KIT SCIENCE WEEK 2025

URBAN.KIT

CLIMATE PROTECTION AND ADAPTION

URBAN GOVERNANCE AND PLANNING

URBAN TRANSFORMATION

MOBILITY AND URBAN SPACE

CONNECTING URBAN SUSTAINABILITY LABS

CONFERENCE BOOK

ENERGY AND DIGITALIZATION

WATER AND URBAN ECOLOGY

RESOURCES, BUILDING, CONSTRUCTION

The conference is part of the KIT Science Week 2025, which is made possible through the funding and support of:

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Urban Transformation –

Connecting Urban Sustainability Labs

Conference Book

Contents

1 Introduction: Challenges of Urban Transformation

Cities all around the world—whether in growing metropolitan areas, shrinking regions, or rural areas—face pressing challenges. These include climate change, biodiversity loss, resource scarcity, migration, demographic change, pandemics, and rapid economic change. Issues such as sustainable land use and construction, the mobility transition, climate protection, biodiversity, migration, and social cohesion demand bold, innovative, and transformative approaches. In addition, digital technologies are profoundly changing our lives. Numerous studies, as well as political declarations of intent such as the 2030 Agenda for Sustainable Development from 2015, the WBGU's main report from 2016, the New Leipzig Charter adopted in 2020, and the EU's Green Deal, among others, refer to these diverse, complex, and highly pressing tasks. The dynamics and scale of urbanization processes highlight the major challenge for urban research: to use scientific methods to shape the complex development of urban spaces, infrastructures, and communities in such a way that they can also cope with future developments that cannot be accurately predicted.

Climate Change and Shortage of Resources

Climate change is evident in many urban areas in the form of heat island effects, heavy rainfall, storms, flooding, and air pollution. Cities must find ways to combat climate change and resource scarcity; in particular, they must become more energy-efficient and environmentally friendly. In order to reduce CO2 emissions in the construction sector, existing settlements and infrastructure must be rebuilt and developed in an economically and socially responsible manner, and urban green spaces must be preserved and expanded, along with other adaptation measures. The challenge for urban planning here is to adapt existing cities to changing conditions and requirements in a sustainable manner.

Housing Supply and Social Services

One of the main responsibilities of cities is to provide all social groups with equal access to education, social services, healthcare, urban green spaces (recreational areas), and culture. The provision of adequate, safe, and affordable housing and energy supplies must be tailored to the needs of different social groups—with a variety of household types, lifestyles, social and ethnic groups, and generations.

Land Policy

Land, its availability, and use play a central role in socially and sustainably oriented urban development. The consequences of linking local land markets with international financial markets are widespread land speculation with sharply increased land, real estate purchase, and rental prices in large cities, but also in rural areas. The ongoing use of agricultural land for new residential and commercial areas runs counter to the goal of sustainable land use. An important area of action for cities is therefore a sustainable land and soil policy that favors internal development over external development and enables polycentric, compact settlement structures and mixed uses in neighborhoods in order to reduce mobility costs, among other things.

Mobility and Infrastructure

People's need for mobility remains unabated. In conurbations in particular, motorized private transport (MPT) as well as buses and trains are increasingly reaching their capacity limits. Conflicts over the use of limited road and traffic space are intensifying, and traffic emissions that are harmful to health and the environment, such as noise, CO2, NOx, and particulate matter, are on the rise. In order to initiate the urgently needed transport transition, sustainable transport concepts are needed that are tailored to the needs of their residents and provide sufficient infrastructure. They must be planned and implemented in a sustainable and climate-friendly, healthy and attractive, inclusive and fair manner. The further development of e-mobility and autonomous driving with the necessary infrastructure, coupled with the possibilities of digitalization, enable convenient services with new mobility services and, at the same time, must be viewed as a major (technical) political challenge.

Digitalisation and Artificial Intelligence

Digitalisation processes are also changing the framework conditions for urban development in the areas of planning and construction of buildings and technical infrastructure systems, in the operation and conversion of built structures, and in social interaction. At the same time, digitalization brings with it new fundamental challenges, such as the digital divide in society, questions of data protection and data security, and market dependencies. At the same time, artificial intelligence as a tool for urban development can help improve quality of life, strengthen participation, and make local government more efficient. One of the challenges is to continuously update, structure, and intelligently link growing amounts of data and to further expand digital skills in administration and (municipal) companies.

Urban Governance

Due to the sectoral organization of sovereign planning administrations on the one hand, but also due to the lack of practical application of scientific findings on the other, it is often not easy for cities and municipalities to translate the results of urban research into effective and binding plans. Municipalities must be enabled to take on and overcome the challenges they face. To do so, they need suitable legal and financial frameworks, the latest scientific findings and methods/software, qualified personnel, and control and design authority over public services, such as public utilities. The challenges outlined above require massive changes in urban structures, organizational, management, and governance processes and cultures, as well as a rethinking or integrated restructuring of the mechanisms of planning and control of settlement areas. This requires a critical review of everyday planning practices, but also the realignment and redesign of training profiles and, last but not least, our lifestyles and economic practices.

Social Cohesion and Participation

Cities are places of social interaction, where much of everyday life takes place. Cities shape the experiences and horizons of many people. Cities play an important role, not only but especially against the backdrop of current developments such as social division, isolation, alienation, polarization, and de-democratization. They enable or prevent social interaction, or direct it, and can thus contribute significantly to social cohesion and participation—or not. Spaces, including public spaces, in today's cities are often shaped by capital, commerce, and private ownership. The essence of communities, the communis, the coming together and meeting halfway, often finds little space and expression. In the future, there will be a need for places, spaces, and occasions to enable encounters, understanding, and social participation, as well as opportunities for self-efficacy and empowerment. In addition to places and spaces, it is also important to design the corresponding processes well and appropriately. Poorly designed or insincere urban participation processes lead to frustration rather than participation and experiences of self-efficacy. It is also important to integrate participation well and closely into administrative action, or to try out new forms of urban governance with other democratic elements (e.g., in "real-world laboratories"). Social cohesion and participation ultimately also promote the resilience of cities and make them socially crisis-proof, especially in times of dwindling growth and experiences of loss.

Urban Transformation – Connecting Urban Sustainability Labs

The conference focuses on the challenges for urban sustainability transformation in a local and international context. It builds on the concept of transformative teaching and research, as envisioned by the German Advisory Council on Global Change (WBGU) in 2011 in its call for a "Great Transformation" – a shift in economy, society, and culture to achieve sustainability. A key focus will be on real-world laboratories, where representatives will share their experiences and reflect on the outcomes of their transdisciplinary projects. In this learning conference, we aim to connect urban labs that actively work on transformative topics, whether they have achieved success or encountered valuable setbacks. The conference brings together a global network of participants, young academics and experienced researchers, scientists, policymakers, decision-makers, urban practitioners, and engaged citizens to explore and discuss the latest trends, challenges, and opportunities in urban transformation. By sharing documented experiences, challenges, and breakthroughs, we foster an open exchange to accelerate urban sustainability together.

2_Conference Programme

Wednesday, October 15th, 2025

10.00 - 12.00	**Excursion to Selected Areas in Karlsruhe**	Meeting point: entrance bldg.11.40
12.00 - 12.30	**Registration** Come Together + Coffee	Tulla exhibition hall, Room 003
12.30	**Welcome and Introduction** Thomas Hirth, Vice President KIT Conference Team	Tulla lecture hall, Room 103
13.00 - 14.00	**Keynote „Real–world Labs for Urban Transformation“** Uwe Schneidewind, Lord Mayor of the City of Wuppertal	Tulla lecture hall. Room 103
14.00 - 15.00	**Plenary 1 – Discovering Urban Sustainability Labs Worldwide** Miji Africa Living Lab, Nairobi Quartier Zukunft – Labor Stadt (District Future – Urban Lab), Karlsruhe Zone Atelier Environnementale Urbaine (ZAEU), Strasbourg ACI Medellín Lab / EDU, Medellín	Tulla lecture hall, Room 103
15.15 - 17.30	**Parallel Workshop Session A** Workshop Session (Round 1) 15.15 – 16.15 Coffee Break 16.15 – 16.30 Workshop Session (Round 2) 16.30 – 17.30 01 - Lab in Discussion: Miji Africa Living Lab, Nairobi 02 - Lab in Discussion: District Future – Urban Lab, Karlsruhe 03 - Lab in Discussion: Zone Atelier Environnementale Urbaine (ZAEU) 04 - Lab in Discussion: ACI Medellín Lab, EDU Medellín 05 - Accelerating Climate-neutrality through Co-creational Pilot Projects 06 - Governance in and for the Anthropocene 07 - Decarbonising and Smart Cities Integration 08 - Resilient Regenerative Urban Economies 09 - Connecting People 10 - Co-Creation and Co-Strategy for Innovative Mobility Solutions 13 - Healthy Cities, Urban Health and One Health	Studio a-h Room 013, 026
17.30 - 18.30	**Coffee & Contacts**	Tulla exhibition hall, Room 003
18.30 - 19.30	**Keynote in Dialogue: Challenges in Urban Futures** Maria Vassilakou, Vienna Solutions, Vienna Hannes Rockenbauch, Linke SÖS Plus, Stuttgart	Tulla lecture hall, Room 103
19.30 - 22.00	**Get together** Fingerfood + Drinks	Tulla exhibition hall, Room 003

Thursday, October 16th, 2025

9.00 - 9.15	**Welcome and Introduction** Conference Team	Tulla lecture hall, Room 103
9.15 - 10.30	**Plenary 2 – Discovering Urban Sustainability Labs Worldwide** Grüne Stadt der Zukunft (Green City of the Future), Munich Interdesciplinary Centre for Transformative Urban Regeneration, Görlitz Community Schloss Tempelhof (Ecovillage), Kreßberg CLIMAS, Vilnius National Laboratory of Sustainability Sciences (LANCIS), Mexico City	Tulla lecture hall, Room 103
10.45 - 13.00	**Parallel Workshop Session B** Workshop Session (Round 1) 10.45 – 11.45 Coffee Break 11.45 – 12.00 Workshop Session (Round 2) 12.00 – 13.00 01 - Lab in Discussion: Green City of the Future, Munich 02 - Lab in Discussion: Interdisciplinary Centre for Transformative Urban Regeneration, Görlitz 03 - Lab in Discussion: Community Schloss Tempelhof, Kreßberg 04 - Lab in Discussion: CLIMAS, Vilnius 05 - Lab in Discussion: National Laboratory of Sustainability Sciences (LANCIS), Mexico City 07 - Neighbourhood Energy Transition 08 - Inclusive Urban Transformation. Creating NEBourhoods together 09 - Inclusive Urban Development 10 - Social Innovation 11 - Experimenting for Sustainability envisioning Rur:ban Futures 12 - Grassroots Urbanization - for Sustainable Urbanism in Africa 13 - Securing Liveability of Cities and Increasing Disaster Preparedness	Studio a-h Room 013, 026
13.00 - 14.00	**Get together** Fingerfood + Drinks	Tulla exhibition hall, Room 003
14.00 - 16.00	**Young Researchers Forum** From Science to Urban Transformation Lightning Talks and Comments	Room 013, 026, 202, 214, 221, 231
16.00 - 17.00	**Poster Session** Networking, Market of Opportunities	Tulla exhibition hall, Room 003
17.00 - 18.00	**Get together** Fingerfood + Drinks	Tulla exhibition hall, Room 003
18.00	**Departure**	Tulla exhibition hall, Room 003
19.00	**Panel Discussion** 13 Questions - A Culture of Debate on the Playing Field: Autonomous Driving in Local Transport: Rescue or Risk?	Tollhaus, Alter Schlachthof 35, 76131 Karlsruhe

Friday, October 17th, 2025

9.00 - 9.30	**Welcome and Introduction** Conference Team	Tulla lecture hall, Room 103
9.30 - 10.30	**Plenary 3 – Discovering Urban Sustainability Labs Worldwide** Living Lab Herk and Mombeek, Brussels StadtManufaktur (Urban Manufacturing), Berlin aspern.mobil LAB, Vienna City as a Living Laboratory (CALL), New York	Tulla lecture hall, Room 103
10.45 - 13.00	**Parallel Workshop Session C** Workshop Session (Round 1) 10.45 – 11.45 Coffee Break 11.45 – 12.00 Workshop Session (Round 2) 12.00 – 13.00 01 - Lab in Discussion: Living Lab Herk & Mombeek, Brussels 02 - Lab in Discussion: StadtManufaktur, Berlin 03 - Lab in Discussion: aspern.mobil LAB, Vienna 04 - Lab in Discussion: City as a Living Laboratory (CALL), New York 05 - 1x1 der Energiewende im Quartier (DE) 06 - New Learning and Action Spaces 07 - Urban Water Bodies|An EUCOR –The European Campus Joint Event 09 - Mobility Transformations in Suburban and Rural Areas 10 - Making Cities ready for AI 13 - Social Justice & Access	Studio a-h Room 013, 026
13.00 - 13.30	**Closing of the Conference** Conference Team	Tulla lecture hall, Room 103
13.30 - 14.00	**Farewell** Fingerfood + Drinks	Tulla exhibition hall, Room 003
14.00 - 16.00	**Excursion to Selected Areas in Karlsruhe**	Meeting point: entrance bldg.11.40

3 Keynotes

„Real–world Labs for Urban Transformation“
Prof. Dr. Uwe Schneidewind

Since November 2020 Uwe Schneidewind is the lord mayor of Wuppertal. From 2010-2020 he was President and Scientific Managing Director of the Wuppertal Institute for Climate, Environment, and Energy, as well as professor for Sustainable Transition Management at the University of Wuppertal. From 2004 – 2008 he was President of the University of Oldenburg. He wrote his PhD and habilitation at the University of St. Gallen, Switzerland. Beside other former memberships Uwe Schneidewind is member of the Club of Rome

Mission Possible - 7 Pathways Towards Successful Urban Transitions
Maria Vassilakou

Thousands of cities across the globe have embarked in ambitious transformation processes. Yet, robust strategies and holistic action plans often face considerable challenges when moving towards implementation. Innovative approaches and excellent research results may never reach beyond first pilot projects. How can we move from pilots to scale? Managing transitions successfully requires new approaches and „tools“ addressing capacity limitations, activating local communities, mitigating risk and steering large-scale processes while „translating“ them into manageable local action plans. Urban Labs are key to sustainable local transformation but they can only unravel their full potential when integrated into systemic change processes, combining testing and experimenting with collaborative governance structures, tools facilitating community action, policy innovation and legal tools easing procurement and investment. Even the smallest of interventions may lead to significant impact when connected to form multiple layered networks spanning across a city. Thinking „big", acting „here“, planning long-term, connecting the „dots" to networks but most importantly building, supporting and steering local and regional eco-systems, are only some of the elementary steps required to take us forward. This keynote will look into 7 pathways towards successful urban transitions.

Maria Vassilakou works internationally as a consultant for urban transformation strategies and transition management with cities and municipalities, educational institutions, international NGOs, multilateral organisations and companies. Previously, she held the office of Vienna's Deputy Mayor for Urban Development, Urban Planning, Transport, Climate Protection, Energy Planning and Citizen Participation (2010-2019). During her 9 years in office, she was responsible for an ambitious and successful transformation agenda with numerous innovative projects, including the introduction of the €365 annual pass for public transport (which led to a considerable shift in the modal split in favour of ecological mobility), several pedestrian zones and shared space projects, new ways of citizen participation and self-organisation of communities, the conversion of several former railway, hospital and industrial sites into new modern districts, the creation of citizen solar power plants and much more. She was responsible for developing Vienna's Smart City framework strategy and numerous other strategic development concepts. Since Vassilakou's time in office and to this day, Vienna has regularly occupied top positions in international quality of life rankings (e.g. 1st place in the Mercer Quality of Life Study since 2010 years unbroken until 2024, 1st place in the Economist ranking 2018 and 2019, 2023, 2024). Today, she shares her expertise and know-how on successful solutions from Vienna. She offers concrete support in overcoming the complex challenges that cities face due to rapid population growth, climate change, growing social inequalities and rapidly rising housing costs. Since September 2019, Maria Vassilakou has been a member of the Horizon Mission Board' Climate Neutral Smart Cities' as an expert on behalf of the European Commission.

The Wisdom of the Many vs. the Power of the Few
Hannes Rockenbauch

Exactly 15 years ago, violence escalated in Stuttgart. Peacefully demonstrating, citizens were confronted by a state apparatus determined to push through a large-scale infrastructure project at all costs. The conflict over the Stuttgart underground station (Stuttgart 21) became a symbol of an outdated planning paradigm that bypassed the public entirely. For a brief historical moment, it seemed as though a democratisation of planning processes was within reach. Far beyond the planning community, it was widely declared that events like those in Stuttgart must never be repeated.

To this day, planners and practitioners continue to discuss how the energy, creativity, and competence of the many can be better integrated into planning processes and used for the common good through co-production. Yet outside of expert conferences and a few urban niches, we are witnessing a broad and systematic rollback. In public perception, the images from Stuttgart have long faded. Around the world, authoritarian tendencies are resurging. In Germany, political majorities—under the banner of the energy transition—are driving forward the acceleration of planning. Democratic participation, as well as the legal standing of environmental associations, is increasingly viewed as an obstacle and faces further restrictions. My thesis, which I would like to put up for discussion today, is this: Despite initial enthusiasm, ideas around renewing planning culture and institutionalising co-production have not taken lasting root—neither in public institutions nor, even less so, in the private sector. The necessary restructuring of administrative and decision-making processes, along with the expansion of binding democratic rights, has not been realised. As a result, there is still no conclusive evidence that, especially at large scales, planning and policy based on the wisdom of the many can offer a truly viable and future-proof alternative to top-down decision-making driven by the power of the few. Instead of moving toward a culture of learning, adaptive, and provisional planning and governance, we risk reverting to the old patterns of command-and-control policies dictated from above.

Hannes Rockenbauch's work spans urban planning, local politics, and civic activism. After studying architecture and urban planning, he taught and researched as an academic assistant at the Institute Foundations of Planning and later at the Institute of Urban Planning at the University of Stuttgart in the field of planning and participation. Since 2004, Hannes Rockenbauch has served as an elected city councilor in the Stuttgart City Council, where he is currently the parliamentary group leader of Die Linke und SÖS Plus. He became known as a leading figure in the resistance against the Stuttgart 21 rail project. In 2010, he participated in the Stuttgart 21 fact check under Heiner Geißler. To this day, he combines his role on the local council with activism in initiatives such as the “Right to Housing” action alliance and the “Free Bus and Train” initiative. Today, Hannes Rockenbauch works as a climate policy campaigner for one of Germany's largest environmental organizations, the Federation for the Environment and Nature Conservation (BUND). There, he is responsible for the BUND's Local Political Forum.

4 Invited Labs

ACI Medellin Lab I EDU, Medellin

Julian Esteban Gomez Carjaval, Christian Alejandro Salas Domingues

Medellín Lab is an innovative knowledge exchange program developed by ACI Medellín, the city's Agency for Cooperation and Investment. It positions Medellín as a "living laboratory" where public officials, urban planners, and international experts can explore firsthand the city's transformative approaches to urban development, governance, and social inclusion. Through immersive experiences—including site visits, academic sessions, and co-creation workshops—participants engage directly with Medellín's integrated urban strategies. These include inclusive mobility systems like cable cars and escalators, community-centered public spaces, and initiatives aimed at reducing violence and fostering resilience. By facilitating multi-actor and multi-level cooperation, Medellín Lab enables cities worldwide to learn from Medellín's experiences, adapt successful practices, and collaboratively address shared urban challenges. Since its inception, Medellín Lab has hosted delegations from various countries, promoting the exchange of ideas and fostering partnerships that contribute to sustainable urban transformation globally.

aspern.mobil LAB I Wien

Jakob Holzer, Martin Berger

The aspern.mobil LAB is an Urban Mobility Laboratory located in Vienna's Seestadt Aspern district. It serves as a collaborative innovation space where residents, researchers, municipal authorities, and businesses work together to develop and test sustainable urban mobility solutions. The lab focuses on areas such as active mobility, shared mobility services, and first/last mile logistics, aiming to assess their spatial, economic, ecological, and social benefits. Operated by an interdisciplinary team from TU Wien—including experts in spatial and transport planning, computer science, sociology, architecture, law, design, and impact research—the aspern.mobil LAB partners with organizations like Wien 3420 AG, Seestadt Aspern district management, and Urban Innovation Vienna. It is one of Austria's five Urban Mobility Labs, funded by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology as part of the "Mobility of the Future" program. The lab emphasizes community involvement, treating local residents as experts who contribute to the co-development, testing, and implementation of innovative mobility solutions. This participatory approach ensures that the solutions are tailored to the needs of the community and promotes a new culture of mobility and innovation within the urban environment.

TU WIEN · wien3420 aspern development AG · urban innovation vienna · aspern stadtteil management

Funded by
Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology

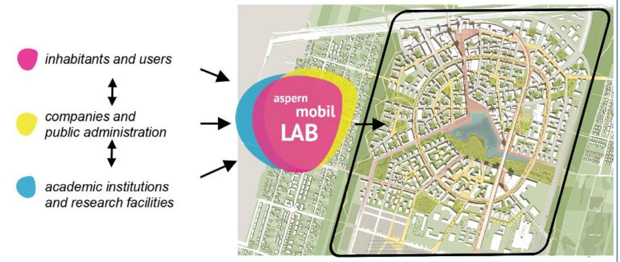
aspern.mobil LAB

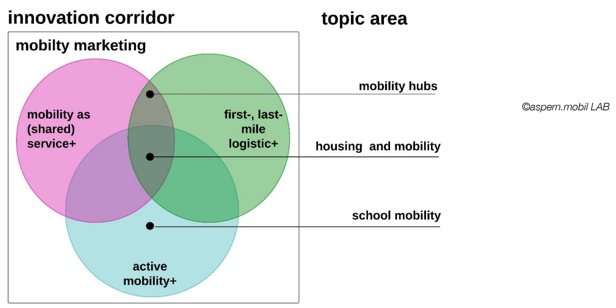
A neighbourhood mobility lab in **aspern** Seestadt

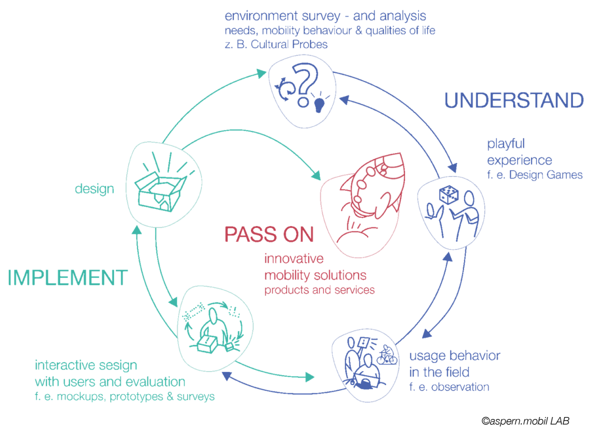
Topics

aspern.mobil LAB was established in 2017 in aspern Seestadt, an urban development area in Vienna, Austria.

The lab creates a space for innovation and supports a new culture of mobility in this extraordinary development area. Inhabitants of aspern Seestadt, local stakeholders, politicians and actors from research, development and business think, develop and act here on an equal footing. Innovative mobility solutions focus on active mobility, shared mobility as a service, first/last mile logistics and mobility communication, and the investigation of their spatial, economic, ecological and social benefits.







Orientation

Successful mobility innovations begin with Understanding diverse mobility needs, which forms the basis of all services at aspern.mobil LAB.
Insights from the Understanding process feed into Implementing, where innovations are developed and tested—from idea to launch, from lab to real-world trials.
With broad experience in technologies, services, and apps, aspern.mobil LAB bridges the gap between administrations and innovators, especially startups. Sharing expertise supports the successful realization of new mobility services at district level.

Impressions of the Lab

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CALL

City as Living Laboratory (CALL) I New York

Olivia Georgia, Aaron Asis

City as Living Laboratory (CALL) is a New York-based organization that unites artists, scientists, and urban residents to collaboratively address pressing environmental challenges, focusing on climate, equity, and health. By fostering interdisciplinary partnerships, CALL aims to transform complex environmental issues into personal experiences that inspire community action. CALL's mission is to harness the combined power of art and science to deepen the understanding of critical environmental concerns within local communities, thereby motivating sustainable solutions. Their vision encompasses the creation of more livable, sustainable, and equitable urban areas, enriched by thriving local ecosystems. This vision is actualized through collaborative projects and programs that blend artistic creativity with scientific insight. The organization upholds values such as creative and holistic problem-solving, interdisciplinary collaboration, personal engagement with local ecosystems, equitable decision-making, sustainable development, and the integration of environmental, social, and economic goals.

CLIMAS, Vilnius Living Lab I Vilnius

Gintrarė Gulevičiūtė

The Vilnius Living Lab, located in Naujamiestis district, Vilnius, Lithuania, is a dynamic, community-driven research environment undergoing a creative transformation of former industrial spaces. Engaging residents, businesses, and cultural entities, it co-creates experimental projects for urban innovation. With a focus on climate change mitigation, its participatory nature positions it as a model for testing and replicating methods across Vilnius. By involving the community in initiatives like urban farming, green energy utilization, and waste reduction, the Living Lab becomes a catalyst for city-wide sustainability. Documenting and analyzing these efforts, it provides evidence-based strategies for urban adaptation to climate change, inspiring similar endeavors in Vilnius and beyond.

StadtManufaktur I Berlin

Anja Steglich

StadtManufaktur Berlin is the real-world laboratory platform of the Technische Universität Berlin. It facilitates collaboration between researchers and partners from politics, business, culture, and civil society to develop innovative solutions for urban challenges. The focus areas include climate adaptation, social cooperation, sustainable mobility concepts, and the transformation towards a circular city. The initiative supports the organization, documentation, and evaluation of real-world laboratory work in the context of urban transformation towards sustainability.

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GEMEINSCHAFT
TEMPELHOF

Community Schloss Tempelhof (Ecovillage) I Kreßberg

Stefanie Raysz

Schloss Tempelhof is a grassroots, democratic living community, located in Southern Germany. Home to 180 people from 0-83 years, it integrates regenerative living, sustainable housing and experimental buildings, alternative education, social and technical experimentation and forward-thinking social systems. Its holistic concept embraces a culture of co-creation, self-responsibility, and ecological awareness. Sustainability is a guiding principle for every aspect of life. The community seeks to regenerate ecosystems (permaculture, agroforestry, soil health), foster inner development (We-process, forum, buddy-system), and build resilient social structures (e.g. solidary long-term food productivity, self-sufficiency, commons) that align with planetary boundaries. It hosts a free school and forest kindergarten, a seminar house, testing fields for transformative, future oriented education for young adults, working spaces for independent learning as well as cultural and sportive events.

Ecovillage Design And Life – Contributions To Transformation

GEN EUROPE
GLOBAL ECOVILLAGE NETWORK

Living Laboratory Practices for Regeneration and Resilience

The Ecovillage Movement celebrates more than six decades of ambitious visions, courage, and collaboration across cultures, continents, and communities.

As a vibrant community pioneering sustainable lifestyles, ecovillagers live in harmony with each other and with the earth, practicing holistic living aligned with five dimensions of regeneration.

Social Resiliency

- Community Building and Participation
- Holistic, Life-long Learning
- Basic Democratic Principles
- Conflict Transformation

Ecological Regeneration

- Eco-Technology
- Regenerative and Circular Systems
- Sustainable Building Methods and Material
- Biodiversity

Economic Sustainability

- Sharing and Solidarity Economy
- Decentralisation
- Self-Sufficiency
- Alternative Currencies and Local Exchange
- Economy For The Common Good and Post-Growth

Cultural Heritage

- Personal and Collective Development
- Community Ecosystem Governance
- Awarness and Co-Creation
- Interconnectedness

Whole System Design

- Deliberately Designed Real-Life Labs
- Collective Identity and Integration
- Holistic Approach and Spirituality
- Networking and Policy Transfer

Contributions to Transformation:
Ecovillages support community building and deliever a broad pool of knowledge and experience in regenerative living. Consultants guide ecovillage formation, regional development, and urban–rural collaboration. Training programs, seminars, and study visits enable exchange, reflection, and co-creation. Ecovillages act as experimental hubs for degrowth, commons, circular and sharing economies, and alternative ownership models. They develop socio-technical innovations, facilitate participatory decision-making, and resolve conflicts. Communities are equipped with tools for cooperation and self-governance, while multidimensional approaches to sustainability are implemented, generating transferable models for resilience, sufficiency, and sustainable futures.

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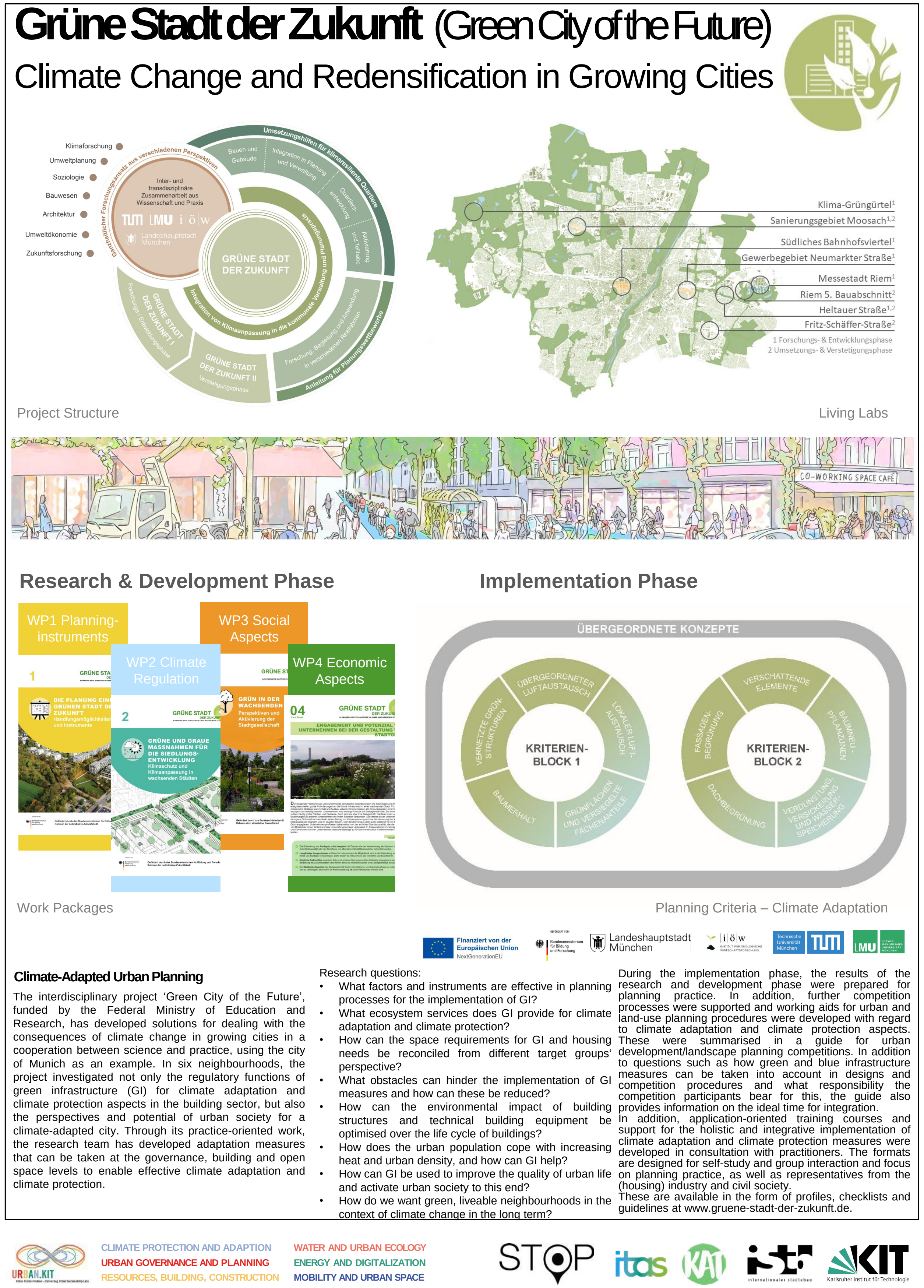
Grüne Stadt der Zukunft I München

Eva-Maria Moseler

Grüne Stadt der Zukunft (Green city of the future) is an interdisciplinary research initiative (2018–2023) funded by the German Federal Ministry of Education and Research. Focusing on Munich, the project explored practical solutions for climate adaptation in urban neighborhoods, addressing challenges like heatwaves and heavy rainfall. Collaborators included the Technical University of Munich, Ludwig Maximilian University of Munich, the Institute for Ecological Economy Research, and the City of Munich. The project developed actionable material, guides, checklists, and case studies, to support municipal administrations and urban planners in integrating green infrastructure into planning processes. Key topics encompass building and urban design, planning integration, neighborhood development, community engagement, and awareness-raising. These resources aim to facilitate the creation of climate-resilient, green urban spaces.



IZS Interdisziplinäres Zentrum für transformativen Stadtumbau

Interdisciplinary Centre for Transformative Urban Regeneration (IZS) I Görlitz

Annica Kögler, Stefanie Rößler

IZS is a joint research and transfer facility of the Leibniz Institute for Ecological Urban and Regional Development Dresden (IOER) and the International Institute (IHI) Zittau of TU Dresden. Established in 2014, the centre focusses on transformation processes in towns and neighbourhoods with limited transformative capacities and in regions affected by structural change. IZS pursues a transdisciplinary approach in which the identification of research needs, the production of knowledge, the pilot application of new solutions as well as reflection and further development take place in close collaboration with stakeholders in urban and regional development. The German-Polish twin city of Görlitz/Zgorzelec and its hinterland serve as a real-world laboratory. Current experiments are being initiated and monitored by the IZS fostering in-migration on the basis of provisional residencies and local climate neutrality.

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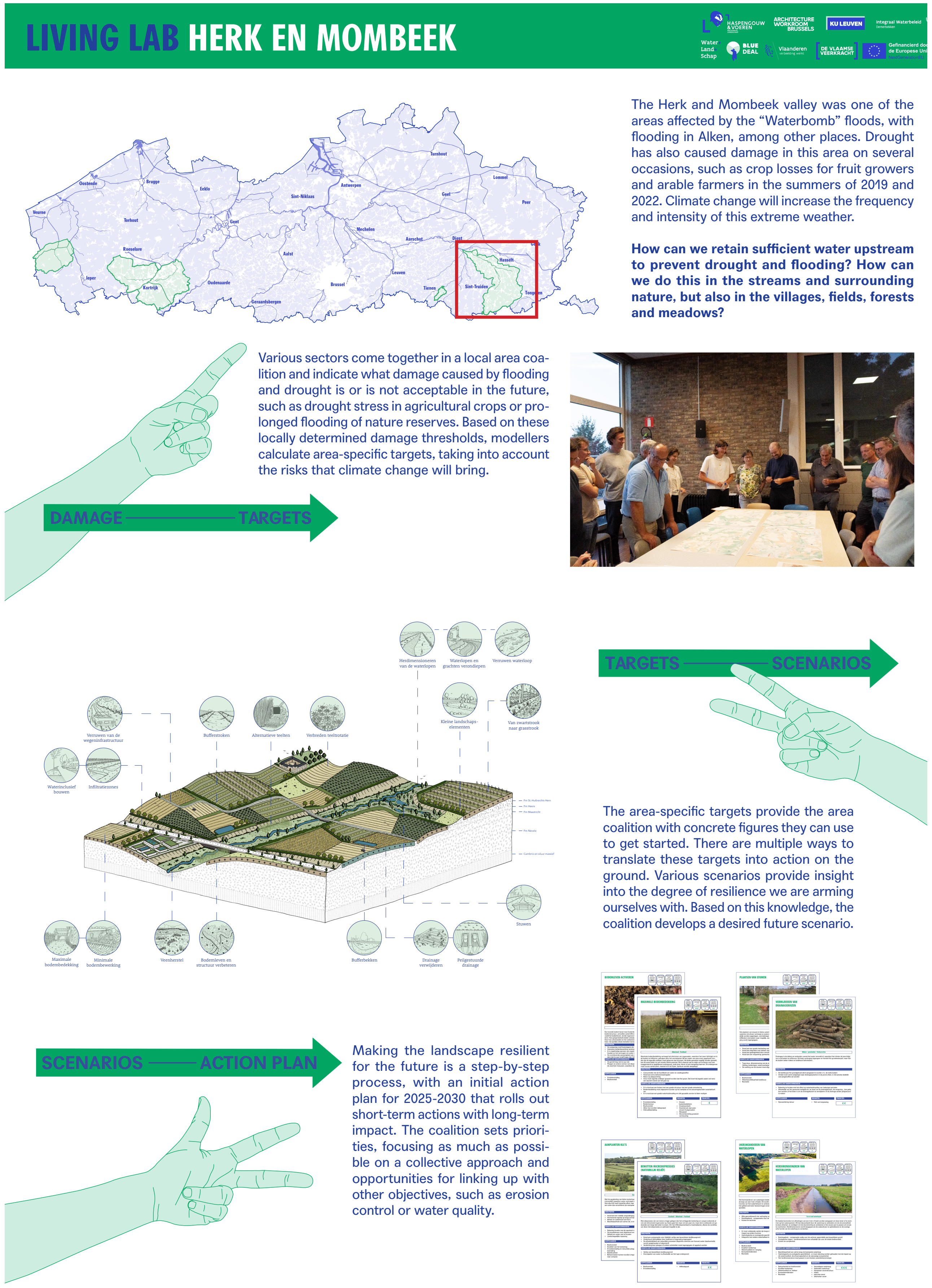
ARCHITECTURE
WORKROOM
BRUSSELS

Living Lab Herk & Mombeek I Brussels

Bram Vandemoortel

How can we retain enough water in upstream areas to better arm the landscape, agriculture and our nature against extreme precipitation and drought? How can we maximise water retention in the landscape to prevent drought and flooding? How can we achieve this not only in the streams and surrounding nature, but also in the villages, fields, forests and meadows? These are the central questions that are being investigated within Living Lab Herk and Mombeek. What is innovative about this Lab is that local stakeholders indicate which damage was unacceptable to them in recent years, and from there, hydrological modelling and design research are used to develop a concrete investment plan. Not an external abstract goal, but one that is formulated locally. A breakthrough in finding sufficient support to roll out many small measures on a large scale.



