new urban development models would imply high opportunity costs. Consequently, the critical question which arises is related to the evolving perspectives of post-socialist cities, more specifically, to the perspectives they have for building a more urban liveable context in terms not only of objects but also of subjective happiness and well-being, which are the "path dependency" driving forces and constraints (the economic, social, cultural and institutional marks left by the four decades of socialism) in the transition process towards the new and sometimes overlapping and conflicting European urban paradigms (sustainable, smart, green, resilient).

It is well documented that the decades of socialism imposed a specific meaning on the concept of liveability as progress and economic prosperity. However, the former communist countries valued "collective values at the expense of individualism". At the same time, cities were regarded as the focal point for applying the desiderate of a classless society (Gentile et al., 2012, p. 291). One could identify an explicit path dependency in the evolution of post-socialist cities, but also drivers of transformation towards new urban paradigms emerging from the convergence of central concepts such as sustainability, smartness and resilience. However, the new perspective still lacks a comprehensive inclusion of individuals' quality of life as the last goal of growth and development. The current approach aims to analyse the patterns of CEE urban transition and the present state from the viewpoint of the liveability concept. We focus on what could make a post-socialist city a 'real' and attractive city from individual citizens' perspectives.

There is a critical perspective on the multitude of concepts and utopias that shaped urban management and planning in CEE countries, highlighting the need for a novel perspective that should enhance not only population welfare but rather individual capabilities and happiness as the purpose of urban development. Therefore, there are four main objectives of the current assessment: (a) To critically assess the urban evolution after 1990 by taking into account the changing patterns and the multiple challenges faced by CEE cities that resulted in convergences or divergences when compared to cities from other EU countries; (b) To emphasise the outcomes of adopting new approaches that are accepted worldwide such as sustainability, resilience and smartness as main paradigms in urban development in post-socialist cities; (c) To highlight the gap between CEE urban area and other EU cities by taking into account both objective and subjective indicators; (d) To discuss the critical points of the urban development rethinking in the CEE countries, based on a "city4me"/ "city4everyone" paradigm, instead of a "city4all", thus reflecting the necessity for a more individual approach instead of a collective one; a development pattern based on the balance between individual interests, the interests of the community and the interests of the environment, focussed on the individual happiness. In essence, our approach is intended to be seen not only as a critical analysis of the development of cities in post-socialist countries but also as a plea for placing human beings at the centre of urban development and planning policies for a more individualised approach focussed on well-being conditionalities and peoples' happiness.

The paper is structured as follows: After the first introductory part, the second part is a theoretical framework of liveable cities in the context of the numerous approaches regarding urban design and development. The third part provides a critical perspective on the post-communist transition of Central and Eastern European cities through the lens of liveability and the fourth part is an operationalisation of the liveability concept based on a comparative analysis between CEE cities and urban areas from other European regions by using statistical and survey data. Finally, the fifth part proposes a theoretical framework that would bridge the new urban concepts to liveability, i.e. the concepts of individual capabilities (*apud* A. Sen) and happiness. In the last part, the conclusions represent a plea for a more individualised approach to the transformation and development of post-communist cities, within an integrated approach to liveability, reflected by the "theory of capabilities".

2 Some Highlights Regarding the Liveable Cities Concept

Cities are highly complex evolving systems that concentrate population and human activities and put increasingly higher pressure on rural areas and the natural environment. They are considered the most important vector of human development/ progress. However, they are not always the best place to live in as agglomeration, discomfort, insecurity, pollution, noise and stress are a part of urban life worldwide (Whelan, 2012). All these have made urban scientists and practitioners look for better ways to manage cities embedded in an extraordinary abundance of new emerging concepts. Each approach focusses on specific issues and solutions for shaping future cities that could improve the urban environment, society, economy, governance systems and institutions (Table 1).

A dominant concept in the scientific literature and policies, the "liveable city", focusses on urban development, individual welfare and social equity. It mostly overlaps concepts such as (objective) quality of life, standard of living, level of living, habitability or well-being, measuring the suitability of urban environment for human living (Burton, 2014; Okulicz-Kozaryn & Valente, 2019; Veenhoven, 2008).

It imagines a city at the centre of human life, aiming to transform the city into a place where it is worth living. Soja (2000) links liveability to urban crisis and the need to promote urban regeneration and renewal in cities threatened by growth-centred policies. However, it is a relatively new concept. The fundamentals can be found in a variety of urban studies. For example, in "The Image of the City" (1960), Kevin Lynch highlights the importance of quality places in cities which are closely connected to human behaviour. He argues that there are several dimensions of a liveable city, among which vitality is the most relevant. In Lynch's view, three aspects of vitality should be considered: sustenance (assuring the basic needs of the population sustainably: adequate food, energy, water and air, while efficiently disposing of waste and diminishing pollution), safety (managing hazards, pollution, criminality and disease in a city) and consonance (which refers to making cities function as organisms that could self-regulate/control their functions in similar ways as human bodies). Besides vitality, Lynch adds two other dimensions of urban life: access (or accessibility to services and places of interest) and fit (between human behaviour and places).

Lynch's perspective considers liveability in cities based on vital functions, physical requirements and human capabilities. Stating that freedom to achieve well-being is of primary moral importance (Robeyns & Byskov, 2021), the capability theory was developed in the late 1970s by Amartya Sen and significantly influenced social justice and human development. Individual capabilities represent the effective freedoms of individuals to do and become things of value (Sen, 1999). It is not a sum of abilities but rather a combination of various functionings that a human being can achieve (Sen,

Table 1 Emerging concepts regarding four dimensions of cities

Environmental	Social	Economic	Governance/institutions
Garden cities	Participative cities	Entrepreneurial cities	Managed cities
Sustainable cities	Walkable cities	Competitive cities	Intelligent cities
Eco-cities	Integrated cities	Productive cities	Productive cities
Green cities	Inclusive cities	Innovative cities	Efficient cities
Compact cities	Just cities	Business-friendly cities	Well-run, well-led cities
Smart cities	Open cities	Global cities	Smart cities
Resilient cities	Liveable cities	Resilient cities	Future cities

Source Moir et al. (2014)

1993). They include basic but also more complex needs: food and shelter, mobility, health and education/knowledgeability, social interaction, a decent standard of living, subjective life satisfaction, security, etc. However, the theory differentiates between the actual assets and achievements of a person or a group ("well-being achievement") and the set of real opportunities each individual has ("well-being freedom") (Gaertner, 1993). Although Sen's theory was designed to be mostly applied to developing nations, we argue that it can be adapted and transferred towards liveability of higher income countries that are confronted with relatively high social, economic or environmental inequalities and injustice.

From the urban governance perspective, liveability deepens and humanises sustainability, smartness and resilience. It focusses on basic goods, services and experiences essential for human life (Caves & Wagner, 2018). One can include here a great variety of elements: strong connections with nature (e.g. proximity to green areas), water and air, clean, effective sanitation services, transport and mobility opportunities, accessible and clean forms of energy, health and educational services, public safety, inclusive neighbourhoods, responsible and trustworthy local authorities, a balance of top-down and bottom-up approaches to ensure citizens' participation in the decision-making process (Kotus & Rzeszewski, 2013). Consequently, liveability reflects the institutional arrangements' ability to address human needs and capacities (Veenhoven, 2014).

As such, liveability results from the quality of the built and natural environment, economic prosperity, social balance and equity, educational opportunities and cultural and recreational possibilities (PLC, 2017) (Fig. 1).

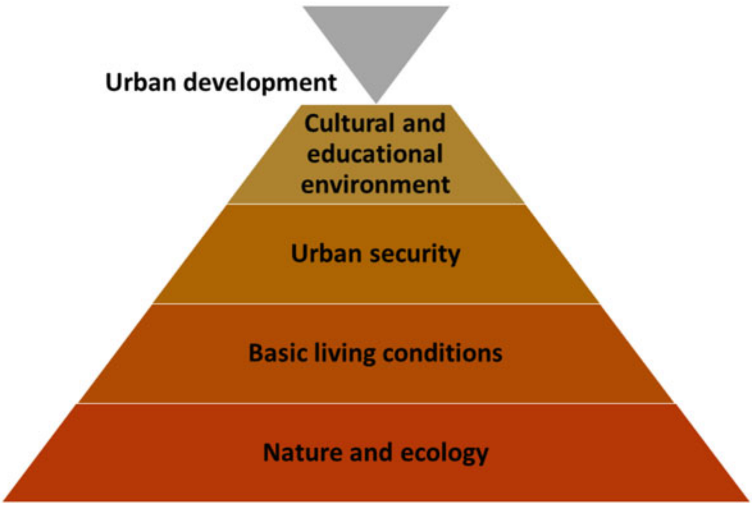

Fig. 1 The concept of liveability. *Source* Own representation, ideas from Wang (2012), Evans (2002) and Lennard (1997)

Thus, on the one hand, liveability includes interconnected social, economic and spatial components; on the other hand, it is linked to the human experience of place. From this second perspective, liveability integrates the quality of human interrelations, social environment and civic participation in the decision-making process. It also involves belonging to one place, which shapes every individual's experience (Gunn, 2007; Kaal, 2011). However, this is also the main limit of the liveability concept: it fails to include intangible qualities of place such as authenticity, vibrancy or distinctiveness (Okulicz-Kozaryn & Valente, 2019). Moreover, it does not include the subjective well-being as such and has to be integrated with complementary approaches that evaluate not just the favourability of urban places but also the level of individual happiness they bring. It can be measured through "Satisfaction with life in this city" which is related to experiencing everything included in urban life (Moeinaddini et al., 2020).

Just like the quality of life, liveability cannot be separated from the subjective component of collective and individual perceptions, feelings and values. It means that the objective dimensions and indicators mentioned above have different degrees of importance from one culture to another, from one country to another and from one city to another (Senlier et al., 2009). Therefore, one should acknowledge that each municipality is unique and that there is no one-fits-all suitable approach to shaping liveable cities (Caves & Wagner, 2018).

3 The Post-Communist Transition of Central and Eastern European Cities Through the Lens of Liveability

The socialist city was embedded in a development pattern that made the transition to the market economy and the Europeanisation process difficult. The first is homogeneity: the typical industrial profile and the reduced urban difference. Secondly: the equal development and equalisation of living conditions. One can add as fundamentals: public property of land and buildings (the private rental market has been eliminated or reduced), limited opportunities in the housing sector (small standardised apartment blocks), while in some cases, the historical buildings and city centres were partially demolished and replaced by a new, more neutral architecture. It was followed by limiting citizens' participation in public life and introducing a strict and rigid order in which decisions were made hierarchically and top-down. Also, from an economic point of view, post-socialist cities are seen as "anomalies" (Robinson, 2004), lagging entities that should return to "normal" economic relations that are specific to the capitalist system (Diener & Hagen, 2013).

Under communist regimes, all "deviations from socialism" were forbidden, while socialist principles were the only criteria for a good public life. Striving for personal financial gain was not encouraged; instead, the focus was on individual contributions to building the communist society (Herrschel, 2007). From the viewpoint of life quality, "socialism is not a moral theory that offers a particular vision of the good life. Instead, it is a theory about how the good life is possible" (Luntley, 1989, p. 15). This understanding views socialism as an instrument, a means of getting to a "better" form of society shaped by "good" moral values. The new political and bureaucratic elite controlled every aspect of social life (which had a privileged lifestyle and a relatively better quality of life). At the same time, the rest of the people were valued only as parts of the productive economic system, not as individuals that should strive for a good quality of life (Herrschel, 2007).

Post-communism brought big changes and significant challenges in the last 30 years. The urban environment, shaped for more than 40 years under the previous system, was adapted and remodelled to match the new conditions of the political, economic, social and cultural transition towards a capitalist society (Cudny & Kunc, 2021). The Europeanisation of post-socialist countries was a process of institutional changes (formal and informal) and structural convergence (economic, socio-cultural, political), which led to profound changes in morphological and functional urban structures. First, the shrinkage: the process of change of property rights (from public to private) and reshaping of the political and institutional framework. There was a stagnation of development and even a decade of urban decline, which resulted in rural and external migration. The consequent negative balance of population (Haase et al., 2016) induced economic decline, increasing social inequalities and individual alienation in cities.

Meanwhile, the excessive commercialisation and densification of the inner-city areas were followed by an unprecedented expansion of build-up space (Sýkora & Bouzarovski, 2012), i.e. office and public buildings in city centres and around, with residential areas in peripheries. However, urban structure/morphology was much more inertial, while socio-demographic, cultural and economic subsystems were the first to need adaptation. The transition was from a compact urban development to suburbanisation and dispersed urban areas (Ianos et al., 2016; Stanilov & Sykora, 2014), which led to "sprawl without growth pattern" (Schmidt, 2011) and significant changes in urban land-use patterns. The result was the "perforated city" (Florentin, 2010; Ianos et al., 2016) and gradual urbanisation of the proximal rural areas, similar to a percolation process (Diappi, 2004). Both processes describe urban areas as simultaneously subject to urban shrinkage and sprawl, profoundly impacting urban life.

All types of disparities emerged, starting with an increasing contrast between capital cities and other major cities, major cities-small cities, intra-urban disparities and centre versus suburban, which are highly visible in the form of increasing social disparities and segregation (Sailer-Fliege, 1999).

Urban policies were oriented towards competitiveness and growth, focussing on the city's attractiveness for business and capital, while social and environmental issues were considered secondary. Meanwhile, numerous scholars clearly state that quality-of-life investments have economic benefits (attraction of skilled workforce and innovative firms) and social and environmental benefits. The need for more commitment towards general well-being and individual citizens' quality of life can also be linked to the low level of governance, transparency and civic engagement. Therefore, they should be prioritised (Ionescu-Heroiu et al., 2013).

At least three essential concepts marked the post-socialist urban transition with different impacts on the liveability of cities, i.e. sustainable, resilient and intelligent, as defining paradigms of current cities.

The question is whether different ways and patterns of urban transformations lead to convergence or divergence with the Western style and features or whether it is preferable to design a more specific and different model of urban development that will creatively include the three paradigms in the actual context of CEE countries.

4 Bridging the Gap—A Comparison Between Post-Socialist Cities and Other Types of European Cities

Our analysis considered the East-West and North-South divide, summarising the specific patterns of cities in these four European regions. We have chosen a limited number of indicators available for European cities and tried to look at spatial differences and specificities of cities from each region. Looking at six selected indicators that cover the economic, social, environmental and cultural dimensions of urban liveability, one can envisage the clear-cut differences that are still present 30 years after the collapse of the communist bloc.

All EU's low-income lagging regions (and cities) are in former communist countries (EC, 2017). A clear West-East divide within Central and Eastern Europe (CEE) is influenced not by city size but rather by the geographical distance to the Western European frontier (Zdanowska et al., 2020). However, notable events have affected either certain regions of Europe or the continent as a whole. They have left their mark on the evolution of urban space and socio-economic change. For example, the economic crisis that began in 2008 marked a decline in GDP in Southern Europe (low-growth lagging regions) to a greater extent than in CEE countries (low-income regions).

Although it started from a low base level, in relative terms, the CEE city experienced noticeable economic growth to "catch up" with cities from older member states. Many cities succeeded during the economic crisis and, especially after that, in overcoming, at least partially, the historical gap.

4.1 The Catching-Up—An Overview of Recent Trends in Liveability

There are apparent differences between economic convergence and the maintenance of visible gaps in the quality of housing between European regions. However, in terms of many of the indicators of housing quality, these gaps remained as pronounced, which can be seen in the average living accommodation area between the European cities and the Eastern EU urban areas considered.

One can also observe the gap between post-socialist cities and other European regions regarding culture-related indicators. However, if considering the number of cinema seats here, the fact that Nordic countries have low values is mainly related to the different behaviour of the population in these countries (less inclined to go to the movies).

As an indicator of high-quality human capital, the share of the population aged 25–64 qualified at level 5 to 8 ISCED from 2014 onwards shows a more diverse landscape of European cities. The difference between different cities in the same region or country can be big while the inter-regional difference could be less pronounced. However, cities from Eastern and Southern EU countries have slightly lower values when compared to the others, while Nordic countries remain the best performers.

Post-socialist countries are once more less advantaged regarding one of the leading environmental issues, air pollution. The traffic problem is not tackled efficiently in most cities in former socialist countries. Moreover, cities that maintained their industrial profile currently face even higher pollution levels (e.g. cities from Silesian Basin), especially regarding particulate matter and Sulphur dioxide. In contrast, other indicators such as ozone have a specific pattern of spatial occurrence (Southern Europe is more exposed to this pollutant due to more solar radiation that creates the condition for the ozone-chemical processes that form the ozone) (Figs. 2 and 3).

In order to look into the similarities between cities and the profile of each class compared to the average values of each indicator, we have included in cluster analysis all six indicators mentioned above. The Analytical Hierarchy Clustering (AHC) method was applied using Philcarto software, and the five-class resulted in typology demonstrates the resemblance between the CCE cities within the European context (Fig. 4).

The majority of CEE cities are included in the first two classes that have some of the most dynamic economies (high growth but coming from a low baseline), also the lowest GDP per capita, the poorest living conditions and some of the highest pollution levels (especially cities from southern Poland and Bulgaria) or average pollution levels (most of the other cities). The exceptions are the Hungarian cities included in a different class with average values for most indicators and a lower economic dynamism but which have valuable human capital (highest share of people with tertiary education).

The indicators used in these assessments cover all the dimensions included in the liveability framework (see Fig. 1) except for security. This specific domain can refer either to economic security or physical safety. The sense of safety and place attachment are predictors of people's and communities' happiness (Mouratidis & Yiannakou, 2022).

The global financial crisis from 2009 to the COVID-19 pandemic significantly influenced people's economic security. Economically vulnerable groups can be highlighted, for example, by looking at the cities' highest share of the population unable to face unexpected financial expenses where some of the former socialist countries have the highest values—Croatia (52%), Latvia, Lithuania, Romania (all, over 40%).

Concerning physical violence, except for Bulgaria, there are no perceived issues in the former communist countries compared to the rest of the European countries.

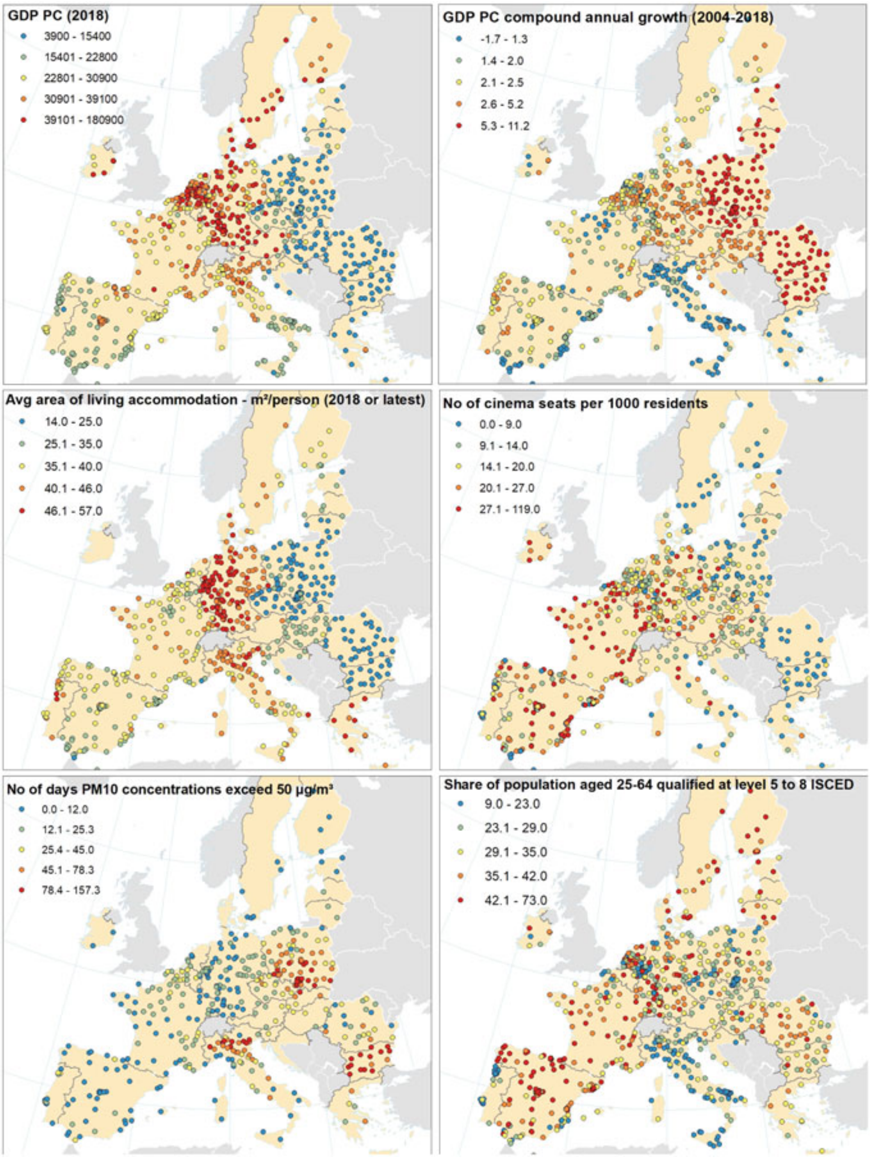

Fig. 2 Selected indicators of liveability by city. *Source* Data source Eurostat, maps made by M. Eva

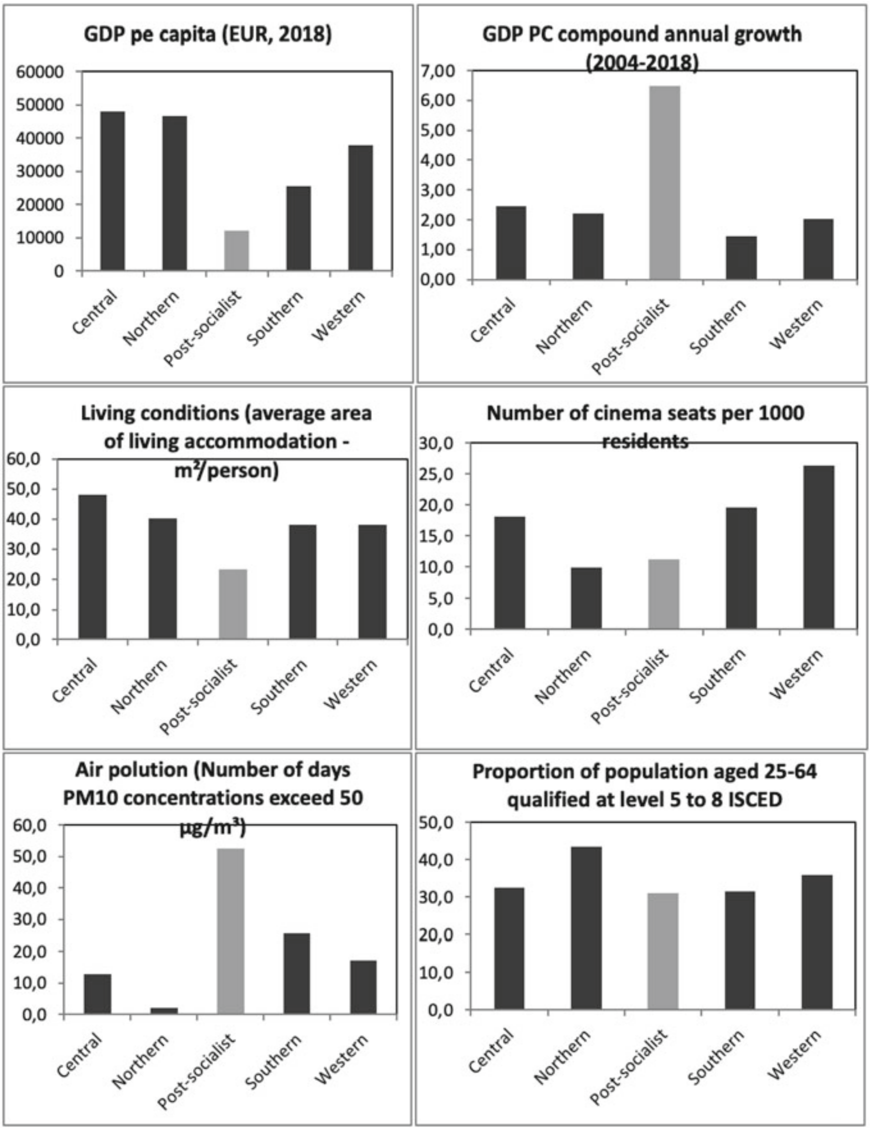

Fig. 3 Selected indicators of liveability by European region. *Source* Data source Eurostat, graphics made by M. Eva 2022

Figure 5 shows the gap in perceived insecurity as vulnerability to crime, violence or vandalism among people living in cities (17.0%) compared to people living in either towns and suburbs (9.1%) or rural areas (5.6%) (Eurostat, 2022). However, according to Eurostat database (2022), in former communist countries, the share of the population of cities that perceive their cities as insecure decreased significantly

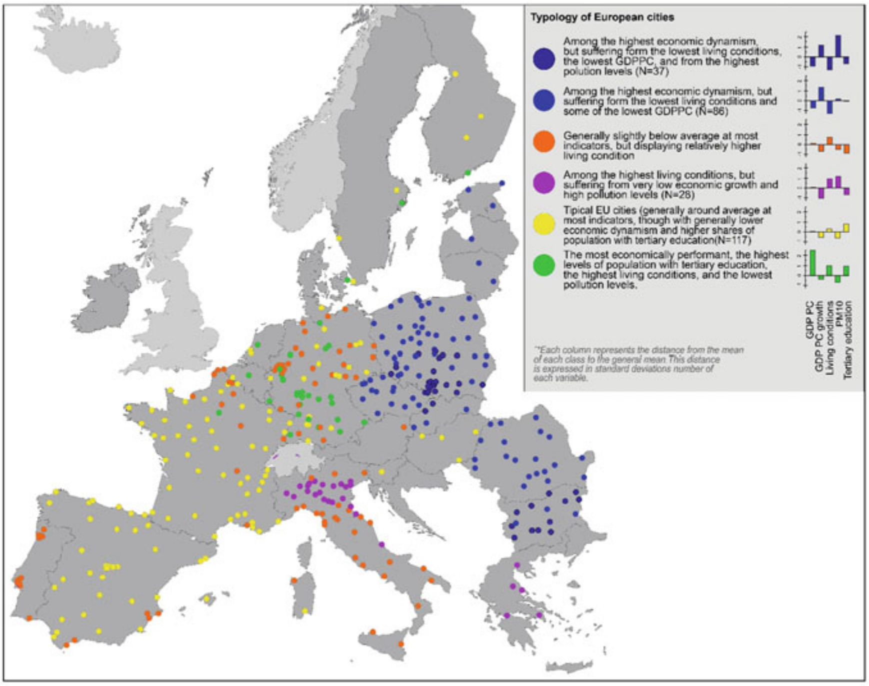

Fig. 4 Cluster analysis using selected indicators. *Source* Data source Eurostat, graphics made by M. Eva 2022

in the last ten years. Even Bulgaria's highest values decreased from 28% in 2010 to 20% in 2019. Meanwhile, in terms of homicides, the highest values are still recorded in the Baltic countries (around 5 per 100,000 inhabitants) and also in Montenegro.

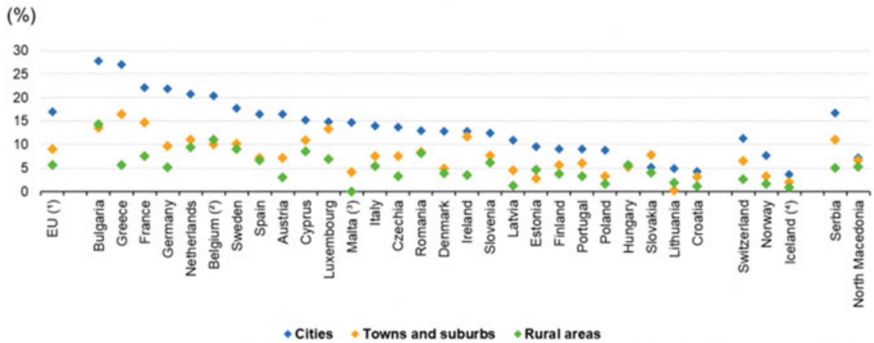

Fig. 5 Crime, violence or vandalism in the area by the degree of urbanisation in 2019. *Source* Eurostat (2022)

4.2 A Subjective Perspective on Living in the City

Analysing the statistical data that describe well-being is insufficient, as liveability is reflected in the subjective experience. Tracing positive and negative perceptions of liveability is essential (Nikolova, 2016). It includes satisfaction with both material and non-material aspects of life and is complementary information to the already described objective indicators.

World Values Survey shows that, in the case of former communist countries, there has been a fall in life satisfaction during the transition. Guriev and Zhuravskaya (2009) demonstrate that satisfaction was lower than the real economic growth for the selected countries. One can notice that transition economies are below the best-fit line in both periods. It fits into the "happiness gap" concept. This gap is higher for the ageing population because of the perception-related psychological factors but also due to objective factors: increasing inequality and subsequent sense of unfairness, decrease in quality and quantity of public goods (in some cases), high volatility or uncertainty of earnings, increase in personal standards and aspirations and depreciation of human capital as new skills become necessary for the new labour market during the transition and afterwards.

Looking at Gallup data and also at the quality of life in European cities survey (2019), and integrating the scores by using the sum-of-ranks method by our categories of cities (Post-socialist, Western, Northern and Southern), one can see exciting evolutions. The most performing in most of the subjective as well as objective evaluations are Nordic cities. Nevertheless, although in 2012 they were at the same level of satisfaction as the Southern ones, the post-communist cities improved significantly in this subjective indicator and are now very close to the Western European cities.

This fact shows a more rapid convergence process than the actual (objective) convergence regarding social, economic, natural and built environment indicators. Even more interestingly, the post-communist countries are at the same level as Nordic countries regarding perceived stress, well below Western and, especially, Southern countries' urban areas (Figs. 6 and 7).

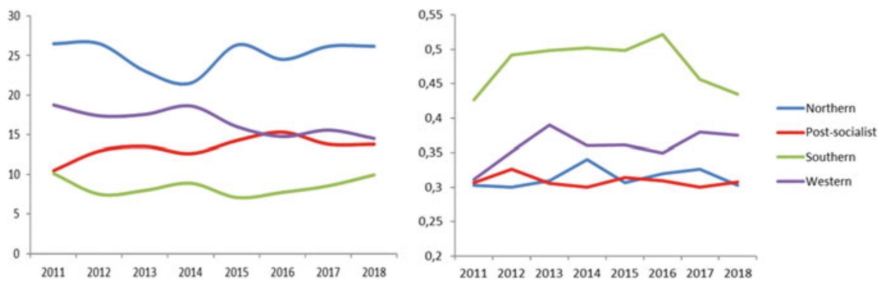

Fig. 6 (**a** City satisfaction and (**b**) Stress experiences assessment in cities from the four European regions (Gallup, 2019).

Fig. 7 Satisfaction with living in the city. *Source* EC/DG REGIO, Perception Survey on the Quality of Life (QoL) in European Cities 2019

On the other hand, subjective indicators show a clear "happiness gap" between post-communist EU cities and Southern EU cities, on the one side, and Western and Northern Europe, on the other. This observation is consistent with many other assessments in the literature arguing that especially the North-Western part of Europe and, more specifically, Germany, the Netherlands, the UK and the Scandinavian countries (plus Denmark) are a large cluster of a high level of happiness (Okulicz-Kozaryn, 2011; Okulicz-Kozaryn & Valente, 2019). The assessment of satisfaction relies on multiple indicators, among which two are the main determinants: amenities (public transport, healthcare services, cultural facilities, green spaces, public spaces and air quality/cleanness) and safety (safety perception, trust and crime victimisation (EC, 2020). Of all these, perceived safety is the stronger predictor of city satisfaction (EC, 2020; Moeinaddini et al., 2020). The values vary significantly among cities included in the survey and are lower in capital cities than in other cities. Meanwhile, the share of people not satisfied with life in the cities and the lowest per cent of people satisfied with life in the cities are in the post-socialist non-EU countries (Fig. 8). These results confirm other scholars' observations and analyses, arguing that post-socialist societies are among the unhappiest countries in the world, even when controlling for income. The Easterlin Paradox applies in their case: the income increase does not appear to increase people's happiness (Nikolova, 2016). Meanwhile, the level of satisfaction, even though low, was increasing before 2020 in most cities.

A liveable city is not only a city for all people but also a city for everyone, a city that is favourable and attractive for different categories of people. The inclusivity of cities was also measured, and the main determinants were the extent to which people think the city is favourable for immigrants and gay and lesbian people, which was also positively associated with quality of life (EC, 2020). It sustains previous studies arguing that tolerance and openness are positive factors of people's satisfaction (EC, 2020; Zenker et al., 2013).

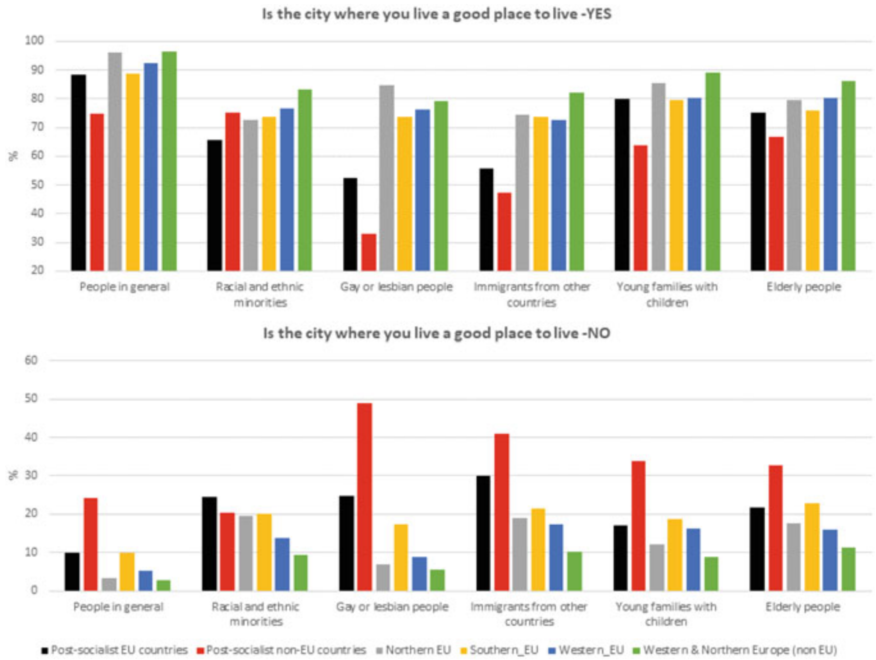

Fig. 8 "Is the city where you live a good place to live?" *Source* EC/DG REGIO, Perception Survey on the Quality of Life (QoL) in European Cities 2019

Post-communist cities are generally places where fewer people are happy to live in. The highest negative difference when compared to cities from other European regions emerges when it comes to sexual minorities and immigrants, while in the case of racial and ethnic minorities, but also young or older people, these differences are less pronounced. Another differentiation can be made between EU and non-EU post-socialist cities, the last category being the least attractive for these more vulnerable categories. An interesting exception is the case of racial and ethnic minorities, as cities from non-EU former communist countries are more likely to be open and favourable.

As far as differences between cities are concerned, one can identify them in terms of attractiveness: sexual minorities and immigrants are less likely to be accepted in cities from Romania, Bulgaria, the Czech Republic, and Slovakia, these are less favourable to the elderly population, though most of these social categories perceive them positively (Krakow, Gdansk, Bratislava, Zagreb, Praha) (Fig. 9).

Another critical discussion is related to the satisfaction with public services and amenities. Urban infrastructure is the basis of a liveable city. To have cities for people (not for cars), reliable, effective and comfortable public transport is an obvious prerequisite. The satisfaction related to public transport is significantly lower in non-EU post-socialist countries. In contrast, in the EU post-socialist countries, although not very high, it is higher in Southern Europe cities. Fewer residents are satisfied

Fig. 9 "Is the city where you live a good place to live for …"—Differences between CEE cities. *Source* EC/DG REGIO, Perception Survey on the Quality of Life (QoL) in European Cities 2019

with public transport in Italy and South-Eastern Europe (the Balkans), where public transport is less used, whereas where more people are satisfied, they will more likely also use public transport (EC, 2016, 2020). As expected, Western and Northern European cities show the highest satisfaction level. In the case of healthcare and education facilities or even sports facilities and recreational areas (such as green areas), the cities in non-EU former socialist countries have the highest dissatisfaction. However, in CEE cities, people are more satisfied when compared to Southern Europe cities. The North-South divide seems more pronounced in this area than the West-East gradient.

Interestingly also, the environmental quality is perceived similarly. Air pollution, noise and cleanliness of cities are regarded as less damaging in the case of former socialist countries than in Southern Europe. In contrast, Northern and Western Europe countries (either or not in the EU) have a much better perceived environmental quality (Fig. 10).

The assessment of EC (2020) concludes that satisfaction with cities' amenities (especially access to green areas), safety and inclusiveness account for 68% of the level of city satisfaction, therefore our analysis highlights the main issues related to the perceived that should be addressed by decision-makers to CEE cities.

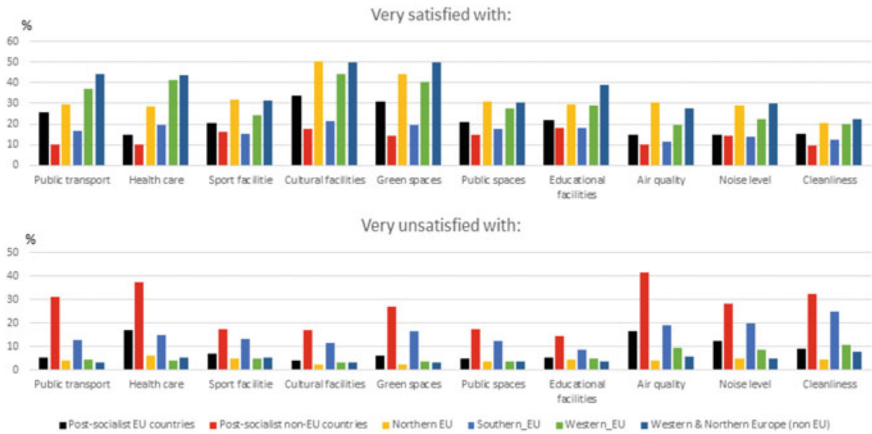

Fig. 10 Satisfaction with public services and environmental quality. *Source* EC/DG REGIO, Perception Survey on the Quality of Life (QoL) in European Cities 2019

5 The Missing Link: A City for Everyone

The analyses above can conclude that the "socialist legacy" may never be overcome (Ilchenko & Dushkova, 2018). Also, the burden of reducing the actual or imagined distance from the West (and the North), in both time and space, remains one of the main concerns of urban policy-makers.

Urbanisation is, in general, and especially in post-communist cities, related to social self-alienation (Redžić & Everett, 2020). The term heteropolitanisation can describe, from this point of view, the best scenario for the future situation of CCE cities. It means the transition from urbanistic and socially homogenous systems put in place by communism to heterogeneous "urban mosaics" (Nedović-Budić et al., 2006), i.e. more diverse and flexible, adaptive systems. The latter enhance individuality, creativity, innovation, connectivity and free participation in public well-being (Gentile et al., 2012). Well-balanced heterogeneity of physical structures and urban functionalities, social groups and mobility patterns increases the complexity of cities and also their adaptive capacity.

In CEE countries, setting people's happiness as the ultimate aim of urban development seems to be a utopia. The post-socialist urban agendas focussed on the economy, i.e. the attractiveness dimension for business and capital, and less on the attractiveness for people. However, keeping young, performant and intelligent people in the city needs more integration into policies. A human resources strategy in administration based on meritocracy needs to be included. Liveability relates to well-being and people's perceptions but less to happiness, belonging to a community, and feelings of solidarity and conviviality. In this respect, see Liveability Index, integrating Social Infrastructure, Walkability, Public Transport, Public Open Space, Housing Affordability, and Local Employment, or the Global Liveability Index focussed on stability, healthcare, culture and environment, education and infrastructure.

The previous urban frameworks focussed on performance, efficiency and competitiveness change in digitalisation, smart specialisation, and sustainable, green city paradigms (Bănică et al., 2020). Integrating these approaches, which can create balanced, environmentally friendly, safe and adaptable but also intelligent and innovative cities, is a solution for happy and liveable cities. This transformation is not easy and has many drawbacks: sustainability is sometimes utopic, resilience might turn into "bad resilience" (opposition to any change), while intelligent cities, if mismanaged, can produce social injustice and environmental issues planning (Ibănescu et al., 2020). Therefore, the operationalisation of these concepts needs careful approaches.