MIJI AFRICA
LIVING LAB
Co-creating Green Change in African Cities

Miji Africa Living Lab I Nairobi

Christer Adelaide Andiiti, Peris Wairimu Njoroge

Miji Africa is a pioneering living lab that supports the innovation ecosystem by co-creating development solutions with low-income, under-served and marginalized communities to promote equitable and inclusive livelihood transformation. In Miji Africa, we are committed to steering innovation solutions through pragmatic, holistic and climate-conscious approaches to mitigate urban poverty, improve livelihoods, and increase community resilience in Urban Africa. In the journey of leaving no one behind, we recognize that low–income and under-served communities, such as informal settlements, which host the majority of Africa's urban population, must be at the heart of innovation implementation and scaling and are key in mitigating climate change.

MIJI AFRICA
LIVING LAB
Co-creating Green Change in African Cities

Contact us
Email: info@mijiafrica.com
Website: Mijiafrica.com
Telephone: +254 743 849 804

The Miji Africa Living Lab supports the innovation ecosystem by accelerating inclusive interventions in African cities

Our Mission

- To promote urban transformation and increase resilience by accelerating innovation access and adoption.

Our Vision

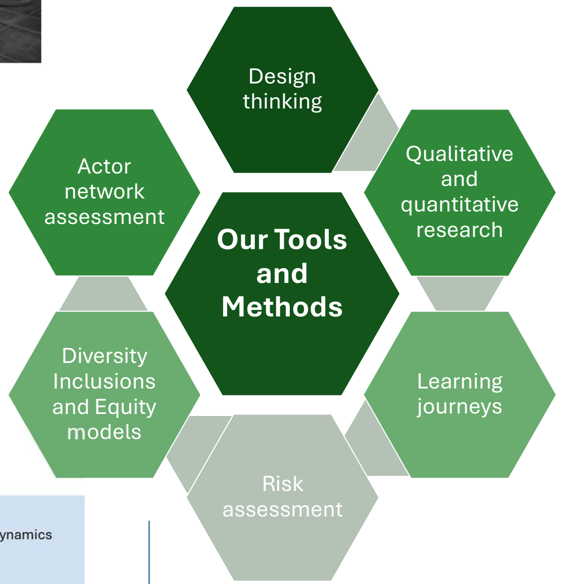
- To champion inclusive, equitable, and climate-conscious urban transformation by facilitating systemic collaborations with local communities and improving urban lives.

Miji Africa flagship areas:
We offer strategic innovation management and sustainable partnership building with local communities.

- STAKEHOLDER ENGAGEMENTS
- PARTICIPATORY RESEARCH
- INNOVATION INCUBATION
- DIVERSITY INTEGRATION
- CAPACITY BUILDING
- SUSTAINABLE PARTNERSHIPS

Potential projects

- ➢ The energy learning journey
- ➢ Promoting mental well-being in low-income communities
- ➢ HITAP stakeholder engagement
- ➢ The HOPE Project



Our Approach

Strategy Development	- Context immersion - Pre-feasibility studies on contextual market culture and dynamics - Stakeholder mapping and analysis - Multi-stakeholder ideation with communities - Risk assessment
Feasibility Testing	- Acceptability and desirability assessment - Resource assessment - Risk assessment
Implementation management	- Installation - Expansion and scaling

Opportunities for change

- Marginalisation of living labs
- Non-contextualised Leapfrogging of technology
- Non-prioritising of community engagement by governments
- Non-wholistic approaches in community engagement
- Lack of resources to invest in research and development in low- and middle-income countries
- Investment beyond research

LANCIS

National Laboratory of Sustainability Sciences LANCIS I Mexico City

Yosune Miquelajáuregui Graf, Carolina Guadalupe Cruz Nunez

The National Laboratory of Sustainability Sciences (LANCIS for its Spanish acronym) of the Institute of Ecology, UNAM, is an academic boundary entity. It is constituted as a node for the generation, integration and synthesis of knowledge that serves as a link between academy, decision-makers from the public sector and the various organized sectors of society. Through innovation in transdisciplinary research, teaching, fostering of stakeholder engagement and providing of ISO:9001-certified services they promote technological development and the co-creation and translation of knowledge that links science and decision-making to support the transition towards sustainability. In the laboratory, different disciplines are combined—biology, geography, scientific computing, environmental sciences and engineering, among others—to consolidate transdisciplinary projects in collaboration with strategic social actors at the national and international level.

Quartier Zukunft – Labor Stadt (District Future – Urban Lab) I Karlsruhe

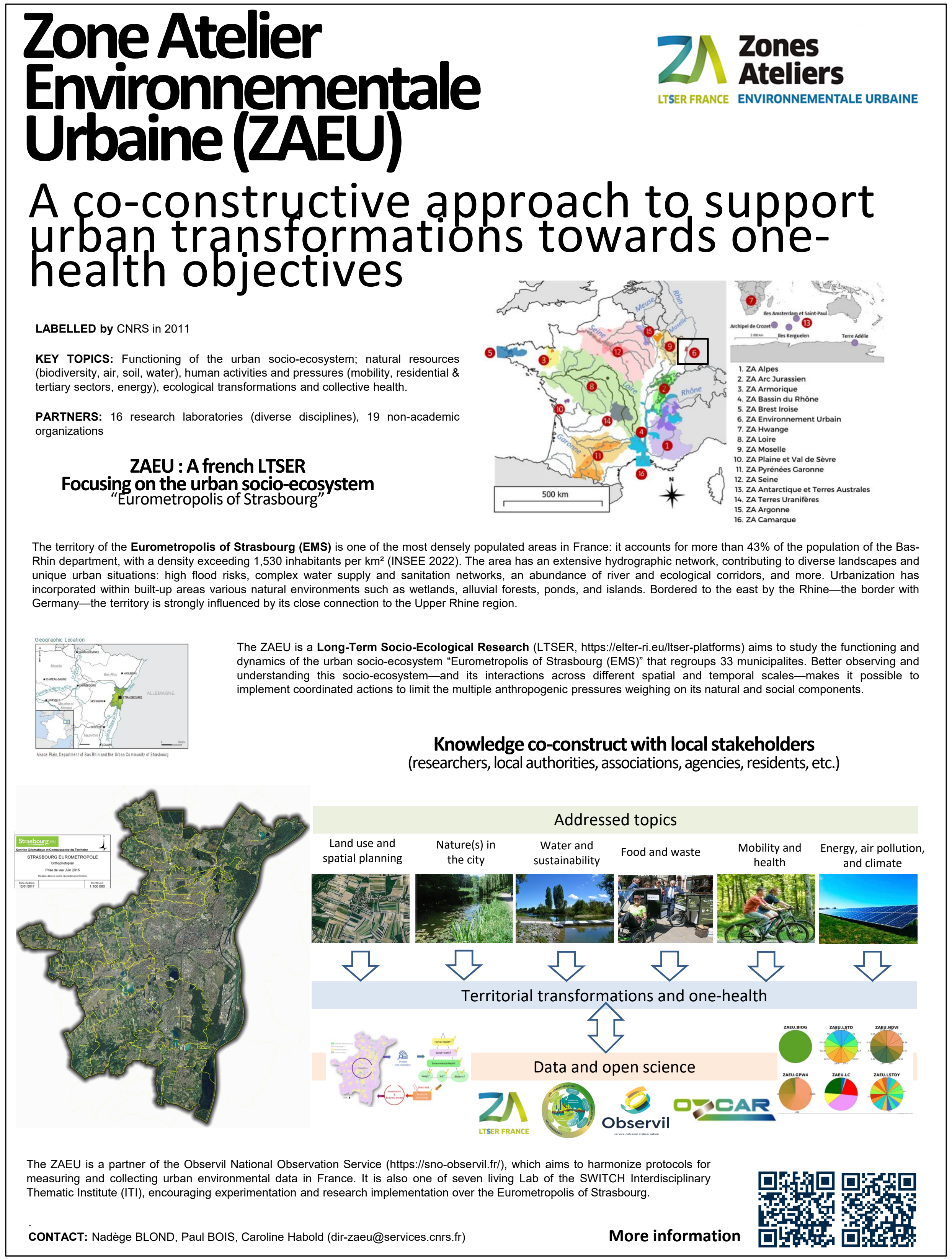
Oliver Parodi, Pia Laborgne

Quartier Zukunft – Labor Stadt (District Future – Urban Lab) is a real-world lab run by Karlsruhe Transformation Center at KIT that aims to collaboratively develop, test and research sustainable solutions for urban living in a long-term participatory process. In the lab residents, researchers, city administration and local stakeholders work together to foster a 'Culture of Sustainability' and transform Karlsruhe's district Oststadt into a livable and sustainable urban environment. Following a holistic approach, focusses are on energy transition, climate protection, sustainable mobility, social participation, and personal sustainability.

Zone Atelier Environnementale Urbaine (ZAEU) I Strasbourg

Nadege Blond

The Zone Atelier Environnementale Urbaine (ZAEU) is an interdisciplinary research initiative based in Strasbourg, France, focusing on urban socio-ecosystems. Established in 2011, ZAEU is a collaboration between academic institutions, including the CNRS and the University of Strasbourg, and local authorities such as the Eurometropolis of Strasbourg. It is part of the French LTSER (Long-Term Socio-Ecological Research) network and contributes to European research efforts on sustainable urban development. ZAEU's research addresses six key themes: food and waste, water and sustainability, energy and air quality, mobility and health, urban nature, and land use. These themes are explored through long-term observations, data analysis, and scenario development to inform sustainable urban planning. The initiative also emphasizes the importance of inclusive governance and citizen engagement in addressing environmental challenges. By integrating scientific research with practical urban management, ZAEU aims to develop solutions that promote ecological, economic, and social sustainability in urban environments.



URBAN.KIT

CLIMATE PROTECTION AND ADAPTION
URBAN GOVERNANCE AND PLANNING
RESOURCES, BUILDING, CONSTRUCTION
WATER AND URBAN ECOLOGY
ENERGY AND DIGITALIZATION
MOBILITY AND URBAN SPACE

STOP itas KAT internationaler städtebau KIT Karlsruher Institut für Technologie

5 Workshops

1x1 der Energiewende im Quartier EnBW Innovation (DE)
Stefanie Jelinek, Verena Gehrmann-Linnerth (EnBW Innovation)

Im Workshop „1x1 der Energiewende“ geht es darum, die Grundlagen einer zukunftsfähigen Energieversorgung in Quartieren verständlich zu machen. Anhand konkreter Beispiele zeigt Jelinek Stefanie, wie die Energiewende auf lokaler Ebene gelingt – mit Fokus auf Innovation, Skalierbarkeit und praktischen Learnings aus acht Jahren Umsetzung. Die Teilnehmenden erhalten Einblicke in typische Herausforderungen, Erfolgsfaktoren und Best Practices für klimaneutrale Quartierslösungen. Ziel ist es, ein praxisnahes Verständnis für die Umsetzung nachhaltiger Energieprojekte zu vermitteln

Accelerating Climate-neutrality through Co-creational Pilot Projects
Louisa Bahl, Felix Schapitz (Reutlingen University)

How The living lab Klima-RT-LAB is jointly developing ways to instiutionalize climate neutrality by 2040 in the city of Reutlingen, Germany. We strive for transferable solutions in four real-life experiments: energy, buildings, mobility and workplace behavior. We invite you to our workshop to discuss two hot topics: First, wastewater heat as an opprotunity for heat pumps? From rivers, treatment plants and sewers to system integration and societal acceptance. And second, how can employees be motivated to adopt climate-friendly behavior? Shared experiences from climate protection campaigns and workshops with executives.

Co-Creation and Co-Strategy for Innovative Mobility Solutions + Decarbonising and Smart Cities Integration
Iordanis Konstantinidis (Hellenic Institute of Transport) +Leire Balzategui Urrutia, Iñigo Bilbao Ubillos (Mobility Lab Vitoria-Gasteiz)

How can cities co-design smarter, greener and more inclusive mobility systems that are transferable and scalable? Through structured dialogue and shared learning, participants will collaboratively reflect on how participatory approaches can leverage citizen-centric innovation to advance sustainable urban mobility strategies and improve urban mobility systems. Thessaloniki's Smart Mobility Living Lab experience will serve as a starting point for broader discussion, offering insights into how cities can co-design mobility solutions that can be adapted and scaled in different urban contexts. + How can data-driven collaboration accelerate the transition to low-emission, inclusive urban mobility? Explore how the Mobility Lab in Vitoria-Gasteiz is transforming urban transport through a regulatory sandbox and a certified data space. This workshop focuses on decarbonising mobility, smart city integration, and inclusive planning. Learn how public-private collaboration and real-world testing environments drive innovation in sustainable, low-emission, and accessible urban mobility

Connecting People
Hannes Wender (FH Osnabrück)

How can universities become catalysts for region-wide sustainability through inclusive, citizen-driven collaboration? This workshop introduces the Lantern Project, a collaborative initiative that brings together university staff, students, local government, and civil society to drive regional sustainability transformation. Through shared visioning, task orchestration, and inclusive dialogue, the lab addresses diverse understandings of sustainability, promotes just futures, and builds on both institutional commitment and grassroots motivation.

Experimenting for Sustainability Envisioning Rur:ban Futures. Creating Inclusive Spaces with Tasty Tables of Utopias
Daniela Pastoors, Rebecca Froese (Centre for Interdisciplinary Sustainability Research (ZIN), University of Münster)

How can marginalized communities be actively engaged in socio-ecological transformation? How can researchers create envisioning spaces that foster sustainability in rural-urban areas? We invite discussion on interactive and creative formats—such as shared food preparation and consumption, artistic and embodied practices—that spark imaginative thinking about desirable futures. Drawing from a real-world laboratory in northwest Germany, we explore “Tables of Utopias” as a central element of our thematic ‘Future Building Blocks’. These events support the local sustainability strategy by offering citizens a “taste” of possible futures and empowering them to co-create them.

Governance in and for the Anthropocene: Building Post-Growth Cities through Co-Creation
Franziska Ehnert, Vanessa Kügler (Leibniz Institute of Ecological Urban and Regional Development)

What governance frameworks and civic practices can support transformative change toward sustainable, post-growth cities? This workshop examines how cities can transition beyond growth-driven models to achieve sustainability within planetary boundaries. Discover how the City Lab promotes civic engagement, co-creation among citizens, government, and businesses, and facilitates holistic urban transformation through innovative governance and transition intermediaries.

Grassroots Urbanization – for Sustainable Urbanism in Africa
Zegeye Cherenet Mamot (Ethiopian Institute of Architecture, Building Construction and City Development, Addis Ababa)

The workshop addresses the burgeoning needs of urban production in Africa at the grassroots level through and by the grassroots themselves. Instead of infrastructure-led, top-down, city-centric, and capital-intensive urbanisation models, grassroots urbanisation claims that community-driven, smaller but networked urban aggregates established primarily on local resources have a better chance of achieving just and sustainable socio-spatial outcomes in Africa.

Healthy Cities, Urban Health and One Health
Richard Beecroft (Karlsruhe Transformation Centre, KIT)

Health is a fundamental human right and a core goal of the SDGs. But how can health be promoted in a future urban context? Which new socio-technical and socio-ecological systems can and should evolve to create synergies between health and other sustainability goals? Could a vision of “One Health”, which integrates the well-being of humans, animals, and the environment, guide such transitions? And which of the evolving concepts can and should be tested in real-world labs?

Inclusive Urban Development

Theodora Psoma, Pantelis Iliadis, Panagiota Fabrikanou (Aristotle University of Thessaloniki)

How can cities design mobility and public space so that blind and partially sighted citizens experience full, independent access to urban life? This workshop examines how cities can be designed to be more inclusive and educational. At the heart of our research practice, we bring together travellers, transportation staff, tour guides, and university students to co-design open cultural spaces, treating them as linguistic contact zones. Focusing on safe mobility for blind and partially blind individuals, equal access to cultural and educational environments, and the preservation of local identity, the lab reimagines urban areas as living and accessible learning ecosystems — spaces that foster connection, equity, and cultural continuity.

Inclusive Urban Transformation. Creating NEBourhoods together

Michael Droß, Jana Köstler (Munich University of Applied Sciences)

How can co-creation with local stakeholders and other actors shape urban development? Part of the New European Bauhaus Lighthouse project in Munich-Neuperlach was ten mini-labs that tackled diverse sustainability challenges - from renewable energy and circular office buildings to inclusive mobility, community farming, and youth cultural spaces. After an introduction, participants work in small groups on the challenges of integrating stakeholders from civil society and other sectors.

Making Cities Ready for AI. The Role of Digital Innovation for Overcoming Multiple Crises

Martin Memmel (German Research Centre for Artificial Intelligence)

can cities become AI-ready and make use of digital technologies in the face of complex, overlapping crises? This workshop examines how the smart city Living Lab in Kaiserslautern addresses the interconnected ecological, economic, social, and democratic challenges of our time. Learn how DFKI and partners use AI and digital tools to support sustainable urban development, support transparent decision-making, and accelerate transformation processes in cities.

Mobility Transformations in Suburban and Rural Areas

Alexandra Anderluh (St. Pölten University of Applied Sciences)

How can regional mobility labs support sustainable transport across urban, suburban and rural areas? AmWy.mobility focuses on reducing car dependency and improving sustainable transportation for people and freight in southwest Lower Austria. This workshop emphasises the importance of integrating urban, suburban, and rural planning, avoiding freight-related design failures, and shifting mindsets to reduce traffic, emissions, and congestion across regional networks

Neighbourhood Energy Transition

Carla Wüller, Katharina Schmidt (RWTH Aachen University)

How can districts accelerate the shift to climate-neutral energy? SmartQuart tests innovative energy technologies across three districts, focusing on intelligent energy exchange, decentralised sector coupling (including mobility, heat, and power), and local optimisation. This workshop explores how the SmartQuart Hub connects producers and consumers to manage energy flows efficiently, replace fossil fuels, and foster public acceptance—advancing Germany's and Europe's climate goals through real-world, citizen-driven transformation.

New Learning and Action Spaces: Interfaces between City and University

Hendrik Weiner (BTU Cottbus-Senftenberg, Faculty of Urban Management)

How can bottom-up learning spaces foster democratic, inclusive, and sustainable urban development? This workshop presents a bottom-up approach to urban transformation through university teaching and civic engagement. It explores how open and inclusive spaces can foster sustainability, democratic participation, and anti-discrimination. By bridging academia and local communities, the lab creates new opportunities for dialogue, experience, and action in urban development.

Resilient Regenerative Urban Economies

Svenja Bickert-Appleby, Verena Hermelingmeier (bonnvivir GmbH)

How can we build resilient and regenerative local economies that help face urgent challenges such as climate change, geopolitical crises and resource scarcities? This workshop invites participants to engage in a co-design session, using the Maarwerk Lab in Bonn as a living case study for building regenerative urban economies. Situated in Bonn-Beuel's industrial zone, Maarwerk is an emerging project that explores circular urban production, local value creation, and new types of cooperation. Building on this case and embarking on a rapid design journey, participants will develop design principles for regenerative urban spaces.

Securing Liveability of Cities and Increasing Disaster Preparedness

Marco Elischer (City of Worms)

How can cities adapt to climate extremes while fostering inclusive, democratic, and civil society-driven transformation? This workshop examines how the city of Worms is adapting to climate extremes by engaging civil society and welfare organisations. Discover how the city's heat network, overseen by the climate adaptation unit, promotes collaboration across departments and with researchers to implement innovative solutions, such as heat action plans and shadow routing. The lab demonstrates how inclusive, cross-sectoral approaches can enhance urban resilience, especially in under-resourced municipalities.

Social Innovation

Christian Peer (Technical University Vienna)

How can social innovation drive sustainable urban development by transforming lifestyles, governance, and empowering inclusive change? This workshop explores how social innovation can drive sustainable urban transformation. Discover how shifting lifestyles, governance, and practices can address pressing societal challenges. The Future Lab focuses on building transformation capacities, fostering inclusive participation, and empowering pioneers of change—ensuring no one is left behind.

Social Justice & Access: Homing, Place Making and Well-being in the Urban Green Transition

Georgia Alexandri (Karlsruhe Transformation Centre, KIT)

Ensuring equal access to resources and services, including those for vulnerable groups, is crucial for achieving equitable urban development. In this workshop, we will explore how different social groups' access to information, energy, and resources shapes experiences of place (un)making and homing within the urban green transition, and how diverse understandings of comfort and well-being influence who feels truly “at home” in emerging sustainable urban spaces.

Urban Water Bodies | An EUCOR – The European Campus Joint Event

Karl M. Wantzen, Yixin Cao (Institut Terre et Environnement de Strasbourg)

Water is essential for life. However, the management of urban aquatic life-spaces (hydrosystems) presents a significant challenge. How can human needs and ecological requirements be harmonised? How can we increase biodiversity and ecosystem functions without creating risks for humans (e.g., through water-borne diseases, or beavers felling urban greenery)? The Urban Human-River Encounter Site approach provides key elements for discussion. In the workshop, we will elaborate on an axiology that helps balance the opportunities and risks in the context of redesign, restoration, or de novo creation of urban water bodies, considering human well-being, biodiversity, and ecosystem services. Urban planning is based upon values of different societal groups. Informed decision-making, especially when long-term practices need to be changed, is another challenge to be addressed. The workshop will be done in a two steps: followed by an open discussion to identify the perspectives and thematics of the participants, we will work on a specific example to produce and discuss practical suggestions.

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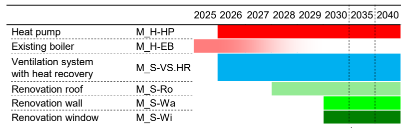
Klima-RT-LAB

Accelerating climate neutrality through co-creational pilot projects

The living lab “Klima-RT-LAB” accompanies, supports, and researches the transformation process of the City(-corporation) of Reutlingen towards climate neutrality by 2040. In four climate-relevant fields of action and by tandem-teams from research and practice, four real-world experiments are being conducted: energy, buildings, mobility, and action. The aim is to anchor the path to climate neutrality in the city administration and municipal companies, to research the institutionalization process of climate neutrality, and to derive relevant transformation knowledge.

Current pilot projects in 2025



Energy

- Hybrid heat pump: Monitoring project during the winter of 2025/26 to compare economic efficiency and model calculations.
- Drainage heat: Development of a heat pump calculation tool that enables the estimation of heat potential and economic efficiency of district heating from sewers, rivers, and sewage treatment plant.

Buildings

- Retrofit Roadmap for a non-residential building: Combining a multi-year techno-economic assessment of retrofit measures with an annual simulation of a hybrid heat pump for a gym and festival hall.
- District heating substations: Heating load calculations for four multi-family houses to determine the requirements for replacing a direct substation by an indirect substation.

Mobility

- Charging infrastructure: Expansion of e-mobility charging infrastructure with smart grid integration.
- Energy-autonomous stops: Pilot stops with photovoltaic supply, battery storage, and demand-optimized control.
- Bidirectional charging: Evaluation of vehicles as flexible storage for grid services and self-consumption.

Action

- Supporting executives: Co-creational workshop series for municipal executives on the status quo of the city corporations’ path towards climate-neutrality.
- Communication for sensibilization: Internal climate-protection campaign with five modules (Paper saving, Energy saving, Veganuary, Fairbruary, Mobility).

Cross-cutting topics

Transformational Research | CO2-Monitoring | Guidelines | Booklet | Monitoring of measures | Gender Equality

SAVE THE DATE

Event on 22.01.2026
„Erforschen, Gestalten, Verstetigen – Klimaschutz für Stadtkonzerne“ in Reutlingen

Want to know more?
Scan for four latest blogposts!

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Klima RT-Lab is funded by
Baden-Württemberg
MINISTERIUM FÜR WISSENSCHAFT, FORSCHUNG UND KUNST

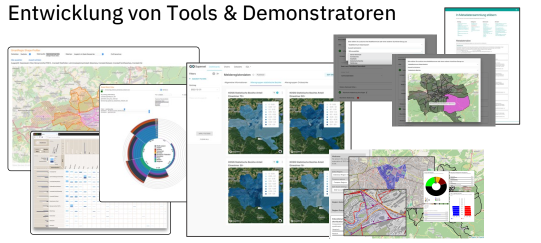
CLIMATE PROTECTION AND ADAPTION
URBAN GOVERNANCE AND PLANNING
RESOURCES, BUILDING, CONSTRUCTION
WATER AND URBAN ECOLOGY
ENERGY AND DIGITALIZATION
MOBILITY AND URBAN SPACE

Das SmartCity Living Lab

Im SCLL werden am Standort Kaiserslautern in Kooperation mit zahlreichen Partnern innovative Ansätze für die Stadt der Zukunft erprobt und erforscht. Wir wollen moderne Technologien im städtischen Raum sinnvoll und systematisch einsetzen, um in verschiedenen Bereichen zu einer nachhaltigen Stadtentwicklung beizutragen.

WO SIND WIR AKTIV?

Entwicklung von Tools & Demonstratoren



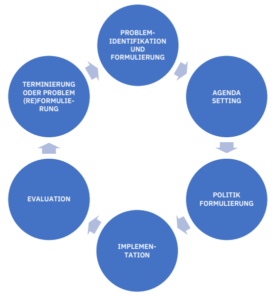
Projektübergreifende Infrastrukturen

- Generische, modulebasierte Webanwendung mit elasticsearch als (big) geodata storage
- Verschiedene Visualisierungen wie superset, leaflet, d3.js oder kepler.gl

Publikationen und Studien

Wissenstransfer

LEITFRAGEN



Wie können wir Digitalisierung und Künstliche Intelligenz einsetzen, um den Herausforderungen in urbanen Räumen zu begegnen?

Wo können wir wirksam werden, um die Transformation urbaner Räume zu gestalten?

PROJEKTE

Ökologische Handlungsempfehlungen – Entwicklungsagentur Rheinland-Pfalz e.V.

Entscheidungs-unterstützung – Carl Zeiss Stiftung

MPSC Kaiserslautern – Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen

Transformation urbaner Lebensräume – Carl Zeiss Stiftung

SDG Monitoring – RPTU Rheinland-Pfälzische Technische Universität Kaiserslautern Landau

Integriertes Monitoring / FCD-Analyse – Bundesministerium für Verkehr und digitale Infrastruktur

Deutsches Forschungszentrum für Künstliche Intelligenz
German Research Center for Artificial Intelligence

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THESSALONIKI SMART MOBILITY LIVING LAB

Real Experiments for Co-creating Open & Inclusive Digital Societies

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS · CERTH/HIT Hellenic Institute of Transport · European Network of Living Labs · thessaloniki smart mobility living lab

THE PILLARS

From data 2 knowledge
Simulation environments
Digital content aggregator
Data spaces
Solutions incubator

Living Lab infrastructure for transition acceleration

Dedicated resources
Competence center
Decision theater
Physical Testbeds

i4byDesign Competence center

Thessaloniki Mobility Living Lab is one example of the open innovation 2.0 ecosystem development (beyond traditional test beds that have usually been technology driven).

Since its start, the Living Lab has evolved from a space where technological innovations are tested directly by users to an innovation eco-system.

Social innovation
Citizens empowering for cross sectorial challenges
Openness
Cross-collaboration
Speed up urban transitioning

Open Innovation Communities ecosystem enabler

www.smartmlab.imet.gr
www.opendata.imet.gr

Facilitating innovation
Improve city's Innovation readiness
Stimulate collaboration in innovation
Clusters & Regional hubs
Manage the complexity
Digital twins OR, AI and BD toolboxes

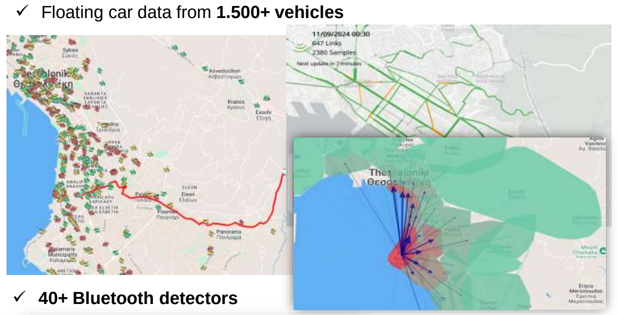
THE ECOSYSTEM

- **30+** mobility eco-system members
- **35+** companies in the mobility & logistics cluster

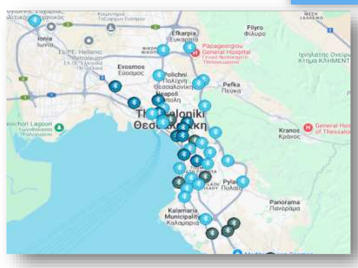
SENSING THE CITY: DIGITAL TRACES IN THESSALONIKI

The Thessaloniki Smart Mobility Living Lab **collects & analyze data to create value by extracting information & knowledge** from it as well as by offering technological solutions & services.

✓ Floating car data from **1.500+ vehicles**

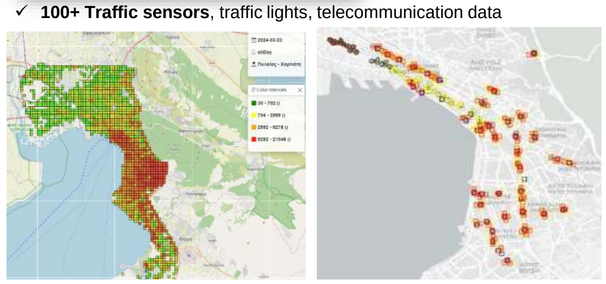


✓ **40+ Bluetooth detectors**



✓ **10+** real time data sources
✓ **20+** open datasets
✓ **240+** bus lines
✓ **3.000+** city assets mapped
✓ **17.000+** local places to collect activity patterns data

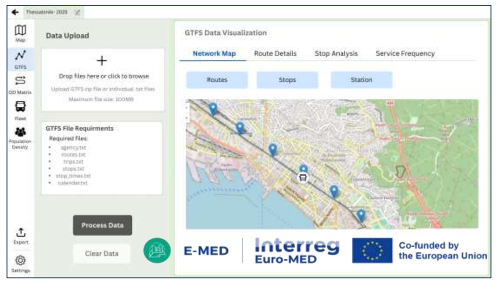
✓ **100+ Traffic sensors**, traffic lights, telecommunication data



VALUE CREATION FOR THE MOBILITY ECO-SYSTEM

✓ **Decision Support tools** for shared and on-demand mobility operators
✓ **Interactive platforms** for policy making for shared micro-mobility
✓ **Real-time monitoring** and citizen information application for traffic demand management

✓ **Multisource platform for emissions monitoring** of energy & mobility sectors of the city
✓ Continuous monitoring of city street congestion to facilitate **timely intervention and management of traffic flow** by authorities
✓ **15-min platform** for the Thessaloniki Municipality
✓ **Dynamic traffic lights management**
✓ Decision support tools for **reducing CO2 emissions**
✓ **Safe Pedestrian Routing** service for citizens
✓ **Monitoring & Quantification** of the Metro Impacts
✓ **Citizen information applications** for congestion and travel time
✓ Tools for **optimal planning & efficient management of PT** for PTOs & PTAs



REACH & IMPACT

50+ pilots implemented in the city
70+ projects supported by the LL infrastructure
300+ citizens actively engaged
500+ daily users accessing LL services
13.000+ monthly users accessing LL services

Contact:
Josep Maria Salanova Grau
CERTH/HIT
Email: jose@certh.gr

GRASSROOTS URBANIZATION

For Sustainable Urbanism in Africa

ECL-AA EMERGING CITY LAB ADDIS ABABA

GRASSROOTS URBANIZATION

Instead of infrastructure-led, top-down, city-centric, and capital-intensive urbanization models, *Grassroots Urbanization* claims that community-driven smaller but networked urban aggregates that are established primarily on local resources have a better chance in achieving just and sustainable socio-spatial productions in Africa.

The attempt is to address the burgeoning needs of urban production in Africa at the grassroots level through and by the grassroots themselves. At the center of it, the assumption is, a healthy socio-spatial formation is indebted to community's ability to grow roots and thereby ground themselves culturally, politically, economically, and environmentally in a place, hence developing a deeper sense of belongingness.

Furthermore, it recognizes the youth as the literal roots of future African societies that has to be empowered to become a responsive and responsible agent in the making of the human habitat.

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Creating NEBourhoods Together

CREATING NEB OURHOODS TOGETHER

HM:UniverCity

Shaping attractive, environmentally friendly and sustainable neighborhoods together

Funded by the European Union

NEBourhoods LIVING LABS

Beautiful, Sustainable, Together – New European Bauhaus

For more than two years, HM:UniverCity, together with Kreativ München as the Transition Hub, has designed, guided, and coordinated the co-creation processes within the project "Creating NEBourhoods Together." Under the leadership of the City of Munich and with the participation of the Technical University of Munich, Munich University of Applied Sciences, UnternehmerTUM, Architekturgalerie München, the Bavarian Research Alliance, the Strascheg Center for Entrepreneurship, the Munich Urban Renewal Society, str.ucture GmbH, Studio Stadt Region, creative professionals, and above all representatives of community associations from Neuperlach, concrete places and initiatives were created during this period. The aim was to transform Neuperlach into a more sustainable and socially inclusive neighborhood. The two years on-site work produced inspiring results: children and young people built nesting sites and shelters for wildlife in the garden of their youth center to make their neighborhood more biodiverse. Residents founded a cooperative to produce electricity together—sustainably, fairly, and locally. A newly built outdoor kitchen, available for free rental, invites people to cook together in public spaces. CHILLspORT, a project with young people, is a collaboratively designed landscape of objects on a schoolyard that invites relaxation and exercise, offering new ways to use school grounds. A large shaded bench with a solar roof provides Neuperlach residents with protection from the sun, serves as a meeting and learning place for a local school, and functions as a charging station.

These and other initiatives were created in co-creative living labs. While living labs share common characteristics, their implementation varies, requiring flexible, iterative planning and management approaches. In this project, the focus was on integrating local residents, politicians, businesses, and municipal authorities into Co-Creation processes aimed at sustainable and socially inclusive development, with support from creatives and artists. Living Labs are utilised to refine and enhance existing project ideas, assess their relevance for the local community, identify prototype locations, and plan for long-term implementation: places that enhance quality of life, inspire pride and care, and serve as tangible milestones for the collective, sustainable, and social development of a neighborhood.

The initiative "Creating NEBourhoods Together," funded by Horizon Europe and coordinated by Sylvia Pintarits, City of Munich, ran until March 2025. Many of the projects initiated in Neuperlach will continue beyond the project period, carried forward by local stakeholders and community actors.

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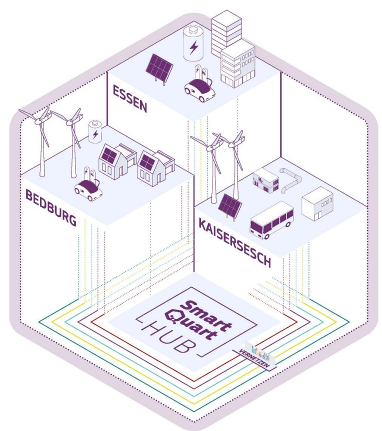
Neighbourhood Energy transition

SmartQuart

Realisation of Cross-Sector and Cross-Neighbourhood Energy Exchange

SmartQuart is intended to serve as the first real-world laboratory of the energy transition, running from 2020 to 2025, to demonstrate that implementing the **energy transition at the district level** is already technically and economically feasible today. To achieve this, the energy transition pilot project is being at three sites in Germany: a new **residential** development in the small town of Bedburg, an **industrial** and commercial area in the municipality of Kaisersesch, and a digital district with residential and commercial buildings in **urban** areas (Essen, Aachen, Cologne).



The core technological element is the **exchange of energy** and **intelligent networking** within and between the districts. Consumption and generation are optimized locally, and any surplus energy is then made available to other districts on a balance sheet basis. An important part of the project is **sector coupling** within the districts to realize the energy transition in the areas of mobility, heating, and electricity. The connection of the individual sectors and districts is achieved through the so-called SmartQuart Hub, an **energy management system** that systematically connects all consumers and producers within a district and controls energy flows.