Sustainability can reconnect urban citizens of former socialist countries with their cities and nature (inside and outside the city), making them more aware of growth's limits and consumerism's drawbacks. It could also make them seek for more participation in the decision-making process, for more public space of connection with the "body" and "the soul" of the city (Kourtit et al., 2021; Wahlstrom et al., 2020). Sustainability creates a bridge between individual benefits, public good and environmental quality. It is a utopia only if seen as an end. Sustainability is a way towards a better and more persistent society. Current approaches to sustainability in CEE cities and worldwide envisage post carbon-cities with green and low-ecological footprint development, active mobility (bicycle use, walking) and access to nearby services (see 15-min city concept) (Mocáka et al., 2022; Svirčić Gotovac & Kerbler, 2019).

Resilience is another buzzword of our times, highly used in academic and public discourse in CEE countries, as it emerges from the unpredictability of our "risk society" (Beck, 1992). The resilience of CEE cities can be illustrated by a variety of indicators—e.g. socio-economic, environmental and spatial—that illustrate their co-evolution and adaptation processes of cities after significant perturbations (e.g. the fall of communism, the economic crisis, COVID-19, etc.) (Sandu et al., 2021). If seen only in connection with conservative approaches, this concept is minimal and sometimes dangerous. Returning to the previous state or resisting change can be seen as a form of "bad resilience", which will maintain obsolete structures and functions. Some scholars link it to the difficulty of former communist cities in transitioning into more liveable cities (Rufat, 2012). For example, preserving unattractive and dysfunctional communist buildings can obstruct modernisation. In CEE cities, the concept of resilience should change in a proactive, evolutionary, adaptive and transformative form that presupposes bouncing forward and not bouncing back. Shocks, either natural or manufactured, must be seen as opportunities for cities to build back better, to restructure and solve institutional, social, economic or environmental issues.

Finally, the concept of smart cities leads to innovation and "personalised modernisation". One of the six dimensions of these cities, unfortunately presently neglected in the former socialist countries, is that of smart people. It is a viable direction to support more liveable cities. Smarter cities not only use more information and communication technologies (ICT) for more effective resources use and lower emissions (which are also objectives of sustainable cities), but they also have more intelligent urban transportation, water and waste management systems, more interactive and responsive administration, secure public spaces, while being also more resilient to present and future shocks (Kutty et al., 2022). Innovative technology can be an opportunity to

Fig. 11 Towards liveable cities—the emerging conceptual framework

synchronise and reconcile individual and collective interests and can be an effective tool for a "city for everyone". However, there is a need for an integrated approach to intelligent solutions, which must be interconnected and adapted to the specific needs of individual users. If smart innovation excludes people or social categories from use, creates social injustice, or if it negatively impacts the environment, the purpose of smart cities fails.

In other words, the concept of liveability in a broader context promoted in today's global world of intelligent, resilient and sustainable cities can fulfil its purpose only if it considers the needs and individual capabilities of the citizens. It will not further atomise post-communist urban societies but will adequately unify and self-organise the social mosaic of CEE countries' cities under a common umbrella.

Focussing on creating opportunities for everyone could be the missing link that would relate the new concepts of urban design and development to the goal of liveable cities (Fig. 11). Nevertheless, even with these new approaches, the necessary measures to ensure that citizens feel satisfied and happy, that they actually enjoy living in the city do not seem to be a concern for the administration of post-socialist cities, even after three decades of reconsideration of development paradigms.

The main question of how to make cities the home of people remains. Kourtit et al. propose a solution: enhancing and relating the "soul and body" analysis to urban attractiveness (Kourtit et al., 2021), which will fulfil the necessity to find a new urban paradigm integrating the residents' happiness.

From our perspective, Amartya Sen's theory of capabilities can be successfully applied in the case of cities from CEE countries in order to harmonise modern approaches to city design and development to the individual needs of individuals and tackle social inequalities and injustice in the cities. It is particularly when it comes to the least developed cities, the capabilities theory could be the link and the key to making cities more liveable, resilient and sustainable. The central idea of this theory is to "enhance substantive freedoms for every single person" (Anand, 2018). The framework imagined by Amartya Sen includes (a) political freedoms—the ability to participate in the decision-making process; (b) economic facilities, i.e.

openness to the labour market; (c) social opportunities for health, education and social equity; (d) access to protection and security (Sen, 1999).

People from cities of CEE countries must learn how to be free after a long period of communism when freedoms were restricted. Moreover, during the transition, societal inequalities increased considerably. Presently, the challenge would be to enhance equity, consider the public good and reconsider the sense of community without returning to a classless, egalitarian model.

From a capabilities perspective, smart, resilient and sustainable cities should enhance the agency and authority of people and empower citizens to embrace a healthy and good life, to choose their path and accomplish their potential without hurting others or damaging the environment.

Human development should be the basis of urban development. Urban governance should consider not just GDP but also life expectancy, health, social equity, reducing poverty, promoting efficient institutions, democracy and participation in the decision-making process. For all these, the instrumental value of participation is essential (Bajmócy, 2021).

6 Conclusions

The current study is broad and brings together many extensive and complex issues. However, it does not intend to approach them analytically but rather to rearrange them, as in a puzzle. These essential pieces give the overall picture of liveability's conditionalities in cities of the former communist countries in Central and Eastern Europe.

One can wonder to what extent the category "post-socialist" or "post-transition cities" is still relevant today (Stenning & Hörschelmann, 2008). However, we argue that the hybridisation between the socialist legacy, the transition period outcome and the new processes of Europeanisation and globalisation induces the specific characteristics of CEE cities. They witness a catch-up development and uneven transformations while maintaining a peripheral position. Transitioning from an egalitarian to an individualistic society and from a centralised decision-making process to democracy does not mean, by default, better economic, social and environmental performance, nor a better quality of life in the cities.

The analysed datasets of both statistical indicators and survey data show that CEE cities significantly improved liveability in the last 20–30 years. They are nowadays relatively close to Southern cities in terms of statistical/objective indicators (but they are both lagging behind Western and Northern cities). However, CEE cities look more dynamic and have a positive evolution, especially in economic terms, while southern cities look rather static. Regarding the perception of people living in cities, the conclusion is that post-socialist cities are still catching-up and concentrating on the highest share of people who are unsatisfied with their lives and with the quality of amenities and services that make cities liveable.

However, there are also discrepancies between the objective and subjective perspectives on liveability, especially in the context of the new emerging paradigms based on the convergence of sustainability, smartness or resilience.

This synergy of new urban concepts and theories in the context of CEE cities can create a novel framework to ensure sustainable, resilient and intelligent modernisation while maintaining a focus on people. Sustainability means enhancing the sense of community by ensuring the opportunity for the participation of all individuals in the decision-making process. Within the smart city context, intelligent project investments should increase the focus on the personalisation of services and technologies to increase the well-being of individuals. In resilience, this is linked to reducing social vulnerabilities, especially in disadvantaged communities exposed to more risks to create preparedness (capacities and knowledge) to respond and remain as secure as possible in extreme events.

Meanwhile, liveability means not just meeting the basic needs of someone but also, and more importantly, enhancing individual freedom and capabilities. The assessment relies on the theory of capabilities proposed by Amartya Sen and Martha Nussbaum, which states the importance of individuals' freedom to choose from different opportunities and to accomplish their full potential while pursuing happiness. Urban decision-makers should consider each city's specificities and aim to produce "cities for everyone". Only by encouraging diversity, individual liberty of choice complementarity with promoting civic solidarity and responsibility for public interest, will this approach induce happiness while producing liveable cities.

The integration of these components can sustain the transition from the liveability of neighbourhoods and cities to the happiness of individuals within their communities, from city4all to city4everyone, by concentrating on awarding opportunities for each person regardless of her/his status and belonging to specific social categories.

The novelty of the approach is that it brings together major themes of urban studies in a Central and Eastern European context: on the one hand, liveability and its life satisfaction subjective component, and on the other, the need to adapt to the current globalised context in which concepts such as sustainability, resilience or smartness are transferred to the reporting mode of urban life. The connection is made by appealing to a theory that originates in the 1970s—the theory of capabilities—which can integrate objective ecological, technological or urban security gains with the subjective needs of individuals.

The limitation of the approach is closely related to its novelty. The broadness of the topics included does not allow for an in-depth analysis of the issues that are only briefly discussed. Also, the indicators are only analysed until 2019 and therefore, do not include the COVID-19 pandemic which has changed the face of the world and cities in recent years. Our future research will focus more on the relationship between urban capabilities and more narrow dimensions of urban liveability, sustainability, smartness or resilience. Also, including more recent shocks will allow us to acknowledge the differentiated impact on individuals and urban population beings and functionings.

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A Tale of Two Big Cities Struggling for Their Agriculture Conflict and Oppositions Around Land Farming in the Greater *São Paulo* and *Paris* Regions

Brenno Fonseca and André Torre

1 Introduction

For a long time, agriculture developed alongside cities, which were built in areas of high soil fertility (Bryant & Johnston, 1992; Lohrberg, 2001). Farming or supply centers helped to feed the latter, as did rural areas located in their hinterland, by bringing to city dwellers various agricultural products sold in the central markets. Nevertheless, a double movement has driven agriculture away from the urban agglomerations. A first evolution was linked to globalization: the search for increasing returns on large surfaces allowing economies of scale and lower prices, the lengthening of distribution circuits and the reduction of transport and delivery costs of products have made distant agricultural production very competitive (Gollin, 2010). The second is due to the incessant movement of urban sprawl (Gillham, 2002). It leads to a rapid consumption of soils located near urban agglomerations, and in particular agricultural land, which cannot resist real estate speculation and the need for construction and infrastructure for the city (Castillo et al., 2013). These developments, associated with the weak support for the maintenance of agricultural activities, contributed during the twentieth century, to the disappearance of a significant part of the farms located near the main agglomerations (Livanis et al., 2006).

After a period of remoteness of agriculture from urban agglomerations, the issue of agriculture in and around cities has taken on renewed importance in recent years, in response to the growing demands of populations for healthy and local food (Hamilton et al., 2014; Smit & Nasr, 1992). Consumers and especially urban dwellers ask for

B. Fonseca · A. Torre (✉)
University Paris-Saclay, AgroParisTech, INRAE, Paris, France
e-mail: torre@agroparistech.fr

B. Fonseca
e-mail: brenno.fonseca@agroparistech.fr

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more local products, and become aware of transportation costs and the environmental impact of food miles. Environmental concerns have also increased the willingness to consume seasonal products, corresponding to the climatic and soil conditions of the region. Covid-19 pandemic has increased this tendency (Chenarides et al., 2020): more people are looking for the origin and the traceability of local food, its quality and also its geographical origins (Bakalis et al., 2020; MAPA, 2020). At the same time the issue of supply and food security in large urban centers becomes crucial, linked to the growth of the world population (UN, 2019) and its increasingly urban character. Local, urban, or peri-urban agriculture can provide a part of this supply, especially in big centers and poor areas (De Zeeuw et al., 2000; Dubbeling et al, 2010; FAO, 2007). Although farming activity is often relatively residual in urban agglomeration, it sometimes shows significant dynamism (Opitz et al., 2016). And it is connected with the growing demands of the new inhabitants of the suburban areas, which are looking for open spaces, that they increasingly assimilate to agricultural activities (Van Veenhuizen & Danso, 2007). Then, interest in urban farming appears twofold. Both historic, as the survival of an old alliance between cities and their farm belts, and also very contemporary in the face of the new behaviors of urban consumers (Zasada, 2011).

But despite its benefits to the population and the urban landscape (Madaleno, 2002), agriculture maintenance appears always as a challenge. The implementation and the development of public policies of financial and technical support to urban and peri-urban farmers remain difficult and the inscription of the farming activities on the agenda of urban governance has always been laborious (Ackerman et al., 2014; van Veenhuizen, 2006). But, most of all, regarding the permanent growth of urban households and infrastructures, which is a source of strong land pressure, farming is under the threats of the urban expansion. Agricultural activity tends to disappear from cities, and even from their suburbs, and to move further and further away from urban agglomerations. And this gradual erasure is accompanied by an ever-greater difficulty of maintaining an agricultural activity in the city or around, especially related to the increasing pressures on land (Cavailhes & Wavresky, 2003), which causes oppositions and conflict between supporters and opponents to urban farming. It is well documented in the literature that this competition between various users of soils (farmers, promotors, entrepreneurs, public services…) is one of the major limits of food production in urban and peri-urban areas (FAO, 2011), and that it gives birth to several land use conflicts (Darly & Torre, 2013).

This article focuses on the difficulties of the existence and the maintaining of an urban or peri-urban farming activity, and most specifically on the questions and the problems raised by the presence of agriculture on the fringes or inside large urban agglomerations. The research is focused on the importance of territorial conflicts related to the permanence of food production near big cities, and of their analysis. Our study is based on the example of agriculture in the suburbs and the hinterland of the regions of the Greater São Paulo (Brazil) and Paris (France). Both cities have undermined several actions to encourage territorial agricultural development. The Sustainable Paris Food Plan 2015–2020 (Mairie de Paris, 2015) and the municipal law No. 16.140/15 of the City of São Paulo (CONSEA, 2015) are some examples of the commitment of these cities to their food systems. And both were signatories to the Milan Pact on Urban Food Policy in 2015. This agreement discusses the real engagement of local authorities in the setting of public agricultural policies for urban environment and food security, aiming at articulations between different society actors, allowing guaranteed access to land, adequate school meals and stimulating short production and consumption circuits (MUFPP, 2020). But despite these initiatives, urban expansion puts pressure on these food areas and brings out different types of conflicts that will develop differently according to the local natural and organizational realities.

Our goal is to explore the questions posed by the maintenance and development of peri-urban agriculture in a situation of strong urban sprawl, and to analyze the strategies followed by local stakeholders responsible of opposed land use intentions. In particular, we analyze the types of conflicts between these local actors, and the actions of public bodies in favor of the persistence or the rise of peri-urban agriculture. The novelty factor of our analysis is to highlight and compare the challenges from these two big cities to face land use conflicts for agricultural activities which suffer pressure from urban expansion and infrastructures, despite their differences about historical, natural, climate, and social conditions.

2 Methodology and Presentation of the Case Studies

We base our study on the comparison of two cases of peri-urban agriculture under changes in proximity of large metropolises. The metropolitan region of São Paulo in Brazil and the Ile-de-France region (or greater Paris) in France are emblematic both of the problems of maintaining or developing agriculture in urban areas and of the difficulties and oppositions related to the levels of wealth and development. In fact, these are two major agglomerations, the largest in their country, which have not only a highly concentrated urban center, but also a diffuse urbanization on the scale of an entire region. They are the main economic national center, coupled with an intense and historical agricultural and an important remaining agro-food activity. The problems of maintaining local agriculture are therefore similar, especially with the pressure on agricultural soils. However, there are significant differences, with more informal urbanization, as well as major poverty and much more important criminal issues in the Brazilian metropolis, while the Parisian Region is characterized above all by a very high price of building land because of its very strong economic attractiveness in the European Union.

2.1 The Case of São Paulo Metropolitan Region

The São Paulo Metropolitan Region (SPMR) is the largest urban agglomeration in South America, with more than 21.5 million inhabitants (EMPLASA, 2019), and

47.6% of the population of the State of São Paulo. Its Gross Domestic Product (GDP) corresponded in 2017 to R$1.14 billion, which corresponds to 17% of the Brazilian one (SEADE, 2019). SPMR is the largest industrial complex and the main financial center in the country, with a highly qualified workforce and large communications infrastructure and services. Farming sector counts for 2.04% of the State GDP and 0.13% of the metropolitan GDP (SEADE, 2019). But the City of São Paulo has a very rural dimension, with a third of its territory classified as rural areas, competing with other land uses.

We find different types of Agricultural production in the SPMR (see Fig. 1), like horticulture, fruits, eggs and poultry farming, beef cattle, pig farming productions, etc. In the near east and north sides, one finds fresh vegetables but also fruits and poultry productions. The southern zone is the more active one, with an increase of organic, agroecological, or transition systems, most of them based in horticulture products. The southwest axis is characterized by a traditional subsistence agriculture (potatoes, onions…), whereas pasture and beef cattle productions are mainly located in the northwest metropolitan sector. The northeast peri-urban area, which produces vegetables, is under environmental protection laws. The center-west area is the most urbanized part of the city, with only a few remnants of agricultural production, most of them located in parks, public squares, and community gardens.

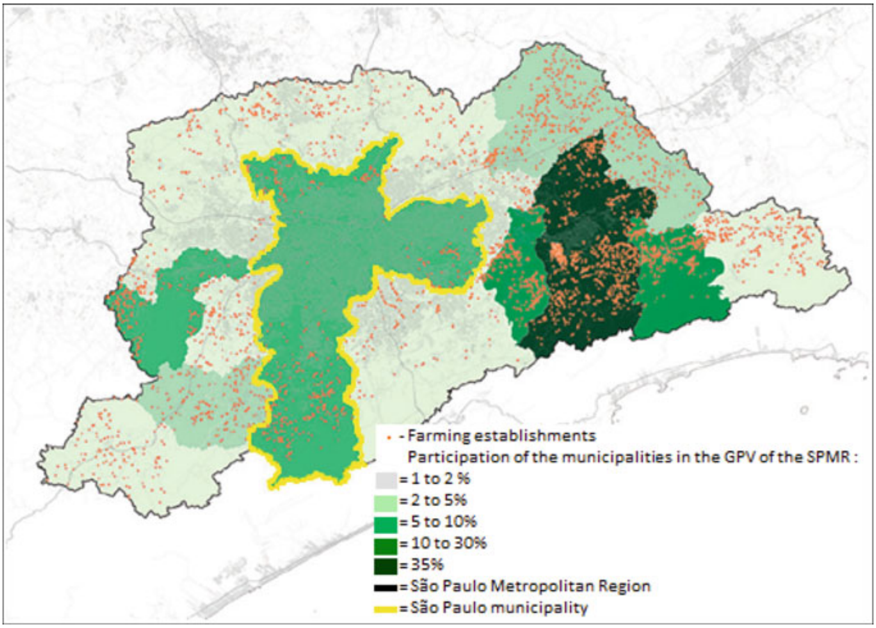

Fig. 1 Locations of agriculture, poultry, and eggs farms and participation of municipalities in the Gross Production Value (GPV) of the São Paulo Metropolitan Region, adapted from Instituto Escolhas e Urbem 2020

2.2 The Case of the Greater Paris Region

The Ile-de-France or Greater Paris Region (GPR) is the first French economic region and the most populated region of France with nearly 12.2 million inhabitants (about 18% of the French population (INSEE, 2020) and 2% of the European population). Its GDP represents 29% of the national one. The workforce is highly skilled, with 37% of French managers and 40% of the national workforce employed in R&D activities. But although the first urban region in France, the GPR is also a large agricultural and rural region (Fig. 2). The regional territory is made up of nearly 80% of rural areas, with 48% of agricultural areas (about 569,000 hectares) and 24% of wooded areas. However, despite the measures put in place to try to control urban sprawl and the anarchic consumption of soils, agricultural land continues to decline at a high rate of about 1,200 ha per year (annual average 2000–2010).

Even if agriculture seems to occupy a reduced economic role in GPR, agricultural lands still take around half of its territory and provide many types of services and products. The region has a high soil fertility for agriculture production. In small agricultural areas close to urban agglomerations it is possible to find vegetables and fruits productions for the consumption of urban dwellers. Moving away from the urban areas, it becomes increasingly normal to find larger farms, with large crops productions such as cereals and with high profitability. Animal production is quite rare, with exceptions to some dairy products areas. But the urbanization sprawl and the urbanization pressures (housing policies, urban infrastructures) are strong on agriculture soils in almost the entire region.

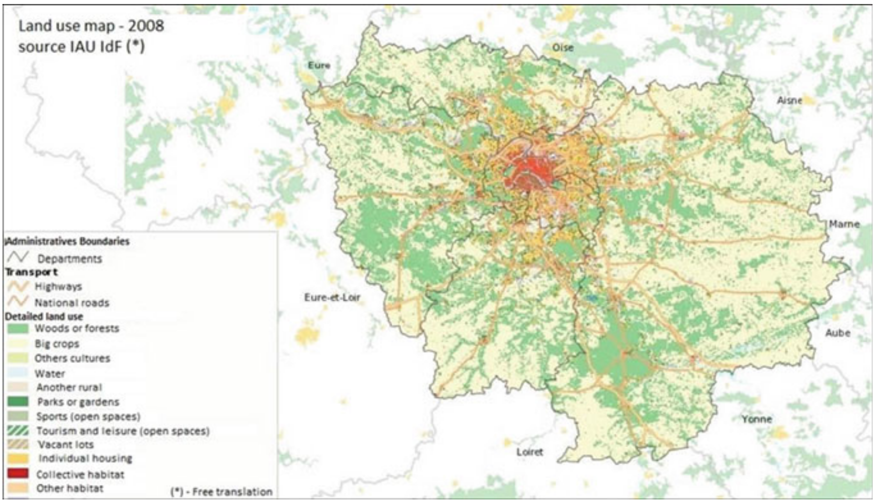

Fig. 2 Land occupation in Greater Paris Region in 2008 (IAU)

2.3 The Method of Analysis

The analysis of the oppositions and the conflicts reported in the two regions is based on different sources. We follow the methodology defined by Torre et al. (2014) for identifying and categorizing conflicts and their links with territorial governance processes. Concerning the case of São Paulo and the absence of reliable legal data, we apply to this issue the extended method used for the cases of developing countries by Magsi et al. (2017). We integrate social networks and media analysis to compensate for this lack of information.

More precisely, we made the following types of investigations on the two areas.

– Expert surveys conducted, at the local level, among resource persons from different professional groups and public bodies like officials, farmers, representatives of local institutions, environmental and nature users, chambers of commerce, trade and industry, water agency representatives, etc. (Annex).
– Analysis of the interactions between the protagonists involved in the conflict (Thomson, 2012). It allows us, by studying the similar or opposite speeches obtained through interviews with local actors and groups of actors, to analyze the hierarchy and power relations, and to identify the origins of the discourses of disagreements and tensions on both agricultural production and land uses in order to understand the governance relations;
– Analysis of the articles published in the daily regional press of the two regions. We identified, selected, and reviewed the main key words related to opposition and conflict about agriculture in two Newspapers: *o Estado de São Paulo* in Brazil (2014–2021) and *Le Parisien* in France (2017–2021).

3 Agricultural Conflict in the Case of São Paulo Metropolitan Region

Historically, agriculture has been increasingly distancing itself from urban centers and leaving space for different land uses associated with urban development, such as housing, road infrastructure, industrial centers, garbage dumps, etc. In the municipality of São Paulo, this dynamic was no different. However, some initiatives were present since the beginning of the last century, such as regional food supply centers and cooperatives of farmers of various crops. From the 1940s on, the city became more populated and presented an expressive growth in its suburbs (Taschner & Bogus, 2001). With this population growth and the concern to feed this growing population, a food supply department and a community garden program were created in the 1980s, present both in municipal schools and in available spaces such as under power lines (Biazoti, 2020). The initiative to integrate agriculture within urban planning strategies in the municipality began its consolidation with the inauguration of an Urban and Peri-Urban Agriculture Program (PROAURP) in 2004, along with the deliberation of horticulture courses, elaboration of a school-greenhouse educational project in municipal schools, and the establishment of decentralized ecological agriculture houses in more rural areas (Valdiones, 2013). As of the 2010s, agriculture has gained visibility through the formation of cooperatives, farmers' associations, and the emergence of activism through the organization of community gardens (Biazoti, 2020).

3.1 A Very Active Peri-Urban Agriculture…

The observations coming from the reports of most of the experts interviewed and in particular from a dossier of a São Paulo City Councilman[1] confirm that the rhythm of urbanization around the City of São Paulo is rapidly progressing, and that most of these new occupations of the soils are done at the expense of traditional agricultural spots. At the same time, farmers who were far from the city became near, and started to participate to the urban supply chains and to the local food provision (Silva, 2013). Nowadays, SPMR is characterized by the co-existence of different types of agriculture. On the one hand, from regional daily press "O Estadão" and based on statements from the interviews conducted locally, traditional areas are declining in front of the rapid urban sprawl, and environmentally friendly Southern neighborhoods, which are adapted to the development of agricultural practices, suffer a lot from clandestine invasions controlled by criminal organizations. On the other hand, new forms of agricultural practices are rapidly developing, within the city or in the outskirts, like community gardens, rooftop farming, community supported agriculture (CSA), or solidarity local agricultural stores. A major movement also appears in the east side, where the electricity distribution networks are installed: in these places, the land owners allow the installation of urban gardens under the lines, which contribute to urban food production.

The metropolitan governance of agricultural land is lacking in the region, at all territorial levels. Municipal state and federal administrations do not converge regarding their approach of agriculture and even their conception of territorial development. The few PROAURP (the Urban and Peri-Urban Agriculture Programs of the municipality of São Paulo), school vegetable garden projects or even social vegetable gardens, are only punctual with no guarantee of continuous funding by the various authorities. The policies devoted to the development of local agriculture, its production, commercialization, and development are quite erratic and changing, and mainly non-coordinated between the different institutions of territorial levels. The implementation of the PDUi (Plano de Desenvolvimento Urbano Integrado, or Integrated Urban Development Plan) elaborated in 2018 was an opportunity to centralize the management and outline a governance of the SPMR agricultural areas. However, in 2019 the institution responsible for São Paulo's metropolitan planning, the Empresa Paulista de Planejamento Metropolitano (EMPLASA), was dismantled,

[1] Gilberto Natalini: https://natalini.com.br/dossie-2a-edicao/ or https://natalini.com.br/dev/wp-content/uploads/2020/04/FINAL_Dossie2_VersaoFinal.pdf.

as were several other councils and institutions, in particular the National Council for Food and Nutrition Security (CONSEA), with the premise of reducing national public spending.

Every new government staff which arrives with local elections (every 4 years) dismantles projects and laws from the previous one. The Urban and Peri-Urban Agriculture Programs (PROAURP) of the municipality of São Paulo, which were created in 2004, have only received intermittent subsidies. Projects like the creation of a house of agriculture or a program to finance agricultural materials among municipal farmers greatly suffered from discontinuities in terms of management and financing. The greenhouse school program, also created and funded by the São Paulo municipal government in 2008 had its activities halted in mid-2016 due to lack of resource allocation: its support to education, food security, and vocational training in various areas have been stopped until 2021. As a result, and given the absence of government leadership for the metropolitan agricultural issue, several territorial actors, with emphasis on real estate speculation, take advantage to advance their urban expansion fronts, generating competition with various functions of the soil, but mainly agriculture.

3.2 …But Several Land Use Conflicts…

The urban sprawl of the greater São Paulo agglomeration creates new housing and urban spaces in areas previously considered rural. The price of agricultural land is quite low compared to other urban land uses (about 1–5 €/m^2 in the most distant rural south zone vs 1,110 €/m^2 in urban areas of Parelheiros (Estadão, 2020), which makes it very attractive for further urban land use occupations and real estate occupations. At the same time, irregular occupations and invasions by local people or new upcomers have increased, taking advantage of the weakening of state and municipal public inspection and low respect of laws. In addition, the fact that many public urban lands still lack land tenure regularization further contributes to real estate speculation. Our researches reveal that all these parallel and contradictory dynamics provoke major urban oppositions and conflicts in the main areas of the SPMR.

Figure 3 and Table 1 reveal the main types of existing conflicts over agricultural areas in the municipality of São Paulo.

Several conflicts are located in the south zone of the agglomeration, especially related to urban infrastructure projects, such as the *Parelheiros* airport, the creation of a local logistics center and part of the *Rodoanel* Ring Road. In this area, major conflicts are linked with the expansion of the real estate market, the irregular land occupations of environmental conservation areas due to water resources, and the setting of local ecotourism pole. The opposition also raised around the *Tupi-Guarani* ethnic villages, with the installation of urban infrastructure, or the expansion of the urban fabric in these environmental protected areas.

In the northern part, the presence of the mountainous areas of *Serra da Cantareira* limits the pressure of urban expansion. But a big conflict is linked with the project of

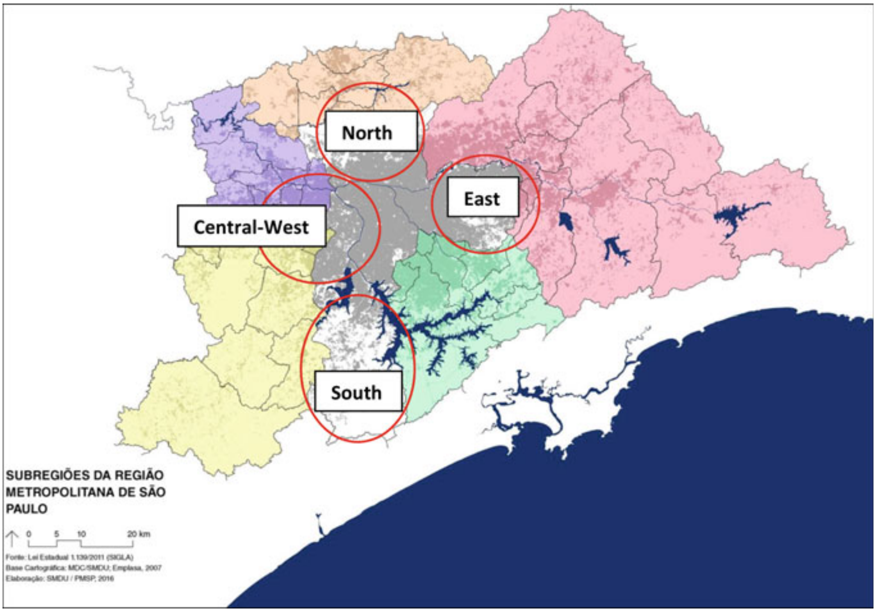

Fig. 3 Conflicts' zones located inside the city of São Paulo and in surrounding sub-regions of the São Paulo Metropolitan Region (PMSP, 2016)

Table 1 Main types of conflicts in the areas of São Paulo's municipality

Main types of conflicts over agricultural lands	South	North	Central-West	East
Urban market	X	X	X	X
Infrastructure ring road	X	X		
Infrastructure logistic center	X			
Urban violence due to socio-economic contrasts			X	
Ecotourism pole	X			
Environmental conservation areas (water and forests)	X	X		
Indigenous villages	X	X		
Irregular land occupations	X			
Urban violence (drug traffic and others)	X		X	X
Unstable land use contracts				X

Source The authors

an urban road infrastructure on the northern stretch of the Ring Road. This project could impact the Environmental Conservation Units and the local agricultural production, but also penetrate into the areas of demarcation and territorial protection of indigenous villages.

In the eastern zone, mainly urban, the conflicts are closely linked to the rapid urban sprawl. Except the production under the electric energy distribution lines, the remaining areas of agricultural use are scarce. Moreover, this place is quite exposed to urban violence, with theft and robbery. The smaller central-west area is also characterized by a high population density, and a continuous urban spread, and most of the conflicts are linked with the extensive urbanization. This area presents huge contrasts between the presence of important universities and high standard business centers, a great economic dynamism, a hub of cultural activities, and luxury housing condominiums on the one hand, and the existence of countless favelas where poverty coupled with the lack of basic infrastructure and adequate power assistance on the other hand. These major differences give birth to many problems of urban violence and conflict.

3.3 …Mainly on Agricultural Lands

Our research reveals that the conflicts related to peri-urban agriculture are increasing in the SMPR, especially regarding the oppositions about different land use or intentions of uses. This is particularly true in areas of agricultural production, under the threat of metropolitan development. Another major problem is the development of violence, theft, and drug trafficking, which impose some limits to the local agriculture practices. We have ranked the various cases of disputes related to the agricultural function of the soil in terms of their geographical areas. The main sources of conflict are arranged in Table 2. They were found through the analysis of the regional daily press, interviews with local experts, and monitoring of social networks and blogs about conflicts linked to the presence of local agriculture.

Table 2 Main sources of conflict in the SPMR

Main sources of conflict in the SPMR
Urban sprawl and real estate speculation
Installation of urban infrastructure—roads, airports, logistics centers
Urban violence due to socio-economic contrasts, theft, and drug trafficking
Lack of comprehensive management of metropolitan agricultural production areas + lack of supportive public policies
Presence of criminal organizations that, together with local elected officials, allow illegal land occupations
Lack of taxation on agricultural and environmental areas

Source The authors

Due to the fact that most of the farmers are concentrated in the south zone, great oppositions in terms of land use appear in this area, linked with the urban developments. Farmers appear to be under the pressure of both classic urban expansion and criminal urbanization: a part of the land is occupied illegally, which generates deforestation, harms areas of water production for urban supply, and expels local agriculture. The development of urban infrastructure projects such as the *Rodoanel*, Parelheiros airport and a logistics center, are also major threat for local agricultural production areas. Farmers and environmental activists mobilize in order to prevent the progress of these works and manifest their opposition. Another major concern is the impact of urban expansion and infrastructure projects on the presence of indigenous villages. The subsistence agriculture is really crucial for the daily lives of the local inhabitant and for the maintenance of the villages. Indigenous peoples and organizations in defense of indigenous rights mobilized against public power and the development of infrastructures for the city.

In the northwest sector, despite its vocation for environmental preservation and its forest resources, various projects cause different types of conflict, due to their urban character and their consumption of agricultural land, like the construction of middle or upper-middle-class residential condominiums with an attractive quality of life with close quick access routes. The activity of production of beef cattle is under the threat of this rapid extension of the real estate market and the urban sprawl.

As reported above the center-west area, with this strong urbanization, has few remnants of agricultural production, mainly in parks and public squares. Here, the conflicts are related to urban housing pressure and urban violence. In the western peri-urban area, the urban sprawl of small local towns and the development of urban road infrastructure in the São Paulo-Sorocaba axis are responsible for the progressive disappearance of agricultural activities. The expansion of the urban area gains more and more space in this disputed territory. And despite the activity of farmers' associations to maintain local agriculture, the proposals for financial gain from the sale of agricultural land contribute to the decrease of this activity.

In the eastern zone the biggest conflicts are related to the expansion of the real estate market, and to the vulnerability of the fragile urban agriculture found under the power distribution lines, which is governed by precarious lending contracts between local farmers and private energy companies. Agricultural activities are mainly threatened by the expansion of the urban network, related to the geographical proximity to the municipalities, and the development of transport infrastructures, more particularly rail and road networks build in order to develop relations on the São Paulo-Rio de Janeiro axis. A series of unsuccessful experiences of organizing farming actors in associations and cooperatives also characterizes this area.

4 Agricultural Conflicts in the Case of the Greater Paris Region

There is a rising concern for farming and food security in the City of Paris and in the GPR Region, mainly raised by urban populations. As a consequence, the search for new relationships to preserve and consolidate agriculture in Ile-de-France leads to the creation of several local initiatives. As the most populated French region, Ile-de-France presents a huge consumer market, and with it, many types and organizations of agriculture are emerging, such as organic products markets, short local supply chains, CSAs, organic food for school canteens, etc. New policies brought by Greater Paris Project are promoting local agriculture, food production, and landscape infrastructures as important levers on its local governance.

4.1 Agriculture: An Unexpected Importance in the Greatest European Agglomeration…

For a long time linked to the supply of fresh products to Paris, marketed via the Central food offices, GPR agriculture is now largely decoupled from the consumption of urban food products. Nevertheless, it remains an extremely strong force at the regional level, with substantial cereal production and short value chains in full revitalization, but above all a dominant land-holding and quite decisive for the future development of the capital. According to recent censuses, the vast majority of agricultural areas are cereals (63.3%), including wheat (4.5% of national production), beet and protein oil and, to a lesser extent, market gardening and specialized crops (horticulture and arboriculture) (Agreste, 2019). Overall, the productions are distributed in two large circles, also called small and large crowns. Market gardening and specialized crops occupy the residues of agricultural areas of the small crown, whereas the dominant holdings of field crops extend instead in a large crown opening onto quasi-rural areas. The economic and political domination of field crops results in a preponderance of large farms and open fields. These landscapes are partially interspersed, in the valleys, by livestock systems and a few groups specialized in market gardening or fruit production.

Agriculture in GPR is never far from the city, and the vast majority of farms can be classified as peri-urban or urban. One in six farmers declare that they have their farm headquarters in an urban center and more than a thousand urban dwellers declare that they have a professional agricultural activity in or outside the city. It is difficult to envisage a growth or even a sustainability of agricultural activity on the border of the central urban area, due to the pressures on land and the anticipation of an increase in the price of land, that it concerns farmers or the many owners of agricultural land. Land pressure on farms closest to urban centers, insufficient land available in urban areas, and the uncertainties that weigh on the planning thus penalize the farmers in their investment decisions and result in a low possibility of redeployment of agricultural land.

This rapid decline in the surface of agricultural land must not be interpreted as a planned disappearance of agricultural activity, and even less of an orderly retreat on homogeneous concentric fronts. In addition to increased annual consumption of farmland, the increasingly complex interpenetration of urban and agricultural functional spaces is at the origin of a permanent reconfiguration of agricultural parcels and a multiplication of places of contact between city and agriculture, especially in the green belt. The urbanization generally follows major extended transportation and connection axes to the main city, which builds a mosaic of differentiated land uses on the scale of the metropolitan area. Contacts between different land uses (agricultural, natural, industrial, residential, in terms of infrastructure, etc.), as well as between different categories of land users or owners (farmers, individuals, public authorities, etc.), sometimes with different interests and visions of spatial planning, promote the confrontation of points of view, oppositions, and hence tensions and conflicts.

4.2 … But with a Low Share of Conflicts…

Conflicts have multiplied over the past thirty years in different places, generally located on the interface between the Paris agglomeration and the natural and agricultural areas (Darly & Torre, 2013). The peri-urban municipalities concerned, with a fairly high rate of urbanization, are expected to become urban. The oppositions about the use of space are above all the question of agricultural land and its usages. Considered as reserves of land, located on the outskirts of the metropolis in extension, they are at the center of all the lusts and anticipations, from agriculture to the residential zone, passing by the industrial productions, service and nature activities, or especially infrastructure serving the city (roads, highways, railways, waste treatment facilities, energy production plants).

Through the crossing of information obtained by the proposed methodology with interviews with local experts, analysis of the regional daily press, and bibliographic research, it was possible to identify more precisely the main origins of conflict in the region (see Table 3).

The expansion of the central city is not easy, because infrastructure projects or housing estates face organized opposition from local residents, who wish to preserve the environment or their living area and mobilize for the preservation of open spaces, in the first place agricultural spaces, close to their place of residence. The spatial constraint is huge, be there the need for infrastructure or the required land for construction areas in the peri-urban municipalities. The possibilities for the continuation of land artificialization are small and tend to shrink, hence the exacerbation of tensions over land use.

The conflicts oppose two major groups with opposite interests: the defenders of the quality of the living environment and the quality of life, and the individuals or legal persons interested in the development or urban occupation of the land not

Table 3 Sources of conflict in GPR

Main sources of conflict in GPR
Urban sprawl and real estate speculation (despite construction in "hollow spaces" x prejudice of inhabitants, eco-neighborhoods, developers)
Installation of urban infrastructures (large consumers of land)—roads, airports, logistic platforms, railroads, subways…
Neighborhood with urban dwellers who complain about nuisances and lack of knowledge about agricultural practices
Lack of regional management of agricultural production areas and of relative importance in public policies to support local agriculture

Source The authors

built. Objections to the disappearance of agricultural land represent 49% of the total litigation in the region. But a contrary movement is developing in parallel, which characterizes the resistance against the regulatory protection of agricultural land, through the local documents like PLU. Challenges to the protection of farmland accounted for 34% of the region's litigation. One must avoid the idea that non-farmers are pushing for the consumption of agricultural land, while farmers are defending their land. The latter are often interested in selling their land, due to higher land prices or expectations of gains and regularly protest against the classification of farmland in planning documents (the price of agricultural land is around 0.9 €/m^2 in unbuilt rural areas (SAFER, 2018) and reaches approximately 2,800 €/m^2 in Meaux, the first urban pole of Seine-et-Marne department, for urban housing uses) (Le Parisien, 2019).

There is no zoning directly related to peculiar categories of conflicts; they are present in several municipalities, located almost entirely in the Departments, most distant from the capital Paris, belonging to the second circular crown of this region. Firstly, there is the presence of a small belt, closer to the urban center of Paris, with few conflicts. Secondly, a large zone in the *Département* of the *Yvelines*, 30–40 km to the west of Paris, in a more "peri-urban" area, seems to be wedged in a stranglehold between the limits of the Regional Nature Park of the High Valley of the *Chevreuse* and the town of *Mantes-la-Jolie* (limit of the Nature Park of *Vexin*). The rest is located in areas considered to belong to the rural green belt of the Region. The layout of these conflicts on the territory can be visualized in Fig. 4.