Aims:

- Development of energy exchange between districts through the power grid
- Adapt the energy supply to a higher share of renewable sources
- Identify how energy flow management can reduce the carbon footprint and costs of energy supply

Key principles:

- Neighbourhoods are working together to increase the usage of locally produced renewable power
- Different optimization targets possible: neighbourhood wise, neighbourhood overarching, minimize costs, minimize CO_2

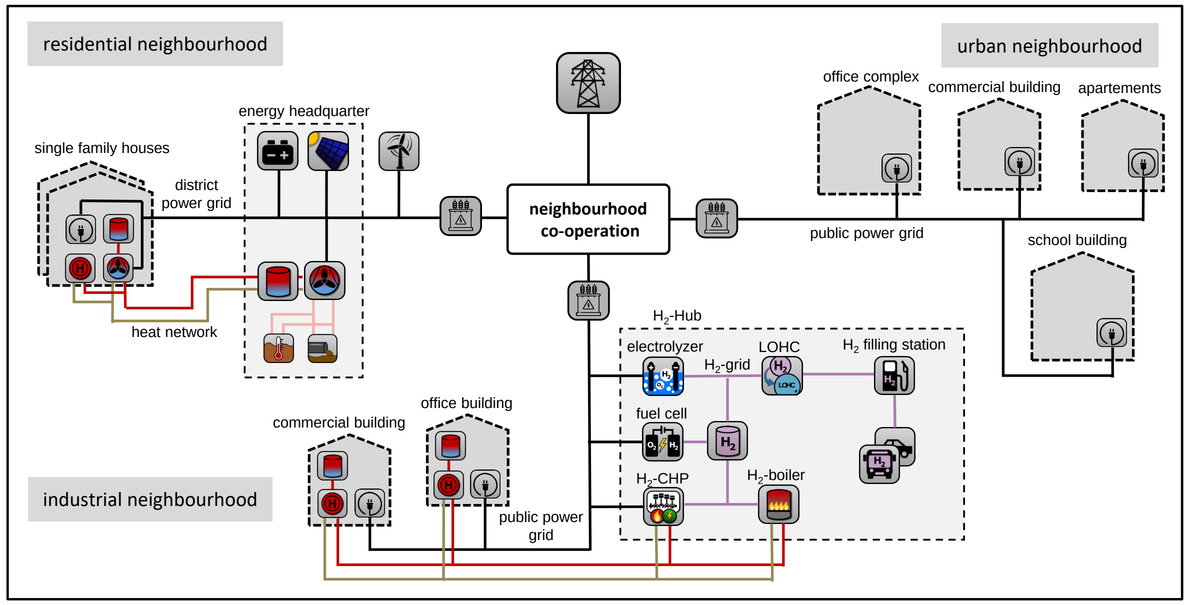


Figure: The residential, urban, and industrial neighbourhood collaborate through power sharing. Each neighbourhood features different types of consumers and distinct consumption patterns.

Structure of the energy systems

The residential neighbourhood relies on the use of a cold local heating network, which is heated by central heat pumps. Wastewater from the settlement and surface geothermal energy serve as heat sources. A wind turbine from the neighbouring wind farm supplies the entire neighbourhood with electricity. To further increase the utilisation of wind power, surplus electricity can be stored in two ways: thermally by charging the heat storage tank using the central heat pumps, or electrically by transferring it to the neighbourhood's own battery storage system. This approach enables the neighbourhood to be supplied with renewable heat and electricity during periods of low wind. Surplus wind power is used by the central heat pumps to fill the heat storage tank or to charge the neighbourhood's own battery storage system. Decentralised heat pumps are used in the residential buildings in the neighbourhood to raise the heat provided by the heating network to domestic water level.

In the urban neighbourhood, energy efficiency measures are being developed for various existing buildings in the residential and commercial sectors, affecting both the operating strategy and structural interventions.

The industrial neighbourhood is dedicated to hydrogen use. Green hydrogen is produced using an electrolyser and distributed to consumers in the neighbourhood via a hydrogen network. The hydrogen network also serves as a hydrogen storage facility, which can be used to balance fluctuations in demand and production. In some buildings, gas boilers have been converted to hydrogen for space heating. An H2 CHP plant supplies the neighbourhood with heat and electricity via a local heating network. In another application, the hydrogen is converted back into electricity via a fuel cell. Due to the distance to the nearest hydrogen filling station, the hydrogen is stored via a LOHC (liquid oxygen hydrogen carrier) and transported to the filling stations.

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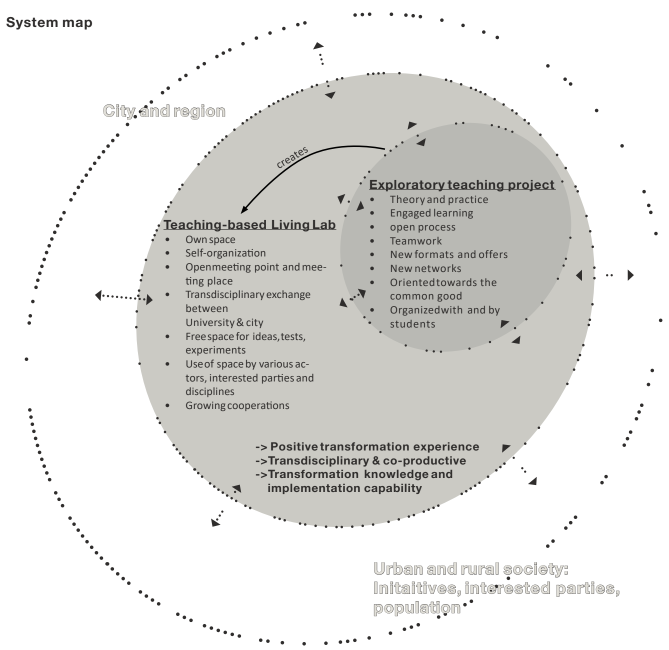
From Exploratory Teaching Projects to Urban Living Labs

Bottom-up Research Spaces for a New Public-Civic Collaboration

Karlsruher Institut für Technologie

System map



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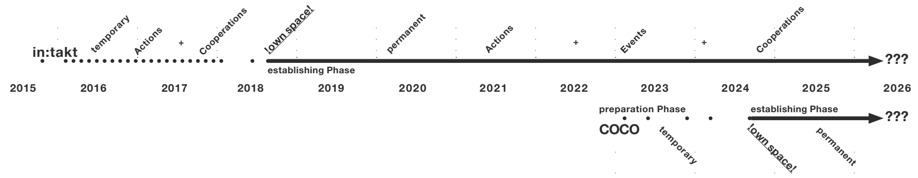
Excerpts from COCOwinter semester 2024-25: Repair Café, opening of the "Open Passage", research workshop "Mobile in old age",
(© Moritz Franke, Ralf Schuster, Melina Ehrenteit, 2024-25)

Timeline



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Keywords
Urban Living Lab, Transdisciplinarity, Co-Design, Co-Production, Third Mission, Co-Education

Abstract
Exploratory teaching projects, expanded to include „engaged learning" (Chmelka et al. 2023) and „live projects" (Harriss et al. 2014), bring the academic sphere into the urban space. They work exploratively, facing open problems, multiple actors, shifting contexts, and sudden change. To this end, they use the participatory design and action research approach (cf. Telier et al. 2011, Chevalier et al. 2013). This turns them into teaching and research projects and offers the opportunity to establish interdisciplinary and transdisciplinary working methods and co-design processes. In open living labs, they create a new urban practice on the cross-cutting issues of urban development, sustainability and democracy. Based on the preliminary work and developments of the city lab "COCO_CommonigCottbus" in Cottbus and "in:takt – Free space for all" in Magdeburg, the framework conditions, processes, opportunities for urban society and challenges for those involved will be presented and discussed.

Living Lab in progress
These living labs were initiated from teaching and are still being developed. They provide low-threshold, non-commercial access for encounters and create a new type of space for engagement, local project work, and mutual knowledge exchange. Its open, networked project structure creates opportunities for transdisciplinary collaboration and co-design processes. Students meet city residents here, and specific activities and formats are developed and tested. Collaborations are developed here, and people work together spontaneously. These interactions create a training space for dealing with diversity, openness, and change, as well as a space for collaborative research on current, open issues. Through teamwork, responsibility is distributed across many shoulders, and students are the protagonists. Thanks to their strong roots in the city and open mindset, these labs address the interdisciplinary themes of urban development, city-making, sustainability, resilience, democracy, and the common good, surpassing disciplinary approaches. The projects ultimately aim to establish a culture of collaborative cooperation and co-creation, forming a basis for the co-production of the city. Designed as open infrastructure, they aim to have a broad impact on urban society.
To achieve this, teaching-based living labs require stable support structures and strengthened resources for organization, networking, and project work. Initially started out of the university, they have not yet received financial support from the local authority or the space owners. Currently, the diverse aspects and tasks, ranging from operation and coordination to content-related work and strategic development, can only be addressed in a rudimentary and selective manner.

Conclusion
To strengthen and further develop the approach of a bottom-up teaching and research space, stronger cooperation is necessary between the university, civil society initiatives, and the public sector. Through a strategic public-civic partnership, an innovative, open, and community-oriented infrastructure could be created. This infrastructure would serve as an urban living lab for co-education, cooperation, community,and dealing with complex social issues and development processes.

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6 Young Scientists Contributions

Energy and Digitalization

Julian Bansen:
Social Networks of the Mobility Transition – The Role of Local Actor Networks in Urban Mobility Transformations

Stefan Bindreiter:
Sustainable Transformation – How can you embed "Gestalt" in Energy and LCA Simulation Models?

Tristan Emich, Tobias Kropp, Kunibert Lennerts:
The Smart Readiness Indicator as an Opportunity to Decarbonise the German and EU Building Stock

Kai Droste:
The Role of Living Labs for Urban Energy Transformation: Insights from SmartQuart and TransUrban.NRW

Panagiotis Gkirmpas:
Estimating Emission Rates from Multiple Road Traffic Sources in Urban Environments

Amando Reber, Barbara Smetschka:
Co-Creating Urban Energy Transition with Living Labs and Urban Digital Twins

Urban Governance and Planning

Maria Eleni Bountola:
Digital Societies and Urban Governance: Adapting Global Innovations in Greece

Stefan Böschen:
Advancing Spatial Literacy in Real-world Labs

Annica Kögler, Stefanie Rößler, Robert Knippschild:
How the Set-up of an Urban Transition Lab influences Experimentation – a Case Analysis of the TRUST Project

Pia Laborgne, Volker Stelzer:
Activating Citizens through Innovation Communities for Inclusive Urban Transformations

Susanne Ober:
Experimenting with Cities – Real-world Labs and Experiments as Tools for Urban Transformation

Iljana Schubert, Paola Yanguas, Anton Sentic, Evelyn Lobsiger-Kägi, Jasmin Oberkalmsteiner:
Distilling Meta-success Factors & Meta-barriers through a Mixed Method Multi-living-lab-approach

Hendrik Weiner:
From Exploratory Teaching Projects to Urban Living Labs - Bottom-up Research Spaces for a New Public-Civic Collaboration

Ressource, Building and Construction

Hanna Bonekämper:
Economic Viability of Urban Vertical Farming. Literature Review & Case Study

Ekaterina Gladkova:
A Living Lab Experiment in a Mass Housing Estate in Tbilisi

Ilirjana Haxhiaj, Jeta Bejtullahu:
Reconstructing Durres: Governance, Sustainability, and Livability in Post-Earthquake Urban Transformation

Markus Szaguhn:
Experimenting for Change: Potential of Employees of Municipal Energy Suppliers as Local Change Agents in Urban Sustainability Transformations

Elke Widmann:
Insulating the Future – The Fiber That Unites Energy Efficiency and Recycling

Elke Widmann:
Reconstructing Education - Prefabricating the Future of University Buildings

Climate Protection and Adaption

Chandana Bhasi:
Repurposing Urban Parking Space to Green Space for Heat Stress Adaptation: Case Studies of Stuttgart, Germany and Bhopal, India

Jayati Chawla:
Examining Race and Class Disparities in Surface Urban Heat in Australia: Towards Environmental Justice in Urban Planning

Julia Fuchs:
Diurnal Patterns and Drivers of Urban Fog in Milan

Svea Krikau:
Predicting Heat-related Risk Using Multi-source Remote Sensing Data on a Regional Scale

Laura Miller:
Urban Infrastructures under Climate Pressure – Exploring Benefits of Transformation Concepts for Long-term Change

Mobility and Urban Space

Clara Aulich:
Exploring the Potential of Mobility Hubs to Enhance Intermodal Private Transport Choices – A Stated Choice Approach in the Surroundings of Karlsruhe

Martin Berger, Jakob Holzer:
Networking Frontrunner Cities: the aspern.mobil LAB "Städte-Dialog"

Yifan Liao:
The Impact of Smart Mobility on Urban Spatial Structure – Comparing Cities in China and Germany

Narek Mirzoyan:
Diesel Bans and Urban Air Quality: A Causal Study of NO2 Emissions in Germany Using Synthetic Control

Haixiao Pan:
Bringing Home Care Services and Female Migrant Laborers by Electrical Two-Wheels

Andrea Reindl:
Promoting Ridesharing in Urban Areas through Accompanying Advertising Measures and Incentives: A Case Study of the City of Ried, Austria

Nicolas Salbach, Miriam Magdolen, Lukas Burger, and Peter Vortisch:
Effects of Sociodemographic Characteristics and Travel Behavior on Urban Neighborhood Satisfaction

Ann-Sophie Voss:
Intermodality and Urban Mobility: User Acceptance and Spatial Planning Implications for Autonomous Ridepooling in Hamburg

Water and Urban Ecology

Angélica Betancourth Arias:
Advances in Urban Flood Damage Assessment: Understanding Floodwater Transferring from Street into Property (INSIDE project)

Denise Boehnke:
Transformative Governance through Embedded Scientific Collaboration

Arend van der Kam, Emiliy Suchy, Josefine Siebenand, Martin Prominski:
Changeability for Transformation: a Strategy for Urban Landscapes in the Anthropocene

Niku Khaleghi:
The Role of Organic Street Networks in Sustainable Urban Mobility

SaeBom Song:
Towards a Smart Circular Urban Future? Analysis of Water Management Visions in Amsterdam and Busan

Marufa Sultana:
Exploring Synergies of Urban Greening for Wildlife in Cities

Energy and Digitalization

Social Networks of the Mobility Transition

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Abstract

This paper conceptualizes living labs as cultural incubators in the mobility transition, embedded in local actor networks. Drawing on theories of cultural power, contested mobility cultures, and networked social contexts, it develops a relational model to understand, how symbolic practices and social mechanisms shape everyday mobility. Empirical findings from the MobiQ project, conducted in three diverse living labs in Baden-Württemberg, combining narrative interviews and ego-centered network maps, reveal how individual mobility practices are influenced by societal roles, infrastructural contexts, and local hegemonies. The paper synthesizes a multi-level framework of mobility cultures and proposes a visual model that positions living labs as tool for cultural negotiation. It argues that sustainable urban mobility policies must account for context-sensitive, culturally embedded dynamics and highlights the potential of living labs to mediate between micro-level practices and macro-level strategies of transformation.

Keywords: mobility cultures, living labs, urban mobility transition, social networks

1. The Mobility Transition

The mobility transition is one of the key challenges for sustainable urban development. Not only in the state of Baden-Wurttemberg it is mere consensus, that this transition cannot be based only on political and planning discourses that too often only focus on technological and infrastructural solutions. However, the relevance of cultural and social dimensions of change are increasingly becoming more politically accepted in order to advance on the path to climate neutrality in transport (Ministerium für Verkehr Baden-Württemberg, 2024).

Following this understanding, mobility is not just a functional process of changing location, but a socially and culturally deeply embedded phenomenon - a form of everyday organization through which belonging, participation and lifestyles are expressed. Thus, the mobility transition needs to be embraced as a triad of new technological solutions, that demand for new organizational and infrastructural structures in order to allow for new practices of mobility (Kesselring et al., 2023) (see fig. 1).

A prerequisite for the success of such a transition lies in the concept of the "energetic society" (Hajer, 2011), which describes a society in which independent, creative actors in business and civil society actively develop solutions for ecological and social challenges. This is associated with a change in the understanding of the role of the state away from centralized control and technocratic interventions and towards a supporting and enabling function in the sense of a more reflexive understanding of democracy (cf. Schmalz-Bruns, 1995). One form of governance, that leverages the energy within the society best, could be a reflexive governance (Voß & Kemp, 2006).

This necessitates a high degree of initiative and creativity from the heart of society. Political and administrative actors take on the task of promoting and demanding participation and cooperative social learning to strengthen society's resilience to an increasingly dynamic environment. This is a paradigm shift towards a governance strategy that recognizes, activates and promotes social innovation.

Yet, when it comes to the arenas in which said transition needs to take place, it is yet unclear which contextual scale to look at. In this paper, I want to put forward, that living labs (RWLs), which are often described as experimental spaces for sustainability, can play a special role here. They are not only places of innovation, but also cultural hubs in which new meanings, practices and networks emerge, where knowledge about sustainability-oriented transformation processes is produced while they are being initiated (Schäpke et al., 2017; Schneidewind, 2014; Wittmayer & Hölscher, 2017).

The aim of this article is to develop a theoretically sound understanding of living labs as cultural incubators in the mobility transition. The empirical foundation is the MobiQ project, in which three living labs in Baden-Württemberg were examined. A combination of qualitative interviews and socio-geographical network analysis makes it possible to shed light on the role of actor networks in urban transformation processes.

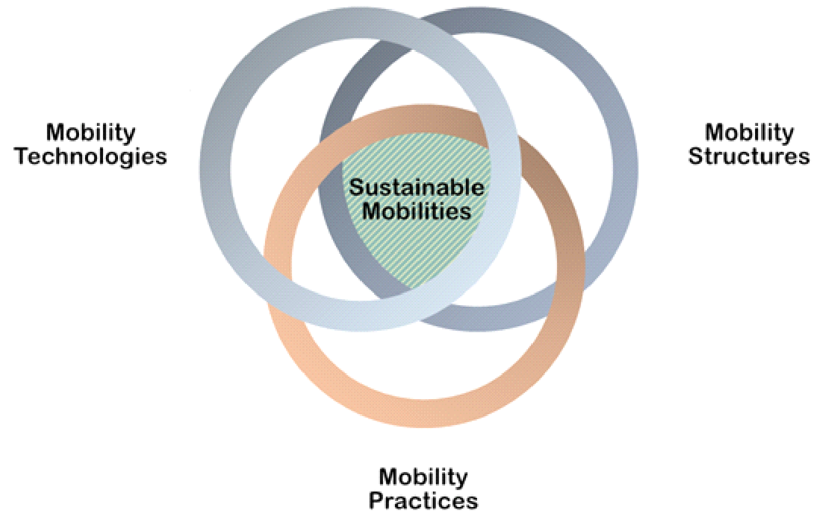

Figure 1: Triad of the mobility transition, Source: (Böhme et al., 2025, p. 13)

2. Actor-centered research for better cultural understanding

The three MobiQ living labs are situated in very different geographical contexts. Rot is a densely populated neighborhood with around 10.000 inhabitants in the district of Zuffenhausen in Stuttgart. Connected to Stuttgart's U-Bahn-system, in general public transport connections are good. The opposite is true for Waldburg, a village with around 2,500 inhabitants between Wangen and Ravensburg in the picturesque Allgäu region of Baden-Württemberg. Here, public transport is mainly available for the school run and a basic bus service to Ravensburg for commuters has been installed.

The living lab neighborhood in Geislingen an der Steige, a medium sized township in the very east of the Stuttgart region encompasses the old town quarter with around 6,000 of the 28,500 inhabitants. (Kesselring et al., 2023)

Right after the start of the project, before the transdisciplinary co-design started, semi structured interviews with inhabitants from all three quarters were conducted. The focus of the interviews was on the interviewee's critical reflection on their own mobility patterns. The results are narrative descriptions of "individual mobility constructions and practices" (Kesselring, 2006, p. 340). As Küsters (2009, p. 40) notes, narrative interviews are best suited for open questions that seek connections between social phenomena. The aim is to determine which, possibly also fallow, networks for the perception of motility (spatial and social mobility) the interviewees have at their disposal, possibly even without them being aware of it. This also includes social capital, which is made up of origin, education, friendships, club memberships etc., but access to technologies such as vehicles, public transport, sharing systems, cell phones, computers, etc. also play a role.

Using the method described so far, a type-specific and a case-specific or “egocentric” (Kahn & Antonucci, 1980) dimension of acceptance conditions for mobility concepts can be derived. The type-specific dimension of acceptance conditions for mobility concepts describes the acceptance conditions derived directly from the specific contexts from the context analysis carried out in the project and can therefore be applied, in principle, to other locations that are very similar to Geislingen, Rot or Waldburg. The case-specific dimension depends on the individual social network structures and challenges in the individual living labs and therefore cannot be transferred to other places. In this sense, it must be determined who is in what kind of relationship with whom and in what spatial radius the people who were interviewed move. Above all, it should be determined where these persons and networks are located that are willing and able to take on active roles in initiating and supporting concrete changes. Additionally, ego-centered network maps were used to illuminate the social network, Alteri, of an interviewee, Ego, thus create a “social map” (Herz, 2012). At the center of such a “social map” is the ego, i.e. the interviewee, around whom he or she places the alteri, usually arranged in a circle. The visual distance to the ego expresses the strength of the relationship between the actors.

Such a map can be created both qualitatively, for example by drawing it during the interview, and quantitatively by filling out a form and evaluating the strength of the relationship in numbers. An example question for an egocentric social network map would be, "Who are important people to you? Please draw them on the map" (Kesselring, 2006, p. 344). This provides a social constellation for the study area, both on a case-specific and aggregated basis. These social constellations in the study area show how socially networked people in the laboratories are on an informal level. Potentials for the joint organization of mobility can be derived from this. The spatial component of the existing mobility patterns is explored using a corresponding ego-centered geographical network map. Here, the ego represents the center of life of the interviewees. This does not necessarily have to be the main place of residence, as social and emotional affiliation can differ from statistical survey data. A corresponding question would be, "What are the most important places in your life? Please draw them on the map." (Kesselring, 2006, p. 344). In the context of MobiQ, it is important at this point that virtual places were permitted too because “space” is a complex social construct, and it shows the importance of geographic space compared to digital space.

3. Synthesis of a Model for Mobility Cultures

To position living labs as cultural incubators of social innovation, one could start the model by Götz and Deffner. (2009, p. 40-41) (fig. 2) which on the one hand does deliver a relational perspective on mobility cultures, that allows for an actor-oriented view as well. Yet, on the other hand, as the authors themselves admit, fails to explain the “nitty and gritty” of urban mobility cultures and could eventually end up in an “infinite regress” (Götz et al., 2016, p. 798). Meaning, it explains the act of practicing a modality because of a particular culture. This in turn limits the value of the concept of culture in the model (Fig 2), because its significance is pushed into the background of planning and political framework conditions, which in turn represent the decisive factors. In short, culture is implicitly presented one-dimensionally and as a consequence of built infrastructures (Götz et al., 2016).

Adding a more nuanced theoretical perspective is needed to help contextualize mobility cultures within local arenas such as living labs. First, the context itself is important. It seems accepted, that only looking at the city level, definitions of mobility cultures become too broad. Rather an actor centric view, based on Simmel’s (1920) micro perspective is needed.

In that sense, individual actions, initially unintentional, must be considered in a context. Friedrichs and Nonnemacher (2014) offer a multi-layered framework for analyzing social contexts. A social context is understood as a socio-spatial, temporally limited structure (network) that provides expectations, opportunities and restrictions for the behavior of the individuals acting within it. Examples include couples, families, companies, residential areas, schools and political parties. Social contexts influence the behavior of individuals through the social mechanisms that these contexts exert on them.

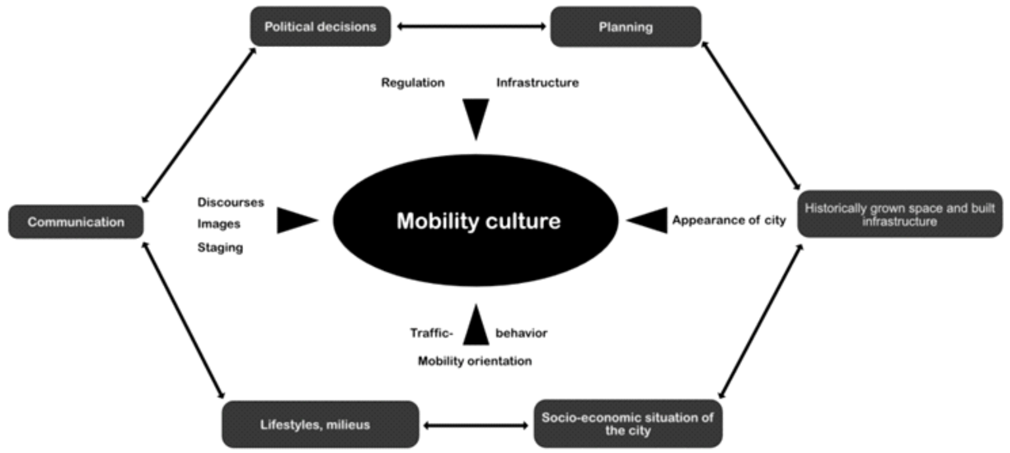

Figure 2: Factors influencing the mobility culture, Source: Götz et al., 2016, p. 40

Family is one of the social contexts influencing mobility behavior that ranks very high within the data in all three of the living labs and in all of the social network cards. One of the interviewees in Geislingen who only uses her bicycle in daily life, describes how caring for her mother, who lives in another city is the only reason why she still has a car:

“Yeah, well. So that’s how it is, I have to, or I try to drive to Heidenheim twice a week to accompany my mother who needs care. And that’s our sticking point, otherwise we might not have a car anymore, but you just can’t get there any other way. Especially if you have a pot of soup with you.” (a58vk, pos. 207)

First, it shows, that it is undebatable and clear who has to do the care work in the family and, second it gives indications for whom public transport is being planned in the region. A social mechanism is a set of interrelated hypotheses that explain how a context effect occurs. This can be complex, especially when different levels of contexts (e.g. national, regional, local) affect an individual simultaneously.

For the analysis of social contexts, Friedrichs and Nonnemacher (2014, p. 7) provide a multi-level model to account for the theoretical relationships between different levels of contexts and the statistical challenges of modeling these levels. Individuals act in multiple contexts, which may have different or even conflicting requirements and expectations. These non-linear “cross-pressures” can lead to normative conflicts that influence the behavior and decision-making of individuals. These different levels of contexts are displayed in the visual model (fig. 3) as the three layers, micro, meso and macro. However, contexts are only one element of cultural power according to Swidler (1995). The example shows, different social mechanism led to the context effect of her having to take the car to do her care work, which creates a conflict between her reluctance of using the car as a means of transport and her obligations towards the family.

Swidler emphasizes the importance of public symbols and practices in comparison to individual belief systems. She argues that culture operates not only through what people believe or have internalized, but through certain collective symbols and practices that exist in the public sphere and shape social structures and dynamics. This cultural power is particularly evident in social movements that create new identities and ideologies, which in turn influence collective action. Cultural power operates through semiotic codes, social contexts and institutions, which together form the structure for the behavior of individuals in society. (Swidler, 1995)

One of our interviewees in Rot, who moved there from Berlin two years earlier, and chose the quarter deliberately because of its good infrastructure (“everything is so close”), goes on explaining, how problems with public transport brought him to buying a car, thus adapting to car-based routines:

“Yes, well, let’s put it this way, we actually usually did it [shopping for groceries] by bus, that we take our trolleys and then – by bus? I mean by train of course, right? Well we haven’t had the car for very long I have to say. We've only had it for a year now, before that we were without a car and at some point it just got on our nerves that the train was becoming increasingly unreliable." (HJHGV, pos.196)

With the ownership of a car comes the adaption to practices of the hegemonic car culture. He gives an insight into this, by admitting that, albeit owning a garage for his car, "[…] sometimes, in the evenings, we try to park comfortably in front of our door […]" (HJHGV, pos.248).

Hoor (2021) ties in with his definition of mobility cultures in the sense that culture both shapes power structures and is shaped by them. He extends Swidler's approach by describing the process of the emergence of cultures of mobility as a result of negotiations and struggles for hegemony, in which culture can have both a stabilizing and transformative effect (Hoor, 2021, p. 170 et sqq.).

Such struggles can only be seen, when looking at practices that challenge the hegemonic car culture in the living labs. Here it is especially interesting to look at the practice of everyday cycling:

"When I come down [the hill at] Schotzacher Straße really fast […] and then, all of a sudden, at the entrance to a property, there's a cycle path on the left that has to be used, so I would have to brake real hard and cross the road to use the cycling path." (HJHGV, pos. 207).

Of course, he does not use said obligatory cycling path, which already is a (minor) act of resistance to the dominant system.

Culture is seen as a dynamic field that shapes and changes social structures, whereby power is reproduced not only through coercion, but also through consent and everyday practices. However, while Hoor leaves the question of concrete measures for transformation open, Swidler's concept of cultural power offers a good starting point: Swidler argues that culture is shaped by external symbols, rituals and institutions, which indicates that cultural transformations could be triggered by targeted symbolic and institutional changes.

While institutional change needs time and mostly employs action on the macro level of a city, living labs can support the macro layer in the identification of the diverse mobility cultures on the subordinate layers within the quarters of a city.

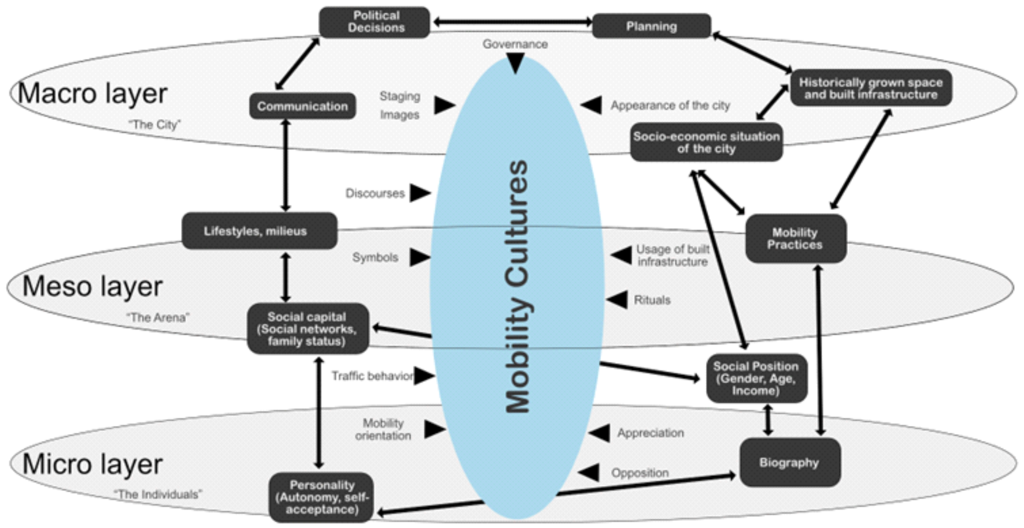

Figure 3: Multilevel perspective on mobility cultures, Source: Own Illustration based on Friedrichs & Nonnenmacher, 2014; Götz et al., 2016; Hoor, 2020; Swidler, 1995.

And therefore, it is important to embrace "culture as a toolkit" in living lab research, especially, when the topic is concerned with transformative mobilities research. Doing so, the living lab can be understood as positioned on the meso layer, identifying local social networks and helping them find their way into "the arena" by employing a methodology, that on the one hand side, sheds a light on the actual and felt living conditions of the individuals (the micro level) and their personal networks, as well as uncovering the macro context of the city. The characteristics (black boxes in fig. 3) on the micro level, the level of the individual, describe the prerequisites of a person, that influence cultures in one place but are not observable. They can only be taken into account by employing interview-techniques. The meso-layer is where the sum of characteristics of the sum of individuals come together and create social capital and perform rituals by using the built infrastructure and create and recreate symbols. All of which influence and are influenced by the local mobility cultures that are part of the overall context. Another part of the context and also influenced by and influencing mobility cultures is the macro layer. There, the characteristics influencing mobility cultures can be analyzed employing discursive methods or statistical methods or methods of observation.

The integrative model proposed in this paper (fig. 3) synthesizes the three conceptual strands presented to illustrate how living labs function, not merely as experimental sites but as embedded cultural nodes within broader actor-networks. This framework potentially provides a lens through which to analyze the spatial, social, and symbolic dimensions of mobility cultures, potentially uncovering windows of opportunity for the local mobility transition.

4. Conclusion

This paper conceptualizes living labs not merely as experimental sites, but as cultural incubators embedded in local actor networks. Drawing on cultural sociology and network theory, it develops a relational model of the mobility transition that foregrounds the interplay between social contexts, symbolic practices, and power structures. Empirical findings from the MobiQ project, which involves three living labs in Baden-Württemberg, illustrate how everyday mobility practices are shaped by family obligations, local infrastructures, and informal networks. Intermediaries emerge as key cultural translators, mediating between individual routines and collective norms.

Reflecting on these findings, I argue that transformative urban mobility policies must embrace the plural, sometimes conflicting cultural logics at play within local contexts. Living labs, when understood as spaces for cultural negotiations, can play a key role in uncovering, activating and moderating such embedded dynamics. However, cultural transformation is neither linear nor universally transferable. While Götz and Deffner tried to present a universal model for the mobility culture in a certain place, I argue that more differentiation is needed. With the presented model a more context sensitive view and a more nuanced understanding of the various mobility cultures in one place is put forward. Yet, considering all the different interplays even on a smaller analytical scale, a lot more interdisciplinary research into the influence factors on all levels is needed.

References

Böhme, U., Kesselring, S., & Urmetzer, S. (2025). Netzwerk für soziale Innovationen der Mobilitätswende. Internationales Verkehrswesen, 77(1). https://doi.org/10.24053/IV-2025-0003

Friedrichs, J., & Nonnenmacher, A. (2014). Die Analyse sozialer Kontexte. KZfSS Kölner Zeitschrift Für Soziologie Und Sozialpsychologie, 66(S1), 1–16. https://doi.org/10.1007/s11577-014-0260-y

Götz, K., Deffner, J., & Klinger, T. (2016). Mobilitätsstile und Mobilitätskulturen – Erklärungspotentiale, Rezeption und Kritik. In O. Schwedes, W. Canzler, & A. Knie (Eds.), Handbuch Verkehrspolitik (pp. 781–804). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-04693-4_34

Hajer, M. (2011). The energetic society: In search of a governance philosophy for a clean economy. PBL Netherlands Environmental Assessment Agency.

Herz, A. (2012). Ego-zentrierte Netzwerkanalysen zur Erforschung von Sozialräumen. Sozialraum.De. https://www.sozialraum.de/ego-zentrierte-netzwerkanalysen-zur-erforschung-von-sozialraeumen.php

Hoor, M. (2020). Mobilitätskulturen: Über die Notwendigkeit einer kulturellen Perspektive der integrierten verkehrsplanung (Working Paper No. 2020 (19; IVP-Discussion Paper). Fachgebiet Integrierte Verkehrsplanung, Technische Universität Berlin. https://www.econstor.eu/bitstream/10419/214892/1/1692365703.pdf

Hoor, M. (2021). Öffentliche Mobilität und eine neue Mobilitätskultur – Grundlagen, Entwicklungen und Wege zur kulturellen Verkehrswende. In O. Schwedes (Ed.), Öffentliche Mobilität (pp. 165–194). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-32106-2_7

Kahn, R., & Antonucci, T. (1980). Convoys Over the Life Course: Attachment Roles and Social Support. Life Span Development ER, 3, 253–267.

Kesselring, S. (2006). Topographien sozialer Möglichkeitsräume. Zur sozio-materiellen Netzwerkanalyse von Mobilitätspionieren. In B. Hollstein & F. Strauss (Eds.), Qualitative Netzwerkanalyse. Konzepte, Methoden, Anwendungen. (pp. 333–358). VS Verlag für Sozialwissenschaften.

Kesselring, S., Simon-Philipp, C., Bansen, J., Hefner, B., Minnich, L., & Schreiber, J. (2023). Sustainable Mobilities in the Neighborhood: Methodological Innovation for Social Change. Sustainability, 15(4), 3583. https://doi.org/10.3390/su15043583

Küsters, I. (2009). Narrative Interviews. Grundlagen und Anwendungen. (2nd ed.). VS Verlag für Sozialwissenschaften.

Ministerium für Verkehr Baden-Württemberg. (2024). Ziele der Verkehrswende in Baden-Württemberg. Ministerium Für Verkehr Baden-Württemberg. https://vm.baden-wuerttemberg.de/de/politik-zukunft/nachhaltige-mobilitaet/ziele-der-verkehrswende-in-baden-wuerttemberg

Schäpke, N., Stelzer, F., Bergmann, M., Singer-Brodowski, M., Wanner, M., Caniglia, G., & Lang, D. J. (2017). Reallabore im Kontext transformativer Forschung. Ansatzpunkte zur Konzeption und Einbettung in den internationalen Forschungsstand. 01/2017. https://epub.wupperinst.org/frontdoor/deliver/index/docId/6629/file/6629_Schaepke.pdf

Schmalz-Bruns, R. (1995). Reflexive Demokratie [Zugl.: Hamburg, Univ., Habil.-Schr., 1994]. Nomos-Verl.-Ges.

Schneidewind, U. (2014). Urbane Reallabore—Ein Blick in die aktuelle Forschungswerkstatt. Pnd Online, 2014(3), 19–24.

Simmel, G. (1920). Philosophie des Geldes (A. Ulfig, Ed.; Repr. d. Ausg. von 1920). Parkland-Verl.

Swidler, A. (1995). Cultural Power and Social Movements. In Social Movements and Culture. University of Minnesota Press.

Voß, J.-P., & Kemp, R. (2006). Sustainability and reflexive governance: Introduction. In J.-P. Voß, D. Bauknecht, & R. Kemp (Eds.), Reflexive Governance for Sustainable Development (pp. 3–28). Edward Elgar Publishing.

Wittmayer, J., & Hölscher, K. (2017). Transformationsforschung. Definitionen, Ansätze, Methoden.

Sustainable Transformation – How can you embed “Gestalt” in Energy and LCA Simulation Models?