4.3 …Mainly Related to the Maintaining of Peri-Urban Agriculture

The inventory of conflicts shows that agricultural activity is rarely an object of conflict in itself in the GPR. The actors of the agricultural sectors are little involved in the oppositions, and conflicts between farmers and residents represent only about 10%

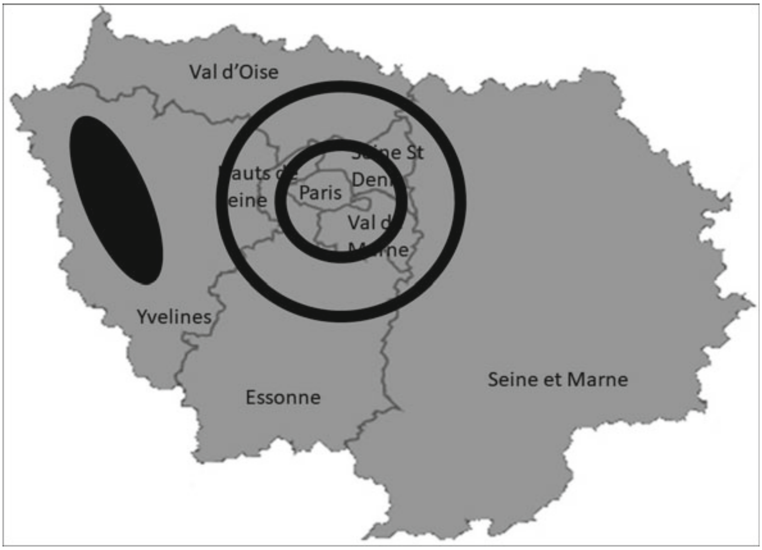

Fig. 4 Conflict zones in the Paris Region. *Source* The authors

of the whole range of conflicts in the region (Torre & Darly, 2014). Overall, challenges related to agricultural activity remain low, and are triggered by local residents who act to ensure that the farming practices applied in the grain fields around them are more respectful of their living environment and the environment (field burning, GMO planting, drilling for irrigation) or to prevent the establishment or extension of agricultural (stable, shed) or industrial buildings related to the development of storage or logistics capacities of storage holdings (commercial elevators, beet transport). Concerns are also sometimes expressed about land groupings and their possible consequences in terms of biodiversity (loss of hedgerows and groves) and natural resources (water). Finally, farmers themselves are sometimes at the origin of appeals, especially against the activities carried out by rural or neo-rural, in the first rank of which are hunting companies, which flourish on the outskirts of the agglomeration.

One case has become now particularly emblematic: the question of agricultural land in the *Plateau de Saclay* in the south of the region, for the construction of a large center for teaching, research, and technological production, mainly organized around the creation of the Paris-Saclay University (the biggest French university, now ranked 13th in the Shanghai ranking). The construction of this peri-urban cluster and the development of transport, housing, and services infrastructures necessary for its functioning demand huge transformations in the use of the local fertile agricultural lands. Compensation measures are adopted, like the creation of a natural agricultural and forest protection zone (ZPNAF) as a way of preserving agricultural land. Partnerships between rural and urban and system of direct sales and short food circuits are encouraged. However, impacts on the drainage system of agricultural lands and the increase in traffic jams remain high. The opposition of local residents and farmers in favor of the preservation of farming areas seems doomed to fail, but the creation of local associations of land users opens the way to negotiation and mitigation between infrastructures and farming areas.

In the North of the GPR the *Europacity* project aimed to install a large commercial, cultural, and leisure complex close to the *Charles de Gaulle* airport, on very fertile agricultural areas. Following multiple disputes between municipalities, public and private actors, farmers, and civil society, the project was recently abandoned by the Central Government. Among the main challenges were the fight against the artificialization of agricultural land and the urban expansion, and the failure to consider local environmental impacts. An agricultural development zone is supposed to be created there, but the future of this peri-urban territory remains quite uncertain. Despite the definitive validation of the agricultural use of that territory, supporters of the project say they are returning to mobilize against this decision and claim about the expected numbers of jobs creation. Stopping this project, however, does not mean in any sense that urbanization processes have ended in the region.

5 Conclusions and Discussion

The objective of this article was to take stock of the oppositions met by peri-urban agriculture in the proximity of big urban areas and the conflicts it can generate, taking the example of two large agglomerations, placed in different situations but confronted with the same type of urban sprawl and consumption of agricultural land: the Greater Paris Region and the Metropolitan Region of São Paulo.

Our research suffers from several limitations, like the peculiarities of the examples chosen and the lack of official statistical data about conflictuality. But it made possible to verify that the main conflicts in those metropolitan regions are based on divergent land uses, in neighborhood pressures with environmental protection zones and with housing market. Considering these scenarios, the most important and opponent actors involved in these disputes are public authorities, housing market, farmers, public demand, and organized crime and energy companies (in São Paulo).

However, we noted important differences between the two situations. In São Paulo the conflicts related to the maintenance of urban agriculture are mainly due to the consumption of agricultural land by the urban sprawl process and the opposition of farmers who see their activity thus threatened. In Ile-de-France, conflicts also come from two other origins: residents who advocate the maintenance of agricultural activity to defend their interests in terms of quality of life (although in some cases these inhabitants may complain about the various types of nuisances caused by the presence of agricultural activities in the territory), and farmers who are denied the passage of their land into a building zone and are deprived of the possibility of making a significant increase in value by selling it.

Mainly, the results reveal that, although the contribution of agriculture in the two case studies is of little importance in the local economies, the permanence of agricultural activities is increasingly supported by the actions of civil society organizations that create projects, associations, and initiatives, often with a vanguard character, to respond to various economic, food, social, and environmental needs. Not only traditional agriculture, but more modern agricultural initiatives such as rooftop gardens and greenhouses on or inside buildings have also presented advantages that go beyond agricultural production per se, such as education and awareness-raising for users of these spaces, as portrayed in Berlin (Specht et al., 2016). The public power comes next, often because of the inertia of the public machine or by waiting for these issues to be really important to be addressed and incorporated into public agendas.

In the case of SPMR, enforcement measures could be improved to prevent the advance of the urban network and the deforestation of natural areas, especially in the southern rural area of the city. However, according to the statements of some specialists, the presence of public power in the territory is not effective. In addition, the relations of local councilmen who illegally negotiate with organized crime organizations for the sale of areas located in forest spaces undermine the actions of the local government. In GPR, the structural complexity of the different levels of decision-making on farmland governance leads to the conclusion that the political actions tend to be more effective on existing conflicts the closer they are to the territory (such as the municipal or intercommunal scales). The departmental level tends to be less responsible for creating policies that go toward the protection of agricultural land (probably because it has few financial resources to support its policies). However, while respecting the legal principle of free administration of local authorities, it is up to the smallest administrative levels to elaborate and apply their policies for the management of existing conflicts.

These results lead us to define some public policy recommendations:

– It is crucial to promote the development of agriculture in the cities and their peripheries because this activity has several virtues: it can help to feed part of the population and supply them with fresh products, especially in developing countries, as seen in the case of food production under power distribution lines in São Paulo; it promotes employment, social reintegration and the activity of many inhabitants; it is a factor of example of environmental, food and agricultural education for the young generations; it contributes to the maintenance of green spaces and thus to the fight against global warming and to the maintenance of a certain level of biodiversity; eventually it contributes to the well-being of local populations through their reconnection of the relations between man and nature, reported in the Paris case.
– Policies in favor of the establishment and maintenance of agriculture must be developed, as a result of the understanding and appreciation of the benefits obtained by agricultural activities in the territory, in particular the preservation of land, the guarantee of well-established property rights or rents, to support access to land, to settle and accompany generational renewal, as well as broadly working toward better rural retirement. Even so, promote local products, sell them on the markets, and enhance their visibility to the population. It seems necessary to ensure permanent budgetary envelopes to agriculture in order to make the commitment to local agriculture officials in theoretical and practical ways. Thus, agriculture

must be integrated into urban planning plans, and it is important to give voice to the local populations, initiatives and therefore also to the opponents, especially during their development phases.

- It is necessary to promote the control of authorized and illegal urban expansions in agricultural areas and the advance of large urban structures or territorial projects that are not essential to the local population. We recommend the legal protection or "sanctuarization" of certain agricultural areas in danger of extinction, through urban planning and the permanent supervision of the public power and civil society.
- Overall, the role and place of agriculture in and around cities needs to be revalued. This type of policy, rather than at the federal or national level, must be carried out mainly at the level of cities and regions, which are the main instigators of this territorial governance because of their knowledge of the field and their sensitivity to the demands and the claims of local populations. With this type of proximity governance, unnecessary conflicts can be avoided, such as those that can occur when instances of a larger territorial scale (of the national or macro-regional/state type) take generalized decisions that do not correspond to the particularities of the territory. For example, in Paris, the various agricultural areas in the crowns around the agglomeration demand different solutions regarding the ways of conserving farming activities and the challenges with other land users and land uses. In São Paulo, the morphologies dictate different perspectives for resolving local conflicts, and the presence of other striking characteristics of certain areas, such as environmental and water preservation, makes it paramount to consider natural vulnerabilities when making decisions about the agricultural management.

Urban and Peri-Urban Agriculture

We consider that urban and peri-urban agriculture corresponds to the activities that can be located within or on the bangs of the city, with the character of providing products mainly for the urban center, and where there is a strong competition between agricultural and non-agricultural land use. Both are presenting convergences, competitions, and tensions with other land uses under urban influence such as housing, sanitation complex, industrial centers, transportation works, natural resources preservation spaces, leisure centers, among others.

Definitions and related questions

According to RUAF,[2] the definition of urban and peri-urban agriculture comes through the cultivation of food, trees, and other agricultural products such as pot plants, herbs, fodder, and extractive plants for fuel production, animal husbandry, fish farming within the urban built environment or on the peripheral edges of cities. Production systems like horticulture, animal production, aquaculture, timber production, but also marketing of raw materials, processing, and procurement systems are present in these agricultural activities. This agriculture, also called metropolitan (Heimlich, 1989), or peripheral urban (Bryant, 1997), benefits from the proximity of urban activities, such as market and cultural infrastructures.

Land use issues.
Agricultural land use in peri-urban areas is subject to strong disputes in relation to other uses, such as housing and urban infrastructure, and to land pricing. The pressures for advancing urbanization and the artificialization of land, as well as the tensions, disputes, and conflicts, stem from the weak valuation of agricultural land vis-à-vis other land uses. This fragility creates real conditions for the transformation of this land use in the face of advancing urbanization and the disappearance of agriculture on the bangs of cities. For farmers, whether or not they own the land, whether or not they have precarious short-term contracts (Munton, 2009), agricultural use comes under pressure from the real estate market with a consequent increase in land prices. These conditions deteriorate the possibilities of financing and long-term permanence of agriculture in these peripheral territories (Péron & Geoffriau, 2007; Piorr et al., 2011).

The need for strategic land use action plans is reported by experts in agricultural, urban planning, and governmental management issues (Mok et al., 2014). Although the perspective of urban planners has commonly considered agricultural activities as rural occupation (De Zeeuw et al., 2000; Pothukuchi & Kaufman, 1999) the new urban planning documents, mainly at municipal and inter-municipal scales, are integrating agriculture as a territorial activity.

In France, several urban documents are governing the land use planning: SDRIF (Regional Planning Plan), SRCE (Ecological Coherence Plans), SCOT (Territorial Coherence Plans), PLUs (Local Urban Planning Plans) that consider agriculture as a real land use, moving from the vision of land reserve to the purpose of the territory. In Brazil, it is the Strategic Master Plans (PDE), or in the Integrated Urban Development Plans (PDUi) the recognition and reservation of their territories for agricultural activities. The debates about the position of these areas and the purpose of the land use that allow to investigate the potential vulnerabilities and opportunities for the development of agricultural activities are disputed both in hearings closed to experts and increasingly in a participatory manner, open to civil society.

Local authorities are increasingly using tools such as land maps and mapping of land use and land sharing as a result of the awareness of these issues. Agro-urban projects, aimed at promoting these agricultural activities and curbing urban sprawl, are being driven by the local inhabitants, civil society, and local associations. An example is provided by the European PURPLE network,[3] which seeks to encourage concerted governance of agricultural areas and productions in peri-urban environments.

[2] Resource center on Urban Agriculture and Food security, which aims to provide assistance, technical support and policy recommendations in this field to local and national authorities, and other local governments. http://www.ruaf.org/.

[3] The Peri-Urban Regions Platform Europe who is representing the interests of peri-urban European regions was set up in 2004. It is striving for greater recognition of these regions in European policy and regulation, and to ensure their long-term sustainability.

Annex

(1) Table 1 Number of actors interviewed according to the type of institution for each study region

Type of stakeholder	São Paulo	Paris
Public sector	6	14
Associative organizations	6	13
Territorial organizations	9	15
Total number of experts interviewed	21	45

Donner des infos sur qui ils sont—OK:
The actors interviewed were:
From São Paulo Region:

Master's student committed and recognized in urban agriculture movements in São Paulo
Director of the Division of Biodiversity Conservation Units of the Municipal Secretariat of Green and Environment and President of the Council of the Green Belt Biosphere Reserve of the City of São Paulo (RBCVSP)
Agronomist, environmental and agro-ecology project specialist at the Secretariat of Agriculture and Supply of the State of São Paulo
Geographer, member of the "Kairós Institute" and supporter of the municipal project of agricultural development "Ligue os Pontos/Connect the Dots" of the São Paulo City Council
Journalist, urban farmer, committed and recognized in AU movements of São Paulo and Co-deputy in the Legislative Assembly of the State of São Paulo
Environment Officer in the Secretariat of Infrastructure and Environment of the State of São Paulo
Sociologist, in charge of supporting the project "Ligue os Pontos/Connect the Dots"
General Director of the Organization "Cidades sem Fome/Cities without Hunger
Coordinator of the Atlantic Forest Biosphere Reserve
Agronomist, responsible for the creation of an environmental and agricultural reserve area in the south of São Paulo, doctoral student in territorial planning
Geologist and data coordinator of the project "Ligue os Pontos/Connect the Dots" of the São Paulo City Council
Member of the "Kairós Institute" and support to the Association of Farmers of the East Zone—AAZL
President of the Farmers' Union of Suzano (city of greater São Paulo)
President of the RBCVSP
Forestry engineer and former coordinator of the RBCVSP
Farmer and former treasurer of the farmers' cooperative of the South zone of São Paulo, COOPERAPAS
Urban farmer involved in shared gardens and tree planting in the city

(continued)

(continued)

Physician and organizer of a shared garden in the Faculty of Medicine of the University of São Paulo
Economist, former president of the RBCVSP
Agronomist engaged in the metropolitan planning of agricultural areas

From Paris Region:

Head of the Urban Planning Department of the CC 2 Morin
President of the Collectif Pour le Triangle de Gonesse (CPTG) and the Val d'Oise Environnement
DDT 91 Head of the Agricultural Economy Department
Referent for Urban Agriculture and Shared Gardens. General Council of Food, Agriculture and Rural Areas—CGAAER of the Ministry of Agriculture, Food—MAA
Director—Coordinator of the Environment Pole of the Urban and Rural Environment Department of the Paris Region Institute (Former IAU)
Delegated President in charge of rurality, agriculture and food of the Essonne Departmental Council + Head of the Agriculture Sector at the Department of Territorial Animation, Attractiveness and Contracts
Deputy General Manager of the Sustainable Territory and Mobilities of the Coeur d'Essonne Agglomeration Community
President of the Chamber of Agriculture of Seine-et-Marne from 2013 to 2019, union experience and Mayor of La Chapelle Moutils
Head of the Agricultural Economy Unit at the DDT of Val'Oise
Doctoral student at the AEV (Agence des Espaces Verts)
In charge of the Agriculture and short circuits mission of the PNR du Gâtinais Français
In charge of the land and installation mission of Terre de liens Île-de-France
Head of the regional service of agricultural economy. SREA/DRIAAF
President of the CARMA Association
Head of the Agriculture Mission of the Technical Expertise Department of the Ile-de-France Regional Green Spaces Agency. (AEV)
In charge of supporting local communities within Terre de Liens
Head of the Agriculture and Rural Development Department of the DDT of Seine et Marne—77
Regional attaché at the Direction Prospective et Aménagement Territorial of the SAFER IDF
President of the Land and Development Commission of the Chamber of Agriculture of Seine et Marne—77 between 2013 and 2019. Today she is the General Secretary of the Territory Commission of the Regional Chamber of Agriculture of IdF. Advisor at CESE—Conseil Economique Social et Environmnemental
In charge of soft mobility and agriculture at the Communauté d'Agglomération Paris-Saclay and Mayor of Marcoussis, Former President of the Agence des Espaces Verts
In charge of the Sustainable Agriculture Mission within the PNR de la Haute Vallée de Chevreuse
Responsible for the Agriculture and Forestry Mission within the Oise Pays de France Regional Park

(continued)

(continued)

Agri-Urban Territory Coordinator for the Roissy Pays de France Urban Community
General Coordinator of Terre et Cité—Plateau de Saclay
Administrator of the network of AMAP's of Île de France—President of ABIOSOL for 3 years
Lecturer at the University of Paris 1, member of Ladyss—Governance and open spaces, Governance Plateau de Saclay
ML—Responsible for planning and landscapes; DF—Responsible for agriculture in the PNR du Vexin Français—(95 and 78)
Director of the CAUE of Val d'Oise (95)
Responsible for Ecological Transition Projects in the Biodiversity—Agriculture Expertise of the Etablissement Public Foncier
Teacher—Researcher and Lecturer in Rural Geography and Agriculture at the University of Paris 8
President of the GAB Francilien and market gardener at Vergers de Cossigny (77)
Landscape designer, video maker at the CAUE des Yvelines (78)
Lecturer in Geography at the University of Paris-Nanterre
Co-founder of the AFAUP—French Association of Professional Urban Agriculture
In charge of Agriculture and Forestry for France Nature Environnement—FNE in Île de France
In charge of the Urban Agriculture study at the DRIAAF and for the City of Paris
Food Policy Officer at the Regional Food Service—SRAL at the DRIAAF
Project manager for methods and prospective in urban agriculture and building greening at the Direction des Espaces Verts et de l'Environnement of the Mairie de Paris
Head of the Resource Protection and Biodiversity Department of the Water Resources and Production Department of Eau de Paris
Head of the Land, SAFER and Structure Control Department of the Regional Agricultural Economy Service—SREA of the DRIAAF IdF
Deputy Director, responsible for Environmental Assessment, the Greater Paris Express and agricultural issues at the DRIEAT—Direction Régionale et Interdépartementale de l'Environnement, de l'Aménagement et des Transports (former DRIEE)
Head of Ecological Transition and Territories at CEREMA (Center for studies and expertise on risks, environment, mobility and development) in IdF
Assistant to the head of the forest, biomass and territory department, in charge of the Territorial Planning Division at the DRIAAF IdF
In charge of the Tertiary pole and relations with the communities of the collective Les Champs des Possibles—Incubator and agricultural cooperative of agricultural and food activities
Trainee from Sciences Po Paris within Les Champs des Possibles

(2) List of the main websites, Facebook, social network pages, and blogs consulted for São Paulo Metropolitan Region

Websites: Jornal Estadão; Jornal Folha de São Paulo; IBGE Cidades; Instituto de Economia Agrícola; Secretaria da Agricultura e do Abastecimento do Estado de São Paulo.

Facebook pages: ADE SAMPA; Armazém do Campo; Associação dos Agricultores da Zona Leste—AAZL; CEAGESP—Companhia de Entrepostos e Armazéns Gerais de São Paulo; Cidades Comestíveis; Cooperapas; DIEESE; Frente Alimenta; GEAU—Grupo de Estudos em Agricultura Urbana; Horta CCSP; Horta da FMUSP; Horta das Corujas; Horta das Flores; Horta do Ciclista; IBGE - Instituto Brasileiro de Geografia e Estatística; Instituto Bauru; Instituto Chão; Instituto Escolhas; Instituto Feira Livre; Instituto Kairós; Mandata Ativista; Metrópole Estadão; Organização Cidades Sem Fome—Cities Without Hunger; Projeto Ligue os Pontos—Prefeitura Municipal de São Paulo; Reserva de Biosfera do Cinturão Verde de São Paulo—RBCV—UNESCO; Secretaria de Desenvolvimento Regional do Estado de SP; Secretaria Municipal de Urbanismo e Licenciamento; Secretaria Municipal do Verde e do Meio Ambiente SP; União de Hortas Comunitárias de São Paulo.

Blogs: https://www.claudiavisoni.com.br/blog/; https://marianabelmont.blogosfera.uol.com.br

(3) List of the main websites, Facebook, social network pages, and blogs consulted for Paris Greater Region

Websites: Le Parisien; Le Monde; INSEE; Agreste; Ministère de l'Agriculture et de la Souveraineté Alimentaire; DRIAAF Ile de France Agriculture.

Facebook pages: Réseau AMAP Ile-de-France, GAB IdF—Groupement des Agriculteurs Biologiques en Ile de France, Bienvenue à la Ferme Ile de France, Cœur d'Essonne Agglomération, La Ferme de l'Envol, Base aérienne 217 Brétigny-sur-Orge, La Base 217, Région Ile-de-France, Préfecture de la région d'Île-de-France, Paris-Saclay, préfecture de Paris Chambre d'agriculture de Région Ile-de-France, Ministère de l'Agriculture et de la Souveraineté alimentaire, INRAE, Jeunes Agriculteurs d'Ile de France, Terre et Cité_Plateau de Saclay, Triangle vert, Abiosol, Les Champs des Possibles, Terre de liens Île-de-France, Val Béton, Grignon 2026, Ville de Paris, AFAUP Association Française d'Agriculture Urbaine Professionnelle, La Cité Maraîchère de Romainville, CARMA, Reporterre, le quotidien de l'écologie, Veni Verdi, Agence des espaces verts d'Île-de-France, Eau de Paris, Non à Europa City, Oui aux terres de Gonesse, France Nature Environnement Ile-de-France.

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Urban Quality of Life Challenges

After COVID: A Circular Recovery in Western European Cities

Joanna Williams

1 The Impact of the Pandemic on Urban Systems

The pandemic has highlighted and exacerbated problems already prevalent in cities (e.g. a lack of affordable homes for key workers near workplaces; lack of robust food supply chains). It has provided us with the opportunity to re-evaluate what cities are for and how they could be in the future. It has enabled people to establish new social practices, which if they persisted could result in new development pathways (e.g. homeworking, active transport). Post-pandemic, there is an appetite for healthier living environments and a greater acknowledgement of the interdependency of humans with the wider ecosystem. Thus, there are potential opportunities to create better urban environments.

Yet, there is uncertainty around whether the pandemic will produce radical change in cities, or merely accelerate those trends already occurring pre-pandemic (Curtis, 2021; Marshall, 2021). Certainly, the long-term trend of remote working has accelerated (Lennon, 2021), which has produced high vacancy rates in retail and commercial spaces (Nanda et al., 2021). There is an increased demand for public space (Sepe, 2021; Ugolini et al., 2020) and improved environmental quality (Sharifi & Khavarian-Garmsir, 2020), which has led to a proliferation of parklets and green cycleways (e.g. Paris, Brussels, Milan, London). However, some authors predict a rapid return to business as usual (Yamagata & Yoshida, 2020). Indeed, CO_2 emissions which fell by 5.4% during lockdown, are predicted to rise by 4.9% in 2021 as the global economy bounces back (Friedlingstein et al., 2021).

There are also questions about who will win and loose from the changes post-pandemic. Certainly, the urban poor have been detrimentally affected, which has led to greater social inequalities (Cole et al., 2020). Low-income groups were particularly affected by a lack of urban food security (FAO, 2020). The closure of street markets

J. Williams (✉)
University College London, London, UK
e-mail: joanna.williams@ucl.ac.uk

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and food banks reduced access to affordable food, particularly during lockdowns. This problem was exacerbated by the length of urban supply chains (FAO, 2020).

The lack of affordable accommodation in cities has meant that lower income groups, live in high density developments, with poor access to green space. The homeless were particularly vulnerable during the pandemic. Some were temporarily accommodated, but longer term solutions are needed. Key workers live far from their workplace, which reduced the resilience of essential services (health, education and transport services) in cities during the pandemic (Alexandri & Janoschka, 2020). In some cities, an attempt to address this problem has emerged as the 15-min city (e.g. Paris, Milan).

This situation has been precipitated by the hyper-financialisation of global cities (Curtis, 2021), which has led to a lack of affordable accommodation for those working in them. However, some believe that changing geopolitics, is beginning to undermine the legitimacy of neoliberal capitalism and the legitimacy of the financialisation cities (Curtis, 2021). For a short time, rental prices in some Western European cities dropped during the pandemic. However, in global cities, like London, the market is already bouncing back. In other less competitive cities, a reduction in land and property value could produce opportunities for new forms of development. This might deliver more liveable cities, where the poor can afford to live and work, in healthier environments.

To build urban resilience to future pandemics, urban systems of provision must be reviewed, to ensure continued access to food, water and sanitation, accommodation, transport and green spaces (Aldaco et al., 2020; Alizadeh, 2009; Banai, 2020; Jack et al., 2020; Mell & Whitten, 2021; O'Hara & Toussaint, 2021). Some highlight the need for local production and manufacturing, to reduce the vulnerabilities in supply chains. Others suggest the use of distributed, district scale technology and activities to promote self-sufficiency, reducing the interruption to provision of food, energy and water supply (Moglia et al., 2021). The need for inclusive rebuilding processes, to strengthen local communities is supported by many authors (Kimani et al., 2021; Moloney & Doyon, 2021).

Authors are also busy writing about the utopian futures which could emerge if new development pathways were adopted (Angiello, 2020; Barbarossa, 2020). It is not my intention to merely add to this literature. In this chapter, I want to discuss an approach to development, which had already emerged in some European cities pre-pandemic–circular development. It had also demonstrated considerable benefits, which in retrospect appear to offer solutions to some of the problems which have emerged post-pandemic. Thus, I suggest that taking a circular approach to urban development could help to build more pandemic-resilient urban systems.

The chapter begins with a definition of circular development. It demonstrates how five circular development strategies could create more resilient and *liveable* cities post-pandemic, drawing from Western European examples. For each strategy, it reflects upon the barriers to implementation. Finally, the potential for a circular urban transformation, post-pandemic, is discussed.

2 Circular Development—A Pathway to Future Resilience?

Circular development (CD) is a novel concept, first introduced (Williams, 2020) and later expanded on by the author (Williams, 2021a, 2022). It offers a new normative, regenerative model for urban development rooted in deep ecology rather than the ecomodernist principles which underpin circular economy. Unlike circular economy, it's focus is on the regenerative development of urban ecosystems, rather than economic growth and efficiency of supply and production systems, economic sectors or individual businesses. Circular development territorialises circularity, embedding circular systems in a specific context at a sub-national scale (unlike CE which has no spatial focus). Thus, it impacts on land-use, infrastructure and the way in which we plan our cities and their hinterlands. It goes way beyond the reuse, recycling and energy recovery from material waste, which is traditionally the focus of circular economy.

Circular development focusses on the need to reduce urban resource consumption and promote the health of the urban ecosystem (including the inhabitants). It alters cities' systems of provision to enable the circular practices of inhabitants to develop. Three actions—resource looping, adaptation and ecological regeneration—are implemented in combination to deliver the circular development pathway (Williams, 2019, 2021a).

2.1 Resource Looping

Resource looping (reuse, recycling and recovery) is enabled through the provision of circular infrastructural systems (e.g. grey-water recycling systems, recyclable infrastructure) and the introduction of new circular processes (e.g. conversion of waste to energy or feedstock). These changes in local systems of provision, can also encourage urban inhabitants to reuse and recycle resources.

Looping can increase the efficient use of resources locally (e.g. water, food, materials, goods, land and buildings), reducing waste and increasing resource security. This is particularly important when supply chains are disrupted, as they have been during and post-pandemic. Cities have long supply chains and large demand for resources, thus, they are particularly susceptible to supply chain disruptions (FAO, 2020). Ongoing disruption (post-pandemic) could provide the stimulus for the creation of local resource loops in city regions, which would also reduce greenhouse gas emissions from transportation and landfill. This will become increasingly important as emissions rebound post-pandemic.

New economic activities can emerge from looping actions (e.g. circular construction, food-reuse cafes, repair workshops, production of biofuel), diversifying opportunities and creating jobs in cities. This could lead to a degree of import replacement, helping to establish more stable and sustainable economic development post-pandemic.

Reuse, recycling and energy recovery schemes can also provide access to more affordable resources (e.g. goods, food, accommodation and heating) for the less affluent in cities. Encouraging circular, social solidarity activities (e.g. collection of ‘waste’ food for food banks; capturing waste heat for affordable warmth; repurposing of buildings to provide accommodation for the homeless) will be essential to protect the burgeoning urban poor post-pandemic.

2.2 Adaptation

The pandemic has increased vacancy rates in cities. It has highlighted the importance of adaptable infrastructure and the re-circulation of land for new uses. The circular development process produces adaptable cities, with space to transform (e.g. pop-up spaces for temporary uses) and grow, as well as infrastructure (e.g. scalable, movable, refittable and flexible) that evolves with changing needs. This reduces wasted resources (particularly land, infrastructure and materials) and embodied greenhouse gas emissions. It can also create new employment opportunities, particularly in the pop-up economy. Underutilised space could also provide opportunities for affordable accommodation and enable low-value circular activities (e.g. food, energy production) to gain a foothold in markets, thus increasing urban resilience.

Circular development introduces processes (e.g. collaborative planning, co-provision) which support learning within communities and encourage self-organisation. Communities become more engaged in the co-provision of services and resources (e.g. community farming, food banks, repair workshops, etc.). The human and social capital generated by engaging in these activities enables communities to innovate and adapt to changing contexts, becoming more resilient post-pandemic. There has been a growth in these projects during the pandemic.

2.3 Ecological Regeneration

Circular development also regenerates natural cycles, which reinforce urban ecosystem services and improve the health of those living in cities. Natural cycles are essential for the provision of clean water, air and fertile soils. They help to manage urban pollution, flooding and heating. Vegetation is particularly beneficial in tackling pollution (air, water and noise), regulating temperature and sequestering CO_2. Ecologically regenerative actions are often operationalised through the inclusion of green and blue infrastructure in the urban fabric (e.g. rainwater gardens, reed beds and green corridors), the management of urban ecosystems (e.g. farming, water management, conservation and forestry) and bioremediation (e.g. phytoremediation of contaminated urban sites).

Green spaces have become particularly popular during the pandemic enabling external socialising and recreation. Green corridors have helped to encourage active modes of transport. There has also been increased engagement in urban farming. Engaging in these activities improves the mental and physical health of urban populations and reduces car use in cities. The regeneration of urban ecosystems is essential for urban inhabitants to build a healthy resilience to future pandemics. The management of urban ecosystems and production of biological products may also generate new economic activities and jobs in the bioeconomy.

An analysis of several European cities, which have adopted this more regenerative circular approach to development pre-pandemic, demonstrated a variety of ecological, economic, community and health benefits (Williams, 2021b and Fig. 1). This analysis is based on existing examples. Thus, the chapter goes beyond the rhetoric of many papers written about urban utopias' post-pandemic. It is based on evidence found in existing cities.

The analysis suggests the potential for circular development to address problems which have arisen or been exacerbated during the pandemic, particularly:

- The poor health of urban inhabitants;
- Urban reliance on imported resources and unreliable, long supply chains;
- Limited adaptability in the built environment, vacant buildings and spaces;
- Lack of space for more sustainable activities in cities;
- Lack of diverse economic opportunities in cities;

Fig. 1 Benefits of a circular approach to development. *Source* Williams (2021b)

– Social inequalities—poor access to resources (food, energy and housing) and green spaces for the urban poor.

In this chapter, I argue that five circular development strategies could help to address these problems post-pandemic, creating healthier, resource-efficient and more resilient living environments. A summary of how each of the circular development strategies produces benefits, which directly tackle the problems generated post-pandemic, can be found in Table 1.

Table 1 Circular strategies, actions and benefits post-pandemic

		Strategies				
		Integrating accessible and connected green infrastructure	Creating circular urban food systems	Circular activities to rebuild the urban economy	Reconfiguring space in cities (for production and liveability)	Adaptive reuse/recycling of buildings
Circular actions	Looping	✔	✔	✔	✔	✔
	Ecological regeneration	✔	✔	✔	✔	
	Adaptation	✔	✔	✔	✔	✔
Benefits	Healthy urban ecosystem and inhabitants	✔	✔	✔	✔	
	Reduce urban reliance on long supply chains for essential resources		✔	✔	✔	
	Create new, diverse economic opportunities	✔	✔	✔	✔	✔
	Enable import substitution		✔	✔	✔	
	Provide space for less commercial, sustainable activities				✔	✔
	Adaptive living environment	✔	✔		✔	✔
	Access to essential resources for urban poor		✔		✔	✔

Source Author's own

In the next sections, the evidence supporting the benefits of circular development strategies is presented, alongside a critical analysis of the potential challenges to successful implementation.

3 Integrating Accessible and Connected Green Infrastructure into Cities

Ecological regeneration will help to restore the health of urban ecosystems. The provision and maintenance of green spaces are central to this process. During the pandemic, there was a significant increase in the use of green urban spaces (Ugolini et al., 2020). The link between ecosystem services and mitigation of the spread of the disease was widely recognised (Everard et al., 2020). The provision of accessible and connected green infrastructure in cities post-pandemic will help improve air quality, reduce heat stress and noise pollution and create spaces for recreation and relaxation (Chaparro & Terradas, 2009; Peng et al., 2012). It will have significant mental and physical health benefits, and thus help the post-COVID recovery (Maas et al., 2009; Stigsdotter et al., 2010). It could also build resilience to future pandemics, by addressing the health co-morbidities (i.e. respiratory, cardiac problems, type II diabetes and obesity) that increase mortality rates amongst those with the disease (Hallegatte et al., 2011).

Green spaces must be accessible (within 1 km of people's homes) to have a significant effect on the mental and physical health of urban inhabitants (Maas et al., 2009). This is particularly important for children, the elderly and people from lower socio-economic groups, who spend the most time close to home. Currently, 44% of Europe's urban population lives within 300 m of a public park(Zulian et al., 2018). However, there is still a great deal of variation in access to green space across socio-economic groups (Hoffmann et al., 2017; Mears et al., 2019; Wüstemann & Kalisch, 2016). The elderly, poor and children often have the worst access. Increasing access to these vulnerable groups should be a priority. This could be achieved using spatial planning, either through placing design requirements on new build development (e.g. adopted by the London Plan 2020) or by the conversion of redundant spaces in poorer neighbourhoods (e.g. parking spaces to parklets in San Francisco and Brussels).

The provision of green infrastructure can also encourage active lifestyles amongst the wider population (Janssen & Rosu, 2015). During the pandemic, there has been a rise in the numbers walking and cycling in cities. The creation of green corridors with integrated active transport networks would help reinforce this practice (Nawrath et al., 2019; Zhang et al., 2020). Active lifestyles reduce obesity, levels of stress and improve the mental health of city dwellers, helping to mitigate acute problems produced by the pandemic whilst increasing long-term resilience (Sallis et al., 2020; Simpson & Katsanis, 2020; Slater et al., 2020). The connectedness of green space is important for encouraging active transport.

The competition for space generated by land and property speculation in some cities creates a significant barrier to the inclusion of green infrastructure (Williams, 2021a). This problem is compounded by the low economic value placed on ecosystem services offered by green space (Gomez-Baggethun & Barton, 2013; Kremer et al., 2016). In space-scarce cities, only high-value activities are competitive. Nevertheless, space for green infrastructure can be designated in spatial plans. It is also essential to underpin land allocation with sustained funding for the ongoing maintenance of green infrastructure, otherwise, it will disappear (Merk et al., 2012).

Designing, managing and maintaining green infrastructure could provide new employment opportunities in cities, across a range of skills (Ten Brink et al., 2017). However, a lack of financial resources for maintenance in some municipalities could prove problematic. Many existing green spaces are being lost in European cities due to a lack of funds for maintaining them. The greater engagement of communities and businesses (user groups) in the co-provision of green infrastructure in residential and commercial spaces might help to address this.

Green gentrification creates a further problem (Jelks et al., 2021). Green space raises the value of land and property in its vicinity. Green gentrification is more likely to occur when parks are established near business districts or designed as green corridors (Anguelovski et al., 2018; Rigolon & Németh, 2020). Low-income groups are priced out of areas with good access to green space. Ironically, greening initiatives are often motivated by health equity goals, such as improving the health and well-being of marginalised groups (Cole et al., 2017; Rigolon & Németh, 2018). Yet, these initiatives often prove more divisive and disadvantage marginalised groups. Instruments for market intervention, like rent control, might help to address this, but are politically unpopular.

In cities where land value is low, there may be greater opportunity for the integration of green infrastructure. However, these are often cities with an industrial legacy and problems with contaminated land. In addition, the tax base for a declining city will be lower, so there is likely to be a lack of municipal resources for land decontamination and maintenance of green infrastructure, which can create a barrier to implementation. The ecosystem services provided by green infrastructure (which offer health benefits; protection from flooding, drought, heating and pollution, and potentially jobs) are undervalued. However, if they were seen to be a solution for tackling economic decline and associated social problems, this could offer a political justification for supporting projects.

4 Creating Circular Urban Food Systems

Around 70% of the global food supply is destined for urban consumption (FAO, 2020). During the pandemic, food supply chains were disrupted. The problems were upstream in the supply chain (processing, transport, distribution and retail). Food supply for larger cities was more affected because, there was greater demand for food and longer supply chains (FAO, 2020). The restrictions on the movement of people, goods and services and other containment measures (such as closing of schools, marketplaces and food banks) affected both food distribution and food availability in urban markets (FAO, 2020).

In Europe, food shortages, associated with panic buying, also led to price increases. This effect, coupled with job losses, disruptions in public food procurement and distribution of food to vulnerable groups, reduced access to food (FAO, 2020). For the urban poor, the pandemic exacerbated food insecurity (Barker & Russell, 2020; Van Lancker & Parolin, 2020). According to Eurostat, 6.6% of households with children in the European Union (5.5% in the UK) could not afford a meal with meat, fish or a vegetarian equivalent every second day.

Localised circular food systems, which combine looping, regenerative and adaptive actions, have the potential to increase food security and reduce reliance on unstable supply chains. Food reuse and growing are central to this. Systems for recovering and redistributing food "waste" are informal and reliant on donations and volunteers. Thus, during the pandemic many food reuse systems failed (Barker & Russell, 2020). If food reuse systems are to become more resilient to future shocks, this informality will need to be addressed.

Another problem is the low value of food waste. To be economically viable, food reuse needs to happen locally. But cities have large demand for food and limited local supply, due to inefficiencies in food waste recovery and redistribution. Thus, it is essential that these efficiencies are addressed to maximise supply. The lack of a strong regulatory framework which requires the reuse of food waste creates a barrier. More robust systems for donation, collection and distribution will be required, coordinated and partly funded by governments (FAO, 2020). Alternatively, strong regulatory frameworks could produce more robust systems.

Paris is at the vanguard of food reuse schemes. French legislation has made it illegal for supermarkets, food markets and restaurants to dispose of edible products. This legislative framework has helped to formalise the reuse of food. Not-for-profit organisations redistribute the food supported by local government. In Paris, this has produced a variety of projects including solidarity cafes, food banks, community kitchens and solidarity fridges. Nevertheless, even in Paris, food supply was disrupted during the pandemic.

An alternative approach to increasing food security comes from Amsterdam. Here the Power-to-Protein project extracts ammonia from sewage to create high-value proteins. These are then converted to food and feedstock. It is estimated that 35% of the primary protein requirement for the city's residents could be supplied in this way (Van der Hoek et al., 2016). This seems a neat solution both to increasing food security and valorising waste. However, indications of the transfer of SARS-CoV disease from wastewater could make this approach very risky (Bogler et al., 2020). Public attitude towards food produced from sewerage and regulation which conflicts with the practice, create further barriers.

Urban food security might also be addressed, by growing food in city regions. For example, Paris has adopted a city-regional approach to food production, implemented through the regional plan and *Parisculteurs* initiative.[1] The former designates municipally owned space for food production surrounding the capital. The latter encourages private landowners to provide space within the capital for urban farming. Certainly, a city-regional approach, reinforced by spatial plans, is needed to improve food security.