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Abstract

Sustainable change in spatial planning is based on a three-column model that integrates environmental, economic and social dimensions to create balanced, resilient and future-oriented developments. When dealing with spatial sustainability, a fourth column can be added, focusing on the spatial "Gestalt". In order to simulate connections and interactions within these 4 dimensions for decision and planning support, we focus on digital decision and planning support tools that include visualisation environments for integrated planning approaches. A special focus is on spatial and energy integrated planning simulations to support local decision makers in strategic inward developments. Based on two examples from our research projects, the paper focuses on the methods used to integrate the design dimension into simulations and models that are otherwise dominated by quantitative methods and processes.

Keywords: spatial simulation and modelling; multi scale approach; interdisciplinary planning; gestalt sustainability;

Introduction

Planning for sustainable urban and spatial development faces the challenge of linking environmental, economic and social aspects, understanding their impacts and interactions, and being able to respond adaptively. In the established three pillars of sustainability, there are numerous approaches to modelling and simulation to make future developments measurable and assessable. These test different structural variants as a basis for discussion. In this way, processes of strategic inward development are to be supported and a contribution made to resource-saving development strategies. Based on two research projects, this article presents how test designs translate qualitative spatial aspects into quantitative models.In the SmartQ+ project, energy and mobility are analysed together to better understand the systemic relationships - including the integration of social aspects such as the demand for e-mobility. Digital tools enable both better data and interdisciplinary analysis within a shared framework. (Bindreiter et al., inPrint) Systematically integrating spatial and design aspects (in terms of structural and urban qualities) is a new methodological approach. The MDAB 2 project illustrates how spatial qualities can become digitally localised and become used for integrative planning processes. (Bindreiter et al., 2025) This article summarises two multi-methodological approaches using different ways to incorporate gestalt/design aspects for decision support in the areas of building LCA (materials), energy and mobility.

State of the Art

Sustainable spatial development

The concept of inward development is an important approach to resource-efficient urban development. It requires urban infrastructure and basic services that are as comprehensive as possible and within reasonable walking distance (Bibri, Krogstie & Kärrholm, 2020). Therefore, redensification is one of the key elements, along with the development of vacant lots and brownfield sites (Grams, 2017). This includes loft conversions, extensions, and additions (Grams, 2017: p. 16).

There exist manual ("Raum+" ETH, 2017) or (semi-)automated methods for identifying these areas ("Building land along railway corridors", Bindreiter, 2018; "Land monitoring", ÖROK, 2024; "Designated, undeveloped building land - ÖROK" Banko & Weiß, 2016; "Floor space potential/ URBEM" Forster, 2016, p. 38ff). All these approaches lack an assessment of the urban context, which is essential for assessment of potentials in terms of compatibility, infrastructure provision, and the overall integration of new developments into the existing urban fabric.

Gestalt Sustainability

The concept of gestalt sustainability highlights the importance of incorporating not only ecological, social, and economic aspects but also the qualitative dimension of spatial design (Pansinger & Prettenthaler, 2023). Gestalt sustainability shapes space to foster interaction, essential for creating resilient, adaptable and sustainable urban structures (Gehl, 2011; Lefebvre, 2001; Sassen, 2000). Space developed in line with principles of gestalt sustainability enables balanced integration of life’s various dimensions, fosters a sense of community and cultural identity, and aligns with ecological values (Pansinger & Prettenthaler, 2023).

Scenario analysis and Planning in variants

Urban planning typically involves multiple solution paths. They usually should be discussed and evaluated in cooperative processes involving various stakeholders and experts. Scenario analysis is a well-established and continuously refined foresight method, originally used in strategic planning in military and economic contexts (Swart et al., 2004). Scenarios have become a key tool in sustainability research, particularly in fields such as climate science, water management, health care and spatial planning (Robinson et al., 2001; Carter et al., 2001). Scenario analysis now encompasses a wide range of methodologies tailored to specific research questions and desired insights (Kosow & Gaßner, 2008). Scenarios are now widely used in urban development, land-use planning (Waddell, 2002), sustainable urban strategies, mobility research (Mitteregger et al., 2019) and technology assessment (Duinker & Greig, 2007), promoting the use of alternative futures and formal foresight processes.

Test Designs

Research Through Design is a methodology where design acts as a means of inquiry. In urban and landscape design, it involves iterative cycles of designing, testing, and reflecting to generate knowledge (Cortesão & Lenzholzer, 2022). Combining test design with scenario methods allows to explore how different design solutions perform under various conditions. The combination of these methods support decision-making and enables to visualise potential outcomes.

Methodology

Based on the premise that Gestalt is the fourth pillar of sustainable development, this dimension must be integrated into both the analysis and the development of test variants. The following section presents methods that embed the design dimension into simulations and models, which are otherwise dominated by quantitative approaches.

1. Analysis of the situation - Description of the status quo

To interpret quantitative data and extrapolate simulation or prognosis results to more abstract spatial scenarios, it’s essential to capture the qualitative context of each specific spatial setting. This enables linking simulation outcomes to spatial typologies.

a) <u>Creation of qualitative prototypes</u>

Different methods support the creation of qualitative profiles: (1) literature research on historical construction, analysis of historical plans and building documentation, (2) GIS research including inventory, clustering of data, and aerial imagery, (3) expert and stakeholder interviews, and (4) creation of representative floor plans or schematic site plans. The spatial analysis considers aspects like use, density, construction methods, building age, materials, adaptability, and location. Profile creation is tailored to each case and depends on available data.

b) Quantification of qualitative characteristics

Quantifying and weighting qualitative traits is central. This may involve manual analysis, expert input, or pattern recognition (e.g., AI). Spatial resolution also significantly affects the evaluation of urban qualities—coarse resolution can obscure variation, while overly fine resolution overemphasizes details. Resource consumption is assessed by incorporating a material- and environment-based evaluation method, using a simplified LCA. This is based on characteristics of test buildings (age, use, etc.) and detailed analyses such as planning documents or test drillings. Results are then extrapolated based on building attributes.

2. Describe what needs to be simulated:

a) Scenario analysis and development variants

Scenarios are widely used to explore alternative futures in planning and guide decisions. In recent years, a wide range of different types of scenarios has emerged (Kosow & Gaßner, 2008). Four main categories are distinguished in the literature: normative, exploratory, and their qualitative/quantitative combinations. BAU scenarios serve as guidelines and references for future decisions and require a high degree of care, especially in the definition of the projected factors. In addition, quantitative-normative future scenarios are developed for decision-making processes. This tests objectives and maps their achievement paths. The key advantage of such an approach is described as 'thinking in alternatives' (Kosow & León 2015). A 'morphological analysis' is applied to explore key factors systematically using a 'morphological box' (Ritchey, 2011, based on Zwicky, 1969), a method well-suited to integration in simulation and visualization tools. These scenarios provide a framework to test different development strategies, with qualitative aspects like typologies and densities informing simulation choices (see Figure 1).

b) Test designs for building developments

Test designs are vital for evaluating urban qualities and estimating quantitative effects (e.g., resource use, energy -> LCA). They also serve as a means of communication in the course of interdisciplinary and cooperatively developed simulation scenarios and variants. These designs need not be highly detailed but should reflect key traits identified through morphological analysis.

3. Analysis of Scenarios and Test Designs based on quantitative Attributes

Using the parameters and factors from morphological and simulation model analyses, both the status quo and variants can be quantitatively assessed. Elaboration of criteria and verification using GIS-based automated context analysis will allow for a comparison between different development scenarios.

In summary, this process effectively incorporates qualitative design and spatial aspects into quantitative simulations and data visualizations. At least two iterations are involved:

1. Qualitative analysis of the status quo and abstraction of (local, individual) spatial qualities

2. Development of scenarios and simulation variants

3. Quantitative analysis of the status quo and the variants

The following section outlines the case studies in which this process was applied.

M1.6 Sonnengasse	**Variant 0** Detached/ Semi-detached House	**Variant 1** Terraced house	**Variant 2** Courtyard house	**Variant 3** Apartment complex
Simplified Illustration				
Plot size	12.740 m²	12.740 m²	12.740 m²	12.740 m²
Footprint area	1.350 m²	3.870 m²	4.310 m²	3.900 m²
Building density	10	30	34	38
Zoning class	I, II	I, II	I, II	III, III
Site coverage ratio	0,21	0,61	0,50	0,92
Gross floor area	2.700 m²	7.740 m²	6.336 m²	11.700 m²
Residents	31	96	96	315
Housing units	14	44	44	144
Parking spots	14	44	44	144

Fig. 1: Comparison of structural variants (within existing zoning regulations) to determine simulation variants in dialogue with the municipality for Project SmartQ+. (Bindreiter et al. (inPrint): p52, Table 10)

Case Studies and Results

The following examples show how specific design and form aspects support the functionality of "Digital Twin" visualizations. These inputs enhance credibility of quantitative results.

SmartQ+ Bruck/Leitha

This project aims to link transport and energy simulation models for municipal planning, visualizing (energy) saving potentials in settlement development and mobility demand impacts in Bruck/Leitha through an interactive interface (Bindreiter et al., inPrint).

Gestalt and design aspects were integrated in consultations with municipal stakeholders. The development of different building typologies (as shown in Figure 2) for designated development areas in the municipality aided communication and scenario definition.. These test designs also served as a foundation for quantitative simulations of future development.

Qualitative methods helped estimate future outcomes (e.g., effects of certain building types, current zoning limits) and guiding strategic municipal decisions (e.g., refining development goals).

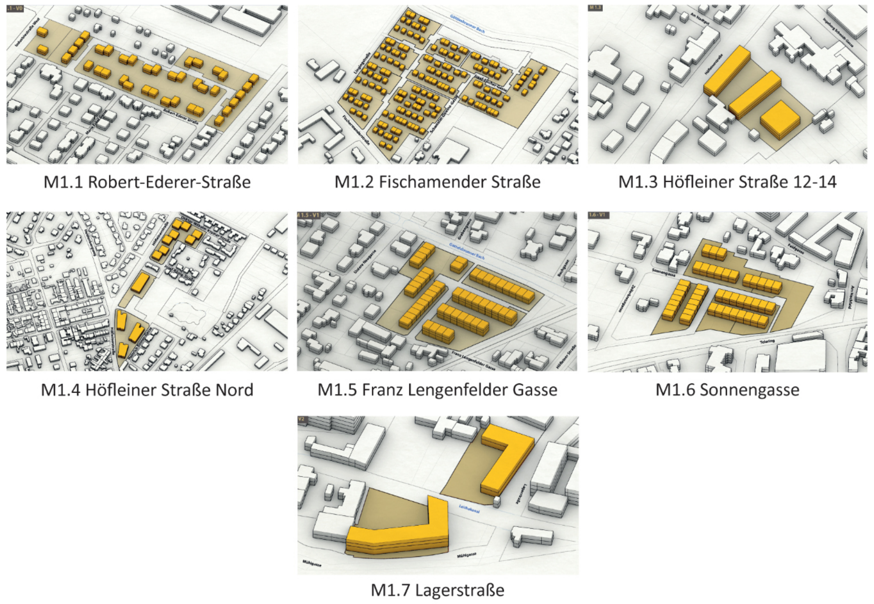

Fig. 2 - Illustration of measures in the simulation variants for interdisciplinary exchange (Bindreiter et al. inPrint: 53, Fig. 18)

Whereas SmartQ focused on qualitative inputs primarily for scenario development and communication, the next project integrated them throughout the entire workflow.

M-DAB2 Spatial Qualities + Development Options

This project assessed resource-efficient growth via inward development variants. T. It developed a holistic method set to assess potential areas and planning options for sustainable inward development. Based on the extended building database from M-DAB (Bindreiter et al., 2021), five archetypal potential profiles (see Figure 3) were defined, based on building and location traits (e.g., period, use, density, environment). Three development pathways were evaluated per profile, with emphasis on minimizing resource use. Digital tools (e.g., machine learning) helped identify similar development patterns across the urban fabric (Bindreiter et al., 2025).

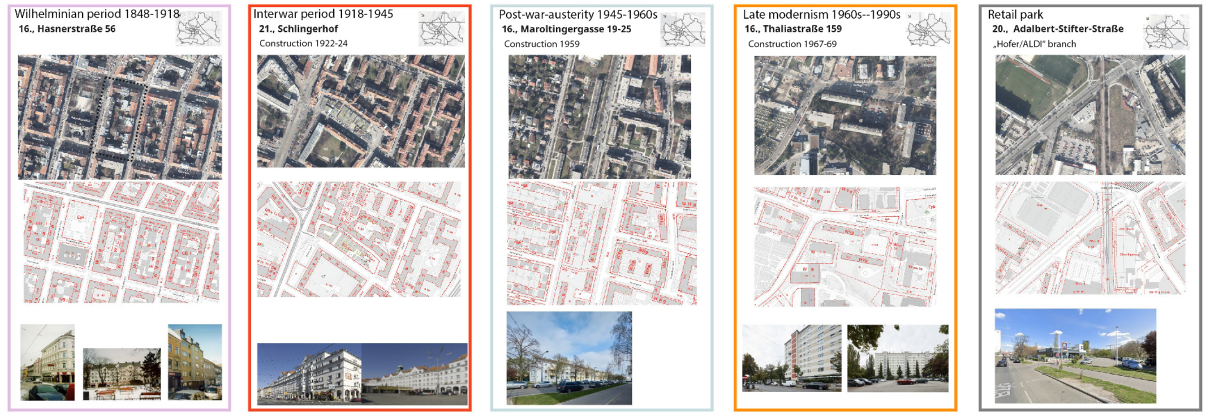

Fig. 3 - Abstract definition and analysis of five different potential profiles for Vienna based on prototype buildings (Bindreiter, et al. 2025: p57, Fig. 16, basemap: https://wien.gv.at/stadtplan)

Identifying and qualifying "potential profiles", required evaluating multiple criteria, including location, building density, and existing infrastructure. A spatial grid at the building block level (approx. 200x200m) was used, offering the right resolution for meaningful urban analysis. A coarser grid blurred local distinctions, while a finer one overemphasized differences. To locate spatial qualities tied to potential profiles, similarity metrics were used to compare urban cells with prototype characteristics. Land use potentials within these profiles were tested through concrete test designs (see Figure 4), demonstrating specific planning options for selected areas. These led to the creation of BIM models, which enabled quantitative ecological and economic evaluations—such as energy use and life cycle assessment (LCA).

Fig. 4 - Concrete test designs based on schematic considerations (Bindreiter et al. 2025: 58, Fig. 18)

Based on qualitative and quantitative analyses of selected potential areas and their development variants, indicator-based potential profiles are created. Digital methods then use spatial similarity to automatically identify and quantify similar potentials citywide, with results appropriately weighted.

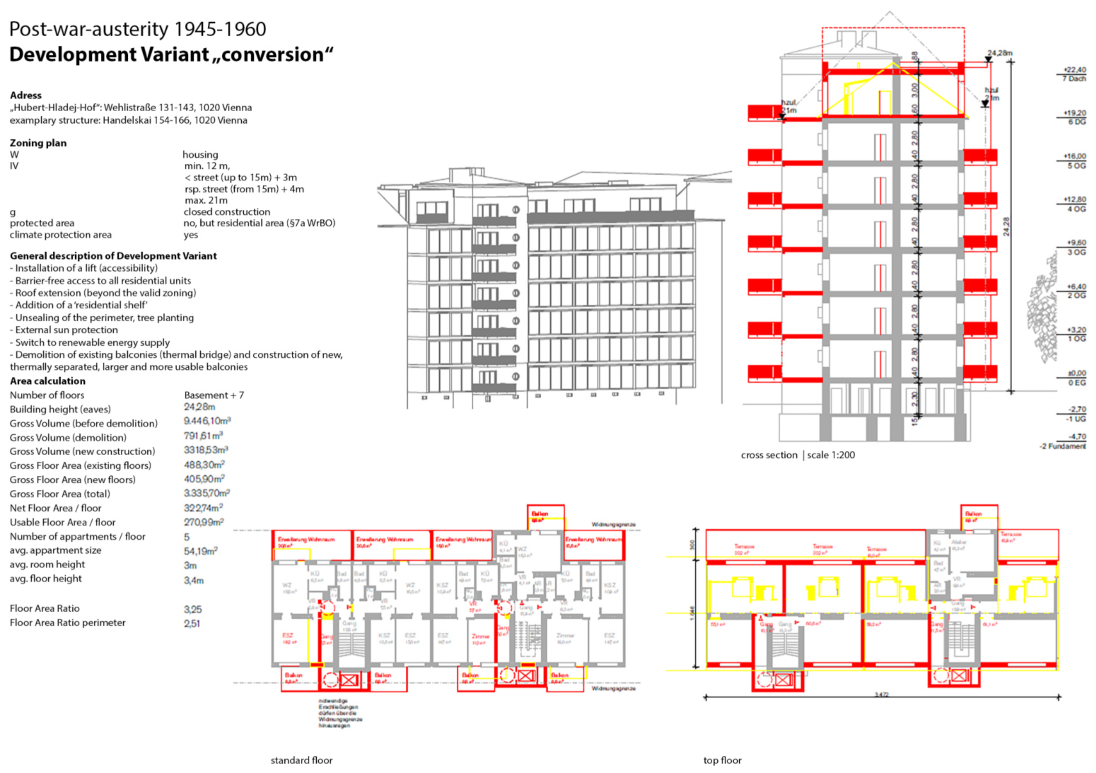

Fig 5: Distribution of grid cells with development potential of at least 1,000 m² Gross Floor Area in the 'extension & attic conversion' development variant (screenshot above, or screenshot sections PP1-PP5 below) (Bindreiter et al. 2025: p. 70, Fig. 25)

An interactive visualization (see Figure 5) displays these potentials using various filtering and weighting options. The proportions assigned to each quality profile can also be viewed in statistics on gross floor area by use or material quantities (see Figure 6).

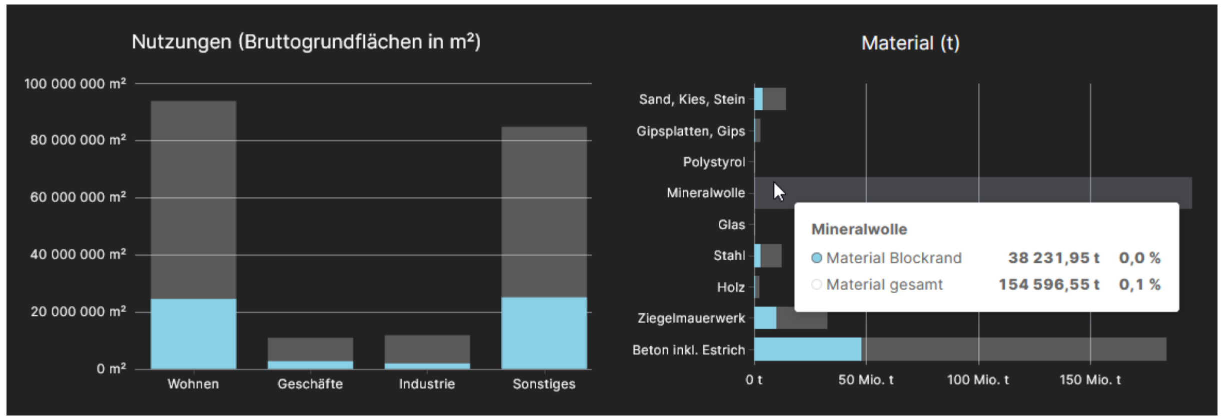

Fig. 6: Building utilisation statistics (left) and material statistics of the building stock (right), each for the whole of Vienna with the selected potential profile 'Blockrand' (Bindreiter et al. 2025: p.74 Fig. 28, Fig. 29)

In addition to qualitative filters, all project results can also be filtered spatially, using criteria such as green space availability, sustainable mobility access, or renewable energy supply.

Conclusion and Outlook

Integrating qualitative considerations and design aspects is vital when "thinking in variants," as it enhances the precision of quantitative analyses. This approach not only aids in forecasting "business as usual" scenarios from existing data but also allows for testing various control and policy strategies. Such flexibility proves especially useful in "evidence-based planning" discourse, demonstrating that "morphological analysis" is well-suited to interdisciplinary work on exploratory software development (e.g., simulation). Implementing this requires a tailored multi-method approach, depending on the available data. It also calls for interdisciplinary collaboration and involvement of local actors to ensure plausible and relevant scenarios. These methods involve recursive processes in which testing alternates with analysis. The status quo analysis is applied to both test designs and development variants. The reliability of derivations and extrapolations from abstracted case analyses can be debated. However, in our experience, combining different methods and extrapolating data—especially through intelligent, interactive visualizations—offers a more holistic view of urban strategies and environmentally and economically sustainable development. AI can assist in this through pattern recognition and similar tasks (e.g., M-DAB2). Considering Gestalt and design aspects also produces valuable communication tools, fostering interdisciplinary and collaborative planning discussions.

References

Banko, G. and Weiß, M. (2016) Gewidmetes, nicht bebautes Bauland. Erstellung von Auswertungen für Österreich. Umweltbundesamt GmbH.

Bibri, S.E., Krogstie, J. and Kärrholm, M. (2020) "Compact city planning and development: Emerging practices and strategies for achieving the goals of sustainability," Developments in the Built Environment, 4, p. 100021. Available at: https://doi.org/10.1016/J.DIBE.2020.100021.

Bindreiter, S. (2018) Ermittlung von Baulandpotentialen an Regionalbahnlinien am Beispiel des S-Bahn-Netzes in Oberösterreich. TU Wien.

Bindreiter, S. et al. (2021) "M-DAB Materialressourcen der Stadt digitalisieren, analysieren und nachhaltig bewirtschaften," Berichte aus Energie- und Umweltforschung. Projektendbericht FFG. [Preprint]. Available at: https://nachhaltigwirtschaften.at/resources/sdz_pdf/schriftenreihe-2022-1-m-dab.pdf (Accessed: February 13, 2024).

Bindreiter, S., Lorenz, W. E., Grabuschnig. L., Dengg, E.A., Wurzer, G., Pachauer, V., Ugljanin, N., Nageler, P., Rasper, P., Fellner, J. et al. (2025) "Materialintensität der Innenentwicklung – Ressourcenbewertung und Lokalisierung städtischer Entwicklungspotentiale (M-DAB2)," Berichte aus Energie- und Umweltforschung. Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie. Wien. Available at: https://nachhaltigwirtschaften.at/de/sdz/projekte/m-dab-2-materialintensitaet-der-innenentwicklung.php (Accessed: April 1, 2025).

Bindreiter, S., Şişman, Y., Rast, L., Sint, S., Hinterseer, S., Selz, E., Mottl, K., Roggenbauer, R. (inPrint) "SmartQ+ Bruck/Leitha – Potenziale der Quartiersentwicklungsplanung auf dem Weg zum Plus-Energie-Quartier", Berichte aus Energie- und Umweltforschung. Bundesministerium für Innovation, Mobilität und Infrastruktur (BMIMI). Wien.

Carter, T.R. et al. (2001) "Developing and applying scenarios," In: Climate change 2001; impacts, adaptation and vulnerability / eds. J. McCarthy, O.F. Canziani, N. Leary, D.J. DokkeK.S. White. - Cambridge : Cambridge University Press, 2001 [Preprint].

Cortesão, J. and Lenzholzer, S. (2022) "Research through design in urban and landscape design practice," Journal of Urban Design, 27(6), pp. 617–633. Available at: https://doi.org/10.1080/13574809.2022.2062313.

Duinker, P.N. and Greig, L.A. (2007) “Scenario analysis in environmental impact assessment: Improving explorations of the future,” Environmental Impact Assessment Review, 27(3), pp. 206–219. Available at: https://doi.org/10.1016/J.EIAR.2006.11.001.

ETH (2017) “Raum+.” Available at: https://www.raumplus.ethz.ch/de/home/.

Forster, J. (2016) Strategische raumbezogene Visualisierung im Kontext der Innenentwicklung urbaner Siedlungs-, Energie- und Mobilitätssysteme am Beispiel der Stadt Wien. Wien. Available at: https://doi.org/10.34726/hss.2016.29797.

Gehl, J. (2011) Life Between Buildings: Using Public Place, Science. Available at: https://doi.org/10.1126/science.1072994.

Grams, A. (2017) Spielräume für Dichte. Der Innenentwicklungskompass als problemorientierte Methode für Verdichtung in kleinen und mittleren Gemeinden. ETH Zürich.

Kosow, H. and Gaßner, R. (2008) Methoden der Zukunfts-und Szenarioanalyse Überblick, Bewertung und Auswahlkriterien. Institut für Zukunftsstudien und Technologiebewertung.

Kosow, H. and León, C.D. (2015) “Die Szenariotechnik als Methode der Experten- und Stakeholdereinbindung,” in S. Niederberger Marlen. In: Niederberger, M. and Wassermann, S (eds) Methoden der Experten- und Stakeholdereinbindung in der sozialwissenschaftlichen Forschung. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 217–242. Available at: https://doi.org/10.1007/978-3-658-01687-6_11 .

Lefebvre, H. (2001) The production of space. 1. publ., reprint. Oxford [u.a.]: Blackwell.

Mitteregger, M. et al. (2020) “AVENUE21. Automatisierter und vernetzter Verkehr: Entwicklungen des urbanen Europa,” Available at: https://doi.org/10.1007/978-3-662-61283-5.

OpenStreetMap Wiki contributors (2021a) Slippy map tilenames – OpenStreetMap Wiki. [Online]. 2021. Available from: https://wiki.openstreetmap.org/wiki/Slippy_map_tilenames (Accessed: April 1, 2024).

OpenStreetMap Wiki contributors (2021b) Zoom levels – OpenStreetMap Wiki. [Online]. 2021. Available from: https://wiki.openstreetmap.org/w/index.php?title=Zoom_levels&oldid=2167744 (Accessed: April 1, 2024).

ÖROK (2024) Österreichische Raumordnungskonferenz - ÖROK-Monitoring Flächeninanspruchnahme und Versiegelung. Available at: https://www.oerok.gv.at/monitoring-flaecheninanspruchnahme (Accessed: May 5, 2025).

Pansinger, S. & Prettenthaler, F. (2023). Gestalterische Nachhaltigkeit. disP - The Planning Review, 59(1), 18–48. https://doi.org/10.1080/02513625.2023.2229626

Ritchey, T. (2011) “Modeling Alternative Futures with General Morphological Analysis,” World Future Review, WFR, pp. 83–94. Available at: https://doi.org/10.1177/194675671100300105.

Robinson, J. et al. (2001) “Greenhouse Gas Emissions: Mitigation Scenarios and Implications,” in B. Metz et al. (eds) Climate Change 2001: Mitigation. Cambridge University Press, pp. 115–166.

Sassen, S. (2000) Cities in a world economy. 2. ed. Thousand Oaks, Calif. [u.a.]: Pine Forge Press (Sociology for a new century).

Swart, R.J., Raskin, P. and Robinson, J. (2004) “The problem of the future: sustainability science and scenario analysis,” Global Environmental Change, 14(2), pp. 137–146. Available at: https://doi.org/10.1016/J.GLOENVCHA.2003.10.002.

Waddell, P. (2002) “Urbansim: Modeling urban development for land use, transportation, and environmental planning,” Journal of the American Planning Association, 68(3). Available at: https://doi.org/10.1080/01944360208976274.

Zwicky, F. (1969) Discovery, Invention, Research - Through the Morphological Approach.

The Smart Readiness Indicator as an Opportunity to Decarbonise the German and EU Building Stock

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Abstract

The European building sector faces urgent challenges: to significantly improve energy efficiency and decarbonize. Digital transformation is essential to unlock potentials. The Smart Readiness Indicator (SRI) provides a framework to assess and promote the smart and digital capabilities of buildings. The SRI offers opportunities for increased energy savings, enhanced user comfort, and improved grid interaction. However, its implementation across Europe and Germany encounters regulatory, technical, and economic barriers. This paper describes the European SRI methodology and provides an adoption strategy for the implementation of the SRI in the German building sector as a blueprint for other EU member states. Thereby the SRI framework is split into a EU-uniform "Basic SRI" and a nation-specific "Individual SRI", the latter incorporating two new domains. The proposed adaptation strategy enables detailed differentiation of building types and greater flexibility for national implementation.

1. Introduction

Innovations arising from the digitalization of entire process chains are transforming entire industries. However, experts from the industry, the construction the facility management domain all agree that the building sector has largely missed the initial wave of digitalization. Nevertheless, the willingness to engage with this topic is steadily increasing.

The potential of digital transformation in the building sector has also been recognized by the European Commission, which, through the EU Energy Performance of Buildings Directive (EPBD), calls for increasing utilization of smart technologies. Based on this directive, a so-called Smart Readiness Indicator (SRI) is proposed. The introduction of a unified EU assessment system is intended to evaluate the technological maturity of buildings - specifically, their ability to interact with users and the energy grid - and to assess whether this enables more efficient building operation. (EPBD, 2024)

The aim of the SRI is also to raise awareness of intelligent building technologies and to make their added value more tangible for building users, owners, tenants, and providers of smart services. It is intended to support technological innovation in the real estate sector and promote an incentive system for the integration of modern, intelligent, and innovative technologies in buildings. The SRI is based on building automation systems as defined in ISO EN 52120.

The European Union is urging its member states and key building sector stakeholders to examine, test, and adapt this assessment method to local contexts - such as the German market. As part of a research project at the Chair of Facility Management at the Institute for Technology and Management in Construction (TMB) at the Karlsruhe Institute of Technology (KIT), a substantial contribution was made by a neutral research institution to independently analyze and further develop the EU assessment system. Based on this research, Germany's official SRI pilot phase was initiated and is being supervised by KIT.

This SRI method, which has seen little practical application so far, offers potential for public visibility and has been investigated and adapted to the German building sector as part of the KIT project. Various building operation strategies and the prerequisites for digital building operation were identified. It became clear that the current classification into residential and non-residential buildings is not precise enough, as this division disregards a wide variety of sub types and their particularities. For example, a small single-family house with only a few square meters is assigned the same domains, impacts, services, and weightings as a large multi-family building. Similarly, office buildings are assessed using the same criteria as hospitals, despite their vastly different functional requirements. Especially since the SRI is a European framework and each member state is required to transpose the SRI into national legislation, there is a risk (similar to what happened with energy performance certificates) that the implemented SRI methods due to their potential diversity may no longer be comparable across countries. The method proposed in this paper addresses this issue by ensuring European-wide comparability while still allowing flexibility and adaptability at the national level

2. Smart Readiness Indicator

The SRI takes into account nine building areas (domains): (1) heating, (2) cooling, (3) domestic hot water, (4) ventilation, (5) lighting, (6) dynamic building envelope, (7) electricity, (8) electric vehicle charging, and (9) monitoring and control.

Each domain contains a different number of questions (services), some of which are derived from EN ISO 52120. In total, there are 54 services, each defined by several functionality levels that represent specific technologies. A service can include up to five levels, with Level 0 representing a low level of smart readiness and Level 4 representing a high level of smart readiness. For the calculation of the SRI score, the levels of each service are assessed independently.

Figure 1 illustrates an example of the service H-1a: "Control of heat emission." The left column lists the five functionality levels (Level 0 to Level 4). The top row presents the seven impact criteria (impacts): (1) energy efficiency, (2) maintenance and fault prediction, (3) comfort, (4) convenience, (5) information to occupants, (6) health and well-being, and (7) energy flexibility and storage. The values from 0 to 3 in each field represent the impact scores of each level on the corresponding impact categories. (Verbeke, Aerts, Reynders, Ma, & Waide, 2020)

Figure 1: Example of the service H-1a: "Control of heat emission" (Emich, 2025)

The seven impacts are further grouped into three key functionalities: (1) optimization of energy efficiency and performance, (2) adaptation of operations to user needs, and (3) energy flexibility. Figure 2 provides an overview of the various SRI components: domains, impacts, and key functionalities.

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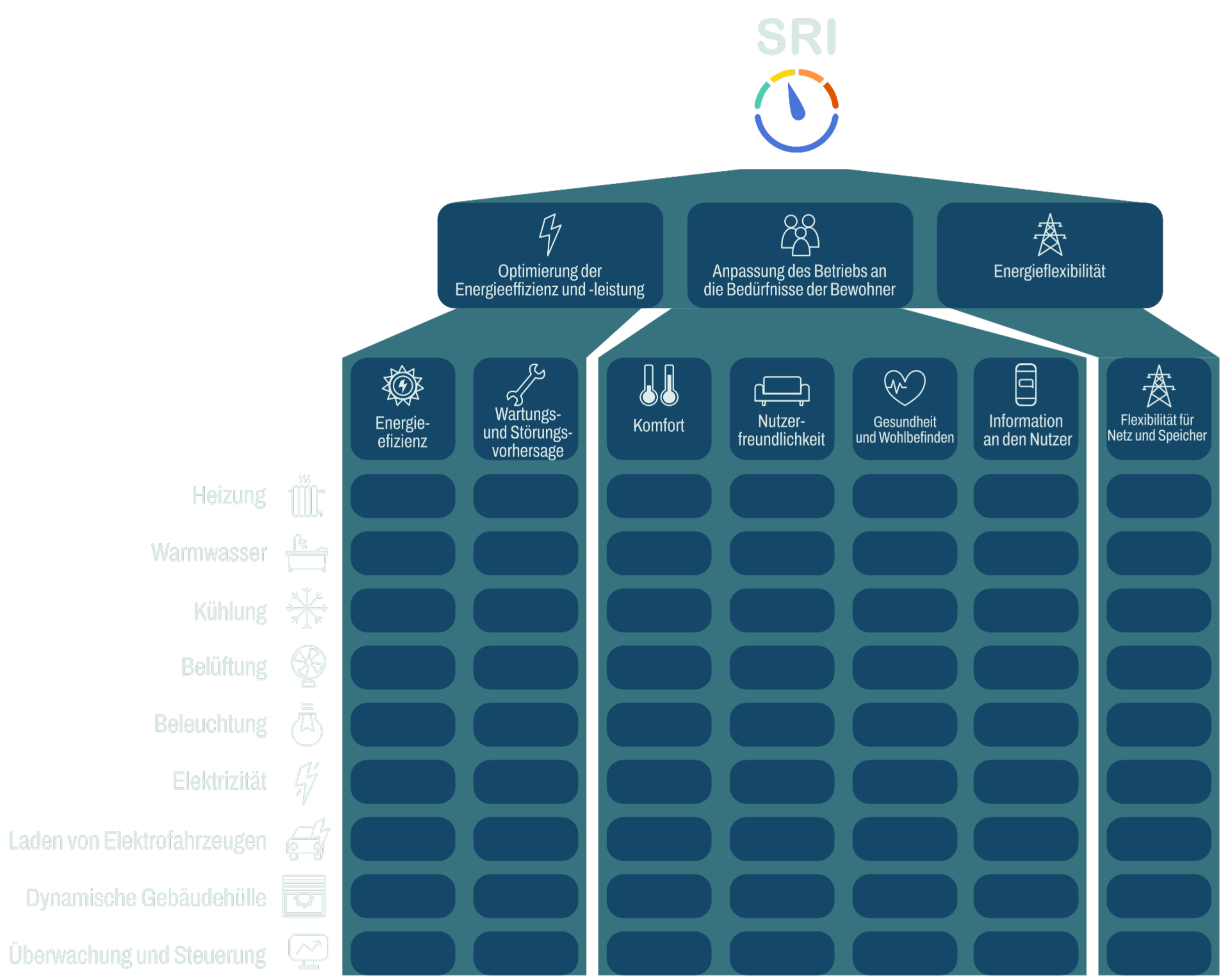

Figure 2: Overview SRI (Emich, 2025)

3. Energy Saving Potential of the German Building Stock

In Germany, there are approximately 2 million non-residential buildings and around 19.5 million residential buildings, with a total energy consumption of about 789 TWh, which accounts for roughly 33% of the country's total final energy consumption. Only a small share of these buildings are new constructions. (dena, 2024) (IWU, 2021)

The German government's climate protection targets call not only for the use of renewable energies but also for the optimization of the operation of existing buildings and their technical systems. Lifecycle management of buildings offers significant efficiency and value creation potential that can be leveraged through digital technologies to strongly support the government's goals. In addition to the construction phase, emphasis is put on optimizing the usage phase through digitalization. This phase is considered the longest, most expensive, and most energy-intensive phase in a building's lifecycle. By increasing the SRI, which varies depending on location and building type, the potential energy savings can be estimated at up to 60% for thermal energy and up to 16% for electrical energy. The advantage of assessing the SRI in detail lies in its comprehensible breakdown into individual domains and impacts, allowing specific potentials to be identified. (Verbeke, Aerts, Reynders, Ma, & Waide, 2020) Additional savings from non-technical process optimization and efficiency are not (yet) considered in this analysis.

A building equipped with intelligent technologies enables occupants to better understand and make informed decisions about their energy use. Transparent consumption and emissions data raise awareness of resource use, which can positively influence climate change mitigation.

Final energy consumption has a direct impact on the annual CO_2-equivalent (CO_2e) emissions of a building. Germany wants to become climate neutral by 2045. Since the market penetration of digital technologies in buildings is still relatively low, there is significant potential in this area to reduce emissions. If an accelerated digitalization of buildings and the power grid infrastructure is implemented, it is estimated that this could contribute approximately 11.7% to the CO_2e reduction target (~36 million tons CO_2e). Accelerated digitalization in this scenario means that digital technologies are implemented more rapidly than today and that more advanced methods - beyond current standards - are applied, following the example of pioneering countries, companies, or ambitious projects. Even standard digitalization measures are forecasted to contribute significantly, with a savings potential of approximately 9.3% of the CO_2e reduction target (~28.8 million tons CO_2e). Standard digitalization measures refer to a scenario with continuation of current practices, using established solutions and measures that reflect industry norms through to 2030. (bitkom, 2024)

4. New SRI-Proposal

To address the need for both detailed differentiation of building types and flexibility in national implementation, a new proposal has been developed (Figure 3). This approach introduces a dual-structured methodology for the SRI, enabling consistency across the European Union while allowing for national adaptation.