However, within Paris, farming is still only on small, temporary, interstitial sites (Demailly & Darly, 2017). Community-owned farms compete with commercial farms for space. Yet, community farms offer the best opportunity to improve access to fresh food for the urban poor. During the pandemic, there was an increase in Parisians buying food directly from commercial urban farmers. However, the food was too expensive for low-income groups. There was also a trend towards more households growing food, but they were more affluent. The urban poor are less likely to engage in urban agriculture projects, due to a lack of financial resources and appropriate expertise. Thus, the scale of food production is limited and does not address feeding the urban poor.

In Lisbon, the *Hortas Urbanas* (community farming) have provided a source of fresh food for the urban poor since the economic crash in 2010. This approach relies on access to a considerable amount of municipally owned land in city regions. In some cities, there is a limited supply available. In others, the local land market prohibits the use of space for low-value activities. Thus, significant market intervention would be needed to secure local food production in these cities (Williams, 2019, 2022).

In less economically successful cities and shrinking cities, access to land would be less of a problem. There would also be greater demand for affordable food. Thus, urban farming and food reuse schemes could have more purchase. However, the degradation of urban ecosystems—soils, air and water—contaminated with pollutants, could affect the quality of locally produced food (Bechet et al., 2018; Brown et al., 2016). This could be tackled by bioremediation programmes, but this is an expensive and longer term strategy.

5 Circular Activities to Rebuild the Urban Economy

Unemployment has been rising in all European countries since the beginning of the pandemic. Approximately, 16.5 million people in the EU were estimated to be unemployed by July 2020, with many more classified as economically inactive (Magrini, 2021). Cities have been badly hit. Those with weaker economies pre-pandemic have seen the largest increases in unemployment, particularly in shrinking cities (Hartt et al., 2021). However, some strongly performing cities have also been affected due to the very specific sectoral nature of the crisis (Magrini, 2021). Those sectors hardest

[1] The Parisculteurs initiative aims to cover the city's roofs and walls with 100 ha of vegetation by 2020. One third of this space will be dedicated to urban farming.

hit are manufacturing, tourism, hospitality and retail. This is particularly a problem for low-income groups and predominantly ethnic minorities (Hartt et al., 2021). However, for manufacturing and retail, it is the acceleration of processes which were already at work pre-pandemic.

Circular development could produce alternative, sustainable employment opportunities post-pandemic. A circular economy creates economic value through using more labour and fewer resources. Thus, it could create new, sustainable economic sectors and jobs. It could also enable import substitution (through the reuse and recycling of residuals and conversion to energy), which underpins sustainable economic development (Jacobs, 1969; Taylor, 2012).

In Europe, the circular economy could create up to 1.2–3 million jobs and reduce unemployment by around 250,000–520,000 (WRAP, 2015). It is estimated that the circular economy could be worth as much as £9–29 billion for the UK (Baddeley & Vergunst, 2016) and €7.3 billion for the Netherlands annually (Bastein et al., 2013). It could also create up to 175,000 jobs in the UK (Voulvoulis, 2015), 54,000 jobs in the Netherlands (Bastein et al., 2013) and 300,000 jobs in France (Ministry for an Ecological and Solidary Transition and Ministry of Economy and Finance, 2018). This also translates into jobs in cities. For example, in London, it is estimated that the circular economy could create 12,000 new jobs by 2030, of which 5% would be in the construction industry (London Sustainable Development Commission, 2015).

Research indicates that the urban bioeconomy also has the potential to provide many new jobs (Biber-Freudenberger et al., 2020; Hetemäki et al., 2017). It exploits latent urban assets in the form of biological models and processes for various direct or indirect economic benefits (Biber-Freudenberger et al., 2020; Lewandowski, 2018). Two processes are integral to the bioeconomy. The first involves harnessing biological assets offered by ecosystem services. Managing these biological assets produces new resources and creates local employment opportunities in a range of areas: urban forestry, conservation, agriculture, energy, water management, carbon sequestration, recreation, health and tourism (Ten Brink et al., 2017).

The second process focusses on the valorisation of biological waste. This is the circular urban bioeconomy, which overlaps with activities in the circular economy. Biological waste is valorised through bioprospecting or biological processes which reduce waste. This is an approach currently adopted successfully in Amsterdam (Williams, 2021a). It is estimated that the sector could produce more than 110 million euros annually and over 1250 jobs (Bastein et al., 2016). In 2017, over 17 million people were employed in the European bioeconomy. This added 614 billion euros to the European economy. Growth areas included bio-based electricity, biochemicals and forestry (Hetemäki et al., 2017).

The adaptive economy could also make a significant contribution to economic growth. It sub-divides into three job clusters: design and implementation of adaptable infrastructure; capacity building in communities; and the pop-up economy. Novel approaches to the design and implementation of adaptable infrastructure are currently being tested in Amsterdam. Certainly, there are early signs that this will require new skills and create new economic opportunities. This sector is likely to be worth 8 million annually, producing 700 jobs (Bastein et al., 2016).

It has been estimated that the pop-up economy also provides new opportunities. In the UK alone, it is worth more than 2.3 billion pounds and currently, employs over 26,000 people. The temporary nature of urban pop-up activities, also increases a city's ability to adapt to changes in the landscape. This approach has proved successful across many European cities including London, Paris, Amsterdam, Berlin and Lisbon. However, the pop-up economy doesn't necessarily produce sustainable jobs, but it does create a degree of economic resilience and prevents the waste of land and infrastructure.

Thus, circular development (circular, bio and adaptive economies) could provide a diversity of jobs across a range of skills sets (Ten Brink et al., 2017, Burger et al., 2019; Hetemaki et al., 2017; Biber-Freudenberger et al., 2020; Lewandowski, 2018). Private investment will be needed to support the growth of the new sectors that underpin circular development. Of course, there will be some hesitancy due to the potential investment risks and longer, time frames for investment returns (Byström, 2018). A regulatory framework will be needed to support this transition, which assures risk-averse investors that there will be a market for their products and services. Currently, the regulatory framework to support this transition is at best limited in coverage and fragmentary (Williams, 2021a, 2022).

Also, educational and training programmes will be required to reskill the unemployed to enable them to access the new jobs created. Public subsidies (perhaps through the investment of public pension funds) and procurement could be used to support circular businesses and industries, at least in the early phases of market development (until take-off), as is the case in Amsterdam (Circular Innovation Programme), London (LWARB Accelerator Programme) and Paris (City of Makers). Certainly, sustained financial support will be required for the circular transformation to be successful, possibly underpinned by the European Green Deal.

6 Reconfiguring Space in Cities (for Production and Liveability)

The impact of the pandemic on urban economic activities will be seen on the ground, as abandoned sites and infrastructure. Space in cities will need to be reconfigured to avoid redundancy. E-commerce, particularly retail, has been undergoing a dramatic transformation over the past two decades. However, the pandemic has accelerated the move to online working and shopping (Felstead & Reuschke, 2021; Nanda et al., 2021). During the pandemic, more people began to work from home and shop online (Kunzmann, 2020). Early estimates suggest that 40% of the European workforce began to do homework full-time (Eurofound, 2020). In the UK, before 2020, it took 40 years for homeworking to grow by 3%, but its prevalence grew eight-fold as people were instructed to work at home during the pandemic (Felstead & Reuschke, 2021).

Over 60% of Europeans shopped online for a variety of goods and services during the pandemic (Eurostat, 2020). In lockdown, 28% of Europeans living in urban areas used online shopping as the main channel for buying groceries, an increase of 10% compared to pre-pandemic levels (PWC Report, 2020). Studies suggest these trends will continue post-pandemic (Felstead & Reuschke, 2021; Nanda et al., 2021). This reduction in commercial and retail activities in cities could result in a reconfiguration of space, which could provide an opportunity to create more liveable cities. Empty shops and offices could be converted into affordable accommodation (Sweeney, 2021). The 15-min city approach, being adopted by European cities, provides affordable accommodation and reduces commute distances for key workers in cities. This not only improves the group's well-being, it increases the resilience of essential services, thus making cities more liveable.

The pandemic may also reduce land and property speculation in some cities (Szmytkowska, 2020), decreasing land value and potentially enabling lower value (circular) activities to emerge (Fainstein, 2016). This is particularly likely in cities experiencing an economic downturn, or where circular activities could provide new employment and investment opportunities (Aalbers, 2016; Perez, 2003).

If cities shifted from being consumers to producers of resources (food, goods, construction materials, energy, etc.), it could help to stabilise local economies and shorten supply chains. It would also have significant economic and environmental benefits, providing adequate incentives for municipalities to intervene in land markets. Paris seeks to create local circular food systems and to localise symbiotic industrial systems to increase resource sufficiency and reduce vehicular emissions (Williams, 2021a).

However, where land and property values remain high, low-value activities will continue to be excluded (Alexandri & Janoschka, 2020). Of course, governments could intervene in this process using various levers (e.g. development tax, rent caps, increased provision of non-market housing and planning) to rebalance activities in the city (Edwards, 2015; Rolink & Garcia Chueca, 2020). Temporary planning permissions (used in Paris, London and Berlin) and circular tendering[2] with land issues (used in Amsterdam) have been used to encourage low-value, circular activities (Williams, 2021a, 2022).

However, this hasn't as yet bought about systemic changes. This is largely due to the financialisaton of the built environment in cities and the reliance of government on private capital (Halbert & Attuyer, 2016). The complexity and volatility of the capital circuits underpinning systems of provision in cities (Halbert & Attuyer, 2016) combined with investment risk aversion, undermines the potential for a circular transition and the reconfiguration of space.

[2] Circular tendering and land issue apply circular criteria to the release of public land or buildings for development across five categories: materials, energy, water, ecosystems and resilience.

7 Adaptive Reuse/Recycling of Buildings

Vacant buildings and sites have emerged in many European cities post-pandemic. Ensuring new infrastructure is recyclable could help to address this problem of redundancy in the future. For example, a systematic approach to recycling the urban fabric is being adopted in Amsterdam. Circular tendering and land issue has encouraged construction companies to produce recyclable buildings, whilst public procurement incentivises them to source recycled materials for building (the City of Amsterdam, Circle Economy and Copper8 2017).

The logistics of adopting such an approach is enabled in the city region by the Circle Scan (a platform monitoring the flows of construction materials), PUMA (a database which identifies the location of precious metals in existing buildings) and logistics centres (where recycled construction materials can be stored). In combination, these instruments facilitate circular construction in cities.

However, capacity (i.e. expertise, supply chains, etc.) still needs to be built within the construction industry to deliver recyclable or adaptable infrastructure. This has cost implications for companies, building new expertise and supply chains. There is also a cost associated with the provision of space for the storage of construction materials in cities and the creation of online platforms enabling markets to develop. Thus, it is important for governments to incentivise the transition using subsidies and regulations.

During the pandemic, there has been an urgent need to accommodate the homeless, which was resolved through their temporary accommodation in hotels and hostels (for example in London and Berlin). Post-pandemic longer term arrangements are needed. Recyclable, pop-up buildings provide one option (e.g. the Place, London). Pop-up, modular constructions limit waste and, being mobile, can be moved between temporary sites in space-scarce cities, where there is competition for land. This provides a more economically viable option. Empty buildings can also be repurposed to provide more permanent accommodation for the chronically homeless (e.g. HAWSE project uses empty garages to provide pop-up bedsits in East London).

Adaptive reuse offers a viable alternative to avoid redundancy. A more systematic approach to temporary, adaptive reuse is emerging in European cities, which should be encouraged. Brokers and websites enabling the temporary reuse of buildings and sites have appeared (e.g. L'Association Plateau Urbain in Paris). Temporary planning permissions and leases have increased support for the practice amongst building and site owners, who now see the economic advantages (Bishop & Williams, 2012). Design competitions for the adaptive reuse of vacant buildings have also been used to support the practice (e.g. Paris Reinvented[3]). However, there are barriers to the adaptive reuse of buildings which need to be addressed. Property speculation; the relatively high cost of refurbishment; and regulations which prevent change in use and major refurbishments, can all create significant barriers to this process.

[3] *Paris Reinvented* initiatives formalised the process of the strategic adaptive reuse of sites and buildings in Paris from 2014.

In less successful cities, the process of adaptive reuse may need to be incentivised, by removing regulatory barriers or providing subsidies. The removal of some legal restrictions on refurbishment, change in use and land decontamination could assist this process. For example, the suspension of planning regulations to allow a temporary development (De Ceuvel) to go ahead in Buiksloterham (Amsterdam) on a contaminated site, resulted in an innovative approach to deal with decontamination. Here, phytoremediation was used to decontaminate land, whilst the new activities were on site. Another alternative might be to discourage new build development in declining areas, using the planning system.

8 Discussion and Conclusions

The chapter presents how five circular development strategies offer a more resilient approach to post-pandemic recovery in cities. They address human health and well-being; lack of food security; redundant sites and infrastructure; unemployment and lack of affordable accommodation. They also encourage and support the more sustainable lifestyle trends which have emerged during the pandemic (e.g. increased use of green space growing food, active transport and homeworking). Overall circular development could make urban environments more liveable post-pandemic.

The ecological regeneration of cities improves the health of the urban ecosystem and those living in it. Redundant spaces could be adaptively reused to provide green space or affordable accommodation for low-income households and key workers. The latter would increase the resilience of essential services and the health of those living in cities. Redundant spaces could be used to accommodate more productive activities (e.g. urban farming, energy generation, circular industries, etc.), which would increase jobs, shorten supply chains, increase resource security and allow import substitution. Together, these changes would also increase economic resilience and reduce environmental impact.

The key barrier to implementation is the undervaluing of the products (e.g. recyclates) and services (e.g. ecosystem services) provided by the circular development. In the neoliberal context, cities rely on private investments and markets to fund circular development. Yet, there is no market demand or incentive for investment. The market is limited by the low valuation of societal goods. There is a lack of regulatory framework (regulation and subsidies) which could signal their value, increasing investment and ultimately demand.

The lack of regulatory framework also produces uncertainty amongst those wishing to invest in circular development, yet substantial resources will be required to overcome socio-technical lock-in. Put simply, the economics are wrong. Until the economic system is transformed to take into account the socio-ecological value of circular development, we are left with limited regulatory and economic levers for implementation.

Implementation challenges will vary with context. In economically "successful" cities, the financialisation of land, infrastructure and services, alongside reliance on private investment for service and infrastructure provision, undermines the potential for circular development. This is because circular activities are undervalued and investors are risk averse, wanting returns in increasingly short time frames. It is also due to the blisteringly high land and property values and the comparative certainty of high returns on luxury commercial and residential development. For circular development to be viable in successful cities, its economic value (and wider benefits) needs to be established and the investment culture of short-termism addressed.

In less economically "successful" cities, the problem is financing circular development without public funding. However, with an initial focus on sustained economic development, innovation and import substitution, a more stable and diverse economy, based on sustainable production as well as consumption, can develop (supported by cheap land). This provides the revenue required for ecological regeneration and socially progressive projects (e.g. affordable housing, food supply for low-income groups). Also supporting the pop-up economy, whilst planning recyclable and adaptable urban environments in less successful cities, will increase urban resilience to future shocks. In the short term, there is likely to be heavy reliance on communities to engage in circular projects which improve resilience (e.g. urban farming/gardening, pop-up activities).

The pandemic has highlighted a lack of resilience in urban systems. It has also provided a window of opportunity, through which we can view alternative futures, offering more attractive, healthy, affordable and resilient places to live. Circular development provides one such pathway, which addresses many of the challenges thrown up by the pandemic. However, it will require significant market intervention in order to be implemented successfully. Nevertheless, the cities which are at the front of this curve, are ultimately likely to prove more resilient to future shocks.

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COVID-19 City Perspective: The Impacts on the Real Estate Dynamics

Pasquale DeToro, Francesca Nocca, and Francesca Buglione

1 Introduction

The coronavirus emerged in December 2019 in China and caused serious consequences on human health. It produced and is still producing, three years later, negative impacts not only on the health sector (Fusco Girard & Nocca, 2020; WHO, 2020) but also on other sectors, including real estate (Kholodilin, 2020; Nicolaa et al., 2020). In March 2020, the World Health Organisation (WHO) declared a global crisis, which led governments to implement contagion containment measures, such as forced closures of all commercial activities except essential services like food supply, medicines and manufacturing. The increasing restrictions after the first phases of virus proliferation transformed daily lives and forced people to reconsider their relationships with others and urban spaces (Spanu & Nuvolati, 2021). In fact, they were forced to live for weeks locked in their homes and performed activities they would normally do outside, such as working, studying and doing sports, indoors (Sharifi & Khavarian-Garmsir, 2020). After the lockdown (March–May 2020) and the restrictions imposed by the Italian government in the following months (curfews, outdoor FFP2 masks, green passes and closed or restricted businesses), activities gradually restarted. The COVID-19 affects not only human health, but also the economy and social behaviour. On the one hand, the health crisis has led to a profound crisis in many activities (especially, in the tertiary sector) linked, for example, to the mobility of people. On the other, it has led to the spread of other previously little-used activities, such as smart working, online commerce and distance learning. The crisis has

P. DeToro · F. Nocca (✉) · F. Buglione
Department of Architecture, University of Naples Federico II, I-80134 Naples, Italy
e-mail: francesca.nocca@unina.it

P. DeToro
e-mail: pasquale.detoro@unina.it

F. Buglione
e-mail: francesca.buglione@unina.it

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produced negative impacts on consumption, investment and trade, causing a supply and demand shock (Allen-Coghlan & McQuinn, 2020) with consequences for the spatial configuration of cities (Florida et al., 2021).

The pandemic has changed the way people live, including finding new places to live, work and socialise. COVID-19 is driving the reshaping of urban spaces in order to cope with changes due to the pandemic (Checa et al., 2020; González Pérez & Piñeira, 2020). One of the sectors most affected by the transition is the housing sector. Indeed, due to the health emergency, sometimes people have to spend much more time in housing that is often inadequate. For this reason, a change in the demand and, consequently, in the supply of housing has taken place. New housing needs emerged because of the pandemic and have influenced and are still influencing the real estate market. Many lifestyles have changed: working, studying and leisure activities are no longer the same as before the pandemic (De Toro et al., 2021).

The purpose of this research is to investigate how the Italian residential market is changing under the effects of the COVID-19 pandemic. This study starts with an overview of the effects of the pandemic on cities from a large-scale perspective (Sect. 2), highlighting the changes that have been taken place and that continue to take place in urban spaces. Then, the focus is on the effects of COVID-19 on the real estate market (Sect. 3), one of the most affected sectors. In particular, the attention is focussed on the Metropolitan City of Naples, where the trend of the prices has been analysed and a survey has been submitted to the real estate agencies. The methodology has been described in Sect. 4 and the results of the survey conducted in 2021 are described in Sect. 5. These results are also compared with the data obtained through a survey on the community and real estate agents operating in the metropolitan area in 2020 in order to understand how the real estate market has evolved in the last two years, that is immediately after the outbreak and two years later. Future research perspectives are then discussed in the conclusion section (Sect. 6).

2 An Overview of the COVID-19 Impacts on Cities

Recent studies have pointed out the relationship between the COVID-19 pandemic and cities and explored the possible impacts. This study analysed a number of reports and studies that explored the ongoing transformations of 'post-pandemic cities' by focussing on mobility, temporary and mixed-use development, building adaptation, housing conditions, flexible designs and reconfiguring public spaces as innovative visions of streetscapes in neighbourhoods.

Mobility has dramatically changed because of the pandemic at the global, regional and city levels. In cities, there has been a marked increase in soft mobility. People started to cycle and walk, while the use of public transport decreased because it was perceived as a possible risk of infection. Therefore, some cities have increased the number of kilometres of bicycle lanes and pedestrian paths. At a time when social distance suddenly becomes essential, the bicycle offers the possibility of safe urban transport (Al-Khalidi, 2020).

In the COVID-19 period, some cities adopted shared mobility solutions (Helbiz, Reby and Lime through apps) of bicycles and electric scooters because people were more inclined to these types of single-person transport for fear of contagion. Several cities around the world (Puentes, 2020) have expanded or are planning to expand pedestrian and bicycle streets, often by reducing the road surface and dedicating part of it to 'slow' lanes (Bradshaw, 2020; Diaz, 2020; Topham, 2020). The city of Montréal, for example, has implemented a temporary 112-km route for pedestrians and cyclists to enable city residents to access parks, schools, essential services and businesses (Copenhagenize, 2020). In Quito, Ecuador, about seventy kilometres of new bicycle lanes have been built (UN-Habitat, 2021). In addition, in Milan, Italy, plans have been made to convert thirty-five kilometres of roads into pedestrian and bicycle paths to reduce car use and improve the city's air quality (Laker, 2020). This can have a long-term impact on the cities' transport systems (WHO, 2020) modifying urban infrastructure in favour of slow mobility. Supporting a shift to non-motorised transport could reduce CO_2 emissions and, at the same time, could improve physical well-being.

During the pandemic period, public spaces and urban streets were reconfigured to become places for promoting social distancing. Events took place outdoors in the streets and squares of cities (McAuley & Spolar, 2020). These temporary changes led to a rethinking of neighbourhood planning. The concept of the 'fifteen-minute neighbourhood' has spread more and more. The mayor of Paris, Anne Hidalgo, has proposed redesigning the city trying to make services much more accessible within walking distance to meet people's daily requirements, such as shopping, healthcare, socialisation and education. (UN-Habitat, 2021).

In many European cities (e.g. Freiberg, Vienna, Valencia and Nantes), there has been an adaptive transformation of public spaces (streetscapes, parklets, pedestrian routes, etc.). The pandemic has proven to be an opportunity for planners to reconsider public spaces. Increasing the quantity and accessibility of green public spaces could also offer psychological and physiological benefits (Newman & Soderlund, 2015; Shanahan et al., 2016).

A solution adopted during the pandemic was the transformation of the sidewalk into an extension of bars, restaurants and shops. More pedestrian space has allowed businesses to spread by providing outdoor seating or marketplaces with improved social distancing ability (Bereitschaft & Scheller, 2020). The parklet is a parking space converted into a miniature public space that is often adjacent to the sidewalk (Young, 2018) and adorned with planters and seats as aesthetic elements and protective barriers. The City of San Francisco is a good example of parklets in the United States, with over fifty permanent parklets and many more temporary ones spread around the city (City and County of San Francisco, 2020). During the COVID-19 pandemic, thanks to San Francisco's 'Shared Spaces Programme', companies applied for provisional permissions that allow them to use the footpaths letting customers sit outside (thus, decreasing contagion without sacrificing social opportunities) or sell retail products (Badger, 2020).

The need for public outdoor spaces, such as parks and green streets, became apparent during the lockdown. Immediately after the reopening of mobility and commercial activities, people rushed into public green spaces (Day, 2020; Mon-Lopez et al., 2020). It has been demonstrated that staying in contact with nature during COVID-19 has reduced symptoms of depression and anxiety (Pouso et al., 2021).

As a consequence of the lockdown, people have adapted the way of living their home spaces, combining in the same place many activities previously carried out outdoors (such as work, sport, play and entertainment). During isolation, people were forced to live and work in their houses and use technologies they did not know before. Digital platforms for online meetings, such as Zoom, Teams and Meet, showed a new way of communicating, experiencing and working. Remote working also influenced the demand for real estate and caused residential prices to fall in city centres and central districts because it was possible to work anywhere, even in peripheral areas, which were more pleasant in terms of green spaces and the size of houses (Florida et al., 2021).

The COVID-19 virus offered a chance to improve building design and endorse new forms of houses by promoting flexibility. Cramped and poor-quality housing was the main factors in spreading the virus (UN-Habitat, 2021). Home's flexibility and adaptability became increasingly important concepts. During the lockdown, it was forbidden to leave houses, so public outdoor spaces were not used/underused. For this reason, people tried to adapt their homes by extending those spaces in their balconies, terraces and courtyards. For many people, these spaces were the only occasion to do some physical exercise and to benefit from open air during isolation. The changes in people's lifestyles and the consequent spatial transformations of houses that occurred during the COVID-19 pandemic period inevitably led to changes in the residential market and caused variations in housing demand and market values. They were influenced by the aforementioned external factors (new forms of mobility and work, housing conditions, etc.).

3 Literature Review: The Impact of the Pandemic on the Real Estate Market

The overview of the impacts of the pandemic on cities shows that one of the most affected sectors is the real estate market, specifically in terms of housing sales and rents. Relationships can be found between the spreading of the virus and changes in user needs, changes in the use of urban spaces and in real estate market trends. In this framework, the analysis of housing price trends (sale and rental prices) reflects changes in housing preferences (Agnoletti, 2021).

The spillover effects on the housing market of the changed working forms are not so much related to the overall demand trend but are mainly concerned with the search for larger houses where people can spend a long time living together, with outdoor spaces and adequate space for smart working. The pandemic did not penalise the housing market as expected, which was instead driven by an increasing focus on the quality of life and the emergence of new housing needs (Hart, 2020).

After the lockdown imposed by governments, several studies focused on the impacts of COVID-19 on the housing market. According to Duca and Murphy (2021), the COVID-19 crisis was very different from the 2008 financial crisis because homeowners were not over-indebted. As a result, household incomes and demand for housing did not collapse.

Moreover, very low mortgage interest rates increased the demand for housing. An Irish study, predicting a number of future residential market scenarios, shows that they are relatively small due to the Irish Government's incentives to reduce unemployment. An increase in housing demand, according to this study, will depend on the duration of these incentives and the mortgages offered by banks (Allen-Coghlan & McQuinn, 2020). Governments in several countries are trying to reduce the unfavourable effects of the pandemic by implementing various actions, like mortgage relief and rent subsidies. (Kholodilin, 2020).

Furthermore, Ulster University in collaboration with the Housing Executive and the Progressive Building Society (Ulster University, 2020) conducted a research on the impacts of COVID-19 on the Northern Ireland housing market in the first quarter of 2020. The beginning of the year 2020 (January–February) was optimistic and these months were followed by a long period of relative stability in the housing market. However, the lockdown measures, at the end of March, led to a 23% drop in property transactions in the first quarter of 2020 compared to the same period of the previous year.

In the COVID-19 real estate market, trends that have changed and will continue to change not only future real estate sales and purchases but also the new needs of investors have emerged. There are new realities to which the COVID-19 property market has had to adapt and, above all, it must reinvent itself. Among these trends, there is the search for new spatial distributions and the size of housing to have larger workspaces and flexible spaces (Assoproprietari, 2020). For example, a study conducted in the UK showed how COVID-19 caused changes in the residential demand. The use of alternative ways of working, such as smart working, has increased the attention on aspects such as comfort and quality of the living area, leading buyers to desire better thermal, acoustic and visual insulation, better indoor air quality and sunlight (Pickford, 2020).

In Italy, most studies have focused on housing demand by conducting surveys among real estate agents or communities (De Toro et al., 2021; Rastrelli & Romanelli, 2021). The aim of these surveys was to understand how habits and ways of living at home changed as a result of the COVID-19 crisis. The main required housing characteristics emerged from the aforementioned surveys were related to larger surfaces, multifunctional rooms, balconies, verandas, gardens, rooftops, outdoor views, sound insulation and co-living services. New needs also included exercise or yoga rooms and flexible spaces for homeschooling or other needs, rooms for temporary functions and the greater use of low-maintenance and energy-efficient systems.

Furthermore, a report based on data from the city of Padua, Italy, analysed the real estate market following the pandemic through a community investigation. The community survey included questions on purchase and rental transactions, market prices and spatial features of dwellings demanded by users. According to the results of this study, there was an increase in transactions in the post-lockdown period, which was higher than those recorded in the same months of 2019, with a 4% increase. In addition, a higher demand for larger housing emerged. The most popular housing type was the flat in the historic centre (+55% compared to the same period in 2009), with an area of more than 100 m^2 and a terrace (40%) or a garden (26%) (Engel & Völkers, 2020).

Another aspect that emerged in the literature concerns the impacts of COVID-19 on real estate services. They emphasised the prospects of real estate agents and the process of selling housing. Some studies highlighted the increasing role of technology through the introduction of virtual tours for a first view of the flats in the buying and selling process, photographic material and accurate property descriptions on real estate agency websites, which can be easily consulted by users (Nicolaa et al., 2020; Pickford, 2020).

4 Methodology

In this study, the real estate market was investigated both analysing price trends from official sources, as the Real Estate Market Observatory (OMI), and through a survey to real estate agents, that represent the point of view of those operating in the area.

The survey was conducted involving real estate operators in the metropolitan area of Naples, Italy. The questionnaire was set up to understand if and how changes in people's housing needs affect the housing market from a demand perspective. In Italy, three main areas characterised by different economic capacities, welfare and health conditions, education levels, employment rates, etc., can be considered: the north, the centre and the south (ISTAT, 2015, 2019). Following this subdivision, the Metropolitan City of Naples, established by Law No. 56 of 7 April 2014 (known as the Delrio Law), is located in southern Italy. It has about three million inhabitants and covers 1171 square kilometres (Fig. 1) (DARA, 2017; Strategic Plan of the Metropolitan City of Naples, 2019).

The development of the survey consisted of the following phases: the definition of the territorial boundary over which to disseminate the questionnaires, the identification of the sample of people to be interviewed, the elaboration of the questionnaire, the distribution of the survey and the critical analysis of the results.

The territorial boundary chosen for the analysis was the metropolitan area of Naples, which includes economically, culturally, and geographically diversified areas (central, peripheral and suburban). The target group of the survey was the real estate agents, in order to capture the perspectives of those who directly work in the residential market. The questionnaire included a short preface describing the objectives

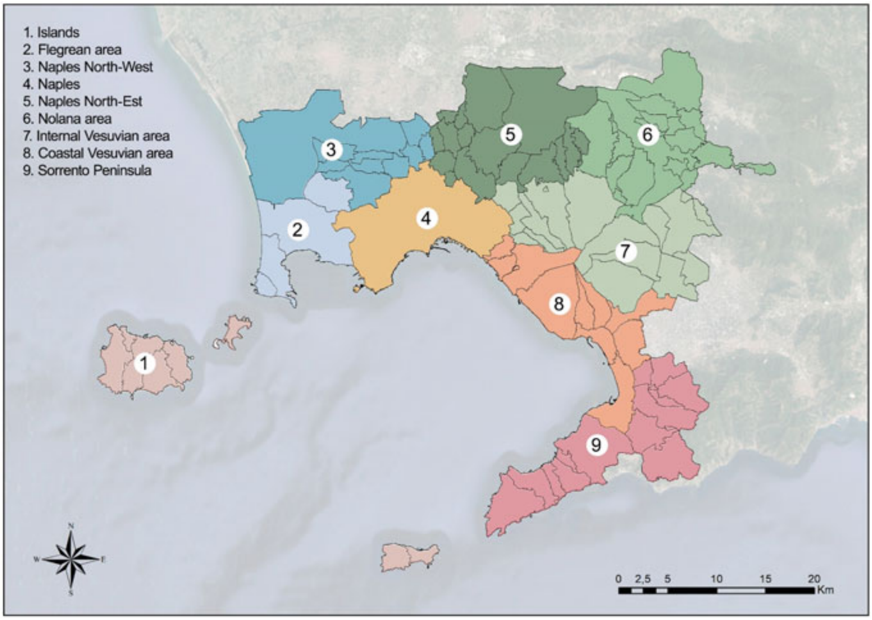

Fig. 1 Metropolitan City of Naples, Italy

of the survey and consisted of eighteen questions. The answers were structured as multiple-choice, with the addition of an open-ended question.

The questionnaire has been submitted to the real estate agents by e-mail with the collaboration of the Federazione Italiana Mediatori Agenti d'Affari (FIMAA). It was filled by thirty-six estate companies active in the metropolitan area of Naples over a two-month period (February and March 2022), using the online tool Google Forms.

The objective of the questionnaire was to understand how purchase and rental prices changed (and continue to change) during the COVID-19 period compared to the pre-COVID period. The survey also aimed to analyse the changes in residential markets by investigating which were the most stipulated types of contracts (purchase or rental), which were the most chosen urban areas when searching for new homes (central area, peripheral area, etc.), which types of properties were most in demand (single-family houses, apartment buildings, etc.) and which features were most required (balconies, garden, garage, etc.). The results of this survey were compared with the results of a previous survey on the same issue, conducted in 2021 in order to understand how the residential market is currently still changing (De Toro et al., 2021).

5 Analysis of the Real Estate Market in the Metropolitan Area of Naples in the COVID-19 Pandemic

In order to illustrate the impact of the COVID-19 pandemic on the real estate market in the metropolitan area of Naples, Italy, an overview of the real estate sector before and during the pandemic crisis was drawn up by analysing real estate prices in Italy and then more specifically in the Metropolitan City of Naples. The data were recorded in relation to the first months of the health emergency characterised by the lockdown and closure of commercial activities (2020), the first recovery phase characterised by the vaccination campaign and coexistence with the virus (2021) and more recent months (2022). Following this overview of market prices, the results of the survey of the real estate agents on the price trend were shown to understand how the residential market has changed (updated March 2022).

In general, the pre-COVID-19 Italian rental market registered an increase (Tecnocasa, 2020a). At the end of 2019, compared with the year 2018, there was growth in terms of buying and selling (+4%) and in the renting sector (+3%) of most Italian metropolitan cities, whereas prices fell by 2.77% (Fiaip, 2019)—a behaviour that was anomalous compared with the rest of the European countries. The data showed that house prices in Italy steadily fell from 2015 to 2019 (Fiaip, 2019).

Data collected by the Italian Revenue Agency show 117,047 residential transactions in the first quarter of 2020 in Italy (OMI, 2020), going down 15.5% compared to the same period in 2019 (OMI, 2020). From April to June 2020, the real estate market became stable compared to the same period in 2019 (Fiaip, 2020). Therefore, although the impact of the pandemic was felt, the end of the restriction measures marked the restart of the residential sector, showing that COVID-19 did not prevent people from continuing to look for a house to buy (Tecnocasa, 2020b).

In terms of rent, in the months of the lockdown and those immediately following the outbreak of the pandemic, houses were rented out at lower prices and many tourist properties were converted temporarily for a few months into residential homes through transitional contracts. Mobility changed for university students and commuters due to COVID-19 because of the new ways of working and teaching used to prevent the spread of the virus, e.g. smart working and e-learning, and so the demand for rent consequently decreased (Cavestri, 2020). The short-term rental market (vacation homes) experienced an increase in demand during the summer season as people who had stayed at home for months during the lockdown felt the need to get away from their place of residence and move to tourist destinations. The Booking.com website shows a 40% increase in bookings for the non-hotel sector compared to 34% in 2019.

The 2021 Nomisma Real Estate Report showed that 93.7% of Italian buyers showed greater interest in larger homes with green spaces (68.9%), that were outside the main municipality (64%) and were energy efficient (70.5%) (Nomisma, 2021). Following the lockdown, the residential market has undergone a change in housing demand, with a greater request for outdoor spaces, garages and large properties with multifunctional spaces (Deganello, 2020). The most demanded house typology was the three-room dwelling placed close to essential services, such as the metro, buses, supermarkets, pharmacies and grocery shops, and equipped with a terrace and balcony or private green area and space for smart working (Fiaip, 2020). Semi-central and peripheral areas were more requested in summer (Deganello, 2020).

The year 2021, which saw an economic and social recovery phase from the health crisis, vaccination campaigns and business openings, showed a favourable trend in the Italian real estate market. According to data from the Revenue Agency, housing transactions recorded +38.6% in the first nine months of the year, with forty-five thousand more homes traded in the first quarter of 2021 (January to March) compared with the same quarter of 2020. From April to June 2021, the volume of house sales increased by 73.4% compared with 2020, with 85,000 more homes traded. In the third quarter (July to September 2021), transactions grew by 21.9% compared with the same quarter of 2020, with a total of over 172,000 homes bought. The considerable increase was due to the rebound effect from the closure of businesses in early 2020 (OMI, 2021).

Between 2009 and 2019, the prices of houses in the metropolitan area of Naples have suffered a sharp decline with decreases up to −50% in some cities (De Toro et al., 2021). Following the market law of supply and demand, as a result of falling prices, housing sales grew towards the end of 2019 (De Falco, 2020). The average price of a flat for sale was around 1870 €/m^2 in 2019 and the most demanded typology of house was the flat, followed by the single-family house (Real Estate Observatory of the Metropolitan City of Naples, 2019). From 2009 to 2020, i.e. before the pandemic, the metropolitan area of Naples recorded an overall reduction of −36.11% in house buying and selling prices. The percentage change in housing prices from 2009 to 2020 showed that prices decreased in the individual metropolitan areas of Naples; it was usually over 15% (De Toro et al., 2021).

In the Metropolitan City of Naples, in January 2022, there were over 49,658 properties for sale and 18,550 for rent. The price trend registered a general increase in the metropolitan area of Naples from 2020 to 2022. The average price of apartments for sale (2100 €/m^2) was about 21% higher than the average regional price even if the average price of apartments in the individual municipalities was extremely uneven in the Metropolitan City. In fact, in many municipalities, the prices varied widely from the average provincial values, which were less than 1600 €/m^2 or more than 2600 €/m^2. The most dynamic municipalities in terms of real estate (i.e. with the largest number of properties for sale or rent) were Naples, Giugliano in Campania, Pozzuoli, Nola, Casoria, Marano di Napoli, Torre del Greco, Casalnuovo di Napoli and Portici. The municipality with the most affordable real estate prices for apartments was Liveri (600 €/m^2), while Capri (9300 €/m^2) and Sorrento (6400 €/m^2) had the highest prices (Real Estate Observatory in the Metropolitan City of Napoli, 2022).

From the real estate agent survey, 36.1% of the respondents recorded a slight decrease in the residential market price, while 30.6% of them did not record any substantial change compared with the pre-COVID period (Fig. 2). Furthermore, 25% of the respondents saw signs of market recovery with an increase in residential prices, while 5.6% of the respondents experienced a sharp increase in the prices of houses for sale. This inhomogeneity was the result of the survey being conducted

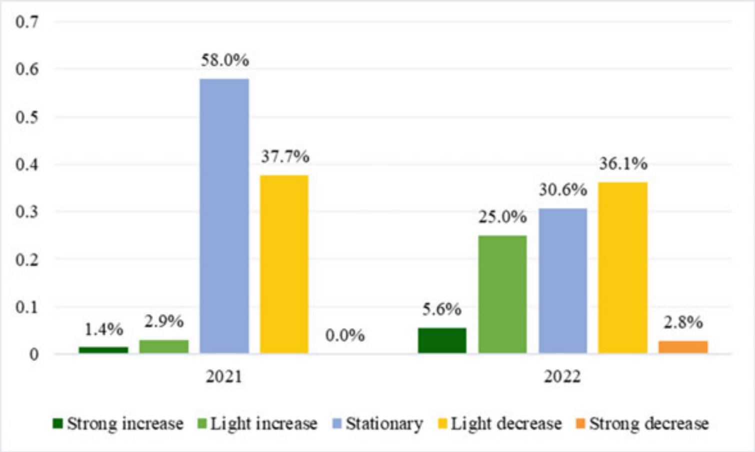

Fig. 2 Agents' responses to buying and selling price trends compared with the pre-COVID period: comparison between 2021 and 2022

on a massive area characterised by strong geographical, spatial and geopolitical differences, as most of the respondents were based in the municipality of Naples. However, compared with 2021, the real estate market showed signs of recovery because only 2.9% of the respondents in the previous survey recorded a light increase in market prices, and 1.4% recorded a strong increase. Most respondents (58%) noticed a stationary market in 2021 with a prevalence of decreases compared with the increase in house prices. House prices are highly dependent on the law of supply and demand. More demand, prices tend to rise; more supply, prices tend to fall. As a result, the rise in house prices in the metropolitan area of Naples is indicative of a new-found ferment in the residential market, which shows a desire of residents to look for housing again.

The majority of the estate agents reported a slight increase in requests for residential properties in the first months of 2022 (55.6%), with 13.9% of them believing there was substantial growth (Fig. 3). In contrast, 14% of the agents believed there was no change compared with the pre-COVID period, while 11.1% believed there was a slight decrease in house searches, and 5.6% believed there was a strong decrease.