At its core, the methodology comprises two complementary components: a Basic SRI and an Individual SRI.

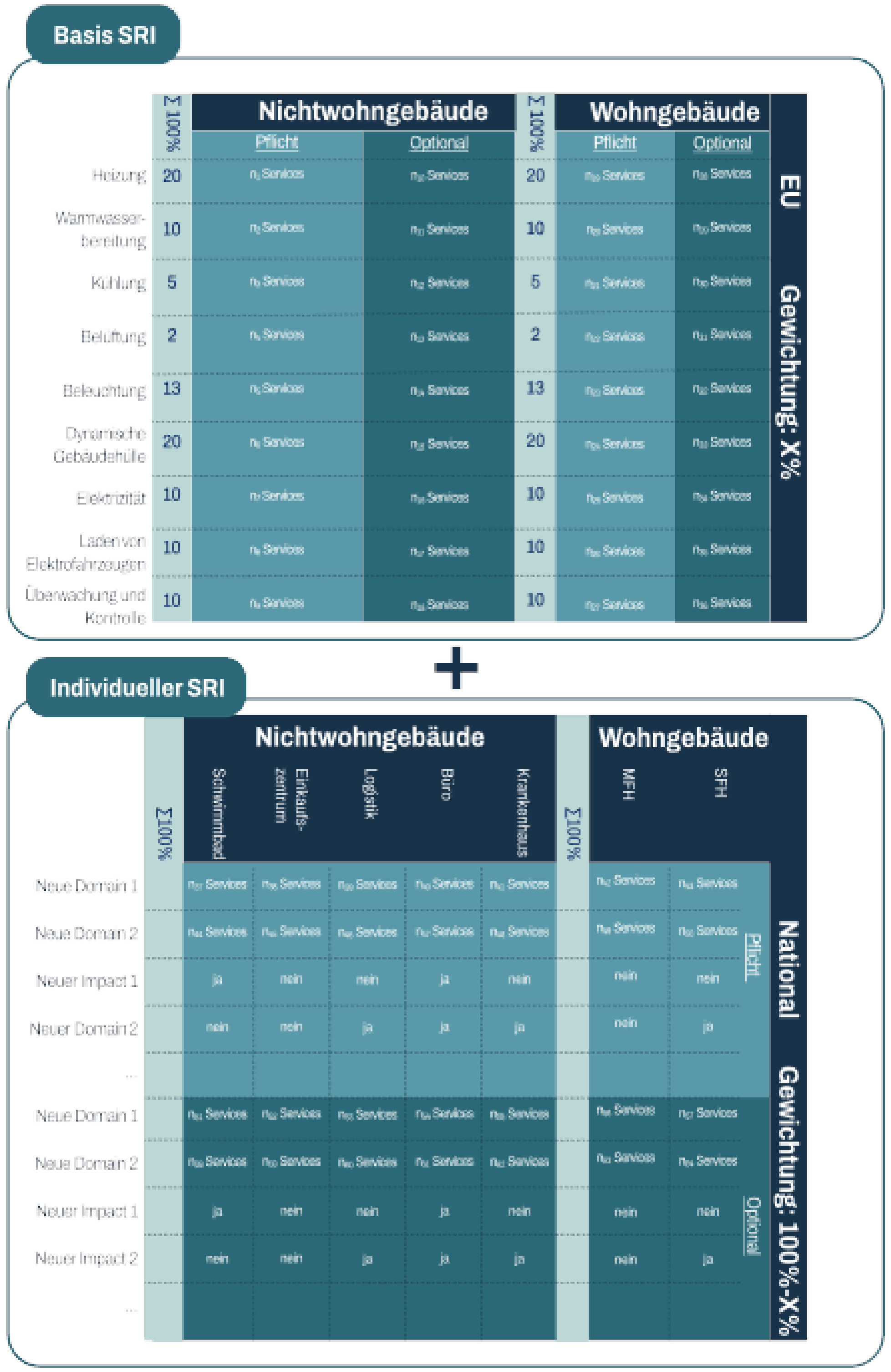

Figure 3: Dual-structured SRI approach

Basic SRI: Standardization Across Member States

The Basic SRI serves as the standardized component, uniformly applied across all EU Member States. It distinguishes between residential and non-residential buildings and consists of a predefined set of domains, each containing a fixed number of services. These services are classified as either mandatory or optional, and the domain weightings follow a fixed scheme aligned with the current methodological framework. This ensures comparability, transparency, and consistency across regions.

Individual SRI: National Customization

In parallel, the Individual SRI allows each Member State to define additional elements tailored to national priorities and specificities. Within this framework, Member States can define separate criteria (domains, services, impacts, weightings) for residential and non-residential buildings, which may also be designated as mandatory or optional. This component introduces essential flexibility into the system, facilitating greater relevance at the local level while maintaining alignment with EU-wide objectives.

As part of the ongoing research within the KIT project, two preliminary domains have been developed in discussion with key building sector stakeholders for inclusion in the Individual SRI for the German market:

- Facility Management
- IT Infrastructure

These new domains with incorporated services and weightings are subject to further validation and refinement through additional studies.

5. Discussion

The proposed dual-structured methodology for the SRI offers a promising solution to the challenge of balancing EU-wide standardization with the need for national flexibility. By separating the SRI into two components - a Basic SRI that is consistent across all Member States, and an Individual SRI that allows for local adaptation - the approach attempts to address the heterogeneity of building stock, regulatory environments, and national priorities across the European Union.

The Basic SRI, as proposed by the European Commission, provides a uniform framework that enables comparability, transparency, and cohesion. It ensures that fundamental aspects of building sustainability - defined through a fixed set of domains and services - are assessed in a consistent manner. This is particularly important for cross-border benchmarking, reporting, and EU-level policy evaluation. The inclusion of both residential and non-residential categories helps capture essential differences in building use and performance requirements, though the fixed structure may limit its sensitivity to national or regional particularities.

On the other hand, the Individual SRI introduces a level of customization that is critical for relevance at the national and local levels. Member States can define additional domains, impacts, and services that reflect country-specific challenges or policy goals. The Individual SRI can be further enhanced to address sub types of residential and non-residential buildings and thus to better address their individual characteristics. However, the development of necessary custom indicators poses challenges in terms of validation, consistency, and methodological robustness. There is a risk that excessive flexibility could undermine the comparability and credibility of the overall SRI framework if not carefully managed.

A key unresolved issue is the relative weighting between the Basic and Individual SRI components. Determining an appropriate balance is essential to avoid overemphasizing either uniformity or flexibility. If the Basic SRI is weighted too heavily, EU Member States may have little incentive to invest in meaningful national customization. Conversely, if the Individual SRI dominates the weighting, the comparability between countries may be diminished.

6. Conclusion

In summary, the dual-structured SRI approach is a forward-looking and pragmatic framework that acknowledges the diversity of building environments across Europe. While promising, its successful implementation will depend on addressing key methodological issues, ensuring the validity of national adaptations, and establishing a transparent and balanced weighting mechanism. Future work should focus on pilot testing, stakeholder engagement, and the development of clear governance structures to guide the use and evolution of both SRI types, the EU-wide, uniform Basic SRI and the nation-specific Individual SRI.

References

bitkom. (2024). Klimaeffekte der Digitalisierung 2.0 Studie zur Abschätzung des Beitrags digitaler Technologien zum Klimaschutz in Deutschland. Berlin.

dena. (2024). DENA GEBÄUDEREPORT 2024. Zahlen, Daten, Fakten zum Klimaschutz im Gebäudebestand. (D. Energie-Agentur, Hrsg.)

Emich, T. (2025). Weiterentwicklung eines Verfahrens zur Ermittlung der Intelligenzfähigkeit eines Gebäudes und dessen Optimierung. Karlsruhe: Karlsruher Institut für Technologie (KIT).

EPBD. (2024). Von https://eur-lex.europa.eu/eli/dir/2024/1275/oj abgerufen

IWU. (2021). 6. Energieforschungsprogramm der Bundesregierung Forschungsdatenbank Nichtwohngebäude Primärdatenerhebung zur Erfassung der Struktur und der energetischen. (I. W. GmbH, Hrsg.)

Verbeke, S., Aerts, D., Reynders, G., Ma, Y., & Waide, P. (2020). FINAL REPORT ON THE TECHNICAL SUPPORT TO THE DEVELOPMENT OF A SMART READINESS INDICATOR FOR BUILDINGS. (R. a.– E. EUROPEAN COMMISSION/Directorate-General for Energy/Directorate C - Renewables, Hrsg.) Brüssel.

The Role of Living Labs for Urban Energy Transformation: Insights from TransUrban.NRW and SmartQuart

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Abstract

The transformation of urban energy systems is critical for achieving climate neutrality. Living labs provide real-world environments for testing innovative energy solutions by integrating technological, regulatory, and economic aspects. This study presents key insights from two major German living lab projects: TransUrban.NRW and SmartQuart. TransUrban.NRW explores low-temperature district heating and cooling (DHC) networks operating at near-ambient temperatures. By maintaining low network temperatures, the system enables the use of uninsulated piping while leveraging thermal interactions with the surrounding soil for heating and cooling gains. SmartQuart demonstrates a decentralized, interconnected energy system across three districts, each functioning as a distinct living lab with unique energy infrastructures. The project investigates energy management strategies that optimize ecological and economic objectives both within individual districts and at a system-wide level. Both projects illustrate the role of digitalization, sector coupling, and advanced DHC concepts in enhancing energy efficiency and decarbonization. The findings provide insights into implementation challenges and the scalability of these solutions for broader urban applications.

1. Introduction

The transformation of urban energy systems is a central pillar for achieving climate neutrality. This transition requires not only technical innovation but also practical pathways for implementation under real-world conditions. Living labs have emerged as key instruments for this purpose, enabling the integration and testing of technological, regulatory, and economic innovations at the district scale. They create environments where diverse stakeholders can co-develop, validate, and refine energy concepts based on actual system performance.

This paper presents insights from two major German living lab initiatives: TransUrban.NRW and SmartQuart. Both projects aim to accelerate the urban energy transition but focus on different systemic challenges. In the following these projects and particular research efforts are outlined.

2. Low-Temperature District Heating in Practice: Insights from TransUrban.NRW

The TransUrban.NRW living lab project focuses on the urgently needed transformation of the energy supply in the lignite-dominated Ruhrgebiet in Germany. Therefore, four districts were initially planned as living labs, each featuring different characteristics for the application of innovative district heating and cooling (DHC) networks. The characteristics of these districts vary from newly built to existing buildings, which require building envelope insulation and heating system upgrades to enable them to connect to innovative DHC networks. Innovative DHC networks are defined as 4th and 5th generation DHC networks [1], [2]. They are also called "cold" DHC networks because of their low operating temperatures. The operating temperature ranges from 0 to 35 °C for the 5th generation and from 30 to 60 °C for the 4th generation. In the literature the 5th generation is defined that the network temperature is lower than the temperature demand. Therefore, an additional booster appliance is needed in the substations [1]. The lower the temperature, the more renewable energy sources can be directly integrated into these networks. Therefore, in this living lab project, multiple renewable heat sources are considered for supplying heat (and cold) to the DHC networks, for instance, data centers, industrial waste heat, wastewater heat, geothermal borehole fields, and free heating/cooling. Additionally, the 5th generation can be built as a bi-directional network, enabling cooling in the buildings via the same pipe infrastructure. In the following, we outline two city district concepts in detail.

2.1. Gelsenkirchen-Hassel: Heat Gains from Uninsulated Pipes and Seasonal Ground Regeneration

The district "Wohnen am Stadteilpark" is being built in Gelsenkirchen. It is divided into two construction sections. One section consists of 36 single-family houses (SFH) and the other section of multi-family houses (MFH), including a children's day care centre.

The SFH are built in the first construction phase. Those buildings are built by the homeowners themselves, resulting in different construction-start and move-in times. To enable homeowners to connect to the DHC network upon completion, the network was laid before the construction phase of the buildings had started.

Figure 1 illustrates the district energy system. The 5th-generation DHC network operates at variable temperatures between 0 and 20 °C, with the operational temperature adjusted according to the soil temperature to reduce losses and enable heat gains. Additionally, uninsulated pipes are employed to further capture heat from the surrounding soil. These measures allow the operator to meet the heating demands of the first completed buildings without supplying heat the DHC network—a performance characteristic that was previously validated using a simulation model[3].

Since this is a 5th generation DHC network, decentralized heat pumps are used in the buildings to boost the temperature up to the desired level for heating and domestic hot water (DHW). Additionally, direct cooling is possible using the cold water from the DHC network in the floor heating system.

The main energy source in the EH for the DHC network is the geothermal field. It is regenerated during the summer months through the cooling demand of the buildings. Additionally, a free heater is used to utilize the outdoor air temperature as a source for the EH. The free heater can be used for heating and cooling the network. Furthermore, the free heater is used as the source for an air source heat pump, which can used to cover peak demands during warm and cold periods.

The initial measurement data from the district looks promising and shows that a large part of the heat demand can be met from the ground through heat gains and the geothermal field.

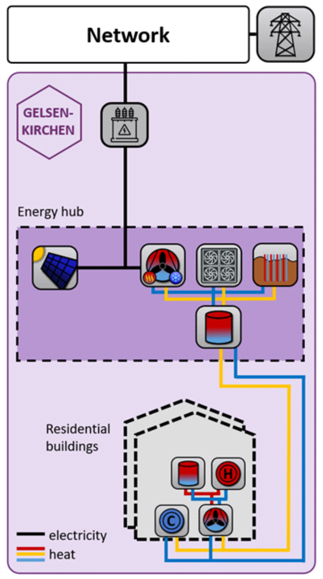


Figure 1: Energy system Gelsenkirchen

Seestadt mg+: Scalable Network Design with Modular Energy Hubs and Wastewater Heat Use

The district Seestadt mg+ is being built in Mönchengladbach. It consists of newly built single-family houses (SFH), multi-family houses (MFH), and a few commercial buildings. The construction process is divided into ten phases over a period of ten years, having started in 2023. One goal of this living lab is to create a blueprint for districts that will be expanded in the future. The first construction section includes four multi-family houses and one energy hub (EH). A depiction of the energy system in the first construction section is shown in Figure 2. Over the course of the construction phases, three EHs will be built in total. Additionally, the DHC network is initially constructed with a tree topology. In the final construction section, the main pipes at both ends will be connected, transforming the tree structure into a ring structure. This design adds redundancy in conjunction with the three EHs.

In the district, a 4th generation heating network with a supply temperature of approximately 40 °C and insulated distribution pipes was planned. Therefore, the temperature can directly be used in a floor heating system with a heat exchanger. For domestic hot water (DHW), each substation is equipped with an electric heater to raise the temperature to 55 °C.

Currently, Seestadt mg+ relies on a state-of-the-art gas boiler as a fallback and redundancy solution during the construction period. Later, the primary source will be renewable. At this stage, the first construction section is supplied by a wastewater heat exchanger in combination with a heat pump. In the future, the main heating source will be a geothermal field located beneath artificial ponds. To enhance its performance, the heated water from the ponds can be used to regenerate the geothermal field in the summer.

Measurement data from the first winter period indicate that most of the demand in the initial construction section can be met by the wastewater-based heat pump. However, on warmer days when the demand is lower, the heat pump cycles too frequently because it supplies more power than the central storage can absorb. To mitigate this issue, the energy hub has been extended with an additional heat pump of smaller capacity.

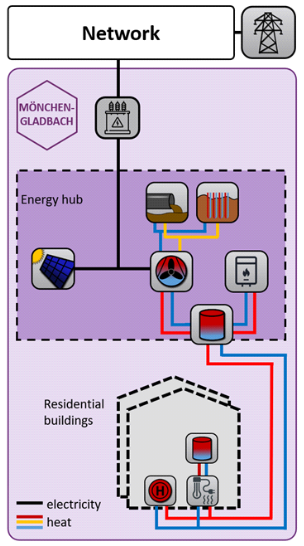


Figure 2: Energy system Mönchengladbach

3. SmartQuart: Interconnected Energy Platforms

The SmartQuart research project is a real-world laboratory that demonstrates how the energy transition can be implemented at the district level to create system-wide benefits. SmartQuart showcases innovative energy transition approaches at the district level by implementing and testing technologies while engaging community stakeholders. The project is driven by six key objectives:

energy-optimal planning, maximizing green electricity, developing sector-coupling technologies, reducing CO_2, developing economic incentives, and participating in value chains. These objectives create a real-world laboratory across three distinct German districts. By connecting these diverse areas into a single intelligent energy system, SmartQuart explores how decentralized, interconnected districts can optimize energy flows between the electricity, heat, mobility, and hydrogen sectors. SmartQuart serves as a replicable blueprint for the energy transition, which is particularly valuable for regions undergoing structural economic change. The project demonstrates how local energy optimization can contribute to national climate goals while maintaining economic viability.

The project consists of three distinctive districts — Bedburg (the Electric District), Essen (the Urban District), and Kaisersesch (the Hydrogen District) — that are interconnected through the SmartQuart Hub. Each district has a different structure and faces unique energy challenges and solutions, which are described in the following sections.

3.1. Bedburg - The Electric District

With approximately 110 housing units, Bedburg serves as a model for small-town energy transition. The district integrates renewable energy through a dedicated wind turbine and rooftop photovoltaic systems. The heating concept combines a low-temperature network with sustainable heat sources from sewage heat exchangers and geothermal energy. An energy hub houses five heat pumps, thermal buffer storage, and battery storage, controlled by a digital energy management system. This approach enables low heat transfer losses while providing summer cooling and supporting geothermal field regeneration. The district also features electric mobility charging stations. This integrated system achieves near energy self-sufficiency, transforming Bedburg from an energy consumer to an electricity exporter supplying nearby urban areas with green power. Operational experience showed that a two-layer storage system reduces heat pump cycling compared to multi-layer systems due to undersized buffer storage. Detailed monitoring data is being used to train and validate models for scalable transfer to other districts.

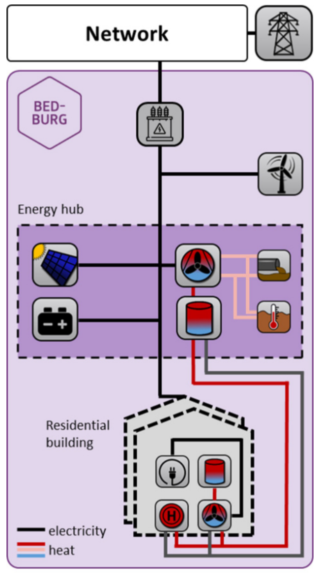
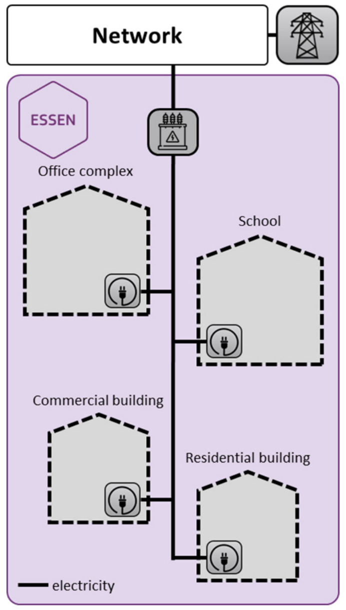


Figure 3: District energy system Bedburg

3.2. Essen - The Urban District

The Essen site develops urban energy transition strategies by virtually bundling representative existing buildings: a school, an office complex, a commercial property, and a residential building. The project employs a modular classification system for building typologies, creating transferable decarbonization solutions for space-constrained urban environments. The building decarbonization approach combines analysis of various insulation standards with cost-optimized energy systems designed to achieve zero operational emissions by 2040, based on Essen's projected emission factors. Digital measurement systems provide essential data for this empirical approach, creating a blueprint for decarbonizing Germany's existing building stock.



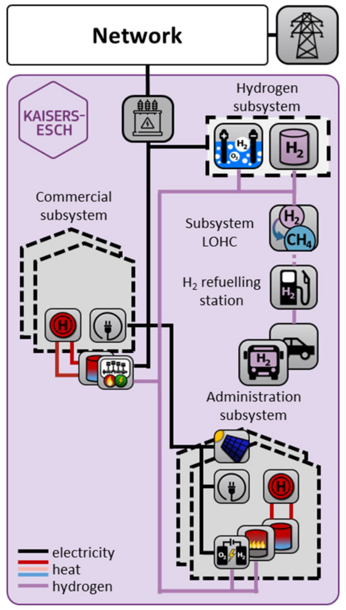


Figure 4: District energy system Kaisersesch, Figure 5: District energy system Essen

3.3. Kaisersesch - The Hydrogen District

The Kaisersesch site, situated in a rural setting, demonstrates a complete hydrogen value chain, showcasing how hydrogen enables sector coupling in areas with combined industrial, commercial, and residential usage patterns. The infrastructure features an industrial-scale electrolysis system for green hydrogen production, complemented by innovative LOHC (Liquid Organic Hydrogen Carrier) storage technology that provides substantial daily hydrogen storage and release capabilities. A dedicated hydrogen pipeline network distributes hydrogen throughout the district. Multiple hydrogen applications showcase versatile energy use, including fuel cells and hydrogen boilers for heat production. A hydrogen-based Combined Heat and Power (CHP) unit supplies a district heating network, while a hydrogen refueling station supports public transport buses, demonstrating practical mobility applications. This rural showcase illuminates pathways for integrated hydrogen ecosystems that balance energy production, storage, distribution, and diverse consumption patterns across multiple sectors.

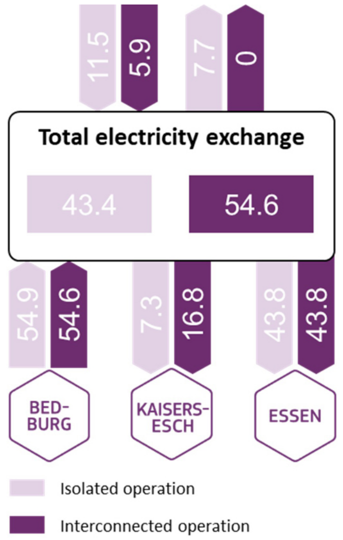
3.4. SmartQuart Hub and Interconnected Districts

The SmartQuart Hub functions as the central integration platform, networking the three disparate districts into a cohesive energy system. This hub gathers extensive data on energy consumption and production while incorporating external data streams, including weather forecasts and electricity market conditions. The hub consolidates the districts into a multi-district system, executes economic viability analysis, and facilitates the incorporation of additional virtual assets.

The technical implementation uses a mixed integer linear programming (MILP) optimization model structured within a four-level hierarchical framework: component, building, district, and network. This model was specifically developed to study potential electricity exchange between districts and enable coordinated control across the system. Since the three districts are not spatially contiguous, electricity exchange through the SmartQuart Hub occurs exclusively for balancing purposes.

The model employs a rolling-horizon approach using the Gurobi optimization solver. Two primary scenarios are analyzed: isolated operation (districts functioning independently) and interconnected operation (with power exchange between districts). Figure 5 illustrates the energy exchange between the districts vor an exemplary day. It shows, that the interconnected operation enables significant power trading between districts, with Bedburg functioning as the primary exporter while Kaisersesch and Essen serve as importers. This demonstrates the enhanced efficiency and optimization potential of coordinated multi-district energy management.

This system enables researchers to examine various optimization strategies and identify regulatory barriers that could impede full-scale implementation. For spatially connected districts, this approach facilitates future utilization of local flexibilities across different districts, enabling optimization of local resources within a decentralized energy system.



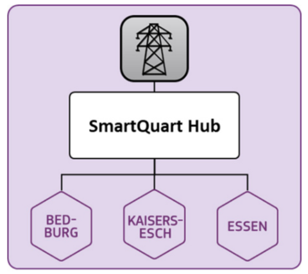


Figure 6: Interconnected Neighborhoods, Figure 7: Electricity exchange between the districts in MWh for one day (19.04.2024)

References

[1] S. Buffa, M. Cozzini, M. D'Antoni, M. Baratieri, and R. Fedrizzi, "5th generation district heating and cooling systems: A review of existing cases in Europe," Renew. Sustain. Energy Rev., vol. 104, pp. 504–522, 2019, doi: https://doi.org/10.1016/j.rser.2018.12.059.

[2] M. Wirtz, L. Kivilip, P. Remmen, and D. Müller, "5th Generation District Heating: A novel design approach based on mathematical optimization," Appl. Energy, vol. 260, p. 114158, 2020.

[3] K. A. Droste, R. M. Karuvingal, T. B. Schreiber, and D. Müller, "Numerical Analysis of Possible Heat Gains from the Soil for a Cold District Heating and Cooling Network in Germany," presented at the The 18th international Conference on district heating and cooling , Bejing (China), 4 Sep 2023 - 6 Sep 2023, Beijing, China: The 18th international Conference on district heating and cooling , Bejing (China), 4 Sep 2023 - 6 Sep 2023, Sep. 2023. [Online]. Available: https://publications.rwth-aachen.de/record/1012288

Estimating Emission Rates from Multiple Road Traffic Sources in Urban Environments

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Abstract

Quantifying emissions from multiple air pollutant sources in urban areas is crucial for understanding each source's contribution to urban air quality (AQ) levels. This study aims to apply and evaluate a methodology for estimating emission rates from multiple road traffic sources in a European city centre. The methodology combines a Computational Fluid Dynamics (CFD) dispersion model to calculate pollutant concentrations with a Bayesian-based algorithm to estimate emission rates for each source. The city centre of Augsburg, Germany, is used as the case study for this application. Due to the absence of a dense AQ monitoring network, synthetic observations are generated using a dispersion model with added Gaussian noise. The results demonstrate promising accuracy in estimating emissions from individual sources, particularly when a high number of observations are incorporated into the Bayesian algorithm.

Co-Creating Urban Energy Transition with Living Labs and Urban Digital Twins

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Abstract

Urban energy transition requires citizen-centred approaches to enhance awareness, perception, and acceptance, which are key to implementing Positive Energy Districts (PEDs). While technical tools like Urban Digital Twins (UDTs) enhance scenario modelling, their full potential lies in combining them with citizen-centred approaches and participatory formats, such as Urban Living Labs (ULLs). This study presents an integrated living lab framework applied in four European cities – Stuttgart, Vienna, Rotterdam, and Wroclaw – that merges technical modelling with co-creative methods for energy transition. Three tailored interventions address energy awareness, flexible energy consumption and PED engagement. Gamified tools, questionnaires, and stakeholder workshops are employed to develop UDT-based scenarios and energy-saving strategies at the neighbourhood scale. This approach bridges the gap between technological innovation and societal acceptance through participatory experimentation, contributing to the EU goal of 100 PEDs by 2025.

Introduction & Theoretical Background

The transition to Positive Energy Districts (PEDs) is a key goal of the European SET-Plan, targeting 100 PEDs by 2025. PEDs are energy-efficient, flexible urban areas with net-zero emissions, managed through renewable energy (Joint Programming Initiative Urban Europe, 2025). The energy transition requires inclusive decision-making processes (Bottero et al., 2021). While technology is crucial, recent research highlights the pivotal role of stakeholder engagement – particularly the active involvement of citizens and urban actors – in determining the success of PED implementation (Bossi et al., 2020). While citizen participation in urban planning is well established, their involvement in energy-related decision-making remains underdeveloped – posing a major challenge to sustainable energy transitions. In socially or structurally complex districts, collaborative approaches are needed to align energy goals with local needs. Daily energy use – supply, demand, consumption and flexibilization – plays a key role in these efforts.

Urban Digital Twins (UDTs) support both precise energy scenario modelling and participatory formats that engage citizens. Embedded into living labs, UDTs connect urban governance, energy experts, and local communities by making technical solutions understandable and fostering citizen-led transitions. Real-world laboratories (Ramaswami et al., 2023) and gamification (Orwin et al., 2015) have proven effective for collaborative learning, sharing local knowledge (Maas et al., 2023), and testing climate strategies under real-life conditions. For UDTs to succeed, transformation pathways must combine participatory, interactive methods that turn users into prosumers and co-designers (Biresselioglu et al., 2024). Although gamification for energy-saving behaviours (Casals et al., 2020; Saga & Dunk, 2017), serious games for energy efficiency (Meiselwitz et al., 2022) and co-design methods for energy-efficient urban neighbourhoods (Brandt et al., 2021) exist, there are hardly any examples that consider innovative participation formats into a comprehensive participation process for citizen-led energy transitions.

To address this gap, the DigiTwins4PEDs project employs an innovative public participation process using Urban Digital Twins (UDTs) to actively involve stakeholders and citizens. DigiTwins4PEDs simulates urban energy systems with integrated local socioeconomic and demographic parameters to identify and visualise current and future energy demand, renewable potential and different energy flexibility strategies at the neighbourhood scale (Gebetsroither-Geringer et al., 2025). Based on a living lab concept, the project supports ongoing citizen engagement and flexible energy management. UDTs are developed as tools to empower informed citizen participation in the energy transition, with the UDT platform designed for both expert use and accessible communication with the public. Therefore, a living lab framework, including a cross-case study co-creation method and case-study-specific living lab concepts, is implemented across four case studies: Stuttgart, Vienna, Rotterdam and Wroclaw.

Case Studies & Methods

Case Studies

The Nordbahnhof district in **Stuttgart** (Germany) faces urban and social challenges due to Stuttgart 21, a transport and urban development project reshaping the city's rail junction. As part of this, the new "Rosenstein" district is being developed on 85 hectares surrounding the Nordbahnhof district, previously isolated in terms of infrastructure and social integration. The key question arises how to sustainably develop both existing and new neighbourhoods while considering the well-being of current and future citizens within the framework of PEDs. In "Grätzl 20+2" in **Vienna** (Austria), the conversion of the gas-based energy system to renewable sources is part of urban development plans and investigated, including the effects on electricity and heat load management as well as peak loads. In Prinsenland and Feijenoord in **Rotterdam**, (Netherlands), the focus is on innovative cooling concepts to cover the increasing energy demand through photovoltaics and storage solutions without overloading the electricity grid. Kleczków in **Wroclaw** (Poland) requires flexible energy solutions for a heterogeneous development with historic apartment buildings, new buildings and outdated infrastructure.

Urban Living Labs (ULL)

Real-world laboratories enable scientific and societal learning through reflexive, experimental research focused on transformative impact, experimental methods, transdisciplinary collaboration, and scalable outcomes (Schäpke et al., 2018). In urban settings, Urban Living Labs (ULLs) support participatory engagement by testing small-scale interventions with local communities (Afacan, 2023). As co-creation platforms, ULLs involve citizens in experiments and innovations, fostering transformative change (van der Jagt et al., 2019). By incorporating co-design processes, ULLs build long-term science-community partnerships to address local needs with tailored solutions (Mahajan et al., 2022; Zingraff-Hamed et al., 2020).Through collaborative, neighbourhood-based approaches, ULLs activate urban resources and advance resilient urban development (Petrescu et al., 2022, S. 202). They provide a normative framework for guiding real-world experiments toward broader social and environmental goals (Ziehl, 2021), while also strengthening social interaction, practice-based knowledge, and new thinking (Robazza et al., 2024). ULLs promote cross-sector collaboration, supporting urban transformation and innovation across disciplines (Zingraff-Hamed et al., 2019) and offer promising pathways for responsive, participatory, and sustainable urban transformation (Belfield & Petrescu, 2024; Frantzeskaki et al., 2018).

Combining ULL and UDT

DigiTwins4PEDs aims to use a UDT platform to share knowledge on benefits and actionable insights for citizens to accelerate the citizen-led energy transition. This pathway is supported by participatory interventions to enhance awareness, acceptance and engagement along energy supply, demand, consumption and flexibilization on a neighbourhood scale. The project explores how participation and 3D models can jointly advance the energy transition, integrating findings into a living lab framework with a cross-case study co-creation method and case-study-specific living lab concepts with individual interventions. To support the technical development of the UDT platform with social data, a short online questionnaire is used during the interventions. It includes standardized psychometric questionnaires to assess place attachment (APAS: Abbreviated Place Attachment Scale (Boley et al., 2021; Zahnow, 2024)), well-being (WHO-5: Well-Being Index (Brähler et al., 2007)) and resilience (CD-RISC-10: Connor-Davidson Resilience Scale (Connor & Davidson, 2003; Wollny & Jacobs, 2023)).

Results

Living Lab Framework for the Use of Urban Digital Twins

A living lab framework for the use of UDTs was developed in DigiTwins4PEDs, which is a) understood as a living, dynamic framework; b) adaptable to the individual case study areas. It identifies the following target groups: 1) young people for awareness raising, 2) tenants who can change their behaviour and demand change, 3) owners and landlords as decision makers. Within this framework, three interventions aim to engage citizens with energy topics and highlight savings potential across building types, ownerships, and municipal plans. These interventions inform end-users about energy supply, demand, consumption and flexibilization strategies via storylines which link to their daily energy consumption and allow joint learning and developing pathways towards PEDs. To explore the influence and effects of changes in energy use, the 1st intervention "Activation and Energy Transition" raises awareness by linking daily activities to energy use (e.g. cycling to charge a phone, exploring load profiles) to shape citizens' perspectives on impact, timing and costs associated with energy. The 2nd intervention "Flexible Energy Consumption" promotes co-creation of knowledge about personal load profiles using smart meters in a gamified setting, encouraging experimentation with energy use. The 3rd intervention "Positive Energy Districts (PEDs)" uses the interactive UDT platform to review energy scenarios, discuss next steps towards energy transitions, and identify barriers and solutions. The energy-saving potential is visualized at the neighbourhood scale to encourage action, as shown in Fig. 1.

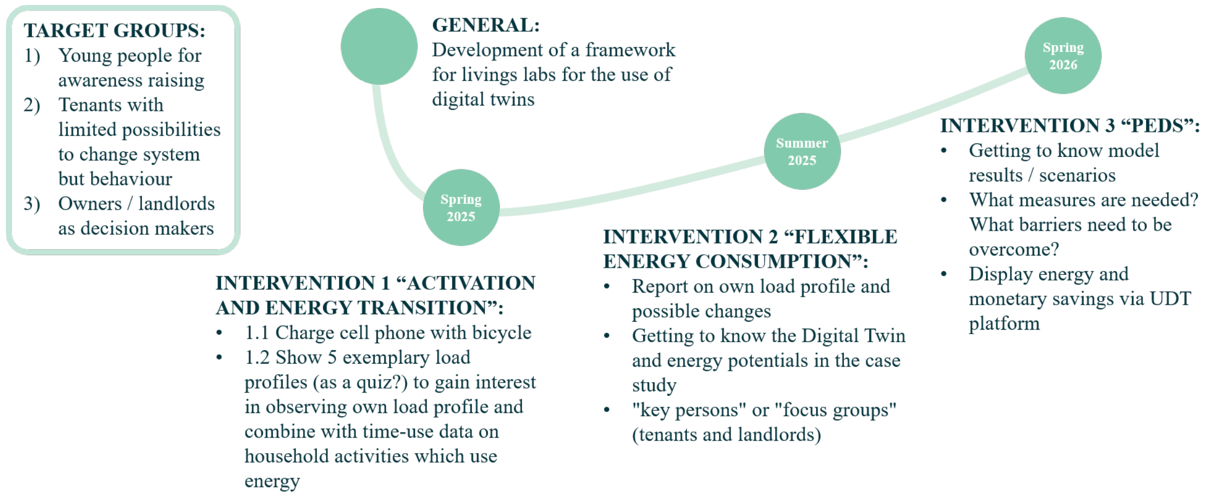

Fig. 1: Original framework idea for a cross-case study co-creation method (Reber, 2024)

Integrative Process in the Living Lab Framework

To drive a citizen-led energy transition via PEDs, living labs with targeted on-site interventions can translate technical tools like UDTs into actionable insights (Robazza et al., 2024). The process involves three steps: I) idea of PEDs, II) 1st prototype UDT platform and III) 2nd prototype UDT platform – structured in a matrix combining A. UDTs, B. ULLs and C. Stakeholder Workshops, based on stakeholder analysis and load profiles (see Fig. 2). Embedded in the 1st intervention, short online questionnaires help with better knowledge on key factors for UDT scenarios, which will be tested, discussed and further developed with a prototype in the 2nd intervention. Citizens from diverse backgrounds (city administration, homeowners, tenants, children and young people) are invited to stakeholder workshops (e.g. focus groups). Based on initial results and tested UDT scenarios on flexible energy use and behaviour, the UDT platform can be iteratively improved. In the 3rd intervention, the final UDT platform will be presented to the public as a concrete contribution to PED development. The entire process will be communicated via the cities' official participation platforms, including workshop announcements, links, and feedback collection. The implementation steps and experiences will be analysed after the first round of interventions (Reber & Smetschka, forthcoming.

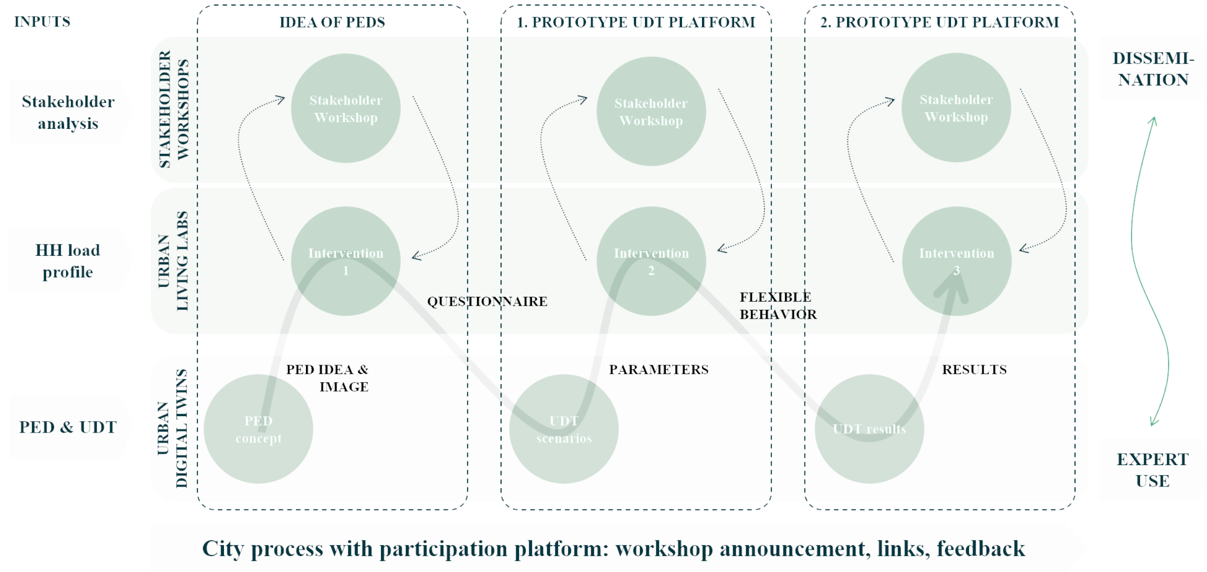

Fig. 2: Matrix for the integration of UDTs and Living Labs (Reber & Smetschka, forthcoming)

Development of the Questionnaire

Given the challenges of climate change and the need for climate protection and adaptation, the short online questionnaire gathers data on individuals' type of energy supply, daily energy use and attitudes toward PEDs. It assesses perception, awareness and acceptance of the energy transition across social, behavioural, technical and economic dimensions, aligned with production, storage and demand. The data supports energy assessment with MAPED and covers demographics, neighbourhood attachment, environmental awareness, housing situation, well-being, resilience, energy behaviour and perception, building modernisation and energy systems, household appliances and energy consumption, energy knowledge and support needs.

Before implementing the interventions in the case study areas, a pre-test was conducted in a socio-demographically similar setting to the Nordbahnhof district (4th Sustainability Days as part of the IBA'27 Festival #2 in the Neckarpark district). The goal was to raise awareness on "What is energy and how do I perceive it in the context of climate change?". The intervention included a load profile demonstrator, a climate quiz, a smoothie bike and the developed questionnaire. The load profile demonstrator playfully visualises the average daily energy load profile in Germany and possible future changes. With the help of sliders, citizens can recognise how typical load profiles could change throughout the day as a result of heat pumps, electric vehicles and solar energy. The climate quiz (DEAB e.V., 2020) assesses one's own ecological footprint to show how many earths would be needed for the respective lifestyle. With the smoothie bike, citizens were able to mix a smoothie using their own muscle power and learn in a vivid way how much energy everyday activities require, as shown in Fig. 3.

0 1 2 3 4 5 6 7

Tab. 1: Overview of the data categories and their interconnections

Data Categories		Energy production[1]	Shift heating / cooling to electricity[2]	Refurbishment	Flexibility	EV	social / socio-demographic[3]
Aim	Production	x					
	Storage	x				x	
	Demand		x	x	x	x	
MAPED	Social						x
	Behaviour	x	x	x	x	x	x
	Technical	x	x	x		x	
	Economic				x	x	
Questionnaire	Demographic Data, Neighbourhood Attachment, Environmental Awareness						x
	Housing Situation, Well-Being, Resilience, Energy Behaviour & Perception				x		x
	Building Modernisation & Energy Systems	x	x	x			x
	Household Appliances & Energy Consumption					x	x
	Energy Knowledge & Support Needs	x		x		x	x

[1] e.g. PV potential, energy provided by other renewables, energy community
[2] e.g. district heating, heat pumps
[3] e.g. perception, motivation, awareness, knowledge, acceptance

Lessons Learned from the Pre-Test of the 1st Intervention in Stuttgart

Fig. 3: Load profile demonstrator, climate quiz and smoothie bike during the pre-test of the 1st intervention in Stuttgart (Reber, 2025)

The pre-test showed that the load profile demonstrator, the climate quiz and the smoothie bike are low-threshold tools to successfully engaged both children and adults. Almost all participants were willing to take part in the quantitative online questionnaire survey afterwards (95% response rate with 1:1 support). While adults showed interest, few were inclined to discuss energy issues, underscoring the need for playful, age-inclusive participation formats.

Discussion & Conclusions

The DigiTwins4PEDs project addresses a key gap in the energy transition by integrating UDTs, ULLs and behavioural change strategies to promote a citizen-led shift toward PEDs. While the EU SET-Plan targets 100 PEDs by 2025, current efforts show that technology alone is not enough – active citizen engagement and inclusive decision-making are essential, yet still underdeveloped in energy planning. This contribution presents an integrated living lab framework embedding UDTs into participatory interventions, translating complex energy data into accessible insights. By tailoring interventions for young people, tenants and homeowners, the project empowers citizens to co-shape local energy futures. Three interventions – on awareness for energy(transition), flexible energy consumption, and PED – aim to increase interest in energy use, particularly in terms of consumption and flexibility.

The Stuttgart pre-test showed that gamified tools like the load profile demonstrator, the smoothie bike and the climate quiz effectively attract all age groups and introduce energy topics playfully. However, deeper engagement and discussion were limited in casual festival settings, emphasising the need for playful, low-threshold formats to gather data and engage participants. Due to the diverse characteristics of the case study areas in Stuttgart, Vienna, Rotterdam, and Wroclaw, a stakeholder-specific and adaptable flexible approach within an integrated framework is crucial. This framework aims to bridge expert systems and lived experience in order to develop local solutions that align with both climate targets and social needs. The approach presented thus strengthens the role of cities as experimental spaces for co-creation, learning and transformation in the energy transition.

References

Afacan, Y. (2023). Impacts of urban living lab (ULL) on learning to design inclusive, sustainable, and climate-resilient urban environments. LAND USE POLICY, 124. https://doi.org/10.1016/j.landusepol.2022.106443

Belfield, A., & Petrescu, D. (2024). Co-design, neighbourhood sharing, and commoning through urban living labs. CODESIGN-INTERNATIONAL JOURNAL OF COCREATION IN DESIGN AND THE ARTS. https://doi.org/10.1080/15710882.2024.2381792

Biresselioglu, M., Demir, M., Solak, B., Savas, Z., Kollmann, A., Kirchler, B., & Ozcureci, B. (2024). Empowering energy citizenship: Exploring dimensions and drivers in citizen engagement during the energy transition. ENERGY REPORTS, 11, 1894–1909. https://doi.org/10.1016/j.egyr.2024.01.040

Boley, B. B., Strzelecka, M., Yeager, E. P., Ribeiro, M. A., Aleshinloye, K. D., Woosnam, K. M., & Mimbs, B. P. (2021). Measuring place attachment with the Abbreviated Place Attachment Scale (APAS). Journal of Environmental Psychology, 74, 101577. https://doi.org/10.1016/j.jenvp.2021.101577

Bossi, S., Gollner, C., & Theierling, S. (2020). Towards 100 Positive Energy Districts in Europe: Preliminary Data Analysis of 61 European Cases. Energies, 13(22), 6083. https://doi.org/10.3390/en13226083

Bottero, M., Dell'Anna, F., & Morgese, V. (2021). Evaluating the Transition Towards Post-Carbon Cities: A Literature Review. SUSTAINABILITY, 13(2). https://doi.org/10.3390/su13020567

Brähler, E., Mühlan, H., Albani, C., & Schmidt, S. (2007). Teststatistische Prüfung und Normierung der deutschen Versionen des EUROHIS-QOL Lebensqualität-Index und des WHO-5 Wohlbefindens-Index. Diagnostica, 53(2), 83–96. https://doi.org/10.1026/0012-1924.53.2.83

Brandt, T., Schmeling, L., deBronstein, A. A., Schäfer, E., & Unger, A. (2021). Smart Energy Sharing in a German Living Lab: From Participation to Business Model. In J. Halberstadt, J. Marx Gómez, J.

Greyling, T. K. Mufeti, & H. Faasch (Hrsg.), Resilience, Entrepreneurship and ICT (S. 221–262). Springer International Publishing. https://doi.org/10.1007/978-3-030-78941-1_11

Casals, M., Gangolells, M., Macarulla, M., Forcada, N., Fuertes, A., & Jones, R. V. (2020). Assessing the effectiveness of gamification in reducing domestic energy consumption: Lessons learned from the EnerGAware project. Energy and Buildings, 210, 109753. https://doi.org/10.1016/j.enbuild.2019.109753

Connor, K. M., & Davidson, J. R. T. (2003). Development of a new resilience scale: The Connor-Davidson Resilience Scale (CD-RISC). Depression and Anxiety, 18(2), 76–82. https://doi.org/10.1002/da.10113

DEAB e.V. (Hrsg.). (2020). Ökologische Fußabdrücke—Handreichung.

Frantzeskaki, N., van Steenbergen, F., & Stedman, R. (2018). Sense of place and experimentation in urban sustainability transitions: The Resilience Lab in Carnisse, Rotterdam, The Netherlands. SUSTAINABILITY SCIENCE, 13(4), 1045–1059. https://doi.org/10.1007/s11625-018-0562-5

Gebetsroither-Geringer, E., Padsala, R., Hainoun, A., Agugiaro, G., Biernat, S., Reber, A., Smetschka, B., Gao, W., Horak, D., Falay, B., & Coors, V. (2025). A Participatory Planning Framework using Urban Digital Twins Supporting the Co-Creation of Flexible, Positive Energy Districts. REAL CORP 2025 Proceedings/Tagungsband, 65–76. https://archive.corp.at/cdrom2025/papers2025/CORP2025_115.pdf

Joint Programming Initiative Urban Europe. (2025). Positive Energy Districts (PED). JPI Urban Europe. https://jpi-urbaneurope.eu/ped/

Maas, F., Wolf, S., Weber, M., Fiedler, M. L., Zottmann, N., Lester, M., Hohm, J., Sessler, L., Schmitt, K. P., & Balser, A. (2023). „ hubbel“: A Hybrid Letterbox That Stimulates Civic Participation Through Local Information Sharing in Neighbourhoods. 1826–1841.

Mahajan, S., Hausladen, C., Sanchez-Vaquerizo, J., Korecki, M., & Helbing, D. (2022). Participatory resilience: Surviving, recovering and improving together. SUSTAINABLE CITIES AND SOCIETY, 83. https://doi.org/10.1016/j.scs.2022.103942

Meiselwitz, G., Moallem, A., Zaphiris, P., Ioannou, A., Sottilare, R. A., Schwarz, J., & Fang, X. (Hrsg.). (2022). HCI International 2022 - Late Breaking Papers. Interaction in New Media, Learning and Games: 24th International Conference on Human-Computer Interaction, HCII 2022, Virtual Event, June 26–July 1, 2022, Proceedings (Bd. 13517). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-22131-6

Neumann, H.-M., Hainoun, A., Stollnberger, R., Etminan, G., & Schaffler, V. (2021). Analysis and Evaluation of the Feasibility of Positive Energy Districts in Selected Urban Typologies in Vienna Using a Bottom-Up District Energy Modelling Approach. Energies, 14(15), 4449. https://doi.org/10.3390/en14154449

Orwin, L., Kist, A. A., Maxwell, A. D., & Maiti, A. (2015). Using gamification to create opportunities for engagement, collaboration and communication in a peer-to-peer environment for making and using Remote Access Labs. 2015 3rd Experiment International Conference (exp.at'15), 230–236. https://doi.org/10.1109/EXPAT.2015.7463271

Petrescu, D., Cermeño, H., Keller, C., Moujan, C., Belfield, A., Koch, F., Goff, D., Schalk, M., & Bernhardt, F. (2022). Sharing and Space-Commoning Knowledge Through Urban Living Labs Across Different European Cities. URBAN PLANNING, 7(3), 254–273. https://doi.org/10.17645/up.v7i3.5402

Ramaswami, A., Pandey, B., Li, Q., Das, K., & Nagpure, A. (2023). Toward Zero-Carbon Urban Transitions with Health, Climate Resilience, and Equity Co-Benefits: Assessing Nexus Linkages. Annual Review of Environment and Resources, 48(1), 81–121. https://doi.org/10.1146/annurev-environ-112621-063931

Robazza, G., Priego-Hernández, J., Caputo, S., & Melis, A. (2024). Temporary Urbanism as a Catalyst for Social Resilience: Insights from an Urban Living Lab Practice-Based Research. BUILDINGS, 14(6). https://doi.org/10.3390/buildings14061513

Saga, R. S., & Dunk, R. (2017). Gamification in a Living Lab: Energy saving challenges in student halls. Journal of the Institution of Environmental Sciences, 26(4), 32–39.

Schäpke, N., Stelzer, F., Caniglia, G., Bergmann, M., Wanner, M., Singer-Brodowski, M., Loorbach, D., Olsson, P., Baedeker, C., & Lang, D. J. (2018). Jointly Experimenting for Transformation? Shaping Real-World Laboratories by Comparing Them. GAIA - Ecological Perspectives for Science and Society, 27(1), 85–96. https://doi.org/10.14512/gaia.27.S1.16

van der Jagt, A., Smith, M., Ambrose-Oji, B., Konijnendijk, C., Giannico, V., Haase, D., Lafortezza, R., Nastran, M., Pintar, M., Zeleznikar, S., & Cvejic, R. (2019). Co-creating urban green infrastructure connecting people and nature: A guiding framework and approach. JOURNAL OF ENVIRONMENTAL MANAGEMENT, 233, 757–767. https://doi.org/10.1016/j.jenvman.2018.09.083

Wollny, A. I., & Jacobs, I. (2023). Validity and reliability of the German versions of the CD-RISC-10 and CD-RISC-2. Current Psychology, 42(5), 3437–3448. https://doi.org/10.1007/s12144-021-01670-2

Zahnow, R. (2024). Place type or place function: What matters for place attachment? American Journal of Community Psychology, 73(3–4), 446–460. https://doi.org/10.1002/ajcp.12722

Ziehl, M. (2021). Transdisciplinary real-world experiments and arts-based research practices. Co-producing urban resilience at Gangeviertel in Hamburg. RAUMFORSCHUNG UND RAUMORDNUNG-SPATIAL RESEARCH AND PLANNING, 79(4), 396–410. https://doi.org/10.14512/rur.69

Zingraff-Hamed, A., Huesker, F., Lupp, G., Begg, C., Huang, J., Oen, A., Vojinovic, Z., Kuhlicke, C., & Pauleit, S. (2020). Stakeholder Mapping to Co-Create Nature-Based Solutions: Who Is on Board? SUSTAINABILITY, 12(20). https://doi.org/10.3390/su12208625

Zingraff-Hamed, A., Martin, J., Lupp, G., Linnerooth-Bayer, J., & Pauleit, S. (2019). DESIGNING A RESILIENT WATERSCAPE USING A LIVING LAB AND CATALYZING POLYCENTRIC GOVERNANCE. LANDSCAPE ARCHITECTURE FRONTIERS, 7(3), 12–31. https://doi.org/10.15302/J-LAF-1-020003

Urban Governance and Planning

Digital Societies and Urban Governance: Adapting Global Innovations in Greece

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Abstract

Digitization is transforming urban governance, reshaping decision-making processes, citizen participation and sustainability strategies. This study explores how advanced digital policies in urban centers of countries such as Estonia, USA, the Netherlands, India and Singapore can be adapted to Greece to enhance transparency and administrative efficiency. Through a comparative analysis of academic literature, policy documents and case studies, innovative solutions such as e-voting, digital identities and participatory platforms are examined, highlighting the role of technology in modern multi-level governance. Emphasizing the concept of digital societies, the study investigates how digital reforms can strengthen citizens' connectivity with institutions, fostering a more participatory model of urban governance. The findings show how urban digitization reinforces these connections through digital tools, shaping citizens' political behavior and increasing their trust in political mechanisms.

1. Introduction

The rapid digitization of society has fundamentally reshaped the mechanisms of urban governance, transforming the way cities interact with citizens, manage data and implement public policies. In today's profoundly interconnected global reality, cities are emerging as genuine laboratories of innovation. Within these urban environments, technologies are not only tested and implemented, but are also designed to offer transparency, improve efficiency and strengthen democratic participation. Concepts such as 'smart governance', 'e-democracy' and 'digital citizenship' have moved beyond theoretical debate to actual policy practice, especially in pioneer countries such as Estonia, the United States, the Netherlands and Singapore. Meanwhile, contemporary phenomena such as the rise of artificial intelligence, the growing importance of cybersecurity, the need for digital literacy and the emergence of 'digital societies' are shaping new conditions for participation and governance in urban space. This paper explores how internationally renowned digital governance practices can serve as a source of inspiration and a strategic planning tool for similar reforms in Greece. Although the country has recorded significant steps in the digital transformation of public administration, significant barriers remain, such as inequalities in access to infrastructure, low levels of digital literacy and low trust in institutions. Through a comparative analysis of policies such as e-voting, digital identities and participatory digital platforms, this study attempts to answer the following key questions:

- What are the conditions for successful implementation of digital governance in an urban environment?

- How can the Greek experience compare and benefit from international practices?

- What is the role of citizens in building more participatory and sustainable digital societies?

Focusing on the broader context of digital transformation, this paper emphasizes that technology is not only a tool for operational modernization, but also a driving force in reshaping the relationship between citizens and institutions. In this context, Greece is invited to reposition itself in the 'digital chessboard' of global urban governance, not only as a recipient of technologies, but also as a potential creator of innovative, participatory and secure digital solutions.

2. Theoretical Framework

The study of digital societies and urban governance highlights the close and dynamic relationship between technological innovation and the functioning of institutions at the local level. Digital societies constitute a new social and cultural context, in which technology is fully integrated into human interactions, the economy and public administration. They are characterized by a rapid flow of information, new models of participation and technological mediation of everyday life (Sadiku, Chukwu, AjayiMajebi & Musa, 2022). Digital technologies are now reshaping models of political participation and accountability, enhancing tools such as digital platforms, smart city applications and e-government (Kapopoulos, 2021). Within this context, urban governance acquires particular importance, as Local Government Organizations (LGOs) function as key implementers of innovations in the field of digital transition. As Heywood (2014) highlights, local government, being closer to the citizen, is a crucial field for promoting participation and social cohesion. Of particular importance in the context under study is the concept of the smart city, which Anthopoulos (2021) describes as a complex ecosystem, which is composed of eight key pillars: smart infrastructure, transport, environment, services, governance, economy, living and citizens. This concept is not limited to technological applications, but also concerns the holistic approach to sustainable, interoperable and participatory urban development. “Smart governance”, as one of these key axes, presupposes the use of ICT to improve transparency, accountability and the ability of citizens to participate effectively in decision-making processes. Smart governance, as a sub-axis, requires the use of ICT to enhance transparency, accountability and participatory decision-making. Especially in the Greek reality, the integration of these practices requires not only technological upgrading, but also a transformation of the local administrative culture. Of decisive importance for the theoretical approach is the concept of policy transfer, the process of transferring and adapting international innovations to the domestic context. Greece, as a member of the EU, adopts many of the principles of digital governance and smart cities, however, implementation depends on the national and local institutional framework (Kapopoulos, 2021). Examples such as citizen participation platforms (e.g. IMC in the Municipality of Thessaloniki) or the use of G2C and G2E tools, show the evolving nature of local governance in the digital era. Therefore, the theoretical framework of this study is based on the intersection between technological innovation, institutional adaptation and local political action. It focuses on how global practices are transformed and integrated into the Greek local governance system, in order to enhance participation, accountability and effectiveness.

3. Methodology

This study employs a comparative qualitative policy transfer analysis, aiming to identify best practices in digital governance that may be applicable to the Greek context. The methodological framework draws on the model proposed by Dolowitz and Marsh (2000), which analyzes who transfers policy, what is transferred, from where and how, as well as the constraints and enabling factors affecting transfer success. The comparative design follows the logic of a Most Different Systems Design (MDSD) (Lijphart, 1971), in order to extract relevant insights from countries with significantly diverse political, social, and institutional environments. The five selected countries—Estonia, the United States, the Netherlands, India, and Singapore—represent a spectrum of administrative traditions, digital maturity, population scales, and citizen engagement levels. Case selection was based on theoretical sampling, which focuses on identifying cases that provide empirical richness and contrasting approaches to the implementation of digital governance policies (Ragin, 2014). Data collection relied exclusively on secondary bibliographic research, including peer-reviewed academic literature, white papers, international evaluations, and official government reports, focusing on the period from 2015 to 2024. The analysis adopted a heuristic comparative approach, identifying policy patterns that remain effective across heterogeneous contexts. The policy transfer framework thus enables context-aware and adaptive policy learning, emphasizing transferability and cultural fit rather than mechanical replication.

4. Results and Discuvssion

This chapter presents the core comparative analysis conducted using a “Most Different Systems Design” (MDSD) approach, focusing on the cases of Estonia, the USA, the Netherlands, Singapore, and India. Despite systemic and institutional diversity, each of these countries offers distinct lessons for enhancing digital public governance— particularly in the Greek context. Through a structured comparison, we identify transferable practices, success factors, and potential adaptive innovations.

4.1 What Is Transferable: Key Digital Practices

A series of cross-national digital governance mechanisms emerges as promising for policy transfer:

• (a) Digital Identity and Unified Service Access:

Estonia’s e-ID system represents one of the most advanced models of state-wide digital identity. Similarly, India’s Aadhaar system, although controversial due to privacy issues, showcases the power of biometric integration for streamlining citizen access. These could be partially adapted to the Greek initiative of a unified “Personal Number”.

• (b) Civic Participation through E-Platforms:

Countries like the Netherlands and Spain provide powerful cases of participatory digital democracy. Municipal platforms such as Open Stad and Decide Madrid allow citizens to co-shape urban policy (Table 2), indicating the feasibility of integrating similar tools into gov.gr.

• (c) Interoperability and Data Transparency:

Singapore’s Smart Nation infrastructure combines real-time sensors, interoperable datasets, and transparent civic dashboards. This model shows how cross-agency data sharing can elevate both urban intelligence and citizen trust.

• (d) Local Autonomy and Technological Decentralization:

U.S. cities like Boston and San Francisco demonstrate strong municipal agency in technological experimentation. Offices like New Urban Mechanics act as local incubators of digital solutions (Table 3), an idea transferrable to Greek municipalities.

COUNTRY	PRACTICE OR TOOL	DESCRIPTION
ESTONIA	e-ID, i-Voting	Unified electronic identity for full access to public services / Remote electronic voting with secure and easy access from anywhere
NETHERLANDS	Municipal e-consultation	Participatory budgeting and digital citizen input platforms (OpenStad Amsterdam, Open Urban Platform Rotterdam
USA	Civic Innovation Labs	Local innovation units for public digital services (New Urban Mechanics Boston)
INDIA	Aadhaar	Biometric ID system linked to service access
SINGAPORE	Smart Nation	Centralized smart governance and sensor-based infrastructure

Table 1 – Major digital public sector practices across five comparative cases, as derived from secondary sources. (Bountola, 2025)

4.2 Lessons Learned: Success Factors and Barriers

Certain contextual conditions have either enabled or prevented the implementation of digital governance reforms:

• Political Will and Consensus:

Estonia’s long-term political commitment to digitalization has crossed party lines. In contrast, uncoordinated efforts in parts of the USA show how lack of consensus derails initiatives.

• Digital Divide and Social Inequality:

In India, Aadhaar’s rollout exposed serious gaps in rural digital literacy and internet access. Singapore and the USA face similar challenges in underserved regions.

• Administrative Capacity:

The Netherlands illustrates how investing in digital advisors and local public servants ensures sustainability and adaptability of platforms like Open Stad (Table 2). The continuous interaction between citizens and trained staff also reinforces institutional trust and allows for feedback loops that improve service delivery.

• Pilot Flexibility and Institutional Learning:

Singapore’s use of policy sandboxes has fostered iterative improvements and social acceptance—critical in contexts where public skepticism is high. This approach allows early adjustments and feedback, helping authorities refine services before full implementation.

Table 2 – Comparative Overview of Digital Participatory Platforms and Transfer Potential to Greece

Country	Platform / Tool	Functionality	Institutional Level	Transferability to Greece
Netherlands	Open Stad	Co-creation and e-deliberation on local urban projects	1	🟢
USA	Boston’s CityScore	Real-time data dashboard for evaluating city services	1	🟡
Estonia	Rahvaalgatus.ee	Citizens initiate and support law proposals online	2	🔴
Singapore	OneService App	Integrated service access and citizen issue reporting	2	🟡
Spain	Decide Madrid	Participatory budgeting, digital voting and citizen-led proposals	1	🟢

🟢 High (fits gov.gr goals) — Institutional level:
🟡 Medium (in progress) — 1: Municipal
🔴 Low (Lacks infrastructure — 2: National

Table 2 – Comparative analysis of digital participatory tools across selected countries and their strategic relevance for Greek public governance reform (Bountola, 2025).

4.3 Transferability to Greece: Risks and Adaptation

The Greek digital governance environment is shaped by both opportunity and constraint. Key considerations for the successful adaptation of external models include:

• Cultural Trust Gap:

Public mistrust in data privacy and central authority remains a major hurdle. This requires robust awareness campaigns and transparent governance procedures.

• Uneven Local Readiness:

Municipalities across Greece show asymmetrical digital capacities. As such, a "multi-speed" implementation strategy should be prioritized, starting with pilot cities.

• European Alignment and Funding:

Greece could leverage EU programs (e.g., Digital Europe, Horizon) to cofinance its transitions without relying entirely on national resources.

• Hybrid Model Formation:

The goal is not replication but synthesis: combining participatory budgeting elements from the Netherlands with open data logic from Singapore to build locally grounded civic tech tools.

In order to better understand the enabling and limiting factors in Greece's digital governance transition, the table below presents a strategic SWOT analysis.

Table 3 - Strategic SWOT Analysis: Greece's Readiness for Digital Governance Reform

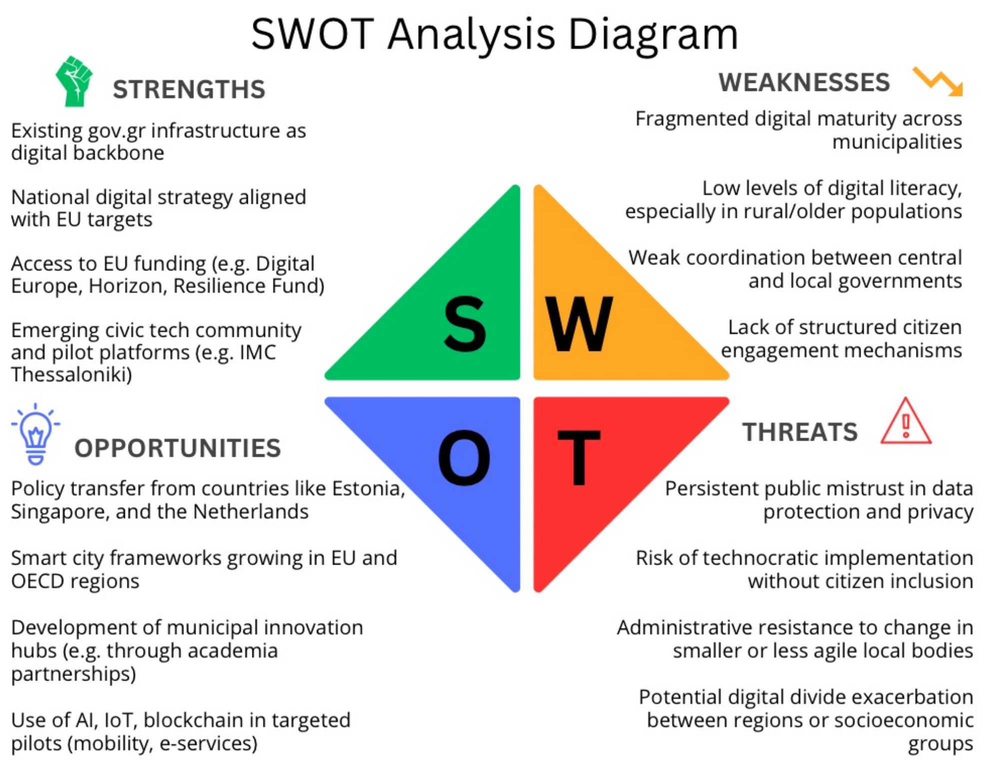

Table 3 – SWOT analysis of Greece's capacity to adapt global digital urban governance models (Bountola, 2025).

4.4 Visual Insights and Strategic Mapping

Visual tools enhance the strategic understanding of where transfer opportunities lie. Layered Circle Map showing the relationship between Greece (center) and thematic policy areas (inner ring), specific transferable innovations (middle ring), and their originating countries (outer ring).

(fig. 1) Policy transfer potential for Greece

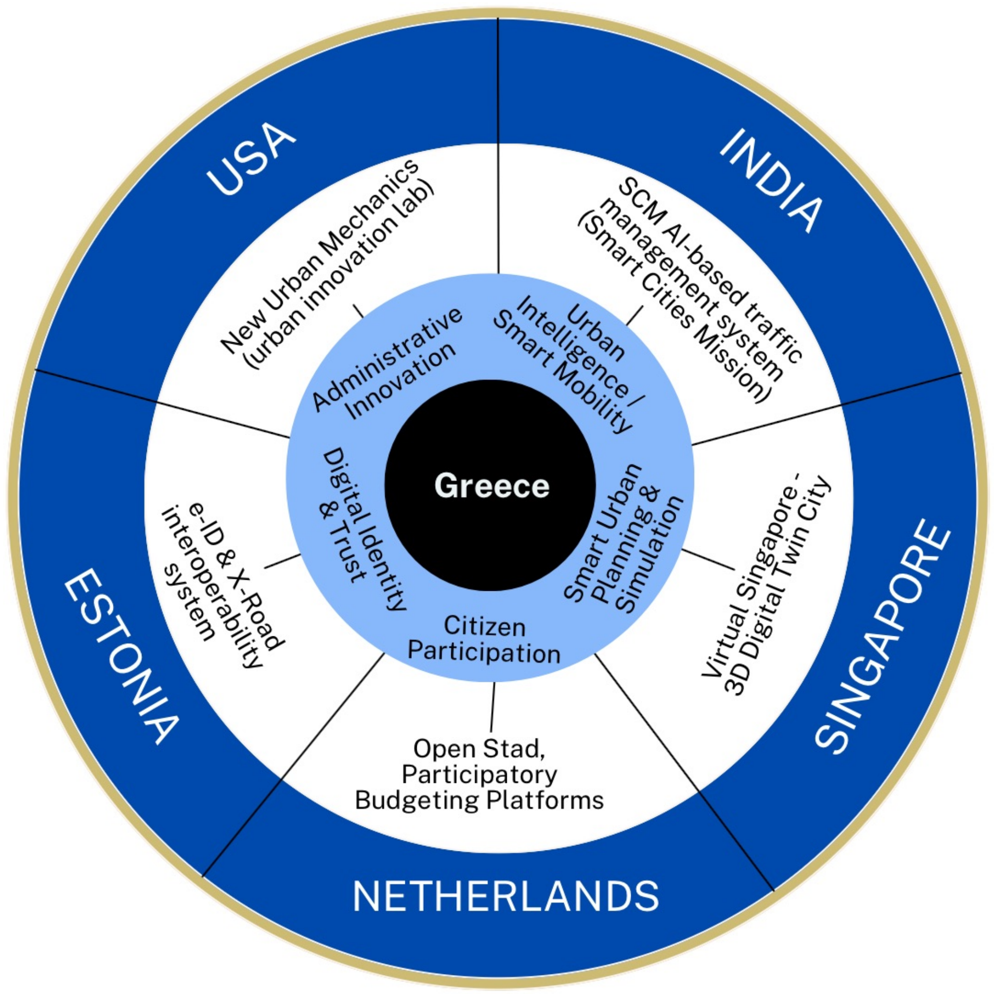

Figure 1 – Layered mapping of Greece's digital governance needs, policy areas, and transferable innovations from five global models. (Bountola, 2025).

Furthermore, the evolution of Greek digital governance has been depicted through a five-point timeline reflecting key institutional moments.

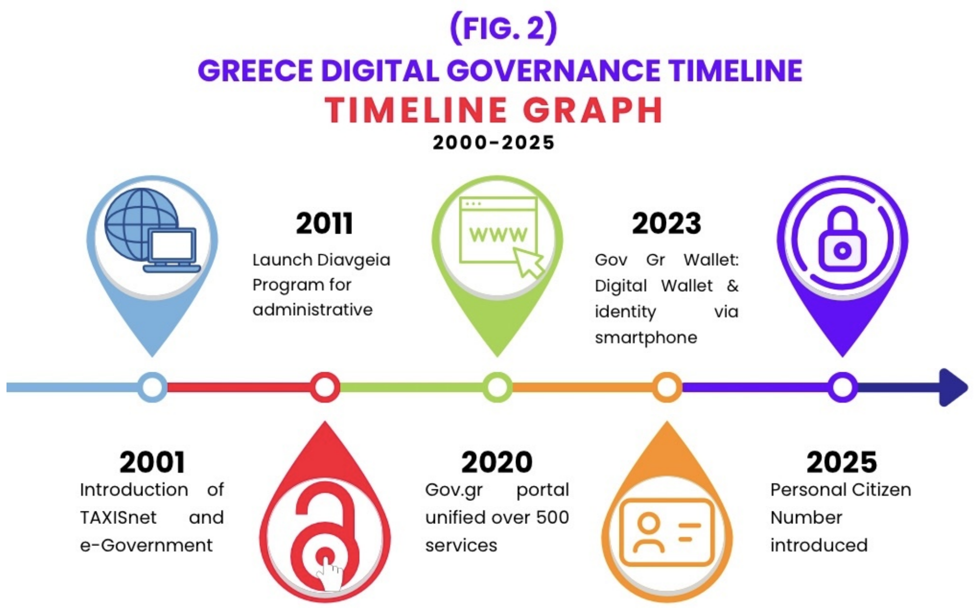

Figure 2 – Timeline of Digital Governance Milestones in Greece. (Bountola, 2025).

5. Conclusion

The digital transformation of urban governance has the potential to significantly improve the relationship between citizens and institutions. By adapting successful models from countries like Estonia, the Netherlands, India, USA and Singapore, Greece can strengthen its urban governance framework, enhance transparency, and promote more participatory decision-making. However, this transformation requires careful planning, investment in infrastructure, and continuous education to ensure that all citizens can benefit from these digital advancements.

As Greece moves forward in its journey towards a **digital society**, the lessons learned from these international case studies can provide a roadmap for future policies and initiatives that aim to create more sustainable, inclusive, and efficient urban environments.

References

Anthopoulos, L. (2022). Exypnes poleis kai efyis diakyvernisi [Smart cities and intelligent governance]. Kritiki. Ayuntamiento de Madrid. (n.d.). Decide Madrid: plataforma de participación ciudadana. Retrieved May 28, 2025, from https://decide.madrid.es/

City of Boston. (2025). CityScore. Boston.gov. Retrieved May 28, 2025, from https://www.boston.gov/departments/analytics-team/cityscore City of Boston. (n.d.). Mayor's Office of New Urban Mechanics. Boston.gov. Retrieved May 28, 2025, from https://www.boston.gov/departments/new-urban-mechanics

Ekathimerini. (2025, May 26). Personal number to be issued via gov.gr starting June 3. Retrieved May 28, 2025, from https://www.ekathimerini.com/politics/1270877/personal-identification-number-pato-be-issued-via-gov-gr-starting-june-3/

Gemeente Rotterdam. (2025). Open Urban Platform Rotterdam. Retrieved May 28, 2025, from https://www.rotterdam.nl/open-urban-platform-rotterdam

Heywood, A. (2014). Eisagogi stin politiki [Introduction to politics] (K. Zepou, Trans.). Epikentro. (Original work published 2002)

Ho, E. (2016). Smart subjects for a Smart Nation? Governing (smart)mentalities in Singapore. Urban Studies, https://doi.org/10.1177/0042098016664305 54(13), 3101–3118.

Hoe, S. L. (2016). Defining a smart nation: the case of Singapore. Journal of Information Communication and Ethics in Society, 14(4), 323–333. https://doi.org/10.1108/jices-02-2016-0005

Kapopoulos, D. G. (2021). Ilektroniki diakyvernisi: Koinonikos kai oikonomikos metaschimatismos [Electronic governance: Social and economic transformation].

Diavlos.

Monetary Authority of Singapore. (n.d.). Overview of regulatory sandbox. Retrieved May 28, 2025, from https://www.mas.gov.sg/development/fintech/regulatory-sandbox

Musunuri, S., & Rama Prasad, M. V. (2020). Digitalisation and Government of India initiatives. In V. P. Gupta (Ed.), Digitalisation & innovations in business (pp. 10–18).