Regarding renting, agents were asked both in 2021 and 2022 how house prices had changed compared with the pre-COVID period. In 2022, 41.7% of the estate agents experienced a slight increase in prices, with 16.7% noticing a strong increase, in contrast to 2021 when they recorded no change or prices falling (Fig. 4). In addition, in the 2022 survey, 27.8% of the respondents did not record any substantial changes, but 13.9% recorded a light decrease. Compared with 2021, there was an increase in rental prices. In 2021, the decrease was recorded by 39.1% of the respondents, but only 13.9% in 2022. This means that the rental market is also recovering. With the outbreak of the pandemic and the restrictive measures that forbade people to leave their homes and specially to go to work in presence, the demand for rental properties

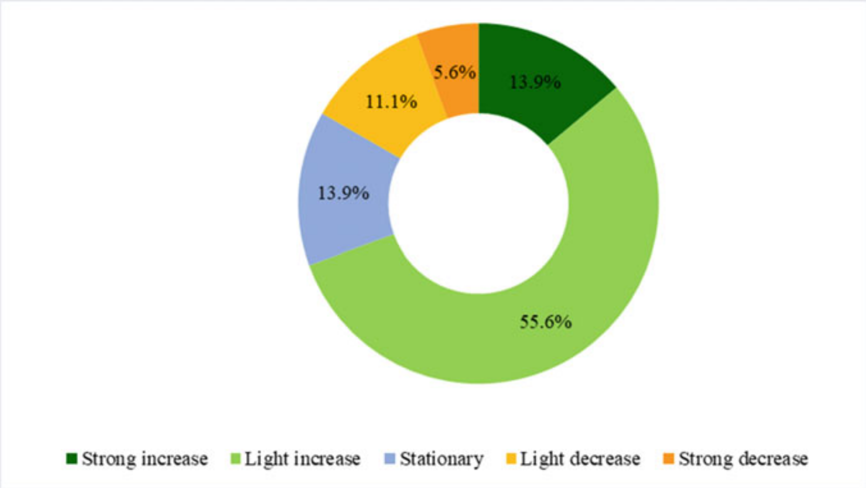

Fig. 3 Buying and selling requests compared with the pre-COVID-19 period (2022 data)

had dropped dramatically because a part of the rents came from the demands of off-site students or commuting workers.

With regard to the rental market, 47.2% of the real estate agents reported a slight increase in enquiries for residential properties in the first months of 2022, with 30.6% believing that there was no substantial growth (Fig. 5). In contrast, 19.4% of the agents

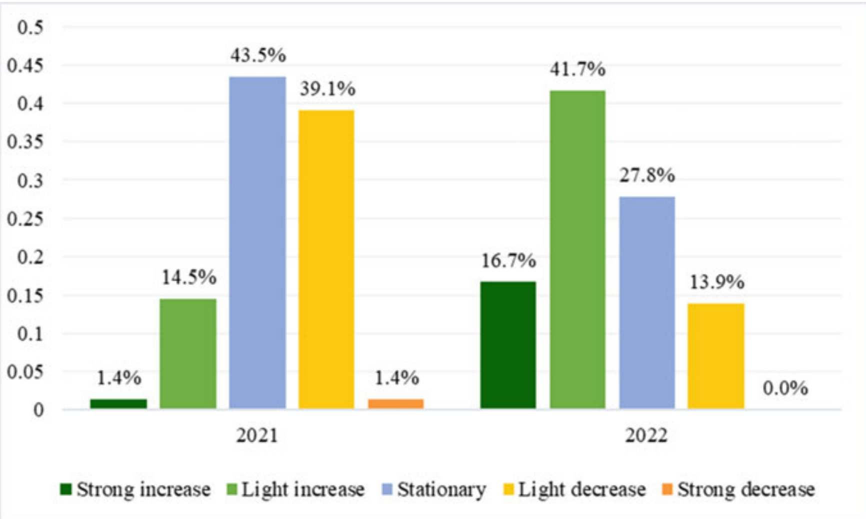

Fig. 4 Agents' responses to rental price trends compared with the pre-COVID period: a comparison between 2021 and 2022

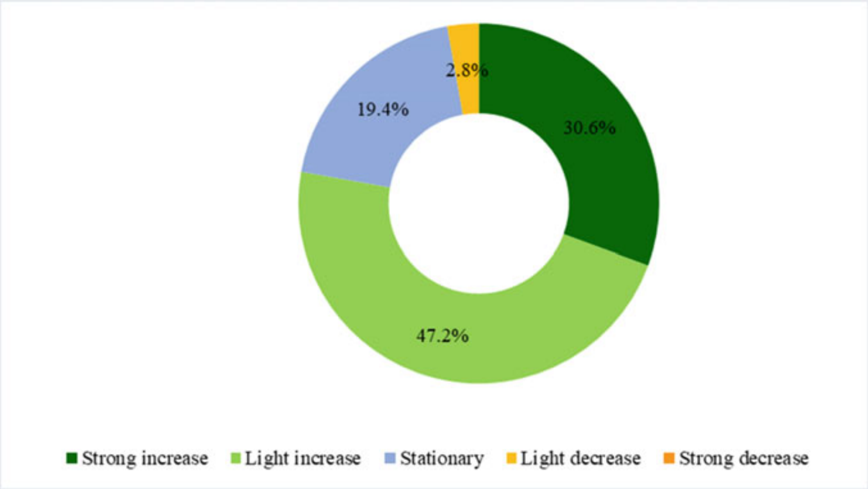

Fig. 5 Rental requests compared with the pre-COVID-19 period (2022 data)

believed that there was no change from the pre-COVID period, while 2.8% believed that the search for homes decreased slightly.

The survey of agents did not only focus on the analysis of market prices or purchasing volume, but also on new housing demands. COVID-19 did not penalise the housing market, but stressed the focus on the quality of life and the emergence of new housing needs. For this reason, the pandemic may have important and lasting consequences on human lifestyles and therefore on the structure and organisation of cities (Florida et al., 2021). There are, in fact, relationships between the changes that take place in cities and changes in the real estate market. Consequently, analysing the impacts of the pandemic on the housing market can lead to reflections on the possible future transformative dynamics of cities, starting from the evaluation of consumer requests and current supply and demand trends.

The changes in demand subsequent to the pandemic should certainly be examined in relation to changes in lifestyles and reduced movement due to government restrictions. In the Metropolitan City of Naples, following the lockdown, most of the potential buyers chose a central or semi-central location and opted for a three-room apartment (De Toro et al., 2021). Among those who wanted to buy a house, the highest percentage referred to users between 25 and 34 years of age, i.e. the younger population who still see the city as a possibility for the location of their home because it is more active and attractive in terms of services. The central areas of the city have continued to be the most popular in March 2022 (40.0%), as shown in Fig. 6. Semi-central and peripheral areas saw an increase immediately after the lockdown, but the situation seems to be leaning towards central areas again now.

During the COVID-19 pandemic, workers gave up commuting by working from home (Eurofound, 2020; Wong, 2020), which reduced transit demand and transport. As shown by a community survey conducted in the Metropolitan City of Naples,

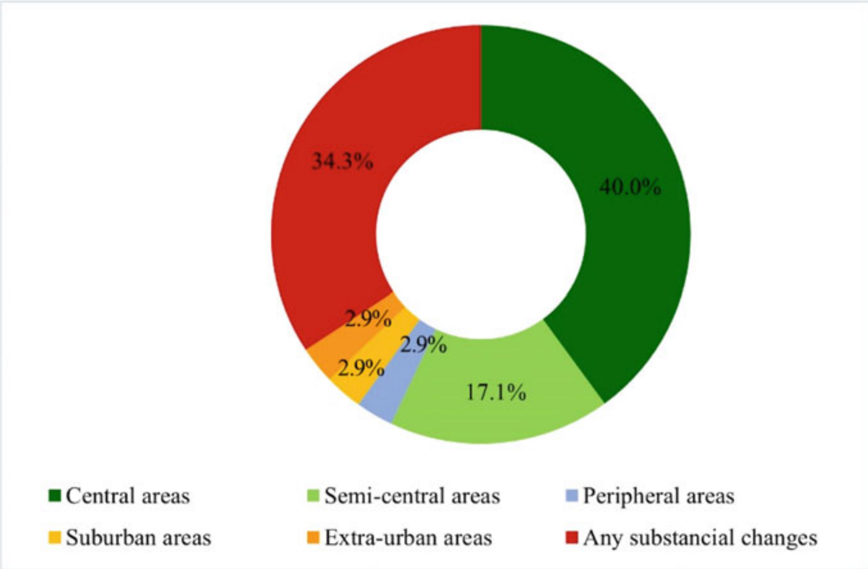

Fig. 6 Urban areas requested by users compared with the pre-COVID-19 period (2022 data)

about 80% of workers had to work remotely and were forced to use their home spaces as work places assuming, however, that their homes were sufficiently suitable to carry out such activities at a distance (De Toro et al., 2021). The COVID-19 temporarily changed the way of working, introducing the possibility of smartworking. With the end of the pandemic many workers will return to the office, while others, after experimenting with more sustainable working methods (smartworking reduces the use of private transport and therefore environmental pollution) will continue to work from home. Indeed, one of the advantages of lockdown during the first six months of 2020 was a drastic decrease in atmospheric pollution due to the reduction of road transport traffic (Venter et al., 2020). A long-term use of smartworking could provide an opportunity to promote healthier lifestyles for humans and the environment (UN-Habitat, 2021). Smartworking can also affect real estate demand and change residential apartment prices in inner cities and neighbourhoods (Florida et al., 2021).

The most popular types of contracts requested by users in the pre-lockdown period (February 2020) were purchases (78%), confirming the trend of February 2022 with a slight reduction (61.1%). The most required type of property in 2022 has been the apartment (37.1%), especially in the city of Naples due to its urban conformation, although 22.9% have demanded a single-family house, in contrast with 2021 when the apartment and the single-family house were at the same percentage (Fig. 7). This was due to the lockdown when people started to look for larger houses with gardens to manage the restrictions imposed by the government, whereas now, people are returning to pre-COVID requests for the type of house and its location.

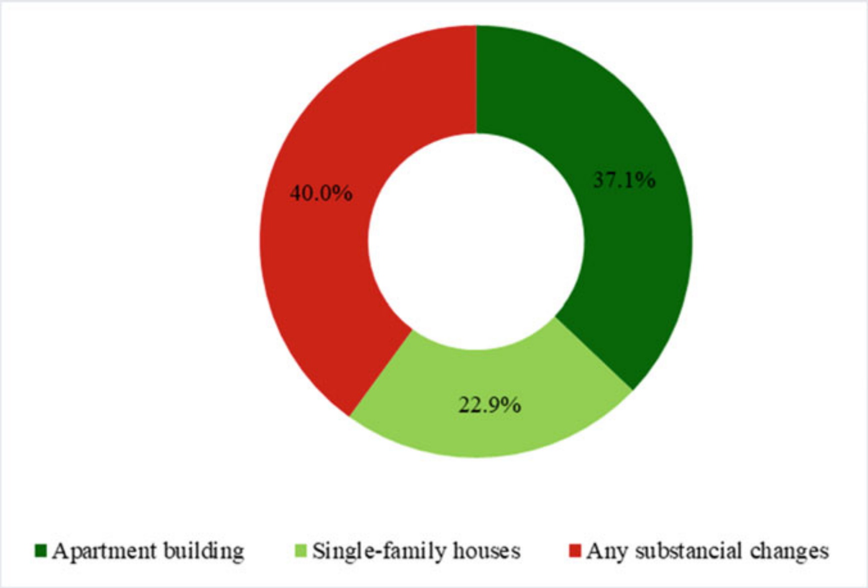

Fig. 7 Typology of houses requested by users compared with the pre-COVID-19 period (2022 data)

The most requested spaces for the purchase of new homes are gardens or terraces (86.1%), followed by balconies and communal parking (Fig. 8). Terraces and balconies offer an opportunity to alleviate the social isolation imposed by quarantine (Poon, 2020). Green spaces in buildings, including rooftop and vertical gardens, can also make urban living spaces more attractive, thereby raising market prices and possibly helping to meet physiological and psychological needs (Newman & Soderlund, 2015).

In addition, the agents responding to the survey noted that buyers were looking for larger rooms, spaces inside and outside the home for more liveability and privacy and more usable space. The agents pointed to the increased demand after the COVID-19 crisis, although they explained that buyers were less affluent and had more difficulty accessing mortgages.

During the pandemic, urban spaces such as squares, parks and streets have become outlets for people able to relieve mental stress due to the health crisis (Leigh, 2020). The mild climate of Naples could host many of these outdoor spaces. However, the city has a very dense spatial conformation, with a dense urban fabric that leaves little space for green areas within private homes. For this reason, the only open spaces the population can enjoy are public, closed during lockdown. So, the housing demand with COVID-19 has changed because people have felt a greater need to have private open spaces, to enjoy even in situations of health crisis. As emerged from the community survey people have found their living spaces inadequate (De Toro et al., 2021). The houses with the most rooms were more appropriate to meet the housing

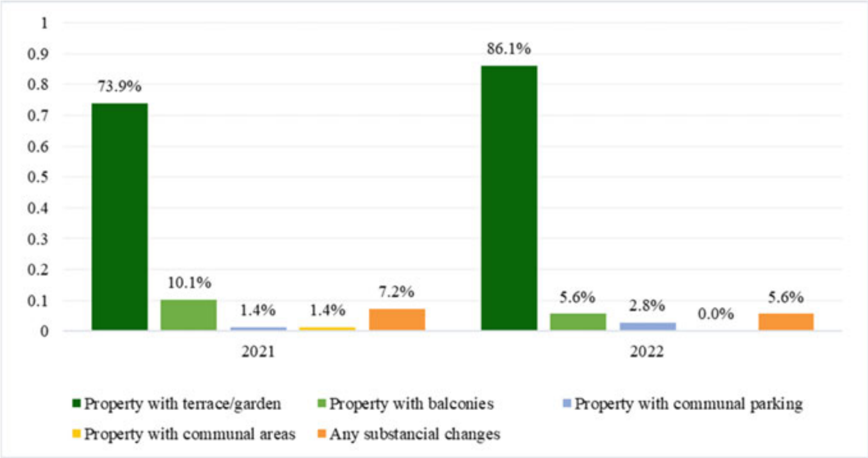

Fig. 8 Features of houses requested by users compared with the pre-COVID-19 period: a comparison between 2021 and 2022

needs that emerged during the pandemic because they allowed activities to be carried out indoors that normally take place outdoors. Other features demanded by buyers were better natural lighting, better internet connections, better sound insulation in their spaces and separation between day and night areas. The quality of indoor air, visual comfort, noise and thermal pollution have also been brought to the attention of new demands in the search for new homes.

6 Conclusions

This research analysed the change in the housing market following the health crisis that hit the world in March 2020. One of the main questions was whether and how the pandemic changed housing organisation, people's lifestyles and renewed market demand in the short or long term.

The purpose of analysing prices is to investigate changes in supply and demand in relation to the changed housing needs that emerged with the pandemic. An increase in prices in specific urban areas or certain types of housing or characteristics such as the presence of green areas, terraces, a large square footage, could reflect a higher specific demand of those interested in buying a house, in accordance with market laws.

Analysing the real estate dynamic can represent a useful support in the identification of incentives by government to improve housing conditions and in orienting strategies and actions in urban development.

Flexibility and adaptability have become two key concepts during the pandemic. With isolation, people were forced to live in their homes, which in some cases were inadequate. Some homes did not allow residents to adapt their daily routines at home due to limited space. The small houses in metropolitan cities and the lack of outdoor spaces did not prove adequate to handle the stress of quarantine.

The data analysed reveal people's willingness to stay in the central areas of the Metropolitan City of Naples, even though they proved inadequate to handle the health emergency. Food for thought might concern a change in spatial planning in terms of location. Understanding where people would buy a house could lead to questions about city planning as well.

As a result of the pandemic experience, domestic space will have to expand to accommodate functions once performed in workplaces, thus triggering a centrifugal real estate market that will sacrifice central locations in favour of larger living spaces in more peripheral areas, due to changing needs and work patterns with the alternative or continuous use of smartworking. This could lead to a re-evaluation of rural villages or abandoned tourist resorts in favour of metropolitan cities and megacities, the rediscovery of traditional and identity-based housing values and the rediscovery of natural places towards a new urban vision. Indeed, some Italian cities in the pandemic era have shown migratory trends towards peripheral areas and smaller inter-municipal poles, which have seen some positive signs for the first time after years of depopulation (Agnoletti, 2021).

The results of the analysis show that the homes sought by the pandemic are larger, more spacious and technologically equipped, with green spaces such as gardens, balconies and terraces. The research will therefore focus on new houses, which are already prepared for the renewed housing needs, while on the other hand, the push for renovations supported by government incentives will emerge. Building renovation bonuses provide tax relief that lead to improved indoor living comfort and the pursuit of ecological transition goals.

Therefore, this moment of different demands for houses can be seen as a drive in renovation in line with what is required by national and international documents to face climate change. That is, riding the wave of this change in needs, to initiate building renovations in terms of environmental sustainability.

The Energy Performance of Buildings Directive (EPBD) by the European Commission is a legislative proposal to achieve the European Green Deal goals by 2030. The construction sector plays a key role in achieving these goals and climate neutrality. In order to avoid an overall temperature, increase of 1.5C, it is necessary to initiate far-reaching changes to decarbonise many buildings. This is because among the main contributors to the climate crisis are homes and offices. According to recent surveys, they are responsible for about 40% of all energy consumed and 36% of the EU's energy-related greenhouse gas emissions (European Parliament, 2021).

Among the main causes, there are poor thermal insulation and heating systems based on fossil fuels. Energy savings in the buildings described above can be achieved through building renovation. The latter can improve the thermal integrity of buildings, and thus reduce energy demand where necessary.

In conclusion, energy-efficient building design can improve indoor temperatures while reducing carbon emissions. This could have wider effects, helping to reduce negative impacts on the environment and mitigate climate change. From an environmental point of view, investments in retrofitting would generate a number of benefits, in terms of reduced energy impacts, reduced air emissions, reduced climate change impacts, increased recycling of building materials and soil protection (ENEA Annual Energy Efficiency Report, 2021).

Therefore, COVID-19 can be considered not only in a negative perspective because of the effects on human health and the economy, but also as an opportunity to initiate a scientific debate on how to plan cities and homes. With social distancing, new forms of social interaction have been experimented. For this reason, an in-depth study of the physical dimension of the territories will be necessary with the aim of addressing the modified social needs in spaces capable of promoting collective well-being (Spanu & Nuvolati, 2021). Urban forms of cities should be more compact, with adequate densities, with equal access to services. Slow, sustainable, non-motorised and public transport should be available in cities, along with well-designed and accessible public open spaces. In addition, housing projects should allow natural ventilation, have outdoor spaces, a more flexible floor plan distribution, in order to improve urban lifestyles. Probably these measures will not play an active role in ending the current pandemic, but they will help make cities more resilient to stressful, more inclusive, and sustainable in accordance with Goal 11 of the Agenda 2030 (UN-Habitat, 2021).

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Actors of Urban Health at World and Continental Scales: An Intercontinental Comparison of Urban Health Actions Using Topic Modeling on a Large Worldwide Web Mining (2000–2021)

Céline Rozenblat, Daniela Mariño, and Raphaëlle Bidault-Waddington

1 Introduction

Since their apparition in the Neolithic period, cities were always planned according to the care of health of their inhabitants. However, the apparition of cities per se made emerge new health issues that did not existed in the paleolithic period of the nomad hunter-gatherers: new modes of living and relations to the environment and resources led to deep change in the etiological and pathological ecosystem and in the ways by which they cause and transmit various diseases (de Leeuw, 2017). There is a co-evolution of health and cities. Epidemies and diseases appeared because of the proximity to animals and deficient water management, but urban proximity has also caused disease clusters. Later, health issues in cities were fundamentally transformed with the industrial revolution (and hygienist policies), characterizing the shift to the Anthropocene in the early nineteenth century, and its increasing detrimental because of the human impact on the planet. A recent publication by Tong et al. (2022) underlines how far the climate change directly affects the mortality, the morbidity, and

C. Rozenblat (✉)
Institute of Geography and Sustainability, Faculty of Geoscience and Environment, University of Lausanne, Geopolis Building-office 3614 - Mouline area, 1015 Lausanne, Switzerland
e-mail: Celine.Rozenblat@unil.ch

D. Mariño
Department of Geography, University of Zurich, Winterthurerstrasse 190, 8057 Zürich, Switzerland
e-mail: daniela-veronica.marino-castro@geo.uzh.ch

R. Bidault-Waddington
LIID Future Lab, 118 Ave de Flandre, 75019 Paris, France
e-mail: rbw@liid.fr

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injuries linked with heat and extreme events. Indirectly, through ecosystem-mediated path, it increases infection diseases or air pollution-related health burdens. These non-communicable diseases, primarily cardiovascular and respiratory disease, diabetes, obesity, and some cancers, develop slowly across the life-course; once developed they can be treated, often at great cost and in technologically intensive ways, but not easily cured. As such, they carry a very substantial social and economic burden. through socioeconomic systems, climate change also creates drought-related mental illness, climate refuge crises, and wars. According to Tong et al. (2022), the urbanization itself, through the increasing land-use change to cities or cropland, is increasing the risk of food and water insecurity, but it is also reinforcing some communicable or non-communicable diseases: COVID-19 could be one of the epidemics that emerged from this unbalanced relation with the natural environment and animals. This new transition that impacts urban health, necessitates the mobilization of technological innovation and inventions, but merely it needs the adaptation and transformation of the social and spatial structures of cities (de Leeuw, 2017).

Addressing such questions requires systemic thinking, because the challenges posed by the Anthropocene raise complex, multidimensional social issues to which solutions we should search in multidisciplinary and transversal ways. This systemic vision is not new: since 1986, the Ottawa charter promoted health policies that became the promotion of “Health in all policies” in the Helsinki WHO meeting in 2013. Following this Helsinki statement, the WHO developed numerous actions in transversal sectors, including urban policies together with the UN-Habitat. After some years of supporting networks of cities with the implementation of health policies in each continent, and after having published numerous methodologies of policies models and guides of health impact assessments, the WHO is wondering what should be done next to promote the concern about health in the landscape of numerous public and private actors linked to the cities’ planning and development. Despite the numerous undertaken actions, coordination capacities need a clear vision on what are the problems at stake, and where are the gaps?

In this chapter, we present one of the proposed ways to address these questions, with the goal of identifying the gaps in nowadays urban health issues. The WHO entrusted the task of mapping the existing and missing actions to the International Society of Urban Health (ISUH, 2021). This mapping aimed to identify the gaps for filling in the stock of all previous and ongoing urban health research efforts and stakeholders’ actions. As a part of the ISUH consortium, the IGD-UNIL team implemented a stakeholder mapping and social network analysis of key actors in urban health research and actions. Our aim was to outline the topics appearing in the joint domains of health and urban contexts and the extent of their uptake by stakeholders (actors) such as national, regional, or local governments, international or national organizations, or associations (e.g., NGOs), health institutions or private companies. Thus, this review captured and analyzed the production of scientific knowledge in relation to the actions of other stakeholders to see how far these actions are related to the problems and topics outlined by the scientific authors.

After having identified more than 3 million websites and documents, we compiled 600,000 texts to finally obtain 124,000 usable contents. Treating the material by continent to compare them, we applied a topic modeling method (LDA algorithm), to underline the main associations between different words. We identified 15 topics for each continent, and we highlighted the common or specific issues and subjects of debates and actions for each continent. Specifically, we identified the topics including environmental and urban planning aspects, which addressed urban health issues. We analyzed how far these topics were central for each continent, and how numerous were the actors involved in these transversal domains. The process allowed to identify where actors are missing and where efforts should be addressed to leverage the transformations in urban health for different domains.

In the following sections, we identify the demand from WHO with a short review of literature (Sect. 2), we explain the adapted methodology that we applied (Sect. 3), and we detail the results and discuss them (Sect. 4).

2 The Need of Identifying Urban Health Actions and Gaps

Before identifying the actions and gaps for urban health, we need to discuss the definitions that are offered by the literature. Urban health crosses the two fields of "Urban" and "Health" and is nowadays additionally embedded into the general approaches of the "Planetary health."

Health was defined in the Preamble to the Constitution of WHO as adopted by the International Health Conference (New York, 19 June–22 July 1946) signed by the representatives of 61 States (Official Records of WHO, no. 2, p. 100) and entered into force on 7 April 1948. Health is defined as a "state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." This definition has not been amended since 1948. However, WHO's 1986 Ottawa Charter for health promotion further stated that health is not just a state or an objective of living, but also a resource for everyday life. By this way, health is not only an outcome, but also a dimension impacting the social and personal resources, as well as the physical capabilities: "The three basic components of this definition are the physical, mental and social aspects" (World Health Organization Regional Office for Europe, 1986). By inclusion of the social and psychological criteria, WHO also acknowledged that health is not determined by one single criterion, rather, it is multidimensional in nature. The "determinants of health" are the factors combining to affect the health of individuals and communities. Whether people are healthy or not, is determined by their circumstances and environment (WHO, 2017). To a large extent, factors such as where we live, the state of our environment, genetics, our income and education level, and our relationships with friends and family all have considerable impacts on health, whereas the more commonly considered factors such as access and use of health care services often have lower impacts.

The definition is very wide as human beings as a person and part of society were more important than the biological body (Grover & Singh, 2020). In addition, today, it is recognized that humans' and societies' health is intrinsically linked to the whole Planet and can only be achieved within the health of the planet, meaning the ecological diversity and care of the global warming. Planetary health is a field focused on characterizing the human health impacts of human-caused disruptions of Earth's natural systems (Whitmee et al., 2015). Planetary Health is defined as "the health of human civilization and the state of the natural systems on which it depends" (Panorama, 2017). Planetary health is a nascent concept focused on the interdependence of human health, animal health, and the health of the environment (Marselle et al., 2019). It is a new field, and one that needs ideas and solutions that span multiple sectors and disciplines to guide the creative stewardship of our planet to protect our own health (United Nations Framework Convention on Climate Change, 2020).

Urban health is embedded into the previous definitions, but in turn, it encompasses them. In fact, urban health approach suggests that cities constitute major determinants of health, by their capabilities of good social interactions (low spatial segregation), by their morphology encouraging walkability, by their public transportation density limiting the car pollution, by their service distribution that is accessible to all (De Leeuw & Simos, 2017). Besides, as cities gather more than half of the global population, they have a specific role in the relationship between society and natural environment (Gatzweiler et al., 2017): urban health is the capacity of cities to protect and care their inhabitants and visitors, but also, it is the ability to face shocks related to environmental or societal hazards, and to ensure a sustainable relation with the natural environment by a balanced and regulated exploitation of natural resources (like agriculture, mineral, and mining products).

Here, the systemic approach is necessary to clarify the different scales of evolving and uneven determinants and to outline all the feed-back loops between health and other factors (Gatzweiler, 2020). Positive and negative direct and indirect impacts of sectoral policies and private actions occur, whether they are urban, regional, national, or international. The multiplication of powerful NGOs and associations, but also the difficulty to coordinate policies' government actions at different scales and in multiple dimensions led to the necessity of mapping and analyzing the global urban health research and stakeholders.

The ISUH project (2021) on mapping and analysis of urban health research and stakeholders aimed to address this complexity of actors, actions, and determinants: "*while urban health research has made great strides in recent decades, many environmental and social decisionmakers still lack an understanding of the ways their policies and programs can act on key determinants of health, respond to acute health needs and impact health outcomes. Identifying the areas and opportunities for health in urban environments not covered by urban health research thus far is key to promote new research to fill those gaps and to achieving the best possible public health outcomes, by focusing on largely untapped urban determinants and actors. These gaps are likely to include missing evidence on urban policies and health linkages, on the effectiveness of urban health interventions or implementation strategies and new urban health priorities in other disciplines such as urban planning, transportation, housing, construction and energy*" (p. 2). The whole project guided our research approach that consisted in mapping the diverse actors and their impacts according to different dimensions and scales and comparing time and space the maps produced for different continents.

3 A Worldwide Web Mapping to Identify the Gaps of Actions

Therefore, the main issue in our research was to catch the complexity of urban and health ideas and actions that are developed all over the world and to classify and rely on them. We started to gather information through wide web mining. We initiated this web mining by quering associations of keywords related to "*health outcomes*" and "*urban contexts*" to capture every publication related to urban health (Table 1). We did not limit the search to any "*explanatory variables*" or types of "interventions, *actions and policies*"; instead, the aim was to find out them all.

By extending the web mining into both scientific and other online sources, our aim was to outline the appearing topics in the joint domains of health and urban contexts, and the extent of their uptake by stakeholders (actors) such as national, regional, or local governments, international or national organizations or associations (e.g., NGOs), health institutions or private companies.

Thus, this review captures and analyzes the production of scientific knowledge in relation to the actions of other stakeholders, with the goal of identifying how these actions are related to the problems and topics outlined by the scientific authors. The analysis allowed us to address the question with 3 main outputs:

1. Using a global view, we defined the main structure of what is considered urban health and what is the construction of the urban health concepts. This involves elucidating the concepts to be included and their scope.
2. Using data mining and analyzes, we provided structured methods to understand the relationships among these concepts and process them automatically. These methods are reproducible.
3. After processing data, we identified and described which stakeholders are talking about and addressing these urban health topics through actions. Besides, we also identified the topics missing actions of actors.

The method necessitated four main steps to reach the results (Fig. 1).

The web mining was carefully calibrated to focus on urban health issues, using health definitions, and to be represented by language and by continent (Appendix 1). The data preparation permitted homogenizing texts (Appendix 2). The data analysis permitted to build the identification of topics (Appendix 3) that are visualized through networks, and it was fundamental for the interpretation of the health issues (Appendix 4).

Table 1 Associated keywords for the web mining

Explanatory variables	Urban context	Health outcomes	Interventions, actions, and policies
• Urban (urban form, urban policy, urban planning, urban design, etc.) • Built environment • Public amenities • Transport • Active mobility • Co-benefits • Housing, homelessness • Green space, open space, public space, park • Air quality, air pollution • Climate change • Environment • Sustainability • Resilience • Health inequities, health inequalities • Connectivity • Smoking, cigarette, tobacco • Obesity, BMI, overweight • Physical inactivity/ activity • Alcohol, binge drinking, • Substance, cannabis • Poor diet, low-quality diet • Food insecurity • health care system • Health insurance and variants of these	• Urban (urban center, urban form, urban core, urban sprawl, urbanization, etc.) • City • Slum • Town • Metropolitan • Downtown • Suburb and variants of these	• Chronic (chronic disease, chronic illness, etc.) • Health • Non-communicable disease respiratory disease • Infectious disease • Asthma • HIV-AIDS • Tuberculosis • Malaria • COVID-19, SARS-CoV-2 • Diarrheal disease • Cardiovascular disease • Heart disease, • Stroke • Diabetes • Lung cancer • Colon cancer • Road fatalities, traffic fatalities, road safety • Injury • Mental • Depression • Stress, anxiety • Suicide • Wellbeing, happiness and variants of these	• Infrastructure • Legislation/ law • Policy • Regulation • Program • Plan • Campaign • Capacity building • Case study

Source Rozenblat, Mariño, in ISUH (2021)

3.1 *The Web Mining for Urban Health*

We started by initiating comprehensive web mining that was drawn from different web sources (Table 2).

From more than 3 million identified texts and websites, we extracted about 600,000 documents, texts, and web content, that were accepted as usable, and we compiled in the form of text. However, these compiled documents were not all available for open use. The processed texts were determined by the final relevance of

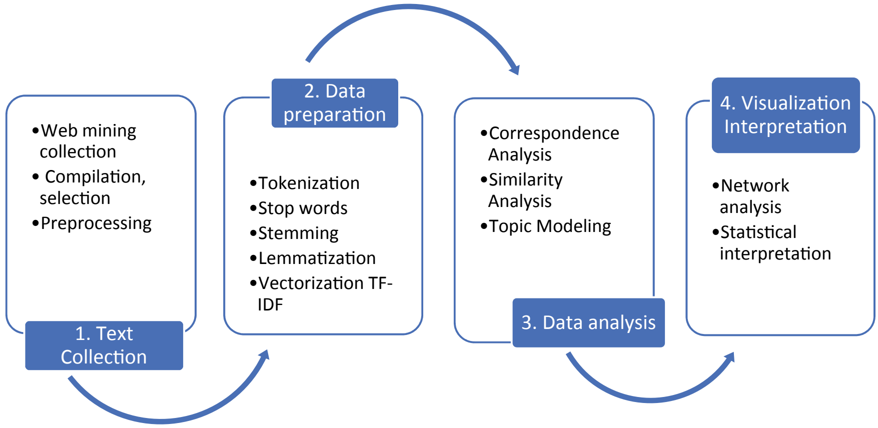

Fig. 1 Four main steps of the methodology. *Source* Rozenblat, Mariño in ISUH (2021)

Table 2 Sources of web mining for urban health (2000–2021)

Sources	Compiled documents	Processed texts
GLOBAL COUNCIL	1944	1164
GLOBAL ETD Search	30,520	13,976
Google	284,000	10,151
LinkedIn	6168	6168
FRANCIS & TAYLOR	72,000	8122
Literature Review	555	555
MDPI	22,799	4946
OAlster Database	750	61
OPEN GREY	11,000	7714
Scielo	20,000	17,773
Science Direct	20,000	18,765
Springer	64,663	28,779
United Nations	1800	1403
Web of Science	61,080	4011
Total	597,279	123,588

Source Rozenblat, Mariño in ISUH (2021)

Table 3 Types of documents analyzed in the TOPIC modeling process

Kind of document	Number
Articles	78,050
Books	8,890
Events	1,100
Legal documents	1,403
News	598
Projects	25,971
Theses	69
Trainings	201
Videos	32
Web pages	7,274
Total	123,588

Source Rozenblat, Mariño in ISUH (2021)

each text and the possibility of analysis. Different kinds of documents were classified as Articles (scientific), Books, Events, Legal documents, News, Projects, Theses, Trainings, Videos, and Web pages (Table 3).

3.2 Identifying Actors of Urban Health

Since the goal is to show action or lack of action, we concentrated on identifying the four different types of stakeholders who concentrate their actions in these topics (from the convergence of the scientific literature) that either are developed or not developed by the actors. Actors were classified according to the category they chose to label themselves when they created their webpages, which is related to the keywords established by the owner of a domain on the internet. The category was obtained from the metadata of each webpage or from a relevant LinkedIn profile and chosen from the full list of labels available. The number of actors by type are listed in Table 4 and the definition of categories are:

Table 4 Four kinds of identified actors (in addition to scientific authors)

Types of actors	Number
Governments	440
Health institutions	595
Organizations	116
Private companies	4,325
Total	5,476

Source Rozenblat, Mariño in ISUH (2021)

- Governments: all institutions related to governments, institutions that serve as public services, or official governments of countries that are normally identified with a governmental domain.
- Health Institutions: all institutions with a keyword related to "health," which can be public or private services, pharmacies, and public health institutions, while others can be related to well-being.
- Organizations: all defined by a keyword as "nonprofit organizations" and "other international organizations" with domains that normally end in.org
- Private companies: general private institutions that were not identified in one of the previous specific categories.

In total, we identified 5,476 different actors, each contributing to one or several debates and topics on urban health. Thus, we can answer the following questions: How much is each topic addressed by actors? What kinds of actors are involved in different topics? In addition, we can identify the main actors.

4 Results

The long period from 2000 to 2021 for which we collected information presents a time issue. The documents captured from websites are not always dated and are usually recent (before 2010, we found that few of them were published on websites). Therefore, a historical reconstruction from 2000 to 2010 made more sense for the topics, using the dated literature, projects, events, trainings, legal documents, or discourses. We propose mapping a historic evolution of urban health topics (Sect. 4.1), but we found it rather difficult to identify the corresponding discourses of actors that are mostly represented on contemporary websites. Therefore, we concentrated our approach, by continent, on the period from 2010 to 2021 to make the connections between actors' discourses and actions as clear as possible (Sect. 4.2).

4.1 The General Historical Perspective

During the period from 2000 to 2021 the (scientific) literature on urban health grew faster than the general publications on the internet until 2017 (Fig. 2). Then, the number of both types of publications dramatically accelerated, which continues now, though it has been even faster for internet publications.

Some topics appeared recently, while others disappeared few years ago. To understand these evolutions and recent trends, we applied global topic modeling

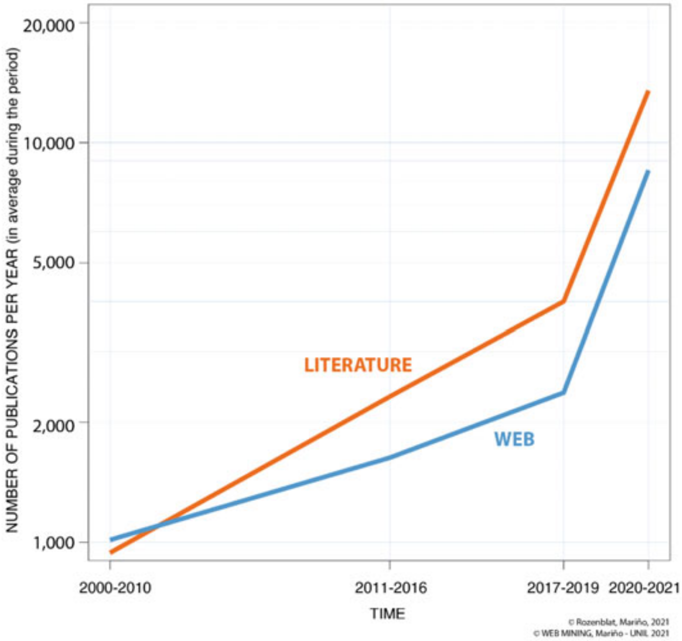

Fig. 2 Evolution of the web documents production on urban health from 2000 to 2021

(comprising the documents of all continents/regions and worldwide) over four periods of time:

- 2000–2010: The first period of 2000–2010 showed no major change after several tests on subperiods; therefore, we created a single period of 10 years. It corresponds to a period when associations and governments begin to publish all their discourses and actions on the web.
- 2011–2016: After 2010, we see an acceleration of the use of smartphones, social networks, platforms, and geolocalization fostering more interaction between people inside local and global communities providing more personal data. Facebook and other applications become popular, and people began to use them as tools for communication, propaganda, and actions. The Spring Arab revolutions were strongly supported by these social networks.
- 2017–2019: We consider 2016–2017 as a major global turning point related to the technological agenda, the semantic web, and the Big Data acceleration in all domains (including health but not only) marked by a clear change in data growth in 2016–2017. The rise of affordable cloud services (Amazon, Microsoft, Google, etc.) facilitates data storage, sharing, and utilization. For instance, AWS (Amazon Web Services) grew specifically during that time with an acceleration of data collection via new generation of smartphones, apps (e.g. Quantified-Self apps health, sport, and well-being domains shift from niche to massive uses), crowd

mechanism, collaborative platforms, open-science platforms, etc. This exponential growth of data leads in 2017 to the emergence of a new AI spring, thanks to the combination with new and cheaper computing capacities. This third period would extend to the present without the COVID-19 pandemic, which shifted the role of health in all the discourses.

– 2020–2021: The last two years correspond to the COVID-19 pandemic period.

In the analyses, for each period, we distinguished subsamples of the scientific literature from the general websites. The scientific literature is mostly produced by scientific authors, while the general websites represent the actors (national, regional, or local governments, international or national organizations or associations [e.g., NGOs], health institutions, or private companies).

For the eight subgroups of documents, we aimed to identify 15 topics. However, sometimes, the machine learning process was unable to significantly separate two topics according to the level of relevance of the words in a text and the diversity of terms. Consequently, it sometimes results in 15 topics and at others only 14 topics or less. We identified the historic evolution of urban health topics in a synthetic way (Table 5). For the first periods, the relevance of web publication is not good, because actors that we can identify are the only ones able to publish on web. Thus, we concentrate the analysis on the topic, evolution, rather than on the actors themselves.

To better understand the content evolution, we needed to categorize the temporal series of the two categories of publications by comparative themes. This results in six new main categories of themes.

- HEALTH corresponds to the categories HEALTH, CARE, and RISKS.
- POLICIES integrate URBANISM, PLANNING, SERVICE MANAGEMENT at the local scale, and many national policies linked to development, health, or technology.
- COMMUNITY/FAMILY is the aggregation of SOCIAL, COMMUNITY, DEVELOPMENT (without the social care aspects), CHILDREN, EDUCATION, and a part of the FAMILY aspects.
- SOCIAL ASPECTS include all the subjects related to social inequalities, gender, and violence.
- ENVIRONMENT category assembles ENVIRONMENT, POLLUTION, RESOURCES, and CLIMATE.
- RESEARCH remains the RESEARCH class.

In these analyzes, we did not find a FOOD category because these aspects were minor and combined with HEALTH, COMMUNITY/FAMILY, or SOCIAL ASPECTS.