Empyreal Publishing House. https://www.empyrealpublishinghouse.com/pdf/editedbook-of-dr-vijay-prakash-gupta.pdf#page=19 OECD Observatory of Public Sector Innovation. (n.d.). Virtual Singapore – Singapore's virtual twin. Retrieved May 28, 2025, from https://oecdopsi.org/innovations/virtual-twin-singapore/

OpenStad. (n.d.). Home. Retrieved May 28, 2025, from https://openstad.org/

Press Information Bureau. (2025, May 27). Press Note Details. Retrieved May 28, 2025, https://www.pib.gov.in/PressNoteDetails.aspx?ModuleId=3&NoteId=150833 from Sadiku, M., Chukwu, U., Ajayi-Majebi, A., & Musa, S. (2022). Available Online: www.ijtsrd.com e-ISSN: 2456-6470 @ IJTSRD | Unique Paper ID - IJTSRD52243 | Volume -6 | Issue -6. International Journal of Trend in Scientific Research and Development, 6(6), 2068–2071. https://www.ijtsrd.com/papers/ijtsrd52243.pdf

Secure Identity Alliance. (2014). eServices in Estonia: A success story. Retrieved from https://secureidentityalliance.org/publications-docman/public/11-14-06-02-siaestonia-visit-report/file

Advancing Spatial Literacy in Real-world Labs

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Abstract

Grasping the variety and complexity of spatial relations is crucial for urban research. These relations are influenced by numerous variables, develop in virtual and real-world settings, are bridged by slow and fast means of communication and transport, and unfold amidst slabs of concrete and swaths of greenery. By necessity, transformative science, including research in Real-world Labs, needs to address or at least take into account the interrelated and interwoven actor-networks that make up our built and lived environment. In this context, spatial literacy emerges as a promising concept for exploring and navigating spatial relations, deepening our understanding of how they evolve, and identifying opportunities to steer changes towards more sustainable futures.

As a boundary spanning concept for bridging disciplinary divides, the concept of spatial literacy appears in various fields of research and communities of practice. However, while this concept invites a relational perspective, its full potential for the conceptualization and implementation of Real-world Labs has yet to be fully realized.

Based on a systematic literature review on the notion of spatial literacy as well as analyses of case studies on different types of urban Real-world Laboratories, this contribution reflects on the questions how transdisciplinary, transformative research in experimental settings currently conceptualizes space and spatial relations, and how a more nuanced understanding of spatial relations could be fostered. Inspired by relational approaches in social scientific sustainability research, which encourage scholars from diverse traditions to 'walk together in a world of many worlds' (West et al. 2024), this contribution begins by unpacking different understandings of spatial relations, encompassing the full spectrum of phenomena in the built and lived environment. It then examines how these understandings shape current research methodologies and practices in Real-world Labs. This, in turn, enables a nuanced exploration of spatial relations across multiple dimensions, including the material, functional, processual, and practical.

In other words, more comprehensive conceptualizations of space and spatial literacy are brought to bear on the different kinds of experimental settings and approaches to conceptually, epistemologically, and methodologically enrich transformative research in real-world labs. Our reflection on spatial literacy in the context of diverse urban experimental settings highlights how spatial thinking can contribute to sustainability transitions in different contexts.

References

West, S., Haider, L.J., Hertz, T., Mancilla Garcia, M., Moore, M.-L. (2024). Relational approaches to sustainability transformations: walking together in a world of many worlds. Ecosystems and People, 20(1), 2370539. DOI: 10.1080/26395916.2024.2370539.

How the Set-up of an Urban Transition Lab influences Experimentation – a Case Analysis of the TRUST Project

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Abstract

While transformative transdisciplinary research approaches are increasingly valued (Schäpke et al., 2018), there is no blueprint for triggering urban transitions (Franzeskaki et al., 2022) and for fostering their acceleration (Markard et al., 2020). Nevertheless, facing and embracing the multitude and variety of ambitious transdisciplinary approaches, there is a need to support the (inter)disciplinary co-production of "the knowledge how" (Caniglia et al., 2021; Hölscher et al., 2021). The TRUST project (ongoing since 2022) (Maiwald et al. 2024) defines as an Urban Transition Lab (Nevens et al., 2013) and is therefore classified as a transdisciplinary transformative project. Here, ten transition experiments (Sengers et al., 2019) were co-created to foster and empower urban climate governance (Bulkeley & Betsill, 2005, 2013) within a three-years Transition Management process (Wittmayer et al., 2018). The here presented evaluation focuses on the effects of the temporary creation of positions for participating stakeholders in the Transition Team on the results of the experiments. To make these connections, we tested the case reporting scheme according to Bernert et al. (2023). This allowed us to differentiate between the effects of temporary position creation on the experiments.

1. Introduction

Sustainability transition science has put forth a significant importance of transdisciplinary approaches (Defila & Di Giulio, 2019; Schäpke et al., 2024) as a modality to co-create pathways for profound societal change (Grin et al., 2010). Doing so, transdisciplinary researchers are facing complexity and context specificity (West et al., 2019) that challenges cross-case learning. Bernert et al. (2023) has put forth a scheme for supporting cross-case learning between "sustainability-oriented labs in realworld contexts" (McCrory et al., 2020). Since many concepts and constellations of such labs, have emerged, Bernert et al. (2023) sets a "disambiguation of context, lab and experiment" (ibid, p. 5; based on the "modular evaluation by Kampfmann et al. (2023)). As a supplement, this scheme embeds the evaluative framework for sustainability transition experiments by Luederitz et al. (2017) for the reporting on experiments. This provides us an approach to analyse the Transition Management process in the TRUST project, which defines as an Urban Transition Lab (Nevens et al., 2013). Since a lab context and transition experiments were co-created (chapter 2), we argue, that the TRUST Urban Transition Lab concept is nested in the Urban Living Lab perspective (Steen & van Bueren, 2017; Bulkeley et al., 2019; McCrory et al., 2020), that the Case reporting Scheme by Bernert et al. (2023) is based on. We chose to illuminate the Staffing of the Transition Team (chapter 2.1), which comes as one of the "organisational lab characteristics" (ibid.). We chose to examine this characteristic, since the Staffing of the Transition Team drove the Transition Team members to take overk leadership roles in the experimentation phase of the Transition Management process. So, we want to trace the effects of this project funded-led resource distribution on the co-creative experiment dynamics and results.

We lighten the following research question:

> What effects has the multiple creation of positions for the Transition Team in the context of the TRUST project?

The TRUST project was set up in a transdisciplinary manner by the Interdisciplinary Centre for Urban Transformative Regeneration in Görlitz. The Centre states as a Real-World Laboratory since it is a longstanding, well-networked institution, that regularly collaborates with local actors for testing urban sustainability transition approaches in a transdisciplinary manner. Staffing the Transition Team, that we base our analysis on, was both: enabled by the scope of the project funding as well as embedded in the context landscape. After all, it was the result of a co-creative set-up process within a transdisciplinary project consortium. Keeping the complex interplay of Urban Transition Lab characteristics in mind, this could be an appropriate transdisciplinary set-up feature for urban climate efforts in municipalities with low financial power.

In the following, we introduce the TRUST Transition Management approach, its Transition Team and Transition Arena process in more detail (chapter 2). We then present our method of investigation (chapter 3). In chapter 4, we show the results of our intra-case comparative study, that we discuss in chapter 5 (conclusion).

2. TRUST Transition Management Approach

2.1. TRUST Transition Team and Transition Arena Process

The Project "TRUST – Transfer of Urban Sustainability Transition Knowledge: Towards Climate-Neutral Cities 2030 - The City of Görlitz as a Pilot" (2022-2026) is a transfer project, funded by the German Leibniz Association, under responsibility of IOER. The TRUST project aimed to implement an urban innovation system in order to co-create activities and structures for urban climate neutrality by implementing a three-year Transition Management process (03/2022-03/2025) (Loorbach, 2010; Roorda, 2014; Wittmayer et al., 2018). It addresses urban climate neutrality in Görlitz, Germany, across multiple fields – including mobility, energy, local economy, food and consumption and urban development – with local actors from city administration, civil society, the business community, and academia collaborating throughout (Fig. 1). Three primary formats were established: The Transition Arena and a two-level Transition Team composition. Staged in the Transition Arenas the project progressed through several phases (Roorda, 2014; Wittmayer et al., 2018): setup, system analysis, visioning, pathway development by backcasting, experimentation, and agenda development (Fig. 2). Those ten interconnected Transition Arenas regularly attracted around 40 local stakeholders. Here, system, target, and transition knowledge (Caniglia et al., 2017) was progressively co-produced, while the Transition Team was responsible for coordinating, facilitating as well as (in parts) legitimising the process. The Transition Team was organized as follows. It enclosed a steering and an operative format both with different functions. Substantial third-party funding was allocated to create human resources at the operative Transition Team level. This way of resource allocation ensured the facilitation of multi-year process, which included averagely weekly meetings of a convened operative Transition Team group, adaptive co-design of the Transition Arenas as well as supervision and performance in the experimentation phase.

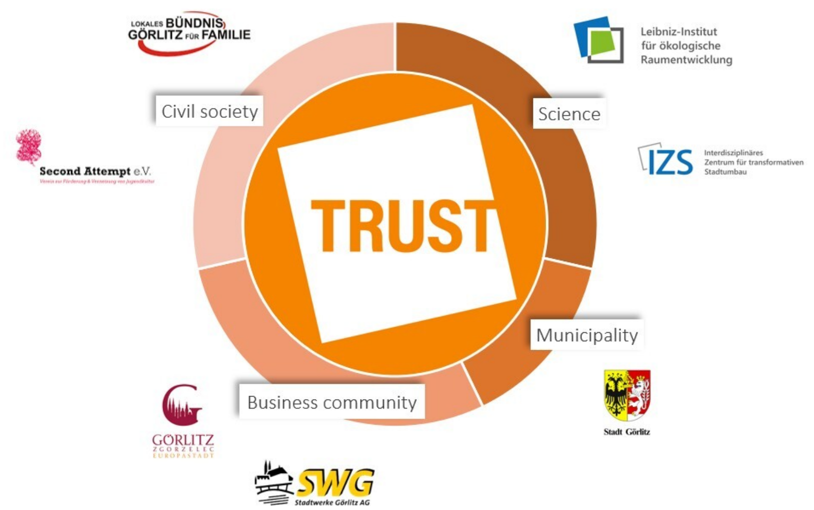

Fig. 1 TRUST partner institutions (illustration: own depiction of IOER): Interdisciplinary Centre for Transformative Urban Regeneration and Leibniz Institute of Ecological Urban and Regional Development (Science), Stadt Görlitz (Municipality), Stadtwerke Görlitz AG and Europastadt GörlitzZgorzelec GmbH (Business Community), Second Attempt e.V. and Görlitz für Familie e.V. (Civil society))

Fig. 2 Overview of the transition arena process (image source: own illustration/IOER)

2.2. TRUST experiments

The TRUST Transition Management process gave rise to a number of transition experiments (Sengers et al., 2019). Under the common motto of promoting the goal of urban climate neutrality, they are assigned to the areas of mobility, food and consumption, urban development, local economy and energy. Fig. 3 shows the TRUST experiments. Operative Transition Team members were ought to function as mediators between project organisation and experimental groups. In 9 out of 10 cases there was a match between the thematic orientation of the experiments and the professional embedding of the transition team members. While the drafts of the transition experiments had their co-creative source in the Transition Arena, most of the Transition Team members took over a significant role in carrying out the experiment ideas. The creation of positions on the operative Transition Team level implied, that there was high availability of human resource as well as access to professionalized (institutional) infrastructures to carry the process of experimenting.

Hence, they carried most of the responsibility in the experimentation phase. This was the case in all, except #4 'Flowering Meadows' and #10 'Initiative 'Untere Jakobstraße'.

Fig. 3 Overview of the TRUST experiments

3. Methodological Approach

In order to get comprehensive information about the effects of the staffed operative Transition Team level on the TRUST transition experiments, we analysed them along the suggested analysis features of output, outcome, process and input by Luederitz et al. (2017), which Bernert et al. (2023) refer to.

We based our empirical research on systematic process observation, team members-questionnaire as well as a reflexive workshop with the Transition Team at the operative level.

The questionnaire was ought to fill the gaps of process observation. The timing of the questionnaire was in the end of the Transition Management process (March-April 2025). Most of the experiments had been completed by this time. We included all experiments in the study that were completed or at least as much progressed in their approach to display not only input-features, but also process- and output-features. The questionnaire mainly addressed the members of the Transition Team on the operative level since they were mediators or drivers and, therefore, were informed about the progress of the experiments. We summed the gathered information from the questionnaire and the process observation and reflected our evaluation upon a reflexive workshop with the Transition Team (April 2025). We assessed the data using qualitative content analysis (Mayring & Fenzl, 2022).

4. Results

Obviously, a huge span of factors influenced the emergence and development of transition experiment-ideas. Our experiment analysis about the effects of staffing the operative Transition Team showed the following results. We present them along the features, as they are figured by Luederitz et al. (2017) Our empirical data represents information on output-, process- and input features, while outcome features are not represented. There are two reasons for this. Features of the category "Outcomes" where highly determined by the TRUST lab-focus on climate neutrality. Those were 'Intra- and intergenerational justice', 'Socio-ecological stewardship and democratic governance' as well as 'Precaution and adaption'. Nevertheless, there were further outcomes represented within the experiments. But all the evaluated experiments have in common, that outcomes had not been achieved so far.

4.1. Output Features

We identified a clear linkage of the Transition Team staffing to the localisation of capacity building (relates to the feature 'built capacity'), and related to this, 'actionable knowledge'-accumulation. In the cases, where the Transition Team members played key roles in the experiments, we observed a concentration of actionable knowledge-genesis and capacity building in the institutions they represented. In most cases, we saw the implicit strong linkage between actionable knowledge-genesis and capacity building, since capacities are related to useful, practical knowledge, of "how to transition" (Hölscher et al., 2021). Though not all of the TRUST experiments gained capacity building, there was "actionable knowledge" generated in nearly all cases – and, with a shared logic of accumulation. The often-emerged logic path was, that in the represented institution existing skills, structures and networks (ergo capacities), generally, were used, and which were then supplemented by an experiment-specific capacity build-up.

To illustrate this, we describe this mechanism using experiment '#1 Waste Matching': The municipal business development organisation took over the implementation of the experiment idea. As part of the preparations for a related activity (which was in this case a survey aimed at local companies) the organisation used its existing technical infrastructure, expertise and network relationships. The combination of these existing capacities (or resources) led to topic-specific capacity building and the associated generation of actionable knowledge.

This can also be very clearly displayed along experiment '#2 Reusable Bag Dispenser'. While the idea for the experiment was co-created, the essential activity of the experiment – which was in this case the construction of the kangaroos – was localized at the organisation that was represented by a staffed Transition Team member. The 'built capacity' relates in this case to the construction (skill). Existing networks for spreading the bag dispensers were used. Actionable knowledge was especially generated along efforts to set-up a collaboration with supermarkets.

We found this displayed mechanism in nearly all cases. This also appeared in another experiment. In the '#4 Flowering Meadows'-experiment, the protagonist was not a staffed Transition Team member, but a Transition Arena-participant, who represented a locally established organisation for environmental protection. The representative brought in obviously the most appropriate professionalized capacity (knowledge, skills, networks) and took over the steering role of the experiment. This elucidates this mechanism Capacity Building (including actionable knowledge-genesis) is allocated, where the most appropriate – and ready for use – capacities is already accumulated.

In turn, we observed, that the spread of actionable knowledge genesis or capacity building within the experiment group depended very much on the grade of shared decision-making. This, vice versa, depended on assumed factors like idealism, spread of resource availability, social cohesion, etc. This feeds into the analysis of the process feature 'collaboration' (chapter 4.2).

We also recognized, that other output features, those are 'accountability', 'scalability' and 'transferability', were relating to the allocation of capacity building, and therefore, they were depending on the represented institutional representative or structure.

The experiment '#10 Initiative 'Untere Jakobstraße'' displayed an exception. Here, neither the available human resource of the Transition Team representative, that was assigned to the experiment group (within topic group Mobility) nor related institutional capacities were channelled into the development or support of the experiment. Our investigation brought up, that this was due to an absent, even interpreted lightly conflicting, understanding of the institutional affiliation of the Transition Team member to the traffic calming topic.

4.2. Process Features

The applied methodological approaches (feature 'sound methodology') were determined by the executors. As already stated, in many cases this was characterised by the Transition Team members or representatives who had the most thematically appropriate capacities available. Therefore, the staffing of the operative TRUST Transition Team led to the utilisation of represented institutionally common methods or procedures. The TRUST experiment ideas often suggested a methodological frame. However, all of them showed a great deal of methodological leeway in the implementation approach, which was then filled by the institutionally available capacities.

Deriving from our study, we assume, that 'collaboration' was influenced by the staffing of the Transition Team. Nevertheless, within our methodological approach, we cannot make consistent statements about this influence. It seems sure, that the staffing made the Transition Team members in most cases to kind of collaboration leaders. This means, that they had a big say in how collaboration is designed and who is when included in decision making (regarding decisions that relate to the experiment activities). But we observed, that collaboration within the experiment groups was organised in manifold ways and that this not only depended neither on the resource dominance of the staffed Transition Team members nor on the resource availability of other actors. The same counts for the feature 'transparency', which is linked to collaboration.

4.3. Input Features

Basing on our knowledge about represented professional backgrounds in the operational Transition Team, we found that professional backgrounds in sustainability or even transition related topics are often represented by Transition Team members and therefore, due to their acknowledged role uptake in the experimentation phase, this is related to the involved 'awareness' in the experiment development, execution and outputs. This was due to the fact, that within the addressed organisations especially people with topic related backgrounds, knowledge or even motivation were picked to represent those for the TRUST project topic "climate neutrality in Görlitz".

'Commitment' manifested in the manifold collaborations and support for the TRUST transition experiments. The staffed operative Transition Team representatives, who overtook important roles in the experimentation phase, guaranteed a professional, institutional commitment in executing the experiment.

As mentioned before, forms of collaborations were not mono-causally related to the Transition Team staffing. This also applies to the integration of 'expertise' diversity. The Transition Arenas gathered cross-sectoral professional and experience-based expertise. The representation of expertise in the experiment execution, nevertheless, was strongly influenced by the executing actors, which often where represented by the staffed operative Transition Team representatives. Related institutional, professional expertise had a strong part in the experiment procedures. Anyway, more than half of the TRUST experiments, additionally other sourced knowledge and skills flowed comprehensibly into the experiments' development and execution. Those display the cases with elaborated 'collaboration' (chapter 4.2). This also accounts for 'support', where payment-based institutional / professional involvement and commitment of the Transition Team representatives was a guaranteed support by related institutional resources.

5. Conclusion

We studied the effects of a staffed operative Transition Team, taking up roles in an Urban Transition Lab experimentation phase (Roorda, 2014; Wittmayer et al., 2018). Basing our analysis on the Case Reporting Scheme by Bernert et al. (2023) and Luederitz et al. (2017) we found that the involvement of a staffed Transition Team in the Transition Management experimenting phase does not necessarily affect all experiments' (feature) results. We identified effects on the output features 'built capacity' and genesis of 'actionable knowledge'. Namely the occurrence of an allocation shift, which can also influence other output features: 'accountability', 'transferability' as well as 'scaling up' and 'scaling out'. We further identified a shift in the usage of 'sound methodology'. Distributing process resources (as positions) to certain actors can lead to a focus shift in methods and procedures. In addition, we examined the effect on 'collaboration', whereas we could not find mono-causal linkages between Transition Team Staffing and forms of the latter. Since collaboration remains independent of Transition Team Staffing, also collaboration-related input features like 'commitment, 'awareness' and 'support' cannot be steered only by Transition Team Staffing. Nevertheless, in the TRUST experiments, it demonstrably led to higher as well as reliable representation of 'awareness', 'commitment' and 'support'.

Transition Team members, that had kind of a steering role and most available capacities, did not necessarily make important decisions alone. But we could see, that they gathered the most capacity building. This was definitely urged by the Team Staffing. On the one hand, this led to institutional capacity building at the involved members of the TRUST project consortia – as it was aimed. On the other hand, responsibility uptakes, activation of civil resources and broad capacity building may be traded for this, since responsibility was pushed onto or took over from actors with existing resource pools. We further explored, that the TRUST process met with existing pools of professionalised structures, which could generate impressive outputs without additional support. We therefore rise the question, what it was about the TRUST process, that finally led to the execution of their already available capacities.

References

Bernert, P., Wahl, D., Von Wehrden, H., & Lang, D. J. (2023). Cross-case knowledge transfer in transformative research: Enabling learning in and across sustainability-oriented labs through case reporting. Urban Transformations, 5(1), 12. https://doi.org/10.1186/s42854-023-00056-w

Bulkeley, H., & Betsill, M. (2005). Rethinking Sustainable Cities: Multilevel Governance and the „Urban" Politics of Climate Change. Environmental Politics, 14(1), 42–63. https://doi.org/10.1080/0964401042000310178

Bulkeley, H., & Betsill, M. M. (2013). Revisiting the urban politics of climate change. Environmental Politics, 22(1), 136–154. https://doi.org/10.1080/09644016.2013.755797

Bulkeley, H., Marvin, S., Palgan, Y. V., McCormick, K., Breitfuss-Loidl, M., Mai, L., von Wirth, T., & Frantzeskaki, N. (2019). Urban living laboratories: Conducting the experimental city? European Urban and Regional Studies, 26(4), Article 4. https://doi.org/10.1177/0969776418787222

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., König, A., von Wehrden, H., Schäpke, N. A., Laubichler, M. D., & Lang, D. J. (2021). A pluralistic and integrated approach to action-oriented knowledge for sustainability. Nature Sustainability, 4(2), Article 2. https://doi.org/10.1038/s41893-020-00616-z

Defila, R., & Di Giulio, A. (Hrsg.). (2019). Transdisziplinär und transformativ forschen, Band 2: Eine Methodensammlung. Springer Nature. https://doi.org/10.1007/978-3-658-27135-0

Franzeskaki, N., Hölscher, K., Jäger, J., Holman, I., Tàbara, J. D., Pedde, S., Kok, K., & Silvestri, G. (o. J.). 1 DRIFT, The Netherlands 2 Independent, Austria 3 Independent, Spain 4 Wageningen University, The Netherlands.

Grin, J., Rotmans, J., & Schot, J. (2010). Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change. Routledge.

Hölscher, K., Wittmayer, J. M., Hirschnitz-Garbers, M., Olfert, A., Walther, J., Schiller, G., & Brunnow, B. (2021). Transforming science and society? Methodological lessons from and for transformation research. Research Evaluation, 30(1), 73–89. https://doi.org/10.1093/reseval/rvaa034

Kampfmann, T., Bernert, P., & Lang, D. J. (2023). Toward a modular evaluation approach of real-world laboratories: Findings from a literature review. Research Evaluation, 32(1), 128–143. https://doi.org/10.1093/reseval/rvac029

Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework (No. Vol. 23, No. 1). Governance: An International Journal of Policy, Administration, and Institutions.(Vol. 23, No. 1), Article Vol. 23, No. 1. https://doi.org/14680491, 2010, 1,

Luederitz, C., Schäpke, N., Wiek, A., Lang, D. J., Bergmann, M., Bos, J. J., Burch, S., Davies, A., Evans, J., König, A., Farrelly, M. A., Forrest, N., Frantzeskaki, N., Gibson, R. B., Kay, B., Loorbach, D., McCormick, K., Parodi, O., Rauschmayer, F., … Westley, F. R. (2017). Learning through evaluation – A tentative evaluative scheme for sustainability transition experiments. Journal of Cleaner Production, 169, 61–76. https://doi.org/10.1016/j.jclepro.2016.09.005

Maiwald, L., Jaskólski, M., Knippschild, R., Rößler, S. (2024). Shaping and Strengthening the Regenerative Potential for Local Climate Neutrality. Insights and Reflection from a Transdisciplinary Project in the City of Görlitz. In: Maudsley, Ann; Wallsten, Björn (Eds.) : Towards Regenerative Neighbourhoods: European Cases, Insights, and Initiatives. Vienna : Driving Urban Transitions Partnership, 2024, S.58-63 https://dutpartnership.eu/wp-content/uploads/2024/04/DUTPositionPaper_TowardsRegenerativeNeighbourhoods_v2.pdf

Markard, J., Geels, F. W., & Raven, R. (2020). Challenges in the acceleration of sustainability transitions. Environmental Research Letters, 15(8), 081001. https://doi.org/10.1088/1748-9326/ab9468

Mayring, P., & Fenzl, T. (2022). Qualitative Inhaltsanalyse. In Handbuch Methoden der empirischen Sozialforschung (S. 691–706). Springer VS, Wiesbaden. https://doi.org/10.1007/978-3-658-37985-8_43

McCrory, G., Schäpke, N., Holmén, J., & Holmberg, J. (2020). Sustainability-oriented labs in real-world contexts: An exploratory review. Journal of Cleaner Production, 277, 123202. https://doi.org/10.1016/j.jclepro.2020.123202

Nevens, F., Frantzeskaki, N., Gorissen, L., & Loorbach, D. (2013). Urban Transition Labs: Co-creating transformative action for sustainable cities. Journal of Cleaner Production, 50, 111–122. https://doi.org/10.1016/j.jclepro.2012.12.001

Parodi, O., Ober, S., Lang, D. J., & Albiez, M. (2024). Reallabor versus Realexperiment: Was macht den Unterschied? GAIA - Ecological Perspectives for Science and Society, 33(2), 216–221. https://doi.org/10.14512/gaia.33.2.4

Roorda, C., Wittmayer, J., Henneman, P, Steenbergen, F. van, Frantzeskaki, N., Loorbach, D.,. (2014). DRIFT-Transition_management_in_the_urban_context-guidance_manual.pdf.

Schäpke, N., Stelzer, F., Caniglia, G., Bergmann, M., Wanner, M., Singer-Brodowski, M., Loorbach, D., Olsson, P., Baedeker, C., & Lang, D. J. (2018). Jointly Experimenting for Transformation? Shaping Real-World Laboratories by Comparing Them. GAIA - Ecological Perspectives for Science and Society, 27(1), 85–96. https://doi.org/10.14512/gaia.27.S1.16

Schäpke, N., Wagner, F., Beecroft, R., Rhodius, R., Laborgne, P., Wanner, M., & Parodi, O. (2024). Impacts of real-world labs in sustainability transformations: Forms of impacts, creation strategies, challenges, and methodological advances. GAIA - Ecological Perspectives for Science and Society, 33(1), 4. https://doi.org/10.14512/gaia.33.S1.2

Sengers, F., Wieczorek, A. J., & Raven, R. (2019). Experimenting for sustainability transitions: A systematic literature review. Technological Forecasting and Social Change, 145, 153–164. https://doi.org/10.1016/j.techfore.2016.08.031

Steen, K., & van Bueren, E. (2017). The Defining Characteristics of Urban Living Labs. 7(7).

West, S., van Kerkhoff, L., & Wagenaar, H. (2019). Beyond “linking knowledge and action”: Towards a practice-based approach to transdisciplinary sustainability interventions. Policy Studies, 40(5), 534–555. https://doi.org/10.1080/01442872.2019.1618810

Wittmayer, J. M., van Steenbergen, F., Frantzeskaki, N., & Bach, M. (2018). Transition Management: Guiding Principles and Applications. In N. Frantzeskaki, K. Hölscher, M. Bach, & F. Avelino (Hrsg.), Co-creating Sustainable Urban Futures: A Primer on Applying Transition Management in Cities (S. 81–101). Springer International Publishing. https://doi.org/10.1007/978-3-319-69273-9_4

Activating Citizens through Innovation Communities for Inclusive Urban Transformations

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Abstract

Community-based coordination patterns are becoming increasingly relevant for fostering innovation (Ferdinand 2018). According to von Hippel (2005), in innovation communities, actors come together based on their personal interests to openly and non-proprietarily exchange and collaboratively develop innovative ideas within specific thematic areas. Innovations emerge in innovation communities through a collective and collaborative process without a formalized structure (Franke & Shah 2003; O'Mahony & Lakhani 2011). The thesis of the work behind this presentation is that such innovation communities can play a critical role in activating society and fostering inclusive transformations by embedding energy transitions in local contexts. While the concept has primarily been applied to business and organizational development, there is growing potential to transfer it to the context of sustainability transitions. By building collective commitment, trust, and resource mobilization, these communities empower diverse stakeholders to take ownership of climate action.

Leveraging networks of knowledge, infrastructure, and financial resources, they serve as catalysts for broad societal participation. A key challenge is to balance structured support with the promotion of individual responsibility and creative agency. This presentation draws on insights from the project "Strengthening and Consolidation of Innovation Communities to Implement the Recommendations of the Climate Citizens' Council of the Freiburg Region" (Innovation Campus Sustainability, ICN). The transdisciplinary project actively facilitates cooperation between civil society, research, politics and business to ensure an inclusive and participatory energy transition. It addresses critical questions such as: How can the urban energy transition engage and activate a broader segment of citizens? What is the role of innovation communities in promoting democratic participation and social sustainability? By addressing these questions, this presentation will highlight pathways towards a more inclusive and community-driven approach to urban transformation. It aims to generate transformative knowledge for bottom-up approaches and to highlight the role of transdisciplinary research in achieving more inclusive, community-led urban transformations.

Experimenting with Cities – Real-world Labs and Experiments as Tools for Urban Transformation

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Abstract

Cities are constantly changing and are central to the sustainability transformation. By 2050, two thirds of humanity will live in cities (WBGU, 2016). In cities, sustainability challenges are concentrated and overlapping in a variety of ways (ibid.) and at the same time they have great leverage to try out and promote sustainability. In real-world laboratories, cities are "made" together, i.e. sustainability is tested and researched in a joint process with relevant stakeholders. "Making a city" here refers to experimental testing in order to experience and live a sustainable world of tomorrow. Real-world laboratories and real-world experiments have (different) potentials to shape the transformation process.

As an infrastructure, Real-world labs can enable experiments and support transformation process-es in the long term. They serve to test specific sustainability contributions and provide action-oriented knowledge about transformation processes (see Caniglia 2021). In doing so, it is essential to consistently distinguish between "Real-world labs" and "experiment"in theory and practice. In common, individual experiments or series of experiments are often named as 'Real-world labs". This leads to misunderstandings, scientific errors and feeds the criticism that Real-world labs are nothing really new. However, Real-world labs can only truly develop their scientific and transformative potential when they are installed as permanent (infra-)structures.

Although the term "real-world lab" is a comparatively new term and its general meaning is still being debated, an (original) theoretical and conceptual understanding has emerged: "A real-world lab refers to a transdisciplinary research and development facility that serves to carry out sustainability experiments in a spatially defined social context, initiate transformation processes and consolidate scientific and social learning processes." (cf. Parodi et al, 2023). Based on this and considering the corresponding nine core characteristics of Real-world labs (ibid.), this article introduces a clear distinction between lab and experiment.

In scientific practice, experiments are essential for generating knowledge –either deductively to find theories or inductively to test theories. There are also different types of experiments in sustainability research (Caniglia et al. 2017). "By "real-world experiment" we mean a scientifically sound, transdisciplinary and transformative experiment that intervenes in real-world, social con-texts and does justice to the experiment-related core characteristics of real-world laboratories." (Parodi et al. 2024, p. 219). The characteristics of a common scientific experiment (e.g. controllable conditions, theoretical embedding, documentation, knowledge generation) are supplemented by others (e.g. implementation in a concrete social and cultural context, (temporary) shaping of society) in "real-world experiments".

In the discussion of lab and experiment, this contribution creates a clear conceptual distinction between Real-world labs and real-world experiments. This is of central importance for the further conceptual foundation of Real-world lab research and practice. For example, it makes it easier to answer central questions, such as how to deal with failure (real-world experiments may explicitly fail, while the failure of a Real-world lab should at least not be aimed for); it contributes to better planning and more targeted expectation management (e.g. Real-world lab structures should re-main reliable, while experiments should certainly change and their effects should be gradually reversible).

The distinction is illustrated in greater depth using examples from the urban Real-world lab "District Future – Urban Lab" in Karlsruhe's district Oststadt. The "District Future" lab was founded in 2012 and is thus a pioneer Real-world lab. As examples, various forms of experiment are presented, including sustainability experiments, self-experiments and the real-life experiment "Your balcony net", which can advance an urban transformation.

References

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., … & Lang, D. J. (2021). A pluralistic and integrated approach to action-oriented knowledge for sustainabil-ity. Nature Sustainability, 4(2), 93-100.

Kraas, F., Leggewie, C., Lemke, P., Matthies, E., Messner, D., Nakicenovic, N., … & Wanner, M. (2016). The Relocation of Humanity: The Transformative Power of Cities. WBGU-German Ad-visory Council on Global Change.

Parodi, O.; Steglich, A.; Bylund, J. (2023). Real-World Lab. In: Handbook Transdisciplinary Learning. Ed.: T. Philipp et al., 287–296.

Parodi, O., Ober, S., Lang, D. J., & Albiez, M. (2024). Real-world laboratory versus real-world exper-iment: What makes the difference? GAIA-Ecological Perspectives for Science and Society, 33(2), 216-221.

WBGU (2016). Humanity on the move: Unlocking the transformative power of cities. Flagship Re-port. See: https://www.wbgu.de/en/publications/publication/der-umzug-der-menschheit-die-transformative-kraftder-staedte (27.02.2025)

Distilling Meta-success Factors & Meta-barriers through a Mixed Method Multi-living-lab-approach

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Abstract

Living labs (LL) are increasingly recognized as powerful approaches to develop innovative real-world applicable solutions for complex problems, through the collaboration of diverse stakeholders in experimentation and learning-oriented environments. The strength of LL lies in the co-creation of social and technological innovations which are often highly contextualized to match local socio-technical configurations. However, this contextual relevance also makes the transfer of findings and applications, and the ability of living lab innovations to move beyond the niche, more difficult. To support the later, it is key to understand and facilitate learning and knowledge spread in the form of scaling out (replication of successful interventions or processes), scaling up (institutional and policy changes) and scaling deep (individual learning, changing behaviour and values). The SWICE project brings together learnings from six diverse LL situated in different socio-political settings in Switzerland. In particular, SWICE work package 8 focuses on distilling meta success factors and barriers, to foster learning and knowledge spread across the Swiss LL community and beyond. To this end, we apply a two-step approach, the first step being a systematic literature review of barriers and enablers affecting the ability of LL to achieve their micro (individual or local changes), meso (concrete outcomes, products relevant across different communities) and macro (societal impact)-level aims. To aid systematization of literature findings, we developed a synthesized framework building on the innovation systems and strategic niche management frameworks from sustainable transitions research, barrier and enabler typologies drawing on empirical LL studies, and literature on learning and knowledge spread. In a second step, we evaluate the literature findings within the context of the SWICE LL to identify context-specific barriers of the Swiss LL landscape. The poster will provide details on the SWICE project and the process of identifying meta-enablers & meta-barriers. These findings support the overall aim of the project to develop policy tools and infrastructure that support LL-based sustainability-focused societal transitions.

From Exploratory Teaching Projects to Urban Living Labs – Bottom-up Research Spaces for a New Public-Civic Collaboration

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Abstract

Exploratory teaching projects, expanded to include "engaged learning" (Chmelka et al. 2023) and "live projects" (Harriss et al. 2014), bring the academic sphere into the urban space. They work exploratively, facing open problems, multiple actors, shifting contexts, and sudden change. To this end, they use the participatory design and action research approach (cf. Telier et al. 2011, Chevalier et al. 2013). This turns them into teaching and research projects and offers the opportunity to establish interdisciplinary and transdisciplinary working methods and co-design processes. In open living labs, they create a new urban practice on the cross-cutting issues of urban development, sustainability and democracy.
Based on the preliminary work and developments of the city lab “COCO_Commonig Cottbus” in Cottbus and “in:takt – Free space for all” in Magdeburg, the framework conditions, processes, opportunities for urban society and challenges for those involved will be presented and discussed.

Keywords: Urban Living Lab, Transdisciplinarity, Co-Design, Co-Production, Third Mission, Co-Education

Topic Area: Urban Governance and Planning and Experimenting for Sustainability

Problems dealing with Complexity

Today, we are already experiencing the effects of the climate crisis, thwarted by growing skepticism about state structures and open hostility to progressive concepts. Transformation as an answer is sometimes under fire. To learn and to train how to deal with complexity is needed. This include how to educate in open, real and cross-sectoral settings and how to enable independent problem-solving skills.

"Solving the problem" is the central goal of many planning projects, as well as a key argument for decision-making and choosing a particular solution. However, as early as the 1960s, Rittel and Webber (1973) pointed out that social issues always have social and cultural components and are therefore "wicked problems" (Rittel & Webber, 1973). Such problems are impossible to solve unambiguously. They involve incomplete or contradictory knowledge, as well as complex groups of people with different opinions. This makes them intertwined with other problems. They require a transdisciplinary, iterative learning process instead (Bieling, 2020).

To do justice to this fact, design and planning must address complexity and avoid oversimplification. They must also contradict narratives that praise oversimplification or ignoring complexity as a solution. The task at hand is to understand urban processes and urbanity in their entirety and work with them openly (Dell, 2014, p. 34). Sustainability and resilience must serve as the basic approach. Design and planning must also take a stance when these necessary approaches are politically discredited.

The paper outlines an open and democratic approach to addressing this challenge. It posits that co-creation and the capacity for self-organization within the framework of openness, inclusion, and appreciation are essential for addressing the issues surrounding the design and development of our cities and communities — that is, wicked problems and complexity — in a constructive and approachable manner.

Teaching Projects

Teaching projects convey and develop practical content in university teaching. They often use examples from practice as a basis for students to develop concepts, but they separate practice from the work process under the guise of wanting to develop fundamental knowledge and understanding. The advantage of this approach is that the work can be purely disciplinary, allowing students to think freely and work in a closed, safe space. However, this turns a difficult problem into one that is easier to solve and eliminates complexity.