Regarding urban health, health topics were preponderant during the entire period, most often more numerous for WEB than for LITERATURE. The contents of the topics evolve toward CARE (appearing after 2011) and HEALTH ASSESSMENT (appearing in 2017). MENTAL HEALTH appeared and remained present on the WEB after 2011 but does not appear per se in the LITERATURE. EPIDEMY essentially

Table 5 Evolution of topics for all continents and worldwide over four periods (2000–2021)

LITERATURE 2000-2010	WEB 2000-2010
Number of documents	Number of documents
10,217	11,018
Average number per year	Average number per year
929	1,002
14 - TREATMENTS	1 - PATIENT TREATMENT
11 - PREVALENCE (PREDISPOSITION)	5 - HIV
10 - POPULATION AT RISK	6 - GENERAL HEALTH
2 - MEDICAL EDUCATION	13 - CLINICAL ISSUES
3 - BUILT ENVIRONMENT	14 - GLOBAL SOUTH EPIDEMY
4 - URBAN PLANNING	10 - HEALTH AID
0 - FAMILY HEALTH	2 - PREVALENCE
1 - MATERNITY	12 - SUBURBS POLICY
9 - LIFE-STYLES	3 - LIFE-STYLES
5 - POVERTY IMPLICATIONS	8 - YOUTH BEHAVIOR
7 - VIOLENCE & MINORITIES	0 - VIOLENCE EXPOSURE
12 - NATURAL RESOURCES	4 - SOCIAL INEQUALITIES
8 - CELLULAR RESEARCH	11 - SUICIDE
6 - MODELLING	9 - AFRICA
13 - SCIENTIFIC PRODUCTION	

LITERATURE 2011-16	WEB 2011-16
Number of documents	Number of documents
13,970	10,353
Average number per year	Average number per year
2,328	1,726
11 - LETHAL DISEASES	4 - GENERAL HEALTH
2 - HEALTH POLICY	5 - EPIDEMY
10 - SOUTH PREVALENCE	6 - MORTALITY
9 - SOUTH GOVERNANCE	12 - MENTAL HEALTH
4 - HEALTH MEASURES	1 - NATIONAL HEALTH
14 - URBAN PLANNING	2 - HEALTH CAPACITIES
3 - TRAFFIC SAFETY	3 - HEALTH CARE
5 - COMMUNITY PRACTICES	8 - COMMUNITY ENGAGEMENT
12 - FAMILY HEALTH	9 - ADOLESCENTS RISKS
8 - POVERTY IMPLICATIONS	0 - INFORMAL CITY
7 - ENVIRONMENTAL ISSUES	7 -HUMAN DEVELOPMENT
6 - CELLULAR RESEARCH	14 - WOMEN RISKS
0 - MODELLING	11 - DATA SCIENCE
1 - MEDICAL RESEARCH	13 - BEHAVIOR STUDIES
	10 - AFRICA

LITERATURE 2017-19	WEB 2017-19
Number of documents	Number of documents
12,211	7,238
Average number per year	Average number per year
4,070	2,413
4 - GENERAL HEALTH	8 - MENTAL HEALTH
8 - TREATMENTS	10 - EPIDEMY
10 - HEALTH IMPACTS	11 - GLOBAL HEALTH
3 - HEALTH & CARE SERVICES	0 - CARE SERVICES
11 - SOUTH HEALTH & FOOD	5 - HEALTH CONTROL
12 - HEALTH MEASURES	2 - SOUTH HEALTH ASSESSMENT
7 - URBAN PLANNING	6 - HEALTH ACCESS POLICIES
5 - URBAN TECHNOLOGIES	7 - REGIONAL ECONOMIC CHALLENGES
9 - HEALTH EDUCATION	3 - COMMUNITY
13 - HEALTH CULTURE	1 - EXPLANATORY BEHAVIORS
0 - GROUP DIFFERENTIATION	4 - GENDER INEQUALITIES
1 - DOMESTIC VIOLENCE	9 - YOUTH VIOLENCE & SUICIDE
6 - ECOLOGY	14 - SEXUAL PREVENTION
2 - MODELLING	12 - CLIMATE CHANGE
	13 - ENVIRONMENTAL AID

LITERATURE 2020-21	WEB 2020-21
Number of documents	Number of documents
29,675	17,027
Average number per year	Average number per year
14,838	8,513
1 - COVID	0 - CARDIO-VASCULAR DISEASES
2 - LETHAL DISEASES	2 - COVID
3 - HEALTH ASSESSMENT	8 - MORTALITY
7 - SMART CITY	10 - INFECTIOUS DISEASES
8 - URBAN PLANNING	12 - MENTAL HEALTH
14 - MOBILITY SERVICES	11 - GLOBAL AID
12 - HEALTH EDUCATION	14 - HEALTH ASSESSMENT
13 - CARE COMMUNITIES	13 - HEALTH ACCESS
11 - SEXUAL VIOLENCE	9 - SERVICE DEVELOPMENT
5 - SOCIAL POLICIES	1 - REPRODUCTION
9 - RESOURCES MANAGEMENT	7 - SOCIAL STRESS
10 - CLIMATE CHANGE	4 - WOMEN CARE
0 - WATER	6 - COMMUNITY VIOLENCE
6 - MODELLING	5 - SUSTAINABILITY
4 - DATA FOR SOUTH	3 - AFRICA

MAIN THEMES OF TOPICS
- HEALTH
- REGIONAL OR URBAN POLICIES
- COMMUNITY / FAMILY
- SOCIAL ASPECTS, GENDER, SEXUAL & VIOLENCE
- ENVIRONMENT
- RESEARCH
- AFRICA

Source Rozenblat, Mariño in ISUH (2021)

concerned the Southern countries during 2000–2010, and it has expanded worldwide from 2011 until today's era of the COVID-19 pandemic.

Regional and urban policies linked to health-focused more on PLANNING and BUILT ENVIRONMENT in the LITERATURE throughout the period than the WEB documents. Instead, the WEB documents produced by governments, institutions, and private actors were interested in SUBURBS POLICIES between 2000 and 2011; between 2011 and 2016, policies were essentially national (in the previous category); and after 2017, interests emerged in HEALTH ACCESS POLICIES and SERVICE DEVELOPMENT or REGIONAL ECONOMIC CHALLENGES.

The family level is present in the LITERATURE until 2016 and is replaced by COMMUNITY ENGAGEMENT between 2011 and 2016. CARE appears more recently, in 2020–2021, in the LITERATURE.

VIOLENCE, POVERTY, and SOCIAL INEQUALITIES dominate the social aspects in the period 2000–2010. These transformed in 2020–2021 into SOCIAL STRESS. WOMEN'S RISKS appear on the WEB after 2011, boosted by the #metoo movement, and after 2017, DOMESTIC VIOLENCE, GENDER INEQUALITIES, SEXUAL PREVENTION, and WOMEN'S CARE emerged.

The topics on ENVIRONMENT are very limited in the urban health context. This theme is present in the LITERATURE as of 2000 but only appears on the WEB after 2017 with CLIMATE CHANGE and SUSTAINABILITY issues.

The RESEARCH topics are essentially treated by the LITERATURE. Only between 2011 and 2016 were DATA SCIENCE and BEHAVIORAL STUDIES diffused among a larger set of public and private actors. Perhaps this evolution reveals that these methods are currently more integrated into the other thematic topics and no longer constitute spotlights of interest.

In sum, the evolutions of the types of documents and topics demonstrate the emergence of community and gender issues that surpass the family level. Thus, the collective local communities seem useful to address health issues. Environmental topics become more visible but remain weaker in urban health discourses and actions of stakeholders than in the literature, where they grew significantly. The urban planning issues for health, underlined in the literature for more than 20 years, have not truly managed to come to light as an essential topic for government and private stakeholders. Thus, urban planning seems to remain an overlooked part of the general discourse on urban health, while it is still a crucial factor for the ways of living that lead to better health for citizens.

4.2 Topic Modeling by Continent Revealing the Actors and the Gaps 2010–2021

For the more recent period 2010–2021, we can go deeper in the analysis as the information is much more representative of the actors involved in the different topics. We built two kinds of relationships: the word compositions of topics and the contributions of actors to topic formation, calculated using the words written by all actors (including scientific authors). With these two types of relationships, we built graphs composed of two types of linkages between topics and words and between topics and actors.

Using this logic, scientific authors participate in the definition of topics but are not represented in the graphs for two reasons. First, they are very numerous yet have a small weight (i.e., each author is associated with one specific idea in the topic and does not produce actions for the ideas). Second, graphically, it is easier to simultaneously identify the topics that are in the center of institutional actions and the ones that are not priorities for action among actors outside the academic world. Topics that have generated more action will have their own network of actors. Topics that have few actors will have a weaker action network.

To interpret the regional graphics, it is useful to note that:

- Size of the box—indicates the frequency of actors in each topic; larger size means greater frequency of active actors.
- Color was made redundant to the size and also indicates the frequency of each topic regarding the actors; darker colors indicate greater frequency of active actors.
- Linkages—indicate the words defining the topics or the actors participating in topics, the color changes respectively to show the link between words and topics and actors to topics.

Thus, the topics (represented by large squares) that are neglected by stakeholders and not linked with other topics by common words are in clear orange, and the topics for which many stakeholders write about and describe actions are in dark red. Strong topics are the ones that appear more frequently and that are linked with other strong topics.

Many topics share some common words or actors creating a system of indirect linkages between topics. Presenting this system of topics' interactions, pictures reflect the system thinking that we claimed necessary to understand the way health is integrated in all urban policies. However, rather than commenting on the whole pictures, we will focus on the place of the urban and environmental policies linked to health and on the specific topics appearing for each continent.

4.2.1 Africa

The total number of documents concerning urban health that we identified for Africa is much higher (approximately 11,700) than that for Europe or North America (Table 13 in Appendix 1). Most of these documents (more than 86%) are articles or books written by scientists from outside Africa (from developed countries), and very few are legal documents (1%) or projects (8%), and other documents comprise the actions of private companies. Therefore, African urban health is a very important issue in the scientific community but occupies limited space in the actions specifically published by local actors.

Regarding the actors' contributions to the 15 topics, higher frequencies appear for private companies, which contribute 75% of the words (lemmas) of all the topics, followed by UN and other international organizations (17%), health institutions (7%), and governments (2%) (Table 6).

Table 6 Topics for Africa by types of actors

Topics	Number of actors				Total frequency of actors
	Governments	Health institutions	Organizations	Private companies	
HEALTH MEASUREMENTS				7	7
GENDER VIOLENCE				3	3
CARE SERVICES	1	16	2	55	74
SEXUAL RISKS	1	1		10	12
SOCIAL SERVICES		8		51	59
SPATIAL PLANNING	1	1	3	15	20
TRAFFIC ISSUES	1			9	10
DEVELOPMENT AND FOOD	1	2	4	59	66
MEDICAL FACILITIES			1	1	2
WATER MANAGEMENT			3	10	13
CHILDREN'S EDUCATION		1		29	30
FOOD RISKS				3	3
MEDICAL RESEARCH				2	2
WOMEN'S CARE AND SERVICES		3		10	13
ENVIRONMENTAL ISSUES				11	11
Total	5	32	13	275	325

Source Rozenblat, Mariño in ISUH (2021)

The graph details the topics, the main words forming them and the main actors (Fig. 3). Words appearing in the center, e.g., mental and pregnancy, are not the most frequent terms, but they contribute to the strongest topics. These strongest topics are CARE SERVICES and DEVELOPMENT AND FOOD. These two topics comprise the highest contribution of actors outside academia.

SPATIAL PLANNING deals with urban land and space management, plans, roads, and economies. The main actors of this topic are international organizations including the UN Center for Human Settlements. The subsequent actor is Raising Voices (Kampala, Uganda), which in addition to its main role of preventing violence against women and children, is involved in urban policies by building local networks and alliances together with global dialogs.

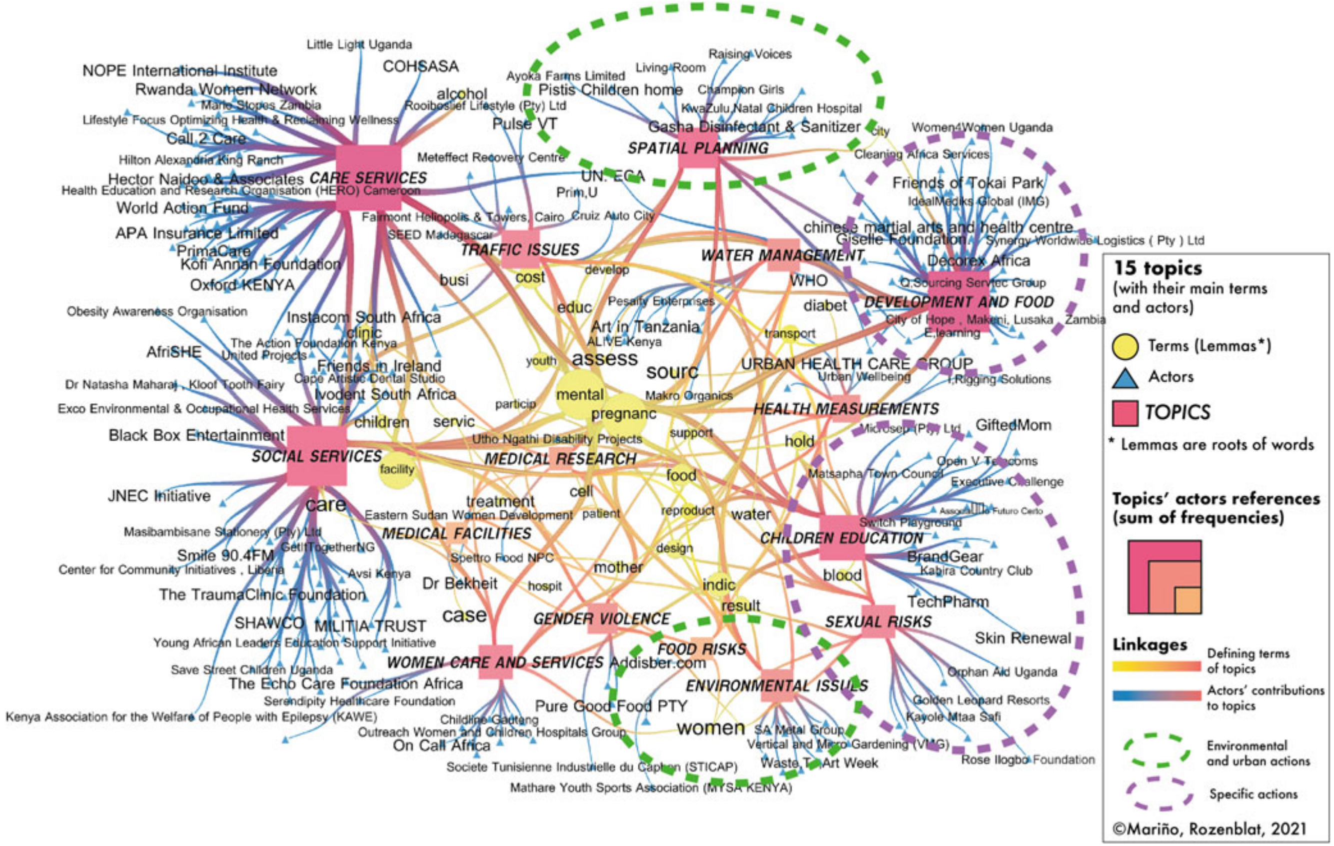

Fig. 3 Topics of urban health and actors for Africa

TRAFFIC ISSUES and WATER MANAGEMENT are other topics. TRAFFIC ISSUES include the actions of many private companies like CLF (Concrete Laser Flooring; Johannesburg, South Africa). WATER MANAGEMENT is more impacted by international organizations such as the UN Centre for Human Settlements, the WHO, as well as by companies such as MAKRO Organics (South Africa), which supplies plant-based solutions to all water-utilizing industries. This topic is close to the DEVELOPMENT AND FOOD because of the high impact of water on the alimentation aspects. Besides, FOOD RISKS is a quite weak topic, more related to the ENVIRONMENTAL ISSUES topic. Here, similarly to other weak topics like GENDER VIOLENCE and MEDICAL RESEARCH, the FOOD RISKS are supported only by private companies (Table 7). Addisber, NYSAPISI in Rwanda and Mathare Youth Sports Association (MYSA KENYA) are engaged in FOOD RISKS. Surprisingly, Nestlé plays a large role in GENDER VIOLENCE together with STICAP (Tunisia) and Pure Good Food. In addition, the topic of MEDICAL RESEARCH is only impacted by Utho Ngathi Disability Projects and Spettro Food, while MEDICAL FACILITIES issues are evoked by the Eastern Sudan Women Development and the Dr. Bekheit Association.

4.2.2 East Asia

The number of documents concerning urban health in East Asia is very close to that of Africa, with 11,000 in total (Table 13, Appendix 1). More than 87% of these documents are articles or books written by scientists, but only 4% of projects are completed by them (half of Africa's percentage). However, in East Asia, many more actors are present (almost 800) than in Africa (325) (Table 7).

On the graph of topics (Fig. 4), the subjects related to territory and planning are the most central ones, despite they comprise the lowest topics in terms of their presence in actors' documents: POLLUTION RISKS, POLLUTION EVALUATION, URBAN AND REGIONAL PLANNING, and DRINKING WATER. These topics are well developed in East Asia, but indirectly because they are related to all urban health issues. The main actors involved in URBAN AND REGIONAL PLANNING in East Asia are the UN Development Program (UNPD) and private companies working for cities including the Purbachal American City, which is building a new city near Dakha (Bangladesh), PT Paramount Enterprise International, which is developing various development projects in Indonesia, and Spear Logistics Private Limited, which operates in India.

For DRINKING WATER, the Chinese company NINGBO HONGCHUANG installs electronic equipment, while numerous private clinics in Manila (StemCell Manila) or in India (Artemis Cardiac Care, located in 6 cities) need safe water equipment for their medical activities. POLLUTION EVALUATION is not conducted by many actors who publish their activities, such as Reliable Pest Control Services Philippines, but this topic is mostly composed of complaints by numerous associations and private companies involved in urban health and care (e.g., CHILDLINE

Table 7 Topics for East Asia by types of actors

Topics	Number of actors				Total
	Government	Health institution	Organization	Private	
RURAL AND URBAN SOCIAL CARE	2	9		66	77
HEALTH FACILITIES AND TREATMENTS	5	18	1	79	103
CHILDREN'S PREVALENCE		6	1	22	29
SOCIAL POLICY DESIGN	9	10	1	158	178
REGIONAL ECONOMIC GROWTH	1	1		38	40
GROUNDWATER RESOURCES	1	3		17	21
POLLUTION EVALUATION		3		16	19
URBAN DEVELOPMENT PLAN				6	6
POLLUTION RISKS				5	5
SOCIAL, HOUSING, AND ECONOMIC POLICIES	1	3		49	53
DRINKING WATER				16	16
DOMESTIC AND SEXUAL VIOLENCE	1			33	34
FAMILY PREVENTION AND CARE	6	14	2	91	113
URBAN AND REGIONAL PLANNING	1		1	10	12
SERVICES MANAGEMENT	2	4	1	85	92
Total	29	71	7	691	798

Source Rozenblat, Mariño in ISUH (2021)

India Foundation or Cingol Medical Global [near Foshan, China]) or by actors developing accommodations that need access to clean water (i.e., Hotel Nikko Bangkok, Marino Royal Hotel of Bangkok, and the Harvest Hotel managed by HII in the Philippines).

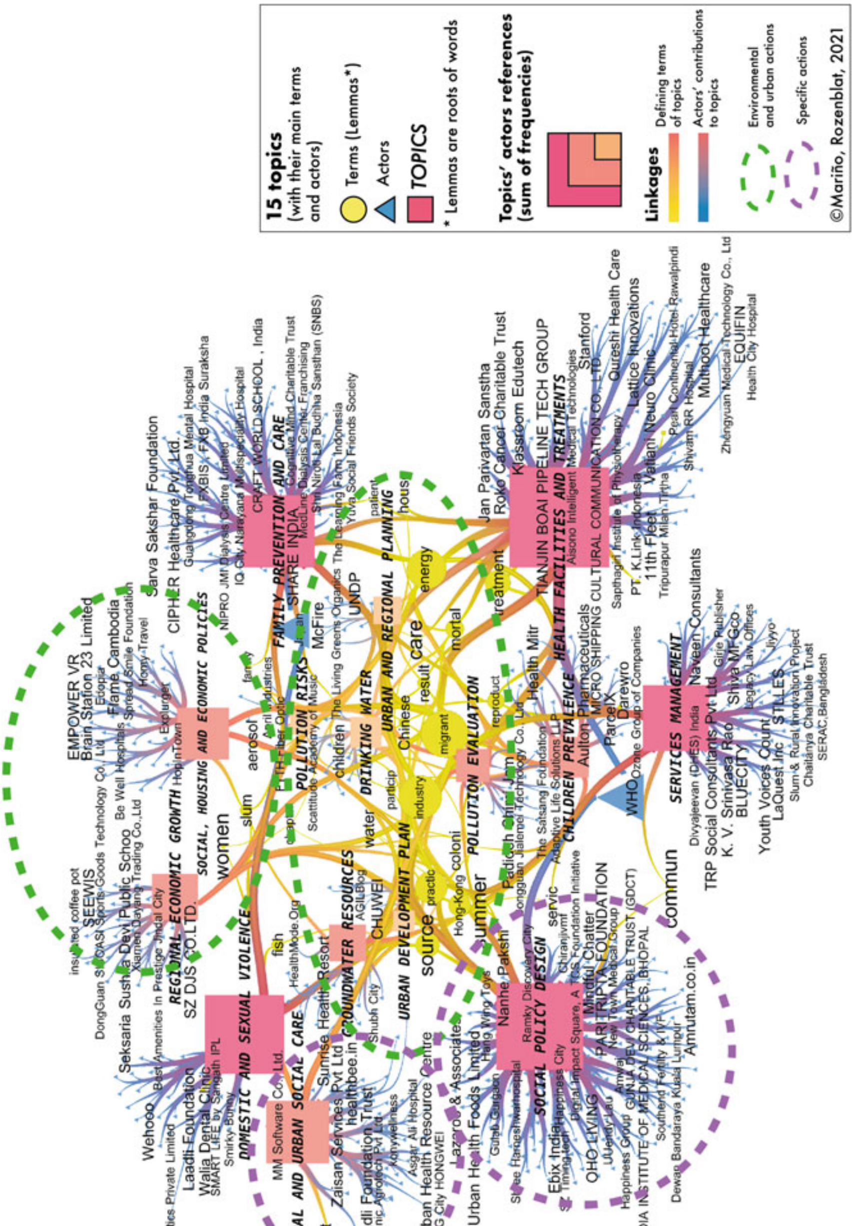

Fig. 4 Topics of urban health and actors for East Asia

In addition, six companies focus on planning, forming the topic of the URBAN DEVELOPMENT PLAN. The following mostly aim to participate in urban development plans: Chengda Pharmaceuticals Co., Ltd., Eros Hotel New Delhi, WK Technology Co., Ltd, WK Audio, AGILBlog, and CHUWEI. This topic specifically discusses plans and methods for cities' development plans and their impacts on public health.

4.2.3 Middle East and Central Asia

The Middle East compilation includes only 155 actors (Table 8), far fewer than the previous categories (Table 13, Appendix 1). Private companies are also predominant in this region for all topics. We did not detect any international organization involved in urban health in this region; they are mostly governments and private sector actors.

Table 8 Topics for Middle East and Central Asia by types of actors

Topics	Number of actors				Total
	Government	Health institution	Organization	Private	
BUILT-UP AND TRANSPORT DESIGN	2			9	11
FOOD AND OBESITY				7	7
SOCIAL VIOLENCE		1		8	9
RISKS		2		6	8
REFUGEES	3	3		27	33
WOMEN'S RISKS				1	1
CANCER	1	2		18	21
WOMEN'S HEALTH AND VIOLENCE				1	1
WOMEN'S PREVENTION	1			2	3
ARCHITECTURE QUALITY				5	5
MATERNITY	3	1		19	23
CLIMATE CHANGE		2		14	16
RESOURCES AND POLLUTION				1	1
EDUCATION TO ENVIRONMENT				8	8
URBAN DESIGN	1			7	8
Total	11	11	0	133	155

Source Rozenblat, Mariño in ISUH (2021)

The graph of topics (Fig. 5) reveals several topics emphasizing cities' infrastructures related to health: BUILT-UP AND TRANSPORT DESIGN, ARCHITECTURE QUALITY, URBAN DESIGN. Middle East region concentrates most of the actors here, and the central Asia has very few to not say nothing.

BUILT-UP AND TRANSPORT DESIGN comprises large builders of planning, such as the government of Turkey, or NGOs, such as NALA (NTD Advocacy, Learning, and Action; Ethiopia). NALA fights against neglected tropical diseases, developing a holistic model that empowers communities to promote behavioral changes among Ethiopian community members to improve access to WASH (water, sanitation, and hygiene). While the NALA NGO works principally in Ethiopia and Somalia, they also develop some programs in Palestine that explain their presence in the Middle East. NALA works with local communities to identify obstacles, map existing infrastructures and community networks, and design and implement locally based solutions, resulting in a measurable reduction in the prevalence of non-transmittable diseases (NTDs).

In URBAN DESIGN, Pace Architecture, Engineering and Planning (Kuwait City) follows a multidisciplinary approach including health, safety, and environment (HSE) that is firmly engrained into its philosophy. Pace plans, designs, manages, and constructs to contribute to built environments with the declared goal of improving all aspects of life, including economic development, public health, sustainability, and social equity. In ARCHITECTURE QUALITY, the actors developing these topics in relation to urban health are high-level hotels such as the Fairmont Palm (Dubai), Wyndham Grand Manama (Bahrain), and the Jeddah Chamber of Commerce and Industry.

Other topics are related to the environment and climate, such as RESOURCES AND POLLUTION and CLIMATE CHANGE. For RESOURCES AND POLLUTION, Optimum CRO is a Turkish enterprise (Ankara) engaged in clinical trials of different phases and post-marketing surveillance studies. Their surveys consider all the aspects of health and clinical research, including environmental aspects, in their analyses of local regulations. CLIMATE CHANGE is related to health themes recently articulated by numerous construction companies, such as Hennessey LLC (operating in Dubai and Abu Dhabi) and Enetric Technology Solution, Design & Construction Engineering (DEC), which often include the concept of smart cities, which is expressed in the name of Smart Dubai.

Besides, a lot of scholar attention is concentrated on the REFUGEES topic, which is very specific to this region and groups the most actors. This topic includes some reports and measures of refugee phenomena, including social precarity, violence against women, and childcare. The main actors participating in this topic are public authorities (such as the Dubai Airport Free Zone Authority, [DAFZA]), different medical centers (such as the Armed Forces Hospitals Southern Region [AFHSR], King Fahad Medical City [KFMC], and Anadolu Medical Center) and very diverse companies including cybersecurity firms (Paramount Computer Systems), hotels (InterContinental Dubai Marina), food providers (Right Bite Nutrition and Catering Services), insurance companies (Orient Insurance), and architectural firms (Six Degrees DXB).

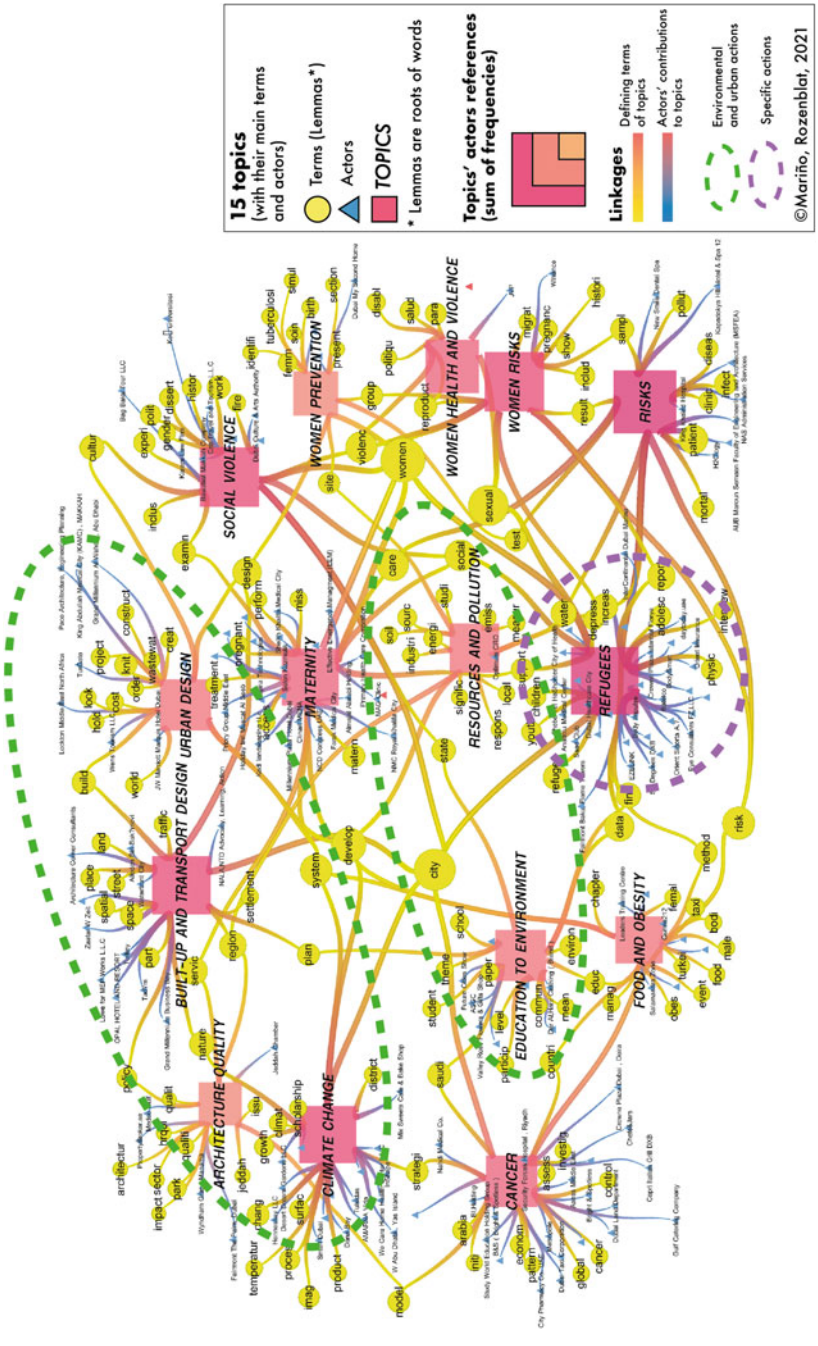

Fig. 5 Topics of urban health and actors for Middle East and Central Asia

4.2.4 Oceania

Oceania presents fewer actors than most of the previous continents/regions; however, the proportion of governments and health institutions in Oceania is larger (they collectively represent 30% of all actors) (Table 9).

Several topics related to the environment and urban actions occupy the center of the graph (Fig. 6). URBAN PLAN DEVELOPMENT, which specifically addresses climate change in growing areas, such as parts of Melbourne including Banyule City, the City of Monash, and Glen Eira City, all in the urban center of Melbourne, or Hume City, which is situated in its northern suburbs. Among the weaker topics in terms of the number of actors is ENVIRONMENTAL CHANGE. This topic is mainly developed by UN-Habitat together with React, a humanitarian charity that

Table 9 Topics for Oceania by types of actors

Topics	Number of actors				Total
	Government	Health institution	Organization	Private	
RISK PERCEPTION	1	3		4	8
ENVIRONMENTAL CHANGE			1	2	3
SEXUAL VIOLENCE	3			14	17
COMMUNITY BENEFIT				8	8
URBAN PLAN DEVELOPMENT	8	12		32	52
WOMEN'S CARE		1		2	3
HEALTH COST AND SERVICES	10	13		35	58
NATURAL ENVIRONMENT	1	2		9	12
INDIGENOUS SPACES	6	7		27	40
CHILDREN'S EDUCATION				6	6
LAND RISK EXPOSURE	5	4		17	26
FAMILY CARE		1		8	9
NATURAL DISASTER INFORMATION	2			6	8
ENVIRONMENTAL URBAN DESIGN	1	2		12	15
GOVERNMENT POLICIES	2	2		11	15
Total	39	47	1	193	280

Source Rozenblat, Mariño in ISUH (2021)

rapidly responds to disasters and emergencies, and The Other Side Landscapes Pty Ltd, a company concerned with landscape and garden maintenance and construction services in Sydney. Interestingly, ENVIRONMENTAL CHANGE is situated between two other topics: NATURAL ENVIRONMENT and ENVIRONMENTAL URBAN DESIGN, with which it shares many environmental terms. The NATURAL ENVIRONMENT topic is dominated by indigenous health associations, such as the Institute for Urban Indigenous Health and the Miwatj Health Aboriginal Corporation. The latter is a regional provider of primary health care services in East Arnhem Land, with seven clinics to care for the health of indigenous communities.

ENVIRONMENTAL URBAN DESIGN is the most specific topic and includes the design for mitigating the impermeability of soils and creating new kinds of pavement to address stormwater. It includes very diverse actors such as architecture companies, restaurants, clinics, and associations such as rotary clubs.

The particularity of Oceania is its specific topic related to INDIGENOUS SPACES, comprising the third largest number of actors. This topic concerns the living conditions of indigenous peoples, their foods, and their spaces, specifically in Gold Coast cities. The topic of Aborigines in Australia engages numerous actors, as the Australian tradition acknowledges indigenous traditions and cultures. Concerning urban health, actors concentrate more attention on being socially disadvantageous. The Auckland DHB renamed its magazine *Te whetū mārama*, which means "planets" in the Maori language. Bennett + Bennett completed the Anzac Square project in Brisbane, which includes the Aboriginal and Torres Strait Islander Memorial, in 2019. During this very symbolic construction, the company consulted indigenous communities.

4.2.5 Europe

European documents on urban health are linked to 831 actors, 85% of which are private actors (Table 10).

Four topics are related to ecology: GOOD FOOD AFFORDABILITY, CLIMATE CHANGE, GREEN ENVIRONMENT, and ENVIRONMENTAL IMPACTS ON HEALTH. GOOD FOOD AFFORDABILITY is a specific European topic, supported by various private companies involved in fitness, food production, and hotels; for example, the German enterprise WELLTHY has proposed new urban health concepts and the British institution Food for Life has updated the guidance for school meals.

The CLIMATE CHANGE category is supported by electric car companies, such as Tevva Electric Trucks, or events, such as Reuters Events Mobility & Automotive, together with various hotels, other accommodations, financial advisers, and supermarkets.

The GREEN ENVIRONMENT topic is related to the planning development of green spaces and related services in cities. It is dominated by the WHO, which is accompanied by the support of numerous city agencies, local associations, and financial institutions to support.

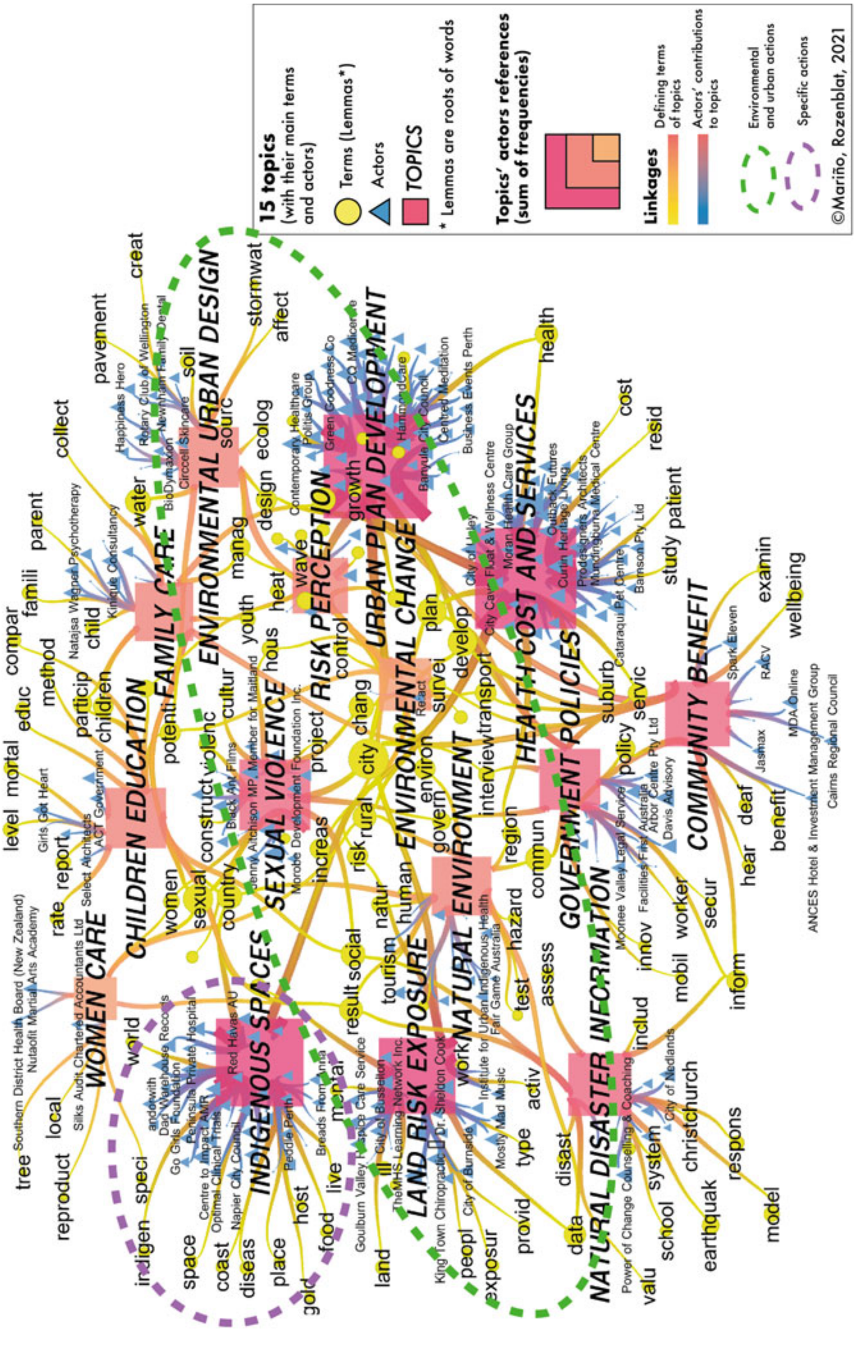

Fig. 6 Topics of urban health and actors for Oceania

Table 10 Topics for Europe by types of actors

Topics	Number of actors				Total
	Government	Health institution	Organization	Private	
ROAD ACCIDENTS	6	7	3	35	51
CHILDREN'S WAY OF LIFE	7	3		55	65
HEALTH RISKS AND CARE	1		1	14	16
ECONOMIC REGIONAL INEQUALITIES	2	1		13	16
GOOD FOOD AFFORDABILITY	5	9		71	85
URBAN DESIGN	4		1	37	42
COMMUNITY HEALTH CARE	14	9		92	115
CLIMATE CHANGE	1	1		19	21
SEXUAL ABUSE IN SCHOOL AND SPORT	2			23	25
VIOLENCE AGAINST WOMEN	10	21		190	221
MEDICAL ETHICS		1		15	16
URBAN LIFE STRESS	2	7		62	71
GREEN ENVIRONMENT	4	3	3	57	67
HEALTH RISKS EVALUATION	3	1		7	11
ENVIRONMENTAL IMPACTS ON HEALTH	1			8	9
Total	62	63	8	698	831

Source Rozenblat, Mariño in ISUH (2021)

Figure 7 reveals the lack of actors in the topic of ENVIRONMENTAL IMPACTS ON HEALTH in Europe, specifically, the lack of governments. Except for the government of Russia, most actors are private educational institutions (such as Ostravska Universität and the Downs Preparatory schools) or technology companies (such as Sistema Biobolsa and BiomiTech UK). Different actions characterize these actors. For example, Sistema Biobolsa produces biogas, fostering reductions in sanitary risks through waste management and preventing respiratory diseases due to firewood displacement. The most important words of this topic are data, measures, indicators and modeling, exposure, pollution, water, and asthma.

More specific urban topics are associated with ROAD ACCIDENTS, URBAN LIFE STRESS, or URBAN DESIGN. URBAN LIFE STRESS is formed by words

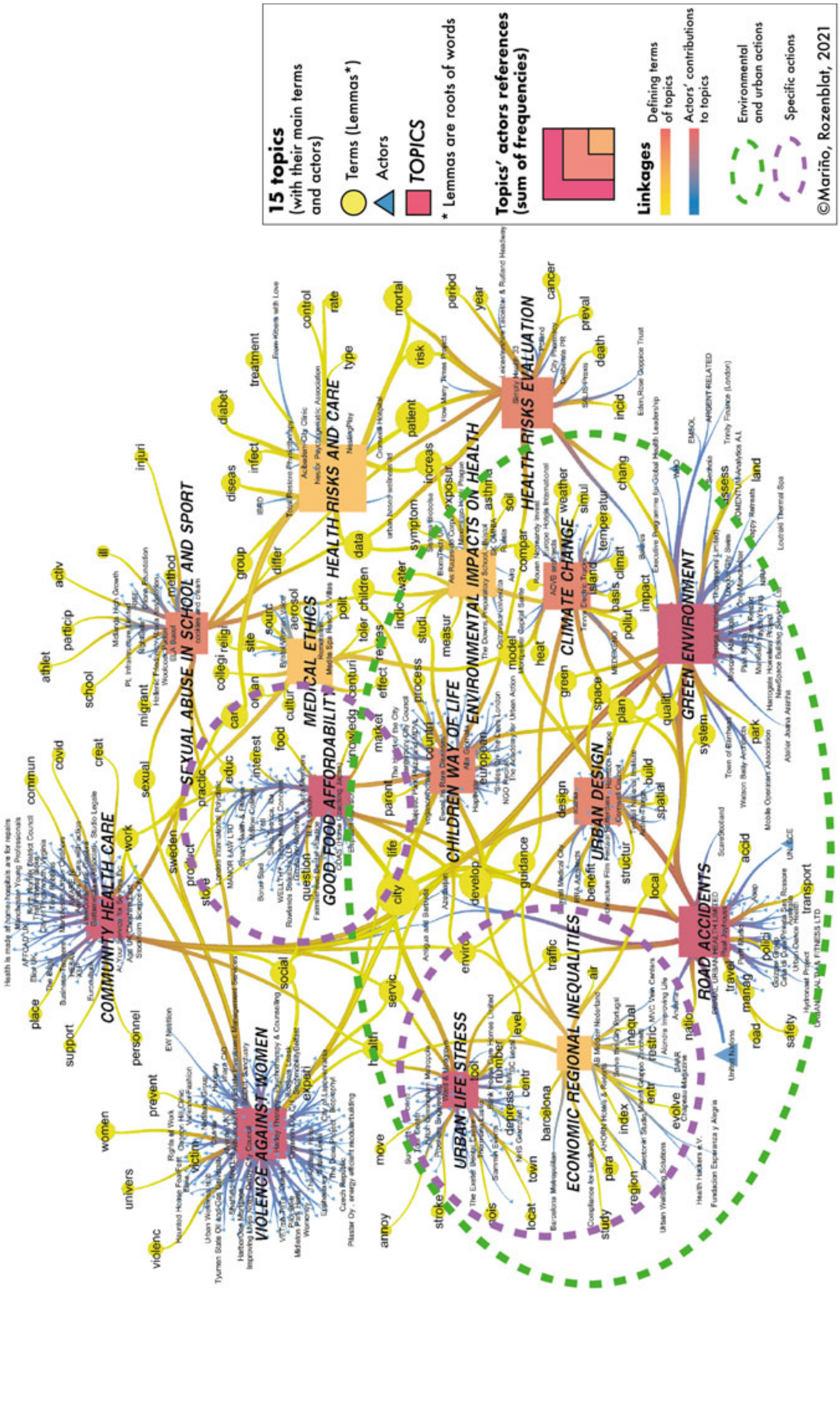

Fig. 7 Topics of urban health and actors for Europe

such as noise, depression, stroke, traffic, and services. Actors caring about this topic include clinical centers and companies such as ELG Planning, which builds schools, hospitals, and homes, and Prochem Engineering, which designs healthier and more efficient production systems for the chemical and food industries.

The URBAN DESIGN topic is led by the United Nations Economic Commission for Europe (UNECE) Steering Committee on Transport, Environment and Health of the UN Pan-European Programme (PEP). This committee addresses key challenges to achieve sustainable transport patterns at national and local levels, to pursue an integrated approach to policymaking, and to put sustainable mobility at the top of the international agenda. The UNECE is followed by several governments, clinics, private companies in architecture, and a few foundations.

Regarding international agencies, while different agencies of the United Nations concentrate their attention on ROAD ACCIDENT, the WHO is specifically related to GREEN ENVIRONMENT in Europe. In contrast to their roles in the previous continents/regions, these international organizations are not present in the European topics with the highest number of actors, demonstrating a lack of mutual attractiveness among all actors and these large organizations.

4.2.6 North America

With more than 2500 actors, North America contains by far the largest group of nonacademic actors. Like Oceania, the representation of governments and health institutions is also higher (22%) than in other continents/regions. The principal invested topics are FACILITIES AND TREATMENTS, COMMUNITY HEALTH CARE, and HEALTH CARE FACILITIES (Table 11).

Three topics directly rely on environment and planning: CLIMATE CHANGE ACTIONS, URBAN HEALTH MANAGEMENT, and ENVIRONMENTAL CONTEXT. The topic of CLIMATE CHANGE ACTIONS includes many policy terms, such as government, state, community, and plan. It is supported by more than 287 actors, including more than 50 city or state departments, such as New York City and San Francisco, with numerous other very small towns. Health institutions appear in this topic, such as the Big Cities Health Coalition or the Health Science Associates, Inc., the Health Tourism International Chamber of Commerce, the Medical Marijuana, Inc., and Urban Design 4 Health. The ENVIRONMENTAL CONTEXT includes numerous companies addressing local issues of health that increase the sensibility to asthma, allergies, complete local urban health programs or systems.

URBAN HEALTH MANAGEMENT topic is created both by institutions needing to manage their health systems and by companies offering them new systems capable of fostering the digital transformation and the management support for their health systems. One of the leaders in this sector in North America is DRT Strategies, which works with numerous US federal agencies, such as the Internal Revenue Service (IRS) (Fig. 8).

INSTITUTIONAL STUDIES is a topic close to these environmental issues. It was developed by companies trying to change people's actual behavioral systems by

Table 11 Topics for North America by types of actors

Topics	Number of actors				Total
	Government	Health institution	Organization	Private	
ENVIRONMENTAL CONTEXTS	12	26	1	148	187
NETWORK MODELING	1	4		27	32
WOMEN'S MOVEMENTS			2		2
MODELING RISK EXPOSURE	1			12	13
CLIMATE CHANGE ACTIONS	38	23		226	287
CANADIAN HEALTH ASSESSMENT				11	11
RISK EDUCATION	3			12	15
GENDER AND MINORITY ASSOCIATIONS			1	1	2
COMMUNITY HEALTH CARE	54	88	1	385	528
INSTITUTIONAL STUDIES				2	2
HEALTH CARE FACILITIES	47	51		304	402
WOMEN'S RIGHTS			1	2	3
SOCIAL SERVICES	18	12	3	108	141
URBAN HEALTH MANAGEMENT	22	24		226	272
FACILITIES AND TREATMENTS	54	100	5	409	568
Total	250	328	14	1873	2465

Source Rozenblat, Mariño in ISUH (2021)

transforming their structural and institutional environments. The two actors involved in this very specialized topic, Noom Inc. and Pearson Koutcher Law, facilitate these structural changes at different levels, the former at the individual level and the latter at the collective and community level.

The NETWORK MODELING topic is also very close to the topics on environment and planning. It is supported by numerous small companies developing new technologies for health and cities based on the latest innovations. On the health side, True Positive MD develops imaging software analytics to assess brain health, covering Alzheimer's disease, traumatic brain injuries, and more. Others such as Z.

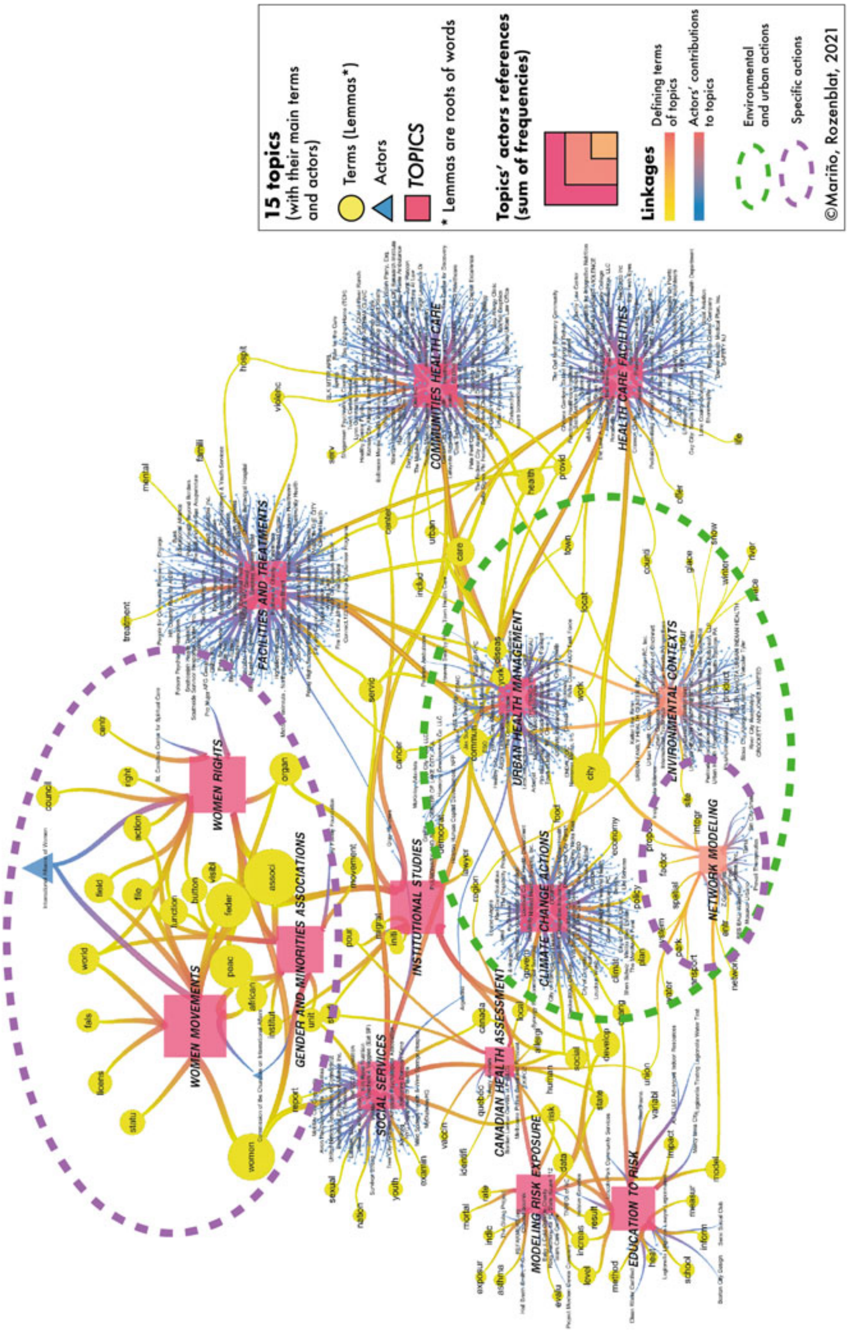

Fig. 8 Topics of urban health and actors for North America

Geoinfo Inc., equip institutions and private companies with state-of-the-art information technology, solve complicated environmental problems. Such environmental companies support cities, such as the town of Conception Bay South, to develop interactive maps of their territories to aid land planning and help inform inhabitants of any troubles or new regulations in their territory. Numerous companies, such as Vuba Corp., are emerging to provide ICT solutions for public transport by developing driverless electric vehicles that are powered by solar energy for zero-emission transportation. Another example is Aclima Inc., which is a purpose-driven technology company dedicated to catalyzing bold climate actions that protect public health, reduce emissions, and advance environmental justice. Aclima has pioneered an entirely new way to measure and analyze air pollution and greenhouse gases, block-by-block and around the world. The Aclima hardware and software technology platform translates billions of scientific measurements from its network of stationary and roving sensors into its Aclima Environmental Intelligence™ for governments, businesses, and communities. A public benefit corporation, Aclima is dedicated to catalyzing bold action to protect public health, reduce climate-changing emissions and advance environmental justice. The company holds a broad patent portfolio for networked, indoor, wearable, and mobile air quality sensing technologies. Aclima is headquartered in San Francisco with offices in Portland and New York City.

Apart from the system, appears MODELING RISK EXPOSURE, which includes some actors, such as Urban Property Solutions based in Texas, providing services to address any health risk in residences or hospitals. Other actors address much more qualitatively the questions of urban health through giving projects (GPN), which build active peer learning communities to share innovations and adaptations, strengthening local social movement ecosystems.

A very specific set of topics for North America concerns WOMEN'S MOVEMENTS, WOMEN'S RIGHTS, and GENDER AND MINORITY ASSOCIATIONS. Despite the low number of actors invested in these topics (respectively, 3, 2, and 2), these actors produced many documents (we collected 173) that became very powerful. As some actors are involved in two of these topics, there are only 5 organizations: The Commission of Churches on International Affairs, the International Alliance of Women, the Earley Family Foundation, the St. Camillus Center for Spiritual Care, Pro Mujer. With their strong production of websites and documents, they heavily impact the analyses with words such as women, association, federation, and African American.

4.2.7 Latin America

Although urban health in Latin America is addressed by a large production of documents (Table 4), the number of actors, except for scientific authors, is below 80 (Table 12).

Generally, the urban health topics in Latin America are weakly concerned with urban contexts and impacts (Fig. 9). The only environmental topics are ACCIDENTS and WATER. ACCIDENTS are essentially related to traffic and residences. It is

Table 12 Topics for Latin America by types of actors

Topics	Number of actors				Total
	Government	Health institution	Organization	Private	
CHILDREN'S PREVALENCE	2			5	7
WATER	1			2	3
SOCIAL DEVELOPMENT	1		4	10	15
MEDICINES	3			11	14
WOMEN'S CARE		1		1	2
RURAL DISEASES				2	2
SEXUAL VIOLENCE	5			4	9
MENTAL HEALTH				4	4
HEALTH CARE				3	3
TREATMENTS				1	1
ALCOHOL AND SMOKING				4	4
MORTALITY				1	1
HEALTH CONTROL				1	1
ACCIDENTS				12	12
Total	12	1	4	61	78

Source: Rozenblat, Mariño in ISUH (2021)

supported only by private entities, with a dominance of local associations such as the NGO Añañau (Cusco, Peru), which works with children and provides young students with health education while offering afterschool programs. We also find companies such as the Brazilian Centroflora Group, a pharmaceutical company. WATER concerns the technical detection of problems in water supplies and is supported by the government of Buenos Aires, the Hospital Presidente Prudente in Sao Paulo, and the enterprise called Pest Total Solutions Control De Plagas in Guanajuato, Mexico.

Latin America sees some specific topics more salient than elsewhere like ALCOHOL AND SMOKING and RURAL DISEASES. These thematic concern different countries like Argentina, Brazil, or Peru, but very few actors. Besides, the topic of SOCIAL DEVELOPMENT concentrates more than 75% of all the documents in Latin America discussing urban health. It mostly comprises the efforts of international institutions such as the United Nations, the UN Department of Public Information, and the UN Population Division.

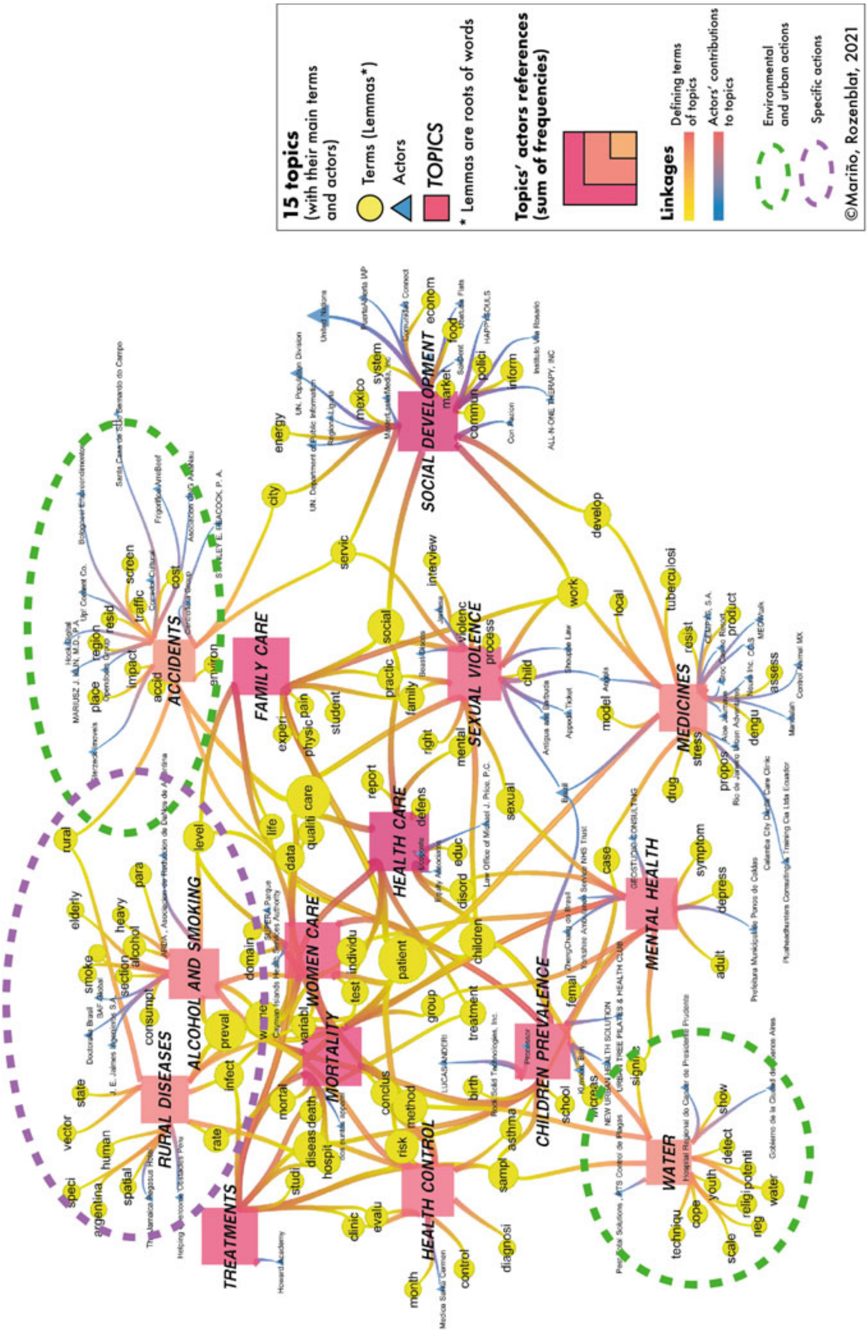

Fig. 9 Topics of urban health and actors for Latin America

4.3 Discussion

This continental overview 2010–2021 preceded by the general topic evolution since 2000 shows first how far environmental and urban planning became more and more important in the themes of public health that are now far to be only reduced to medical issues.

The actions on cities' planning are specifically central in Asia and Middle East, two continents where the urbanization is recent and with a fast trend of growing. Thus, it seems that the discourses, supports, and actions, undertook by the different UN agencies, have been successful; specifically, for these parts of the world where the rapid urbanization was accompanied by a strong institutional restructuration, allowing more transversal urban policies linked to health. Besides, in Africa, medical research remains the core of the health issues and spatial planning and environmental issues are kept in a peripherical position in the topics' structure.

For the "old urbanized" continents, Oceania is the most centered on environmental changes issues. North America and Europe see important topics around urban design and climate change, but they are less central in these systems, remaining apart from the pure medical issues. Latin America, which should be counted in this category of early urbanization, gathers the fewer actors involved in urban health in general, and the topics like accidents and water remain very peripheric.

According to all these observations, it appears that the environmental and planning issues remain quite isolated in some continents like North and Latin America, Europe, and Africa By constrast, East Asia, Oceania, and Middle East, can be better-introduce these environmental and planning issues at the core of their urban health strategies. The national and local institutions of the latter ones seem more adapted to this transversal approach of urban health, to integrate urban planning in the core of the health policies together with medical care and treatments. For the former continents, different causes could be at the origin of the lack of integration of policies and actions: For North America, Latin America, and Europe, the institutions lack flexibility, reducing the transversal political integration and the inclusion of private actions on urban health. For Africa, the weak institutions should be a strong explanation of this situation.

Although both health and cities are universal anthropological constant, some cultural factors (e.g., value and criteria of health, hygiene and well-being, relation to death and extension of life expectancy, reproduction or food habits, gender cultures, etc.) which are not considered here, might also explain some of the geographical differences. Regarding the initial question addressed by WHO to define the lack of actors in the different topics by continent, we can observe from all these continental topic models, that where UN agencies are present in some topics, numerous other private or institutional actors are present as well. It confirms the role of these global agencies in the orientation of action for a multiple set of actors. However, we can wonder whether in the past, UN agencies attracted other actors or if other actors attracted UN agencies.

Generally speaking, the combination of topic modeling and network analysis allows to identify key regional change-makers in each topic. The semantic analysis of natural language for unstructured data using machine learning algorithms represents a replicable and reliable method for gathering topics. However, the resulting topics are not easy to understand without context, and the list of words related to each topic requires further analysis, being a limitation when we generalize the meaning of the topics. For that reason, we developed an expert evaluation of each topic, comparing trends and events according to the years and regions, inclusive of specific actors. In that matter, more granularities would be gained with a distinction between large corporations, SME, and start-ups, among private companies, which account for nearly 80% of total actors, and also appear in the Institution category.

5 Conclusion

This chapter exposed a large study based on a worldwide web mining, which allowed to stress by continent a stakeholders' topic modeling with the mapping and social network analysis of key actors in urban health discourses and actions. The results clearly underline the gaps of actors on different topics, but overall, they show how far the emerging transversal vision of "health in all policies" took different forms and levels of integration in the different continents.

The method we proposed is reproducible and the built relational database is in the hands of the WHO department of Environment and Health, which proposed to make it available publicly. Of course, each method has got a limit and the main limits here are the continental scale of the analysis and the abstract we made of the definitions of actors' interventions. For the continental scale, it is difficult to relate the findings with national or local literature, as the change of scale would make rise the risk to fall in an ecological fallacy (consisting in comparing processes at different scales that are not comparable). In fact, here the actors are not defined locally or nationally but in the context of their continental relative position, which would totally change the absolute visions that local literature reflects.

Nonetheless, the analyzes could be deeper and could explore specific themes to better define the future agenda and the structure of global to local institutions that leverage the private actions, despite bottom-up actions of communities and associations are not negligible. To support future "health in all policy" strategies, it would make sense to further investigate if and how health is of growing concern on the side of urban actors, such as urban planners and designers, and to remap the contribution of urban health actors to innovation ecosystems and urban resilience strategies. The issues of transversal and scales coordination are crucial in these ecosystems: in fact, we could go deeper into the way actors articulate different policies or actions (in economic, social, cultural, and environmental policies) and how far different scales of intervention (local, regional, national, continental, or worldwide) are combined. The temporal scale is also important to evaluate how far discourses lead to actions, and how different actions succeed on the same territories.

The study of the most relevant topics in detail, using methods to compare social trends with crowdsourcing data, is potential research for validating the existing results. The comparison of results with user-generated content using structured surveys can provide future trends and drifts of human needs, in order to create general knowledge for policymakers.

Therefore, it would be worth to continue these kind of explorations for monitoring the changes in urban health actions, specifically in these times of climate change and epidemies that quickly transform our visions and needs for more security, health, and well-being in the future cities that will encompass an increasing part of the humankind. Ultimately, this paradigm shift might induce a redefinition of both cities and health in the future, as part of a redefinition of sustainable livability on the planet. An emerging trend analysis would help to grasp this broader societal transformation in progress.

Appendix 1: Data

Used Languages

The detection of information was completed using only keywords in English. Despite the search language being restricted, the content of text was extracted from diverse languages. For Latin America, Spanish, and Portuguese, most texts were detected in the source Scielo, and in web of science Chinese documents with Mandarin text. In both cases, it was necessary to translate abstracts/summaries because they represented more than 50% of documents for these regions. Other areas, such as Russia and the Middle East, presented documents in local languages and with English translations in the abstract, making it feasible to preprocess these sources by erasing the non-English parts that were manually processed.

Documents per Continent/Region

The documents were classified by the places of interest. We detected either the city names or the country names within the documents. Then, we aggregated documents by country and by region or continent. Numerous documents did not mention any specific place and were classified as "worldwide." These worldwide sources represent more than 62% of all documents (Table 4). The regions with the majority of subjects in the content were Africa, East Asia, and Latin America, although the sources of the information or evidence came mainly from North America and Europe. In other words, most of the content was produced in North America or Europe, but its application of action was focused on projects in cities of Africa, East Asia, and Latin America. This is an important thing to keep in mind when understanding the results presented below, because the numbers reflect the activity and actions of cities themselves, rather than the source of the knowledge and investment in the knowledge production (Table 13).

Appendix 2: Data Preparation

The textual pre-processing is the preparation of information to produce useful data, cleaning errors, and providing organized data, that is optimal for creating analysis. The results of the preprocessing present a bag of words, which is standardized, ranked, and weighted to identify the correlation between terms, to find the understanding in the context. From either whole document texts or their summaries, we extracted the main sentences, formalizing the associated words in "lemmas," which are the roots of words. In order to obtain such words frequencies, the phases of pre-processing are: *Tokenization, stop words, Stemming, Lemmatization and Vectorization* (Bharanipriya & Prasad, 2011; Eldhose et al., 2016; Johnson & Kumar Gupta, 2012).

Tokenization

Tokenization detects the words and transform into "terms" usable as keywords or "tokens." Thus, it means a segmentation of the whole text into words, removing blank spaces, punctuation, signs, etc. (Amudha, 2017). The documents are understood as a collection of statements and this process breaks the statements in tokens and created a list of tokens from the document (Manning et al., 2009).

A codependent needed process is the token normalization meaning a process of canonicalizing tokens to match the tokens with a standardized list to normalize them (Manning et al., 2009), despite differences in the character sequences. For example, *Health, Healthy*, or *City, Cities:* in the context of our document, theses sequences mean the same but they were written in different ways. The same process was applied to the actors' names: for example, *UN-Habitat, UN Habitat, and UN Habitat*.

Stop Words

Stop words erase the articles, prepositions, and words that are not useful for the research, being the process of removing from the text the most common words mainly not important as articles, pronouns, prepositions, etc.; these words don't represent the meaning of the document, creating noise and increasing the length of the document. Their removal reduces the dimensionality in terms of space and terms and avoids non-desired keywords (Vijayarani et al., 2015).

Table 13 Types of treated documents by continent/region

Type of document	Europe	Africa	America[a]	North America	Latin America	Asia[a]	Middle East	East Asia	Oceania	Worldwide	Total
Articles	2882	8946	318	1491	1997	192	981	8964	846	51,433	78,050
Books	540	1231	22	274	224	13	187	1030	204	5165	8890
Events	29	77	8	6	51	3	6	95	10	815	1100
Legal documents	82	71	31	109	49	19	17	36	5	984	1403
News	10	35	1	2	1		1	10	2	536	598
Projects	559	930	109	57	7055	15	97	411	20	16,718	25,971
Theses	1	18	1	1		3	1	8	2	34	69
Trainings	3							1		197	201
Videos		1		1						30	32
Webs	942	415	5	2891	85	4	181	964	322	1465	7274
Total	5048	11,724	495	4832	9462	249	1471	11,519	1411	77,377	123,588

[a]Documents discussing an entire continent without the regional divisions that we used

Source Rozenblat, Mariño in ISUH (2021)

Stemming

The stemming process codifies the position and determines the role of the terms that are more frequent and their correlations in the whole content with the goal to define the meaning of the terms, which is recognized as the method to search for the semantic roots of the words, trying to unify words with same lexical origin. In language, there are many words with the same meaning such as *urban-urbanization-urbanity*, all represent the same context and can be stemmed from the word "*urban*." This process removes several suffixes for the reduction of the number of words and provides an accurate matching between the stems from the bag of words (Vijayarani et al., 2015).

Lemmatization

Lemmatization groups similar terms and categorize/standardize the words (i.e., *Habitat, house, living*), which refers to the use the proper vocabulary and morphological analysis of words, to return to the base form or dictionary form of the word that is called "lemma." Normally, this process is conjugated with the stemming for the reduction of forms and to avoid derivatives forms of words, transforming the words in their common base form, which is useful for the selection of keywords (Manning et al., 2009). In the example of Fig. 3, Health & Healthy, City & Cities could be grouped together.

Vectorization

Vectorization is the creation of the index of words as a dictionary. The creation of a dataset applies the *method TF-IDF* weighting or *Term Frequency-Inverse Document Frequency*, where each word of the document is weighted in accordance with its appearance in the documents, which is an indicator that reflects how important is a word to a document in a collection of documents or textual corpora (Menaka & Radha, 2013). Commonly, the vectors constitute the master list of the most frequently occurring words.

The vectorization requires the "TFIDF Encoding," which is the Term Frequency (tf_{ij}) multiplied by the Inverse Document Frequency. A high frequency of a word means that is an important word in a specific document. The term frequency suffers a critical problem because all terms are considered equally important, affecting the discrimination power in the determination of relevancy (Andritsos, 2016). For that reason, we should apply a method to reduce the effect of terms that occur frequently in the collection of words, but they don't represent the real meaning (Manning et al., 2009). The terms that are transformed into vectors, are ranked in a list according to their occurrence. This process. TFIDF Encoding. is the relation between the frequency of a term in the whole context with the frequency of this term in a specific position of the text, being understood as the importance of the term in a document and the importance of the meaning of the word in different contexts. In other words, this method allows to evaluate how it affects a term, because a term in a substantive position is not the same as in a complement position, a term in a substantive position reflecting better the main idea (Andritsos, 2016; Manning et al., 2009). The problem is solved multiplying the terms frequency by the inverse document frequency, to discriminate between documents. We can summarize that $\mathrm{TFIDF}_{i,j}$ assigns to term i a weight in document j:

- highest when i occurs many times within a small number of documents.
- lower when the term occurs fewer times in a document or occurs in many documents.
- lowest when the term occurs in all documents (Manning et al., 2009).

Appendix 3: Data Analysis

Once the data was cleaned and organized with the two previous stages, we were able to proceed to its analyses.

Correspondence Analysis

The first step for the analysis was to apply a Correspondence analysis for the whole sample and for every sub-sample by continent. The Correspondence analysis (CA) is a multivariate analysis of a contingency table through the row (documents) and column (words) profiles of the relative frequencies of the lexical elements (weighted in chi-square). The chi-square standardization reveals the level of the statistically significant association given by $p < 0.0001$ (Sourial et al., 2010). The correspondence analysis decomposes the inertia of the whole distribution of words in documents (weighted by $\mathrm{TFIDF}_{i,j}$), by identifying a small number of independent dimensions, representing the major differentiations (the main variances). The main purpose of CA is to represent graphically these main dimensions of differentiations. In CA, the projection in two dimensions is formed by identifying the axes (Factors), where the distance between the profiles with the axes is minimized, and the amount of the explained inertia is maximized. The correspondence analysis constitutes the base of the following similarity analyses (Yesuraju & Kiransree, 2013; Meza, 2015).

Similarity Analyses

The analysis of similarity is a technique from the theory of graphs to study the proximity and the relations between the group of elements and the maximal shape of tree, where the number of linkages between two nodes evolve like the square of the number of the edges, trying to reduce the number of those linkages for getting a connected graph without a cycle (Marchand & Ratinaud, 2012). The algorithm of Fruchterman-Reingold (but also many other possible algorithms) builds the *network of the lexical links from the textual corpora and categorizes them by communities of the most related words*. The analysis can be done using a category, a specific term, or with a combination of terms. The results of similarity analysis can be described with a network of terms, or with the alignment of words to evaluate correlation between sources.

Topic Modeling

To identify the main groups of lemmas forming together consistent themes and purposes, we used the method of Topic modeling. Topic modeling is a Machine learning algorithm applied to analyze the words from texts with the objective of discovering themes that can be found inside of them. Also, it is used to discover how those themes are connected to each other and how they are susceptible to change over time (Blei, 2012). It uses the Latent Dirichlet Allocation (LDA) which is a technique to discover topics in a collection of documents (statements) (Blei, 2012; Blei & Lafferty, 2009; Blei et al., 2003; Knispelis, 2016), where topics are assumed to be uncorrelated (Grün & Hornik, 2011). The LDA algorithm works with a given number of topics. For that reason, we needed first to determine the K number of topics. The value of K is measured with the Harmonic Mean method for model selection (Ponweiser, 2012), because the number of topics where a word appears is correlated with the number of distinct senses the word has and it reproduces many of the defined metrics (Steyvers & Griffiths, 2007).

In the learning phase, the LDA process measures the most probable distribution of each word in different points. For defining the new version of the distribution, each point is assigned by weights forming breaks. Each break includes a group of points of the complete distribution, then these points can be merged into the distribution of the correspondent cluster. The collapsed Gibb Sampling uses the *Markov Chain Monte Carlo method (MCMC)*, which is an inference process that proceed one topic at a time but being limited by all the other topics (Smith & Roberts, 1993).

In a set of topics, we initialized a random organization of the topic keeping the evidence values fixed. In each iteration, through the loop, we selected one non-evidence topic, and we resampled it, based on all the other topics and the result provides another sample. We repeat this process iterating 2,000 times (which is estimated sufficient), keeping indicators in every iteration evaluating and storing the log-likelihood. Using those parameters, we calculated the harmonic mean value, which is the K value or the best number topics. The value of the optimal number of topics is applied for running the LDA model, and the Gibbs Sampling method is used for estimating the topics, considering the textual corpora. The number of topics we established according to the distribution of the corpus, where terms with a TF-IDF higher than 0.75% that are considered as the most relevant presents a mean value around 13.91 (the number of topics accepted has been here 14 + 1 error = 15).

Next, the "topic" function was used to extract the most likely topic for each document, then the most related topic is assigned to each document. The topics are defined by a sequence of terms with a major rank. Each sequence of words assigned to each topic is a construct of ideologies where the group of terms represents themes related to the meaning of the statements. Besides other values, the final table incorporate information on the authors/stakeholders with the respective topic, which can be used for the network analysis. Each topic allows the correlation between authors/stakeholders, creating affiliations between them, because we can see how these authors/stakeholders share ideas. The database becomes big data where rows are the authors/stakeholders and columns are their numerous possible shared ideas and topics.

Appendix 4: Visualization and Interpretation

Network Analysis

Specific positions of topics, actors in years and continents, were evaluated using quantitative evaluations. There are numerous algorithms to re-create correlations and simulate behaviors. Some basic analyzes as degree centrality and betweenness are applied with certainty because they are the first steps to underline roles and positions. Their correlations allow the analysis of gatekeeping (low degree and high betweenness), where a statistic graph is the most efficient way to underline them (Rozenblat & Mélançon, 2013).

Interpretation of Social Network Analyses

The graphs resulting from network analysis include the whole analyzes of the *mutual proximities and connections between concepts, stakeholders, and their actions*. The results of the global network of stakeholders/topics and words/topics are presented as a narrative, as well as visually, displaying the network convergences and interdependencies. The high number of stakeholders did not allow to make readable all the actors' names.

According to the dominant words (lemmas) contributing to the formation of topics, we aimed to define each topic to qualitatively identify the general meaning of the association of the strongest words with all the other terms composing the topic. This is an interpretative qualitative stage based on the quantitative weights of the words contributing to each topic formation. In addition, as topics interact with each other through the sharing of words and actors, the meaning of each topic is consolidated by its comparison with the meanings of other topics.

Each document was assigned to authors or stakeholders (actors), countries, or places, aggregated by continent/region, according to their purpose. We can therefore associate authors and stakeholders (actors) according to their contributions to the different topics. We did not consider the academic authors at this stage (although we organized and carefully stored this information for the database). Scientific authors generate most of the content used to create a topic, but this does not necessarily translate into actions and policies (although they contribute to the prominence of the major themes analyzed).

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Same Bed, Different Dreams? Socio-Economic Strata and Differences in Liveability Perception in European Cities

Pui-Hang Wong, Mehmet Güney Celbiş, Karima Kourtit, and Peter Nijkamp

1 Introduction

Where do we find happy people? Research has shown that people living in socially unequal cities tend to be more unhappy (Glaeser et al., 2009). Clearly, the notion of *liveability* may remain an elusive concept (McArthur & Robin, 2019; Sochacka et al., 2021). But if we agree that happiness is a good litmus test of urban liveability, then ensuring equal opportunities and access to public amenities to its dwellers seems to be a plausible objective of urban policies. The *New Urban Agenda*, adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador (2016), envisions to create more sustainable cities through a people-centred, age- and gender-responsive approach to urban planning and development. Particularly, Articles 11 to 13 of the Agenda highlight the vitality of equality and inclusivity in its vision of future cities. However, such great ambitions need a reality check.

Cities are the 'natural habitat' of people, but all cities and their inhabitants are different. Despite the high ambitions and great intentions of the New Urban Agenda, to achieve these laudable goals, it is necessary to know what citizens value the

P.-H. Wong (✉)
UNU-MERIT and Maastricht University, Boschstraat 24, 6211 AX Maastricht, The Netherlands
e-mail: wong@merit.unu.edu

M. G. Celbiş
UNU-MERIT and LAET, ENTPE, CNRS, University of Lyon, 3 Rue Maurice Audin, Vaulx en Velin, 69518 Lyon, France
e-mail: celbis@merit.unu.edu

K. Kourtit · P. Nijkamp
Faculty of Management, The Open University, Valkenburgerweg 177, 6419 AT Heerlen, The Netherlands
e-mail: Karima.Kourtit@ou.nl

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most. However, there is not much clarity on which urban domains policymakers should target and prioritise. Cities as a complex and dynamic matrix continue to nurture, attract and bring together people with various backgrounds and ambitions, physically and virtually, into a unique socio-economic space. In view of the great socio-economic diversity, the idea of liveability among individuals is bound to be different. This presents a fundamental question: Do people of different socio-economic subgroups share the same vision of liveability? If not, to what extent are they compatible in a compact urban space? And last but not least, what are wise policy mechanisms for urban liveability?

The extant literature on liveability, quality of life, well-being, contentment or happiness in cities is predominantly sociological or psychological in nature (e.g. Veenhoven, 2018). More recently, these issues have also been addressed by economists (e.g. Frey, 2018) and geographers (e.g. Ballas, 2021). The present study aims to provide further elucidation to the heterogeneity across urban socio-economic subgroups within a spatial and an individual context. To do so, we conduct a Shapley decomposition analysis to deconstruct the notion of liveable city into seven dimensions, namely *activity*, *mobility*, *human capital*, *security*, *government services*, *social relations* and *natural environment*. By using data from a perception survey, we examine how citizens with diverse socio-economic conditions have been attributing value on these dimensions differently, depending on their gender, age and economic status. Based on the estimates, we further compare how people in 83 European cities value the above seven dimensions differently.

This study aims to identify the relative contribution of urban amenities or attributes to perception of liveability in European cities. It also examines how the relative importance of the attributes varies by the socio-economic backgrounds of the residents. To achieve these goals, we analyse data from the most recent (2019) European Quality of Life Survey (EQLS). The survey contains the perceptions of 30,747 residents on the quality of life in 83 cities in 36 European countries. We first use Shapely decomposition to identify the relative contribution of different urban attributes to people's perception of life satisfaction across three different socio-economic strata (i.e. age, gender and income). As preferences over urban amenities are likely to be diverse between cities, we use the multidimensional scaling technique to visualise the (dis)similarities between the relative contribution of various urban amenities in the sampled cities.

Our study is related to a burgeoning body of literature on city liveability. The notion of liveability has been debated. For example, McArthur and Robin (2019) argue that the use of aggregate metrics of liveability obscures the differentiated quality of life. Roberts and Turner (2005) empirically show that some criteria of liveability could be conflicting in nature. Despite such serious challenges, many researchers have developed various objective and subjective indicators to measure the concept (Sochacka et al., 2021; Southworth, 2003). Some studies take an objective approach and limit themselves to a single dimension. For example, Riggs and Gilderbloom (2016) focus on street traffic and its impact on safety and crime. Polloni (2019) measures and examines noise level and its effect on housing prices, an often-used proxy for 'liveability'. On the other hand, some studies adopt the subjective approach and measure liveability in terms of people's perception of quality of life or life satisfaction, and evaluate a city from a holistic perspective (e.g. Okulicz-Kozaryn, 2013; Zhan et al., 2018). The current study takes the second approach. It is closely related to recent research on *city love* by Kourtit et al. (2021a, 2021b, 2021c), which consider people's attachment and appreciation and search for the drivers of their love towards the cities in which they reside. The present study on cities in Europe defines liveability in terms of people's life satisfaction in their city. It highlights that a city is inherently an unequal socio-economic landscape. Based on this observation, it proceeds by examining whether the definition of liveability varies by people's socio-economic status and their city of residence, with a particular focus on European cities. In the following section, we will explain why the ideations of liveability are likely to be heterogeneous between members of different socio-economic groups.

2 Heterogeneous Preferences for Urban Amenities Within and Between Socio-Economic Strata

Urban agglomerations find their offspring—and continue to exist in present times—due to a great variety of scale and agglomeration advantages (such as joint use of infrastructure, shared access to public amenities like schools or cultural provisions, dense markets, joint exploitation of modern technology). But citizens do not enjoy the same extent such urbanisation externalities; cities house heterogeneous groups in a pluriform context which benefit from the urban economy to different degrees.

This study will explore the perception of the urban living environment characteristics under three different social strata: gender, age and income. Urban amenities may carry different weights for members of different socio-economic groups, as their needs, desires and demands for public goods are often distinct, depending on their social roles, their stages in a life cycle, financial constraints and other place-based conditions. For instance, in the context of the COVID-19 pandemic, economic and subjective well-being of people in cities are found to significantly differ, depending on one's family structure and labour market status (Möhring et al., 2021), socio-economic vulnerability (Celbiş et al., 2022), levels of education, income (Wanberg et al., 2020) and neighbourhood characteristics (Bonomi Bezzo et al., 2021; Celbiş, 2022; Pipitone & Jović, 2021). The same finding can also be generalised to the pre-pandemic period. For example, within the framework of urban ecosystem services, Wilkerson et al. (2018) demonstrated that benefits provided by these services may vary, based on a person's demographic and socio-economic backgrounds. In fact, discrepancies in welfare gains between socio-economic groups are often observed in relation to contextual factors like housing (Smets & van Lindert, 2016; Sripanich et al., 2015), transport (Iglesias et al., 2019), health care infrastructure (Godøy & Huitfeldt, 2020) and recreational facilities (Kim et al., 2019; Roberts et al., 2019).

In this study, we hypothesise that urban dwellers may prioritise urban living environment characteristics such as the quality of environment and public amenities according to their gender, age profiles and income levels.

The focus on age, gender and income is by no means random. Urban necessities may have different weights for different socio-economic groups. A growing number of studies has confirmed that, given by their preferences and social roles, women may demand certain public goods more than men. For example, evidence from a randomised experiment found that women tend to spend more on children's goods when there is a positive income change (Bobonis, 2009). For this reason, they may assign a higher weight to the qualities of schools and health care facilities. Women also exhibit a stronger preference for cultural and recreational amenities (Reynolds & Weinstein, 2021; Whisler et al., 2008). By estimating women's willingness-to-pay for living in a city, Reynolds and Weinstein (2021) showed that women value public transport less. Lots of pandemic-related research has found that women, especially those who are self-employed, alongside with mothers, single mothers and immigrant women, have been disproportionally hit by the COVID-19 pandemic in terms of their livelihoods, health and well-being (Czymara et al., 2021; Graeber et al., 2021; Hertz et al., 2020). As such, future liveable cities should be more attentive to the needs of their female inhabitants and shift focus to facilities that they care the most.

The preference for city attributes is also likely to be different by people's age. For example, Da Schio et al. (2021) found that in Belgium people's attitudes towards urban green spaces vary by age. It suggests that the utility and potential benefits of green spaces can be dependent on the socio-economic characteristics of urban areas in which they are located. The relationship between life cycle and amenities can also be explained by age-specific needs. Public amenities are distributed unequally across space. In university towns, students prefer to stay close to universities or to the city centres for a more vibrant city life. Using data in the city of Stockholm, Andersson et al. (2018) charted the mean age of people living in neighbourhoods in Stockholm and found that different age groups are clustering in different parts of the city and that younger people are attracted to consumption amenities (e.g. shops and restaurants). Letdin and Shim (2019) argued that the demand for amenities is related to commuting distance. They showed that working spouses and households with older kids choose their houses closer to downtown amenities. Using a machine-learning method, Wong et al. (2021) studied life satisfaction of middle-aged and older adults and found that for older adults, higher levels of life satisfaction is related to security, access to cultural facilities and green spaces.

Finally, income level affects both the needs of the urban poor and the difficulties involved in satisfying those needs in an urban setting (Richards & Thomson, 2017). Bounded by their income levels and hence location choice, the urban poor often has less access to services commonly associated with city living (Potts & Bhiwandiwala, 1981). For example, they lack basic amenities and have poor access to information and adequate levels of health care (Arize et al., 2021; Li, 2021). Cassarino et al. (2021) observed that, relative to other subgroups, individuals in low-income communities derive higher satisfaction from a higher perceived sense of safety. Furthermore, safety effects also interact with other city attributes such as access to transport. The provision of transport services may affect urban populations with lower socio-economic status who live in poorer areas less positively, as insecure environments may decrease the effective benefits of these services (Cassarino et al., 2021).

Since people from a lower socio-economic background might benefit more from improved access, for example, to educational support (Engin-Demir, 2009), and they are more vulnerable to various forms of shocks and hazards (Masozera et al., 2007; Zografos et al., 2016), it is of essence to understand the needs of different socio-economic groups in an urban context, as meeting such needs may build up resilience in the face of shocks (e.g. natural disasters and pandemics). Based on the existing findings on the heterogenous demand for urban amenities, we hypothesise that city dwellers display distinct preferences for urban living environment characteristics according to their gender, age and income levels. In order to test this hypothesis, a detailed statistical analysis of multivariate data on cities in Europe will be undertaken.

3 Data

To explore the impact of urban socio-economic heterogeneity on city liveability perceptions in different places, we need comparative databases. In this study, we use data from the Perception Survey on the Quality of Life in European Cities for our analysis. Conducted in 2019, the survey covered a total of 83 cities in 36 countries, including all capital cities of the sampled countries, except Switzerland. After cleaning the data and dropping observations with missing values in the key variables, the final sample consists of 30,747 resident observations, aged between 15 and 99. Among them, 50.6% are female. Table 4 in the Appendix lists all the sampled cities in this analysis.

The main variable, *satisfaction*, is a binary variable. It takes the value 1 if the respondents indicated that they strongly agreed or somewhat agreed to the statement that they were satisfied to live in their cities. We dichotomised the variable for an analytical reason: In a Shapely decomposition analysis, the (pseudo-)R^2 or the log-likelihood of a regression is commonly used as the metrics in the decomposition process (Deutsch et al., 2018; Manchin & Orazbayev, 2018). Since we observed that pseudo-R^2 has yielded more robust results than those using log-likelihood in a series of probit regressions,[1] and that there is no comparable measure for ordered logistic regressions, we used the dichotomised measure for analysis[2]

The analysis captures people's satisfaction levels or attitudes in relation to 14 features pertaining to the city of their residence. These variables are further grouped into seven dimensions, each of which captures an important aspect of city life. They

[1] By robustness, it means that the Shapley values are more stable across different models (e.g. OLS) and model specifications.

[2] Based on our data, results from models using log-likelihood tend to distribute Shapley values equally to all independent variables. In a robustness check in which *satisfaction* is treated as a continuous variable, the obtained Shapley values are close to those using pseudo-R^2 of a probit regression estimation.

are activity, mobility, human capital, security, government services, social trust and environment. *Activity* captures the type of activities which people can undertake in various forms of urban spaces. It has three items: sports facilities, cultural facilities and public spaces (e.g. markets). *Mobility* has only one item, transport. Similarly, *security* has one item, the perceived safeness of the city. *Human capital* comprises of two items: schools and health care. *Government services* has two items: costs and efficiency of administrative services. We use social trust as an indicator of social relations, as it is key to the dynamics of social relations (Schilke et al., 2021). The variable *trust* measures the perceived trustworthiness of the people in their cities. Finally, *environment* contains four items, namely, noise level, air quality, cleanliness and green spaces. Also included are the following control variables: *gender*, *age*, level of *education* (International Standard Classification of Education [ISCED]; levels 0–8), *income* level and the *population size* of a city (log-transformed). The description of the variables and the covariates, with their summary statistics, are reported in Table 1.[3]

4 Methods

The objectives of this study are twofold. The first is to identify the relative contribution of urban amenities or attributes to the variations in satisfaction to city life. The second objective is to examine how the relative importance of the attributes varies by the socio-economic backgrounds of the residents. While the heterogeneity is likely to be dependent on the urban governance, people, geography, environment, culture and history of a city, our objective is, as a first step, to identify them before they can be explained in future studies. In view of this, the findings from this study are fundamental. In this section, we discuss how the objectives can be met by employing a sequential design in the following way. We will employ a Shapley decomposition analysis (Sect. 4.1), followed by a Multidimensional Scaling approach (Sect. 4.2).

4.1 Shapley Decomposition Analysis

To identify the relative contribution of urban attributes to satisfaction with city lives, we compute the Shapley value of each attribute by decomposing the R-squared (R^2) of a regression model. Contemporary social science research has primarily focussed on the coefficient of regressors and defines the importance of a variable in terms of a regressor's statistical and economic significance. But for long already, statisticians have recognised that that is not the only way to quantify the impact of a

[3] The list is by no means exhaustive. However, as will be explained in the methodology section, Shapley decomposition is a permutation-based analysis which is computationally expensive. This limits the possibilities of expanding the set of attributes.

Table 1 Variable description and summary statistic

Dimension	Variable	Description	Range/Distribution	Mean	SD
–	Satisfaction	Feel satisfied to live in my city	0 (disagree)–1 (agree)	0.885	0.318
–	Satisfaction (original)	Feel satisfied to live in my city	1 (strongly disagree): 3.4% 2 (somewhat disagree): 8.1% 3 (somewhat agree): 38.8% 4 (strongly agree): 49.7%	3.349	0.769
Activity	Culture	Satisfaction with cultural facilities such as concert halls, theatres, museums and libraries	1 (very unsatisfied): 6.7% 2 (rather unsatisfied): 10.6% 3 (rather satisfied): 44.9% 4 (very satisfied): 37.8%	3.138	0.856
	Public spaces	Satisfaction with public spaces such as markets, squares, pedestrian areas	1 (very unsatisfied): 7.2% 2 (rather unsatisfied):15.4% 3 (rather satisfied): 51.0% 4 (very satisfied): 26.5%	2.967	0.840
	Sports	Satisfaction with sport facilities such as sport fields and indoor sports halls	1 (very unsatisfied): 9.6% 2 (rather unsatisfied): 16.8% 3 (rather satisfied): 47.3% 4 (very satisfied): 26.36%	2.904	0.897
Environment	Air	Satisfaction with the quality of the air	1 (very unsatisfied): 14.9% 2 (rather unsatisfied): 24.2% 3 (rather satisfied): 41.6% 4 (very satisfied): 19.3%	2.652	0.954
	Cleanliness	Satisfaction with cleanliness	1 (very unsatisfied): 14.8% 2 (rather unsatisfied):23.8% 3 (rather satisfied): 42.4% 4 (very satisfied): 19.0%	2.657	0.949

(continued)

Table 1 (continued)

Dimension	Variable	Description	Range/Distribution	Mean	SD
	Green spaces	Satisfaction with green spaces such as parks and gardens	1 (very unsatisfied): 8.5% 2 (rather unsatisfied):14.6% 3 (rather satisfied): 42.3% 4 (very satisfied): 34.6%	3.030	0.912
	Noise	Satisfaction with the noise level	1 (very unsatisfied): 13.5% 2 (rather unsatisfied):23.4% 3 (rather satisfied): 42.8% 4 (very satisfied):20.3%	2.698	0.941
Human capital	Schools	Satisfaction with schools and other educational facilities	1 (very unsatisfied): 7.6% 2 (rather unsatisfied): 13.3% 3 (rather satisfied):49.4% 4 (very satisfied): 29.8%	3.013	0.856
	Health care	Satisfaction with health care services, doctors and hospitals	1 (very unsatisfied): 12.3% 2 (rather unsatisfied): 17.7% 3 (rather satisfied): 41.5% 4 (very satisfied): 28.5%	2.863	0.966
Mobility	Transport	Satisfaction with public transport, for example, the bus, tram or metro	1 (very unsatisfied): 9.6% 2 (rather unsatisfied): 17.9% 3 (rather satisfied): 42.1% 4 (very satisfied): 30.5%	2.935	0.913
Government services	Efficiency	Satisfied with the amount of time it takes to get a request solved by my local public administration	1 (strongly disagree): 19.0% 2 (somewhat disagree): 23.9% 3 (somewhat agree): 37.2% 4 (strongly agree): 19.9%	2.579	1.011

(continued)

Table 1 (continued)

Dimension	Variable	Description	Range/Distribution	Mean	SD
	Costs	Fees charged by my local public administration are reasonable	1 (strongly disagree): 17.4% 2 (somewhat disagree): 23.8% 3 (somewhat agree): 39.7% 4 (strongly agree): 19.2%	2.606	0.984
Security	Safety	Feeling safe walking alone at night in my city	1 (strongly disagree): 9.1% 2 (somewhat disagree): 17.0% 3 (somewhat agree): 43.7% 4 (strongly agree): 30.2%	2.950	0.910
Social relations	Trust	Most people in my city can be trusted	1 (strongly disagree): 11.2% 2 (somewhat disagree): 22.3% 3 (somewhat agree): 49.1% 4 (strongly agree): 17.4%	2.727	0.878
City size	Population	Population size of the city, in logarithm	11.378–16.278	13.337	1.074
Individual characteristics	Gender	Female = 1	–	0.506	0.500
	Age	Age	15–99	46.185	17.399
	Education level	International Standard Classification of Education (ISCED)	0–8	4.339	1.746
	Income	Had difficulties to pay my bills most of the time within the last 12 months (1—most of the time; 2—from time to time; 3—almost never/never)	1–3	2.570	0.668

Notes For the distributions, sum of all categories may not equal to 1 due to rounding. SD stands for standard deviation. $N = 30{,}747$
Source of data European Quality of Life Survey (2019)

variable. One popular approach is a relative importance assessment based on variance decomposition. As R^2 of a regression model represents the fraction of the variance in the dependent variable explained or predicted by regressors, following the standard approach (Deutsch et al., 2018; Israeli, 2007), the relative contribution of a (set of) variable(s) can be measured by decomposing the R^2 of a regression model. While a typical regression analysis focusses on the marginal impact of a predictor, variance decomposition aims to assess the shares of influence that the variable contributes to the model. However, an assignment of relative importance can be challenging, because regressors in social science research are usually, if not always, correlated

(Grömping, 2007). In view of this, Chevan and Sutherland (1991) and Lipovetsky and Conklin (2001) applied the concept of Shapley value in game theory in trying to address this concern. The idea of their approach is to decompose the R^2 of a regression model by permutating the independent variables of the model. The Shapley value of a variable captures the average marginal contributions of that variable made to a metric measure (e.g. R^2) of all possible coalition models.

To illustrate the method, let us consider a hypothetical model with three independent variables, A, B and C, and a dependent variable Y. In this case, variable A can contribute to explaining the variations in Y in six ways. First, it can join variables B and C to form a 'coalition' to explain Y. In this way, the model contains all three variables. The complement of this coalition would contain only B and C. Accordingly, the marginal contribution of A can be captured by the difference of the R^2s between the two models (denoted as ΔR^2). Further, variable A can form a coalition with variables B and C in three other possible ways: (1) A with B, (2) A with C, and (3) A alone. The marginal contributions of variable A to the R^2s in these three cases can be calculated in a similar way. Note that a Shapley decomposition is a permutation-based method, which implies that we would count ABC and ACB as two different coalitions. Therefore, with 3 variables there are $3! = 6$ possible permutations for each variable.[4] In this example, the Shapley value of variable A is equal to the average of the six ΔR^2s.

Despite its popularity, R^2 is just one of the metric measures. Other possible measures, in the case of probit regressions, are log-likelihood and pseudo-R^2 (Israeli, 2007). Since our main dependent variable *satisfaction* is an ordinal variable, it can be modelled in three different ways: linear models (OLS), probit models (after dichotomising the variable) and ordered logistic models. Each model has its own metrics. As we noted in Sect. 3, among the three models, probit models with pseudo-R^2 give most robust results, and we will use them in the first part of the analysis. We will also normalise the Shapley values in each coalition game by the sum of the values. In this way, the sum will always equal to 1. This property would allow us to compare the relative importance of a variable across models.

To investigate how the relative importance of the attributes vary by the socio-economic backgrounds of individuals, we re-estimate the Shapley value of the 14 variables, by using only the relevant sample in a sequence of subgroup analyses. For instance, to compare the relative importance of an attribute between male and female, we use only observations from males or females as the sample to obtain the estimates. In the age subgroup analysis, the four age groups are 15–34, 35–54, 55–74 and 75 or above. Regarding economic status, responses regarding difficulties faced in covering costs have been shown to represent subjective well-being more accurately compared to actual income (Ala-Mantila et al., 2018; Haller & Hadler, 2006; Johnson & Krueger, 2006). Along similar lines, in our income subgroup analysis, the

[4] To enumerate, they are (1) ABC vs BC, (2) ACB vs CB, (3) AB vs B, (4) AC vs C, (5) A vs (BC), and (6) A vs (CB). Although the order of the variables does not produce a material difference in the calculation of the R^2 in cases (1) and (2), and in cases (5) and (6), Shapley decomposition is a permutation-based method, and we need to take them into consideration in the calculation. We use the Stata Module *Shapley2* by Wendelspiess Chávez Juárez (2015) to perform our analysis.

income groups are distinguished as follows: (1) people who had difficulties to pay their bills most of the time within the last 12 months; (2) people who had difficulties to pay their bills from time to time within the last 12 months, and (3) people who almost never or never had difficulties to pay their bills within the last 12 months. By comparing how the Shapley value of a variable varies across subgroups, we gain a better understanding of how people with diverse social economic backgrounds weight attributes differently.

As mentioned above, Shapley decompositions are computationally expensive. It is difficult to obtain results from a model with 14 features plus 13 covariates. Since our focus is on the seven dimensions, permutations were undertaken at the block level in our analysis. It means that coalitions will be formed among categories instead of individual variables. This leaves us with a coalition game among nine groups of variables (i.e. the seven categories, city population and individual variables; see Table 1 for the grouping). While intra-group distributions are interesting and may give us a better idea how policymakers can improve the liveability of a city, in our initial analysis we found that the distributions between variables within a category are relatively even. Consequently, we opted for a design that features more dimensions but less details within them. This decision also leads us to more interesting results in the city-level analysis (see below). Nevertheless, we present the results from the initial analysis in the Appendix (Table 5).

4.2 Multidimensional Scaling

The next step entails repeating the decomposition procedure, using resident observations from each of the sampled city. This procedure yields 83 sets of Shapley values, one set for each city. Since there are fewer observations for each city, and we found that OLS models using the component variables tend to fit the data better by yielding higher statistical significance for the models, we decided to use OLS models in our estimation for this part of the analysis. To reduce computational costs, we will use the models with only the 14 variables as the benchmark in this city-level analysis.

Henceforth, we will refer each set of Shapley values—seven values for each city—as a city profile. In this part of the analysis, we map the relative positions of cities based on profile similarities. Two cities are said to be similar when they have similar profiles. Since each profile is comprised of seven numbers, it is impossible to visualise them in a seven-dimensional space, and hence some form of data reduction is required. Multidimensional scaling (MDS) fits these purposes well. MDS is a widely used data-analytic technique to represent *similarities* among units as *distances* in a Cartesian space. In brief, we reduce the dimensions from seven to two using a principal component analysis (PCA) of the correlation matrix of the city profiles in order to visualise their differences. Although city clusters can be identified, it should be noted that the data reduction process may render the x- and y-axes not directly interpretable, as they are factors produced by a PCA (Greenacre, 2010).

5 Empirical Findings

5.1 General Findings

In our empirical analysis, we first look at how the relative importance of the seven higher dimensions varies, according to the voices of sampled residents from the 83 cities. In this first model, we regress *satisfaction* on *activity*, *environment*, *human capital*, *mobility*, *government services*, *social relations* and *security*, alongside with *gender*, *age*, *education level*, and *city size* as covariates. Table 2 reports the results of the probit estimation. All attribute variables have a statistically significant association with the dependent variables and carry expected signs. The pseudo-R^2 of this model is 0.214. From Table 2, there is no direct relationship between the number of variables in a category and its Shapley value. It is also clear that, for their low relative importance, demographic controls and city size do not account for much variation in the level of satisfaction. Among the seven categories, environment is the most important. The second and the third most important categories are activity and human capital. Among the seven categories, 'local government services' is the least important. The results suggest that much of the variation in city life satisfaction is related to environmental quality and green spaces like parks, followed by other public amenities such as shops, schools, health care facilities and transport. Individual characteristics do not account for much variation in satisfaction.

5.2 Comparisons Across Social Economic Groups

Do people of various social economic groups value the above-mentioned attributes differently? We re-estimated a similar model by using only the relevant sample, net of the corresponding social group variable (e.g. the gender variable was dropped from the gender subgroup analysis). The estimation results are summarised in Table 3.

Interestingly, the estimation results in Table 3 suggest that the relative importance of the evaluated dimensions is quite similar and consistent. In general, environmental factors are consistently ranked high and accounts for about 25% of the variations in satisfaction. The second most important dimension is activity. Human capital appears to rank third. The relative importance of the other dimensions is less predictable, but it appears that efficiency and costs of government services are less important than the rest.

Some subtle differences however exist. Focussing on the first panel about age, we notice that the preference of older adults is quite different from people of the other age groups. To them, government services, usually the least important item, are highly important, much more than, for example, security. This is reasonable, given the reduced demand for outdoor activities for this group of people. Security is also less important for them, while social trust, which is usually less important

Table 2 Probit estimates and estimated Shapley values

Variable	Coefficient	SE	Category	Shapley value	Relative importance (%)
Transport	0.113***	0.012	Mobility	0.020	9.22
Health care	0.076***	0.012	Human capital	0.029	13.58
Schools	0.119***	0.013			
Public spaces	0.083***	0.013	Activity	0.035	16.36
Sports	0.084***	0.012			
Culture	0.093***	0.013			
Green spaces	0.114***	0.012	Environment	0.052	24.51
Air	0.120***	0.012			
Noise	0.061***	0.012			
Cleanliness	0.080***	0.012			
Safety	0.159***	0.012	Security	0.023	10.89
Efficiency	0.061***	0.011	Government services	0.018	8.47
Cost	0.066***	0.012			
Trust	0.133***	0.013	Social relations	0.019	9.03
Female	0.039*	0.021	Control	0.014	6.33
Age	0.002***	0.001			
Education (9 categories)	(Results Omitted)				
Income (3 categories)	(Results Omitted)				
ln(Population)	−0.022**	0.01	City size	0.003	1.61

Notes SE stands for robust standard errors. The dependent variable is satisfaction of city life (satisfied = 1; 0 otherwise). ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$; $N = 30{,}747$; pseudo R-squared = 0.214. p-values for the coefficients of the education variables are not significant at the 10% level. p-values for the coefficients of the income variables are significant at the 1% level

for people in other age groups, carries a substantial weight as well. For older adults, environment quality remains the most important, a finding distinct from Wong et al. (2021). Findings related to younger people's preference for recreational facilities, captured by the item activity, are similar to what was reported in Andersson et al. (2018).

The preferences between the two genders are largely similar, except that males value government services more than females, while females value mobility and security more than males. If we compare the distributions by age group, the weights are highly similar. This echoes the findings reported in Reynolds and Weinstein (2021), who find that the two sexes have similar demands for natural amenities. However, the importance of recreational and cultural facilities, as well as human

Table 3 Normalised Shapley values of the seven categories, by social economic groups

Group	Mobility	Human capital	Activity	Environment	Security	Government services	Social relations
Age							
15–34	11.77	14.78	18.78	27.85	11.36	7.69	7.77
35–54	8.20	14.98	17.66	26.66	12.40	10.29	9.80
55–74	10.26	14.10	17.32	25.36	13.76	7.92	11.27
75+	9.50	12.18	16.69	23.92	6.24	17.11	14.36
Gender							
Male	8.60	14.84	18.41	26.47	11.19	10.26	10.22
Female	11.50	14.52	17.02	26.86	12.48	8.26	9.35
Income (had difficulties to pay bills)							
Often	9.99	12.15	14.30	27.21	15.07	12.22	9.05
Sometimes	11.91	16.86	16.58	26.72	10.99	6.21	10.74
Never	8.82	13.98	19.14	28.68	11.56	8.87	8.94

Notes Reported are normalised Shapley values which are sum to 1 across columns. There may be small deviations due to rounding error. Estimates of the Shapely value are based on probit models with the binary dependent variable, satisfaction of city life (satisfied = 1; 0 otherwise), using sample with socio-economic characteristics specified under column 1. Model specifications are similar to the one in Table 2, with the corresponding socio-economic characteristic variables dropped (e.g. the age group variables are dropped when the sample is restricted to people aged between 15 and 34)

capital, are comparable between the two sexes, a finding that seems to differ from Whisler et al. (2008) and Bobonis (2009).

Finally, regarding income level, environmental quality again ranks high relative to the other concerns, as is proposed and reported by Lee and Lin (2018), who showed that natural amenities can be a strong predictor of neighbourhood dynamics and may explain the spatial distribution of income in cities. We also found that people with higher economic status assign a higher weight to natural environment. The same holds for the activity cluster, which includes items such as cultural facilities and markets. For people who are financially in good shape, they tend to value these consumption amenities in their cities more than people with a lower income, a finding consistent with Glaeser et al. (2001). Regarding the urban poor, people who are often confronted with difficulties to pay their bills (i.e. lower income levels) value security more than people at higher income levels. As low-income households tend to stay in deprived neighbourhoods, which are usually characterised by a high crime rate (Fransham, 2019; Livingston et al., 2014), this may explain their concerns. In fact, Cassarino et al. (2021) showed that individuals living in deprived neighbourhoods gain higher satisfaction from security. Finally, urban poor also care more about quality of government services. This might be explained by the importance of welfare assistance to this group of people.

5.3 Comparisons Across Cities

If we wish to make a city more liveable, we need to know which aspects of the city make the people living there satisfied with their lives. Cities have their own characteristics, which nurture and attract people with distinct backgrounds and preferences. This section compares the profiles of Shapley values across the sampled cities, and hence, it characterises cities by showing how different categories of features are related to the level of satisfaction of the residents using classical multidimensional scaling (MDS).

Figure 1 graphically represents cities on a two-dimensional plane. The percentage of variance accounted for is 53.2%, with 34.0% on the first dimension and 19.2% on the second dimension. In the figure, the dots represent cities and the distance between them are approximations of the pairwise dissimilarities between cities, based on their profiles after a PCA. With few exceptions, the graph places cities with higher average levels of satisfaction on the outer part. Cities with smaller proportions of people satisfied with their city lives are concentrated in the inner circle. From Fig. 1, we do not detect an obvious relationship between geographical proximities and profile similarities, suggesting that people from the same regions (e.g. Benelux) do not 'like' their cities in similar ways. For example, while Amsterdam is positioned in the top-left quadrant of the graph, Luxembourg is located in the middle part, and Liège and Antwerp are placed at the bottom of the map. A similar kind of dispersion can be observed at the country level. Take the United Kingdom as an example: Manchester is on the left-hand side of the data cloud, while Cardiff is on the far right. London is in the middle, whereas Belfast is in the bottom. The pattern seems to suggest that there are some divisions of labour between cities within a country. Cities in countries that display this kind of pattern seem to develop distinct characters and excel in some selected dimensions. The opposite is observed for Turkey: Ankara, Antalya and Istanbul are relatively close to each other. This may reflect that people in the country have similar preferences when compared with other sampled cities. Another plausible explanation is that these are larger cities in terms of both population and geographical area. In turn, preference and demand are more diverse. On average, since no dimension is substantially worse than the others, no single dimension under- or out-weights the others in explaining variations in city satisfaction.

To gain a better understanding about what the dimensions capture and in which way cities are similar, we added the category axes to Fig. 1. The resulting MDS biplot is based on the average satisfaction scores in each of the seven categories, using observations in the same data set. We normalised the scales of the variables, so that the values are always between zero and one, which make the category scores insensitive to the original scale, and hence they are comparable. With the added scales, this graph provides us with the approximated satisfaction levels for each feature in a city. The plot is presented in Fig. 2.

The direction and the length of each vector indicate the relative scale of the variable. For example, the activity vector points to the south direction, it means that cities located further south of the map have a higher approximated Shapley

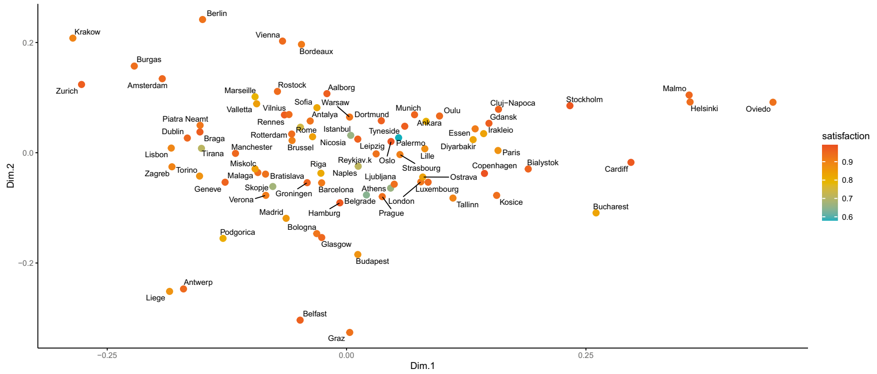

Fig. 1 Two-dimensional representation of city similarity. *Notes* Colour palette on the right represents the average level of satisfaction in each city. Dimensions 1 and 2 in the figure are calculated using classical multidimensional scaling, based on city-level Shapely values

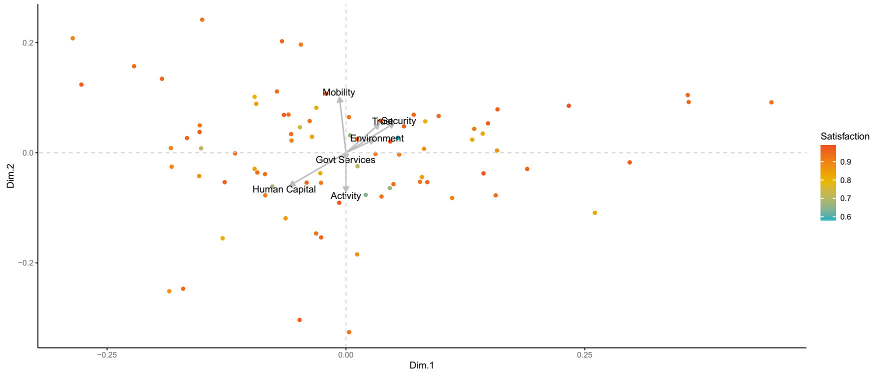

Fig. 2 MDS biplot of 83 cities with seven categories of features. *Notes* Colour palette on the right represents the average level of satisfaction in each city. Dimensions 1 and 2 in the figure are calculated using classical multidimensional scaling, based on city-level Shapely values. City labels are identical to the ones in Fig. 1 but omitted for clarity reasons

value in the activity dimension, signifying that people living in those cities consider activity important in explaining their satisfaction with their urban lives. The length of the vector informs us on the variance in the projections. Although the vectors for the government services and activity are pointing to the same direction, a longer vector for activity means that the same unit movement in the map represents a larger movement in the activity dimension than in the government services dimension. Finally, dimensions which are positively correlated will have their vectors pointed to a similar direction. Independent dimensions are perpendicular to each other.

Consider the human capital dimension. From Fig. 2, we can infer that human capital is relatively more important to people living in Antwerp and Zurich than to people living in Oviedo in explaining their satisfaction with the city. However, the reverse is true for security, social trust and environmental quality. Note that the figure does not say that schools and health care facilities are of lower quality in Oviedo. It just tells us that they are less important factors in explaining satisfaction there. And for Antwerp and Zurich, a high valuation of health care and education captures some of the defining features of liveability for people residing there. Finally, it should also be noted that the two axes account only for about 53% of the variations. The approximations, therefore, are subject to a high degree of uncertainties after dimension reduction.

The direction of the vectors in Fig. 2 seems to suggest that people define liveability in roughly four dimensions: one related to mobility, one to human capital, one to government services and activity, and one to other qualities such as trust, environment and security. Mobility is an important dimension for people living in cities placed in the north position of the graph. Factors in the activity category (i.e. public spaces and cultural and sports facilities) are less important to them, as it points to the direction opposite to mobility. Since these factors are about public services (e.g. transport, government services, markets, sports facilities), the vertical dimension seems to capture the hardware of a city. In contrast, factors on the horizontal (or the 45-degree) dimension capture more abstract demands—namely, security, human capital, social trust and environment quality—for a city. This is consistent with the body and soul framework analysed in Kourtit et al. (2021c, 2022) and Wahlström et al. (2020).

It is also interesting to note that cities with a relatively lower level of satisfaction are concentrated in the middle part of the map (e.g. Athens, Istanbul, London and Rome). These metropolitan cities, along with some cities in Italy and eastern Europe, are densely populated. Therefore, one potential explanation to this ‘unhappy’ result is that, given by the large surface area and population, demands for public amenities are likely to be highly diverse. Heterogeneous forces pull the cities in all four directions, rendering it not only difficult to make everyone satisfied but also difficult to provide and manage the public amenities with high quality.

5.4 Implications and Limitations

What are the implications of our findings in relation to the enhancement of liveability and the reduction of socio-economic discrepancies? As Fig. 2 suggests, although perceptions are diverse across cities and it is difficult to generalise, policymakers may identify people’s preferences and satisfy their demands accordingly, depending on people’s relative preferences for facilities (e.g. recreational facilities) and other less tangible demands (e.g. environmental qualities). Furthermore, as Table 2 shows, in relative terms, environmental quality and leisure facilities are highly valued among residents in European cities. Policymakers may prioritise these demands over others. If the policy objectives are to mitigate discrepancies, based on the findings reported in Table 3, major discrepancies appear to occur mainly among people of different age groups, especially between the younger and the older generations, and between people with a higher and a lower income. In this case, identifying common denominators become important. Based on our findings, again, environmental qualities are major concerns. Overall, our findings suggest that policymakers should invest more on environmental qualities, whether the goals are to enhance liveability or to reduce discrepancies in city life satisfaction.

One major limitation of the study is that it does not consider temporal changes in perception. Innovations create new demand, and new urban challenges emerge from time to time. The outbreak of the COVID-19 pandemic, for example, may induce higher demand for health care facilities. The cross-sectional data and limited space do not allow us to further explore the dynamics sufficiently, as it would entail a conceptual framework different than the city life exposited in Kourtit et al. (2021c). Future research in this area is needed. Secondly, while we included as many variables as they are available in the survey, they are by no mean exhaustive. Important amenities such as information and communications technology (ICT) infrastructure and banking services are not included in the survey and hence the analysis. Their inclusion may affect the key findings presented in this study. Thirdly, though limited, the relatively large number of amenities included in the decomposition analysis forces us to group public amenities in category in order to overcome computational limitations. Our findings are plausibly influenced by the reported categorisation.

6 Conclusion

Modern cities form a complex and heterogeneous amalgam of different socio-economic groups enjoying different living environments. This study aimed to discover the urban attributes that are most relevant to specific urban socio-economic subgroups. Our investigation uncovers a remarkable level of unity in diversity. Satisfactions in natural environment and such public amenities as shops, schools, hospitals and cultural facilities substantially affect the life satisfaction of European city dwellers. To them, a liveable city needs to perform well in these dimensions. Other factors like transport and administrative services, though essential, are relatively less important than other public amenities. Although the differential preferences, needs and demands for urban necessities have been well-documented in the literature, the high level of consistency might not be as surprising as it first appears, as some previous studies have identified a similar pattern. Reynolds and Weinstein (2021), for instance, have found commonality in preferences between males and females for many location-based amenities using data from the United States. Nevertheless, as we have reported, slightly greater differences do exist across income and age groups.

In a recent study on city love, Kourtit et al. (2022) show that levels of city love are significantly different between city districts in Rotterdam, which could be related to the heterogeneous socio-economic and demographic structure of the city. Our findings lend further empirical support to this hypothesis at the city level in Europe. Results from our decomposition analysis further suggest that, while both the body and the soul of a city are important, the body of the city, in terms of its natural environment, seems to have a great potential to bridge divergences in city love across different social subgroups. In other words, an improvement in the urban environment might mitigate the heterogeneity in city love or happiness across social groups.

The need of in-depth and meticulous examination of the needs of the socio-economically disadvantaged city dwellers has become even more relevant when the COVID-19 pandemic overhauled the world. The detection and quantification of variations due to socio-economic attributes with regard to the needs of urban characteristics may potentially help the development of specific urban policies towards targeted vulnerable groups. This chapter serves as a gateway to open avenues for further in-depth research in these areas. Only when cities become more equal and inclusive, as the New Urban Agenda envisages, they can remain to be a liveable place of aspirations and societal progress for all.

In the context of the New Urban World (Glaeser et al., 2020; Kourtit et al., 2013), cities tend to become bigger while the number of cities tend to rise as well. This mega-trend holds for both medium-sized and large cities. In the light of this structural urbanisation of our planet, an inclusive urban policy aiming at mitigating sharp intra-urban socio-economic discrepancies seems to be pertinent. Urban well-being and urban happiness research (including city love research) has to be pursued in close association with socio-economic heterogeneity in cities. Liveable cities of the future should seek to combine city love with socio-economic equity.

Finally, socio-economic heterogeneity and disparity does not only need solid statistical investigations from a macro-urban perspective, but should also address the underlying individual and social layers that shape inequality in liveability. Consequently, a decomposition of research on urban liveability is needed with a particular focus on district, neighbourhood, street and even individual level, so as to map out and explain the determinants of well-being from a micro-cosmic angle. This calls also for advanced statistical and spatial econometric modelling efforts (nowadays called 'urbanometrics'). It seems likely that such urbanometric modelling experiments (taking into consideration geographic autocorrelation phenomena at the subcity level, e.g. neighbourhoods on streets) will be able to shed new quantitative light on complex and interwoven urban liveability challenges.

Appendix: Sample of Cities

See Tables 4 and 5.

Table 4 List of cities

Country	City
Albania	Tirana
Austria	Graz, Vienna
Belgium	Antwerp, Brussel, Liège
Bulgaria	Burgas, Sofia
Croatia	Zagreb
Cyprus	Nicosia
Czech Republic	Ostrava, Prague
Denmark	Aalborg, Copenhagen
Estonia	Tallinn
Finland	Helsinki, Oulu
France	Bordeaux, Lille, Marseille, Paris, Rennes, Strasbourg
Germany	Berlin, Dortmund, Essen, Hamburg, Leipzig, Munich, Rostock
Greece	Athens, Irakleio
Hungary	Budapest, Miskolc
Iceland	Reykjavik
Ireland	Dublin
Italy	Bologna, Naples, Palermo, Rome, Turin, Verona
Lithuania	Vilnius
Luxembourg	Luxembourg
Latvia	Riga
Malta	Valletta
Montenegro	Podgorica
Netherlands	Amsterdam, Groningen, Rotterdam
North Macedonia	Skopje
Norway	Oslo
Poland	Białystok, Gdańsk, Kraków, Warsaw
Portugal	Braga, Lisbon
Romania	Bucharest, Cluj-Napoca, Piatra Neamț
Serbia	Belgrade
Slovakia	Bratislava, Košice
Slovenia	Ljubljana
Spain	Barcelona, Madrid, Málaga, Oviedo
Sweden	Malmö, Stockholm

(continued)

Table 4 (continued)

Country	City
Switzerland	Geneva, Zurich
Turkey	Ankara, Antalya, Diyarbakır, Istanbul
United Kingdom	Belfast, Cardiff, Glasgow, London, Manchester, Tyneside

Table 5 Shapley values of individual variables in an eleven-variable game

Category	Variable	Shapley value (normalised)
Activity	Cultural facilities	7.12
	Sports facilities	7.13
	Public spaces	7.64
Environment	Air quality	10.12
	Cleanliness	9.32
	Noise level	6.35
	Green spaces	10.96
Human capital	School	9.19
	Health care	8.12
Mobility	Transport	10.39
Security	Safety	13.68

Notes Reported are normalised Shapley values with row sum equal to 1. There may be small deviations due to rounding error. Estimates of the Shapely value are based on probit models with the binary-dependent variable, satisfaction of city life (satisfied = 1; 0 otherwise); $N = 30{,}747$. The specification of the probit model is similar to the one in Table 2 without grouping in permutations

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