Exploratory Teaching Projects

Exploratory teaching projects address reality and current issues through an open approach to local action. These projects actively engage with the city and region through analysis and spatial activity. These projects are characterized by an open, collaborative development process aimed at becoming active together on site. To this end, the teaching project is expanding to include the engaged learning approach. Engaged learning involves applying what students have learned in a context outside of the university. They accomplish this by addressing societal concerns, challenges, or needs and producing knowledge in equal, mutually beneficial partnerships (Chmelka et al., 2020, p. 9). Engaged learning goes "hand in hand with a socially emancipated attachment and a personal dedication to a cause, and is oriented towards the well-being of all actors concerned." (Chmelka et al., 2023, p. 113). Exploratory teaching projects actively inquire about students' motivations and interests, approach stakeholders in the city and region, seek cooperation, and strive for realization through collaborative work and co-design methods. These projects also refer to the Live Projects approach (Harriss & Widder, 2014), which aims to leave the ivory tower of academia and contribute to real-world change. They are concrete examples of the implementation of universities' "third mission," i.e., the task of having a direct regional impact.

In exploratory teaching projects, the project work asks about students' motivation and goals and engages fully with the context, actors, and current processes. At the same time, theoretical concepts are introduced and reflected upon within a practical context. The aim is to use reality, with all its complex, unclear, confusing, and unpredictable conditions, as a basis for education. Despite these conditions, or rather because of them, the goal is to develop concepts and approaches with the intention of partially or fully realizing them. It is precisely in the realization process that areas of tension and diverse requirements, framework conditions, and possibilities for dealing with them become apparent.

The project work is designed as an open, self-organized group process. It involves a creative process that begins with discussing problems, conducting research and analysis, generating ideas and concepts, and demanding implementation. The process is accompanied by an examination of theory, reflection on the work and implementation process, and contact with and cooperation among stakeholders. The work is also confronted with rapidly changing framework conditions and questions about the organization of necessary resources. These teaching projects are exploratory, addressing open problems, multiple actors, shifting contexts, and sudden change.

This work is based on two approaches: participatory design (cf. Telier et al., 2011) and action research (cf. Chevalier et al., 2013). Participatory design gives those affected by a design a say in the design process. Action research explores action processes and generates knowledge with those affected through the interaction of action and reflection. When applied, these principles transform exploratory teaching projects into research projects. These projects offer the opportunity to work exploratively and establish interdisciplinary and transdisciplinary methods. They also allow for co-design processes and the joint production of new knowledge. In this way, they pursue a bottom-up strategy that collaborates with interested and affected stakeholders to initiate joint developments.

WANN:ANDERS

Since 2023, the Department of Urban Management at BTU Cottbus-Senftenberg has been working with the exploratory teaching projects approach. Over three semesters, we developed a total of ten implementations within this framework and gained a wide range of experience. It was exciting to observe how the realization of ideas repeatedly brought students and stakeholders together, triggering dynamic processes.
In the winter semester 2023-24, we worked with a student project team consisting of seven students on the topic of COTTBUS:lab. Based on discussions in project seminars, the team approached potential partners in the city and designed and organized four of their own meetings, actions, and networking opportunities in Cottbus. These offerings served as interfaces between the university and urban society, enriching the local urban culture and providing temporary experimental spaces for collaboration. The intensive collaboration within the team led to the idea of continuing to work independently in this direction. The students founded their own initiative: WAMM:ANDERS. Active in the months following the semester, this initiative implemented three further campaigns in collaboration with initiatives in Cottbus. The engaged learning approach was crucial for developing independent positions and initiatives here.

Fig. 1 Excerpts from the WANN:ANDERS team's project work: "Cottbus aufmöbeln 2.0" construction workshop at Rosa; discussion on the Lego model; party setting; and Seedbomb workshop (WANN:ANDERS-team, 2023-24)

Working with exploratory teaching projects yields positive results, including greater engagement with real problems, processes, and structures; selective relationship building; and networking. Participants perceive the project work as a thematic, organizational, and personal discovery and learning process. However, involvement in real processes means that considerably more time has to be spent. In some cases, topics can only be addressed briefly and emerging ideas cannot be explored further. The project results are usually only the beginning of a process. However, the current university structures and rhythms, such as the strong pre-structuring of studies through curricula, prevent continuous work. The partners involved would also like to see more continuity. A lack of supporting resources and stable structures hinders this open process work, which enables independent work, self-discovery by students, value development, and the establishment and maintenance of cooperation with potential partners.

Botton-up Urban Living Lab

Reflecting on this and other preliminary work with the exploratory teaching project approach led to the realization that this type of university teaching requires an independent supporting structure. One way to support student engagement, cooperation with society, and the mutual exchange of knowledge and local project work is to establish a self-organized laboratory space in the city or region. Currently, there are two projects initiated by the author that are following this path: “COCO_Commoning Cottbus” in Cottbus and “in:takt — Free Space for All” in Magdeburg.

COCO_Commoning Cottbus

"COCO" was launched in October 2024 based on a bachelor's project from the BTU Department of Urban Management. It utilizes a previously vacant space in the defunct shopping arcade, the "Schloßkirchpassage," in the city center of Cottbus. Previous exploratory teaching projects created the basis for the university and the city of Cottbus to temporarily support the idea of a city lab involving students through their thematic and networking work. The space was set up and put to use in the first semester. Based on their own project work and in cooperation with other initiatives and research projects, 14 public events were initiated, an Instagram channel was set up and initial collaborations were initiated. Following the end of municipal support, the university is currently funding the project for another year. At the same time, two civil society associations, losmachen e.V. and Opferperspektive e.V., moved into the "Schloßkirchpassage." Young Caritas runs a project space for children and young people in the surrounding area. The aim is to develop closer cooperation with these partners.

Fig. 2 Excerpts from COCO winter semester 2024-25: Repair Café, opening of the “Open Passage”, research workshop “Mobile in old age”, (Moritz Franke, Ralf Schuster, Melina Ehrenteit, 2024-25)

in:takt — Free Space for All

Similar to this, "in:takt" began interim use in 2018 as part of a bachelor's seminar in the Cultural Engineering program at Otto-von-Guericke-University Magdeburg. At the time, it was supported by the city administration and the local housing association. The seminar aimed to contribute to the revitalization of Magdeburg's city center and create a space organized by students for interested and active individuals. As a result, in:takt developed into an interdisciplinary seminar working transdisciplinarily with interested parties and initiatives. As part of this interim use, the project moved three times in total. A wide range of offerings and formats have been developed, including discussions, music events, and workshops, all of which are open to the public. It also promoted cohesion and interaction during the Corona period. Urban initiatives use in:takt as a meeting place. It is a non-commercial space where people can meet, develop ideas, and work on projects. Since 2022, thanks to the support of the university's student council, it has been able to permanently rent space. However, support from the city administration was discontinued at the end of 2019 due to personnel changes. Consequently, further financial support was obtained from the city through an annual resolution initiated by the city council. In 2024, 38 initiatives used in:takt, and 195 events took place there. However, the city's support ended in 2025 due to a decision by the conservative parties on the city council. The university continues to support in:takt.

Fig. 3 Excerpts from in:takt: in:takt on the Breite Weg, senior academy, silent disco, summer party with food rescuers (in:takt team, 2021-24)

Living Lab in Progress

These living labs were initiated from teaching and are still being developed. They provide low-threshold, non-commercial access for encounters and create a new type of space for engagement, local project work, and mutual knowledge exchange. Its open, networked project structure creates opportunities for transdisciplinary collaboration and co-design processes. Students meet city residents here, and specific activities and formats are developed and tested. Collaborations are developed here, and people work together spontaneously. These interactions create a training space for dealing with diversity, openness, and change, as well as a space for collaborative research on current, open issues. Through teamwork, responsibility is distributed across many shoulders, and students are the protagonists. Thanks to their strong roots in the city and open mindset, these labs address the interdisciplinary themes of urban development, city-making, sustainability, resilience, democracy, and the common good, surpassing disciplinary approaches. The projects ultimately aim to establish a culture of collaborative cooperation and co-creation, forming a basis for the co-production of the city. Designed as open infrastructure, they aim to have a broad impact on urban society.

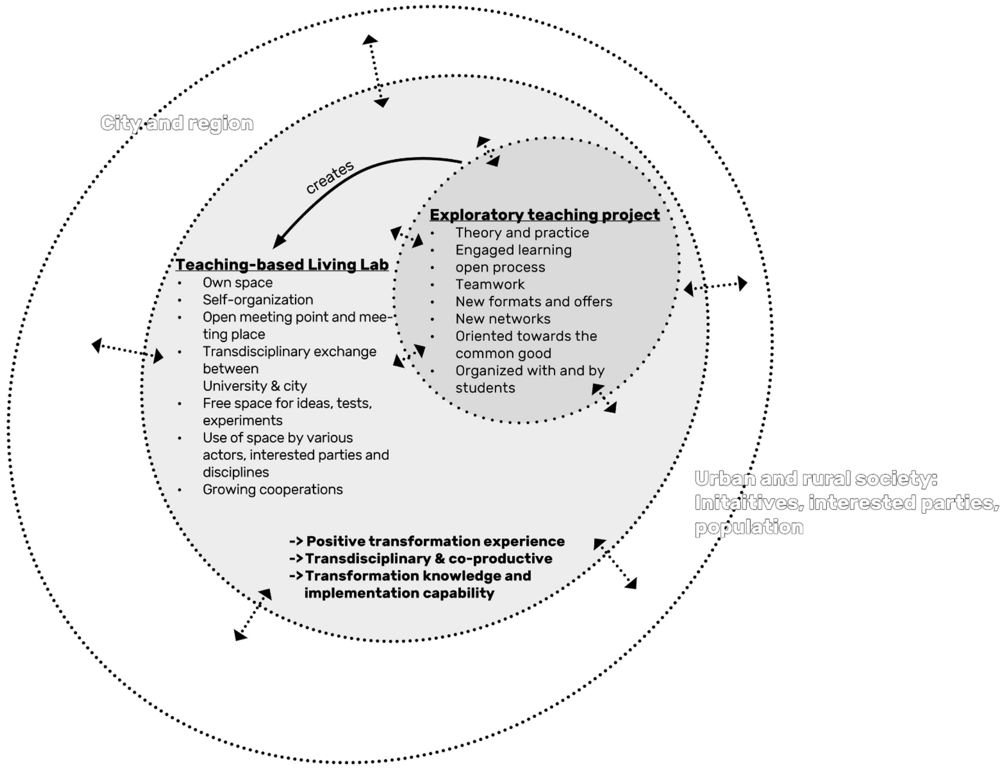

Fig. 4 Structure of the teaching-based Living Labs

To achieve this, teaching-based living labs require stable support structures and strengthened resources for organization, networking, and project work. Initially started out of the university, they have not yet received financial support from the local authority or the space owners. Currently, the diverse aspects and tasks, ranging from operation and coordination to content-related work and strategic development, can only be addressed in a rudimentary and selective manner.

Conclusion

To strengthen and further develop the approach of a bottom-up teaching and research space, stronger cooperation is necessary between the university, civil society initiatives, and the public sector. Through a strategic public-civic partnership, an innovative, open, and community-oriented infrastructure could be created. This infrastructure would serve as an urban living lab for co-education, cooperation, community, and dealing with complex social issues and development processes.

References

Bieling, Tom (2020): Wicked Problems mehr denn je?! Gedanken zu Horst Rittel. In: DESIGNABILITIES Design Research Journal, (7) 2020. https://tinyurl.com/yb54zke8. ISSN 2511-6274

Chevalier, J.M., Buckles, D.J. (2013). Participatory Action Research: Theory and Methods for Engaged Inquiry. Abingdon, Oxon ; New York, NY: Routledge.

Chmelka, A., Griffith, M., Weiner, H. (2023). Engaged Learning. In Handbook Transdisciplinary Learning, ed. Thorsten Philipp and Tobias Schmohl (Bielefeld: Transcript, 2023). DOI: 10.14361/9783839463475-013

Chmelka, Alexander; Anderson, Lindsey; Ferraresi, Eleonora; Griffith, Mary; Klima, Noel; Marsh, Courtney et al. (2020): Communities and Students Together (CaST). A state-of-the-art review of Engaged Learning in Belgium, Finland, Germany, Italy, Spain and the United Kingdom. Available online at www.cast-euproject.eu.

COCO. Initiative CommoningCottbus, accessed on 30.05.2025, https://www.instagram.com/commoningcottbus/

Dell, C. (2014). Das Urbane: Wohnen-Leben-Produzieren. Jovis.

Harriss, H., & Widder, L. (2014). Architecture Live Projects: Pedagogy into Practice (Illustrated Edition). Taylor & Francis Ltd.

Harriss, H., Widder, L. (2014). Architecture Live Projects: Pedagogy into Practice (New York: Taylor & Francis).

in:takt - Free space for all. Initiative in:takt, accessed on 30.05.2025, https://intakt-magdeburg.de/

Rittel, Horst (2013): Thinking Design – Transdiziplinäre Konzepte für Planer und Entwerfer. Herausgegeben von Wolf D. Reuter und Wolfgang Jonas, BIRD. Birkhäuser, Basel. S. 20–38.

Rittel, Horst / Webber, Melvin (1973): Dilemmas in a General Theory of Planning. In: Policy Sciences, Vol. 4, p 155–169. Elsevier, Amsterdam (Neuauflage) in: Nigel Cross (Hg.) (1984): Developments in Design Methodology. J. Wiley & Sons, Chichester. S. 135–144.

Telier, A., Binder T., Michelis, G., Ehn, P., Linde, P., Wagner, Ina. (2011). Design Things. MIT Press.

__Ressource, Building and Construction

Economic Viability of Urban Vertical Farming. Literature Review & Case Study

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Abstract

With advancing urbanization and increasing population growth, cities face the challenge of efficiently utilizing limited cultivation areas. Vertical farming presents an innovative solution for sustainable food production in urban spaces by enabling the cultivation of fruits, vegetables, and herbs on multiple levels within buildings. This allows for the provision of fresh, locally produced goods within urban areas. In doing so, integrating food production into the urban fabric supports the transformation of cities into diverse, mixed-use environments.

Building on this potential, this study examines the economic feasibility of vertical farming in an urban context. economic factors were analyzed to comprehensively assess the profitability of vertical farming. The analysis reveals that vertical farming holds significant potential. However, further research is required to reduce costs and make these products more competitive with conventional agriculture. Additionally, further studies are needed to ensure the long-term profitability and scalability of vertical farming.

Keywords: Vertical farming, Sustainable urban development, Economic Viability

1. Introduction

The increasing population and climate change pose significant challenges to food and nutrition security, as well as to conventional agriculture (Malhi et al., 2021). Due to rising temperatures and the more frequent occurrence of extreme weather events, it is essential for agriculture to adapt to prevailing conditions (Malhi et al., 2021). New technologies and sustainable cultivation methods can help address these challenges (Moghimi & Asiabanpour, 2021). One such method is vertical farming (Moghimi & Asiabanpour, 2021). In this approach, vegetables, herbs, and fruits are cultivated under greenhouse conditions within a multi-layered system (Dachler, 2023; Mir et al., 2022). Vertical farming offers an opportunity for food production in urban areas that face limited availability of land for conventional agriculture (Kalantari et al., 2018). When addressing urban areas, the existing building stock becomes particularly relevant, as most cities are already built. New land is only available to a limited extent. Moreover, many buildings stand vacant and could be repurposed for vertical farming (Arup, 2023). Transforming existing buildings - such as former department stores - can help preserve sociocultural heritage while promoting a diverse mix of uses in inner-city areas.

Although vertical farming presents many advantages, there are also several disadvantages (Moghimi & Asiabanpour, 2021). Due to the high energy and labor requirements, high operating costs can generally be expected (Moghimi & Asiabanpour, 2021). In addition, vertical farming enterprises are still relatively small compared to other types of agriculture and therefore achieve lower economies of scale due to organizational and infrastructural conditions (Arentz & Münstermann, 2013; Moghimi & Asiabanpour, 2021; Naradda Gamage et al., 2020).

Only a few studies have examined the economic viability of vertical farming (Moghimi & Asiabanpour, 2021). Some case studies address the profitability of vertical farming under specific conditions (Souza et al., 2019; Trimbo, 2019; Xavier et al., 2018). However, the results can only be applied to the specific case study and cannot be generalized to the competitive market environment in which vertical farming must compete with conventional agriculture (Moghimi & Asiabanpour, 2021).

Based on this, the following research questions were formulated:

Which factors influence the economic viability assessment of vertical farming?

How can the economic viability assessment of vertical farming be formulated?

2. Methods

A literature review can generally be regarded as a systematic approach to collecting and summarizing previous research findings (Snyder, 2019). A combination of forward and backward literature searches provides the opportunity to include both foundational works and recent research in the review. To identify relevant literature for this research, Google Scholar, KVK – Karlsruhe Virtual Catalog, Researchrabbit, and Elicit were used. Selected keywords for the search included: vertical farming, economic feasibility of vertical farming, urban agriculture economic impact, controlled environment agriculture economics, and renewable energy and vertical farming.

In addition, the economic viability for a case study was determined using the net present value (NPV) method. Within the framework of the NPV method, all future revenues and expenditures are discounted to their present value (Bränzel et al., 2019). Since the initial investment constitutes an expenditure, it is assigned a negative value. This negative value must be offset in subsequent years by generated returns, which are derived from the positive difference between annual revenues and expenditures (Bränzel et al., 2019). Each individual annual return is discounted to the time of the initial investment (Bränzel et al., 2019). The value resulting from discounting decreases the further in the future the inflow or outflow occurs (Bränzel et al., 2019). Step by step, the positively valued annual returns are added to the negatively valued investment (Bränzel et al., 2019). After a predetermined period, the so-called net present value is obtained (Bränzel et al., 2019). If the net present value is positive, the investment is considered advantageous (Carstensen, 2008).

3. Economic Viability of Vertical Farming

In the following, various factors that play a significant role in assessing the economic viability of vertical farming are elaborated. This includes an examination of which economic viability factors are referenced by other authors in the literature and the implications these have for the evaluation of vertical farming.

3.1 Economic Viability Factors

Table 1 provides an overview of the key factors that various authors have examined in the context of the economic viability of vertical farming:

	Banerjee & Adenaeuer (2014)	Moghimi & Asiabanpour (2021)	Gumisiriza et al. (2022)	Van Delden et al. (2021)
Cost				
Acquisition costs	x		x	x
Operating costs	x	x	x	x
Life cycle costs				
Income				
Sales revenue			x	
Subsidies/Funding		x	x	x
Efficiency				
Cost-Benefit Ratio	x			
Margin		x		
Return on Investment			x	
Market Factors				
Supply and Demand				x
Competition	x	x	x	x
Pricing		x	x	
Technological Factors				
Degree of Innovation	x	x		x
Scalability	x	x	x	x
External Factors				
Economic Framework Conditions				
Regulatory Framework		x		
Environmental Influences	x	x	x	x
Strategic Factors				
Choice of Location	x	x		
Risk Management	x	x	x	

It becomes evident that all authors engage extensively with cost and technological factors related to vertical farming. However, the consideration of life cycle costs, particularly with regard to maintenance and repairs, is not addressed in any of the studies reviewed. Climate and environmental factors, which are important for the further development of vertical farming, are discussed by all authors. Nevertheless, potential revenues from the sale of produced goods are largely overlooked.

Similarly, the efficiency of vertical farming - measured in terms of cost-benefit ratio, margin, and return on investment - receives little attention in the studies considered. Product pricing as well as external factors such as economic and regulatory conditions are analyzed by very few authors. This lack of consideration indicates a research gap.

2.1 Methods for Assessing Economic Viability

The principle of economic efficiency aims to establish the most advantageous relationship possible between the desired objectives and the resources required to achieve them. It encompasses both the principle of economy and the principle of productivity (Bundesverwaltungsamt, n.d.). Proper economic efficiency assessments are essential tools that enable decision-makers to make economically sound decisions. Various methods can be applied to evaluate economic efficiency. Depending on the scope of the measure's effects, these methods can be divided into two categories:

Individual Economic Methods: These methods are suitable for measures whose effects on the overall economy are minor and therefore negligible.

Macroeconomic Methods: These methods are used for measures that have significant and non-negligible effects on the overall economy.

Furthermore, these methods differ in terms of how the effects of the measures are evaluated. Monetary methods quantify the effects in monetary units, while non-monetary methods compare the effects using evaluation points (Bundesverwaltungsamt, n.d., pp.).

Cost-Benefit Analysis (Robinson, 1993)

All considerations within the framework of cost-benefit and cost-effectiveness analyses are based on the opportunity principle. This principle defines opportunity costs as the benefits forgone by allocating a resource to an alternative use. Cost-benefit analysis is based on quantifying both costs and benefits in monetary terms. In contrast, cost-effectiveness analysis considers only the cost side in monetary units.

Industry Structure Analysis (Porter, 1997)

According to Porter's framework, the structure of an industry is determined by five central forces: competitors within the industry, bargaining power of suppliers, bargaining power of customers, potential new entrants, and the threat of substitute products. Each of these five forces is associated with specific indicators that influence the intensity of competition within the industry (Kaufmann, 2021).

PESTEL Analysis (Yüksel, 2012)

This analysis is a form of analysis that identifies opportunities and risks arising from the broader context in which an organization operates. It can also serve as a preparatory step for scenario analysis. The acronym PESTEL is derived from the initial letters of the following six factors: Political, Economic, Social, Technological, Ecological, and Legal.

Sensitivity and Scenario Analysis (Tian, 2013)

Sensitivity Analysis: If the outcome of an economic viability assessment is significantly influenced by uncertain assumptions, sensitivity analysis illustrates when, how, and under what circumstances the result changes under given assumptions.

Scenario Analysis: To better represent the relationships among assumptions in economically relevant measures, scenario analysis considers various scenarios. In particular, "best-case scenarios" and "worst-case scenarios" are highlighted.

SWOT (Namugenyi et al., 2019)

The term SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats. To capture the current situation of a company or enterprise, the most important findings are clearly summarized in a four-field matrix.

2.2 Case Study

As part of a study commissioned by the German Aerospace Center (DLR), a vertical farming system with 37 stories was designed and simulated in Berlin (Banerjee & Adenaeuer, 2014). Of these stories, five are located underground, with three designated for aquaculture and two for waste management (Banerjee & Adenaeuer, 2014). Of the 32 above-ground stories, 25 are intended for agricultural production and two for food processing; additional facilities are also included (Banerjee & Adenaeuer, 2014). Figure 1 illustrates how many stories are used for the cultivation of each type of product. With this system, it is possible to produce 3,573 tons of fruits and vegetables as well as 137 tons of tilapia fillets annually at a cost of approximately €3.50–4.00 per kilogram (Banerjee & Adenaeuer, 2014). As a by-product, 2,443 tons of organic waste are generated, from which about three million liters of biogas and recycled nutrients can be obtained for use as fertilizer (Banerjee & Adenaeuer, 2014). The original average cost of €3.75 per kilogram was adjusted for inflation to the 2023 price level, resulting in inflation-adjusted costs of €4.44 per kilogram. Table 2 lists the fixed costs for the vertical farm, Table 3 presents the variable costs.

Figure 1: Simulated Case Study in Berlin (Banerjee & Adenaeuer, 2014)

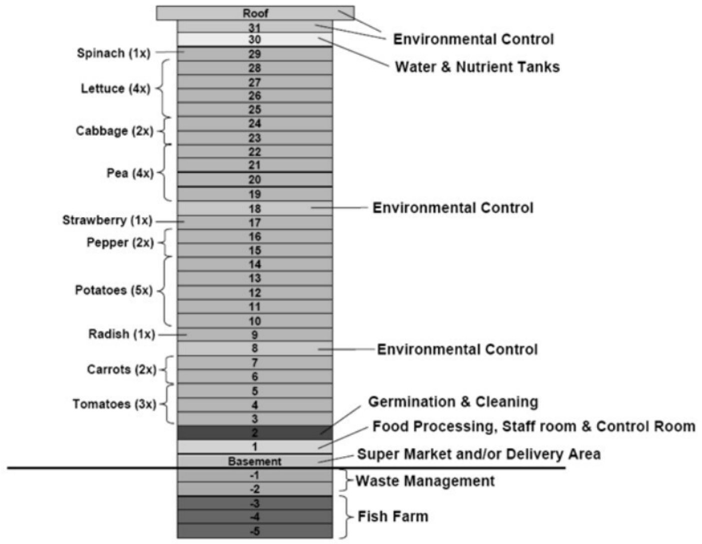

Table 2: Fixed Costs

Fixed Costs	Cost (€)
Building (including Location)	131 991 905[1]
Furnishings	106 914 3621[1]
Total Costs	238 906 267

Table 3: Variable Costs

Variable Costs	Cost (€/a)
Personnel	2 424 974[1]
Energy Requirements	6 377 020[1]
Plant Seeds	52 528[1]
Water (recycled)	0
Nutrients	502 643[1]
Fish Food	150 254[1]
Total Costs	9 507 419

The assessment of economic viability is conducted using the net present value (NPV) method to evaluate the profitability of the system over a specific period. For this purpose, the fixed costs from Table 2 were treated as outflows at time zero, and the production costs of €4.44 per kilogram were used as annual outflows. The German Federal Ministry of Finance (Bundesfinanzministerium, 2022) specifies a discount rate of 0.9%. The calculation using the NPV method, based on a gross profit margin of 38% of the economic turnover, leads to the conclusion—illustrated in Figure 2—that vertical farming is currently not economically viable within a reasonable timeframe, as profitability would only be reached after 47 years. A gross profit margin of 38% would result in a price of €6.13 per kilogram. Figure 3 shows that a gross profit margin of 80% on costs would be required to make this agricultural method profitable within an economically acceptable period, meaning that vertical farming would become profitable after 20 years. However, this gross profit margin would necessitate a price of €7.99 per kilogram. Due to limited data availability, the calculation only takes into account the cost factors listed in Table 1, including the investment costs (fixed costs in Table 2) and the operating costs (variable costs in Table 3).

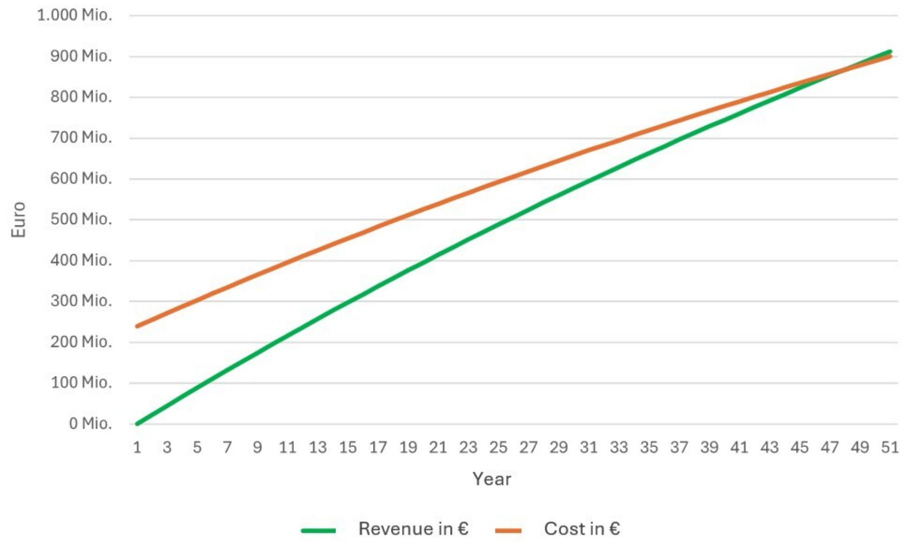

Figure 2: Net Present Value Method with a Gross Profit Margin of 38%

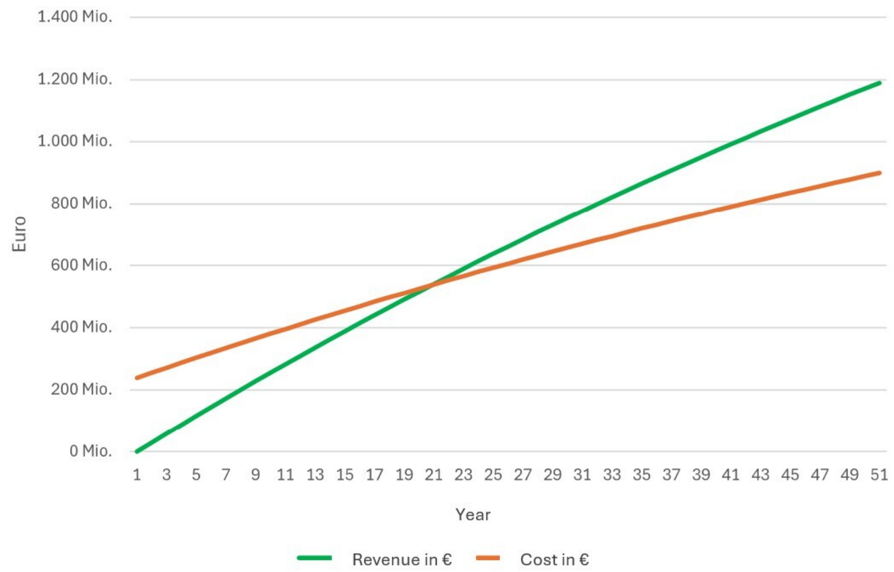

Figure 3: Net Present Value Method with a Gross Profit Margin of 80%

4. Findings and Discussions

In this study, factors that significantly influence the economic viability of a vertical farm were identified. However, the current state of research primarily focuses on technological factors and energy costs associated with vertical farming. In the case of the economic viability assessment based on the study conducted by DLR Bremen, only costs were considered, as no data were available for additional economic factors. The result of the net present value method demonstrates that, when considering costs in isolation, this vertical farm would not be economically viable within a reasonable timeframe without a substantial gross profit margin of 80%. However, the inclusion of additional factors such as efficiency, revenues, and market conditions could lead to a more favorable assessment.

For a more comprehensive economic analysis, it is necessary to also include market factors such as demand, competitiveness, and pricing, as these can significantly influence economic viability. Furthermore, other influencing factors should not be neglected, since both revenues and strategic factors have a considerable impact on the economic performance of vertical farming. The choice of location is particularly significant due to the initial investment costs, which are highly dependent on the city, as well as the availability and cost of energy required for operating vertical farming systems.

5. Further Research

Future research should focus on reducing operating costs of vertical farming in order to enhance economic efficiency. Studies on the implementation of innovative technologies for energy savings, resource efficiency, and cost reduction are of central importance. Additionally, future research should address the overall economic sustainability of vertical farming, considering social, and long-term economic impacts to ensure a holistic evaluation of its viability.

References

Arentz, O., & Münstermann, L. (2013). Mittelunternehmen statt KMU? Ein Diskussionsbeitrag zum Mittelsstandsbegriff. Otto-Wolff-Institut Discussion Paper,1.

Arup. (2023). Repurposing buildings for farming. Retrieved July 16, 2025, from https://www.arup.com/globalassets/downloads/insights/repurposing-buildings-for-farming.pdf

Banerjee, C., & Adenaeuer, L. (2014). Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies, 2(1), 40-60.

Bränzel, J., Engelmann, D., Geilhausen, M., & Schulze, O. (2019). Energiemanagement: Praxisbuch für Fachkräfte, Berater und Manager. Springer Fachmedien Wiesbaden.

Bundesfinanzministerium. (2022). Personalkosten, Sachkosten und Kalkulationszinssätze in der Bundesverwaltung für Kostenberechnungen und Wirtschaftlichkeitsuntersuchungen 2022. Retrieved July 07, 2024, from https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Oeffentliche_Finanzen/Bundeshaushalt/personalkostensaetze.html

Bundesverwaltungsamt. (n.d.). Arbeitsanleitung Einführung in Wirtschaftlichkeitsuntersuchungen (Anhang zur Verwaltungsvorschrift (VV) zu § 7 der BHO). Retrieved June 12, 2024, from https://www.bva.bund.de/DE/Services/Behoerden/Beratung/Beratungszentrum/_documents/tb_wirtschaftlichkeit-pruefen.html

Carstensen, P. (2008). Investitionsrechnung kompakt: Eine anwendungsorientierte Einführung. Gabler.

Dachler, M. (2023). Produktionsmethoden. In Welternährung: Status quo und Ausblick zur globalen Ernährungslage. Springer Berlin Heidelberg.

Gumisiriza, M. S., Ndakidemi, P., Nalunga, A., & Mbega, E. R. (2022). Building sustainable societies through vertical soilless farming: A cost-effectiveness analysis on a small-scale non-greenhouse hydroponic system. Sustainable Cities and Society, 83, 103923.

Kalantari, F., Tahir, O. M., Joni, R. A., & Fatemi, E. (2018). Opportunities and Challenges in Sustainability of Vertical Farming: A Review. Journal of Landscape Ecology, 11(1), 35–60.

Kaufmann, T. (2021). Strategiewerkzeuge aus der Praxis: Analyse und Beurteilung der strategischen Ausgangslage. Springer Berlin Heidelberg.

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. Sustainability, 13(3), 1318.

Mir, M. S., Naikoo, N. B., Kanth, R. H., Bahar, F., Bhat, M. A., Nazir, A., Mahdi, S. S., Amin, Z., Singh, L., Raja, W., Saad, A., Bhat, T. A., Palmo, T., & Ahngar, T. A. (2022). Vertical farming: The future of agriculture: A review. The Pharma Innovation Journal, 11(2), 1175–1195

Moghimi, F., & Asiabanpour, B. (2021). Economics of Vertical Farming: Quantitative Decision Model and a Case Study for Different Markets in the USA.

Namugenyi, C., Nimmagadda, S. L., & Reiners, T. (2019). Design of a SWOT Analysis Model and its Evaluation in Diverse Digital Business Ecosystem Contexts. Procedia Computer Science, 159, 1145–1154.

Naradda Gamage, S. K., Ekanayake, E., Abeyrathne, G., Prasanna, R., Jayasundara, J., & Rajapakshe, P. (2020). A Review of Global Challenges and Survival Strategies of Small and Medium Enterprises (SMEs). Economies, 8(4), 79.

Porter, M. E. (1997). Competitive Strategy. Measuring Business Excellence, 2(1), 12–17.

Robinson, R. (1993). Cost-benefit analysis. British Medical Journal, 307(6909), 924–926.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339.

Tian, W. (2013). A review of sensitivity analysis methods in building energy analysis. Renewable and Sustainable Energy Reviews, 20, 411–419.

Van Delden, S. H., SharathKumar, M., Butturini, M., Graamans, L. J. A., Heuvelink, E., Kacira, M., Kaiser, E., Klamer, R. S., Klerkx, L., Kootstra, G., Loeber, A., Schouten, R. E., Stanghellini, C., Van Ieperen, W., Verdonk, J. C., Vialet-Chabrand, S., Woltering, E. J., Van De Zedde, R., Zhang, Y., & Marcelis, L. F. M. (2021). Current status and future challenges in implementing and upscaling vertical farming systems. Nature Food, 2(12), 944–956.

Yüksel, I. (2012). Developing a Multi-Criteria Decision Making Model for PESTEL Analysis. International Journal of Business and Management, 7(24), 52.

A Living Lab Experiment in a Mass Housing Estate in Tbilisi

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Abstract

This article presents the results of a one-year Living Lab study conducted in the Vaja-Pshavela district of Tbilisi, a mass housing area developed during the 1960s–1970s. The article details the collaborative process between researchers, students, and residents, highlighting the outcomes of a joint student workshop and a pilot project employing tactical urbanism methods to revitalize the neighborhood. The initiative aimed to propose feasible interventions that align with modern urban demands while respecting the social significance of these housing complexes. Through participatory urban design and bottom-up approaches, the project demonstrates the importance of community involvement in shaping sustainable urban transformations. The findings emphasize the potential of grassroots initiatives in fostering adaptive reuse strategies for mass housing estates, ensuring their continued relevance in the contemporary urban landscape. This case study from Tbilisi contributes to broader discussions on preserving and revitalizing post-socialist urban heritage while addressing the evolving socio-environmental needs of residents.

Introduction. Project Background, Objectives and Expected results

The Living Lab project in Tbilisi was implemented within the framework of an international collaboration organized as part of a trilateral initiative involving the Karlsruhe Institute of Technology, Ilia State University in Tbilisi, and the Odessa State Academy of Civil Engineering and Architecture, supported by the Volkswagen Foundation. Since 2016, the international project "Unloved Heritage: Socialist City?" has focused on mass housing districts built during the 1960s and 1970s in the former Soviet republics, exploring their potential for sustainable adaptation to contemporary living standards and emerging challenges, including climate change.

The Living Lab format represents a research method that tests new approaches in real-life settings through active user involvement (Hossain, Leminen, & Westerlund, 2019). In our case, the approach was applied to test proposals aimed at improving the quality of the urban environment in post-Soviet residential microdistricts through an experimental dialogue between researchers, residents, local professionals, the municipality, and district administration. The Lab serves as a platform for knowledge exchange and co-creation of solutions to improve residents' quality of life through the reorganization and enhancement of open public spaces.

On May 25, 2024, the Living Lab "The Green Superblock" was launched in the Vaja-Pshavela microdistrict, Block VI, in Tbilisi (Fig. 1). A temporary office was established in one of the area's garages, enabling continuous on-site interaction with local residents. Block VI is characterized by a significant amount of green space — including mature trees, shrubs, sports fields, green balconies, and community gardens. These spaces serve as a vital resource that enhances the quality of life for local residents. However, the district faces serious challenges: the lack of clear land-use regulations leads to conflicts among neighbors, the neglect of public areas, uncoordinated construction, and insufficient maintenance of green spaces. In many locations, green plots have been paved over or occupied by garages and parked cars. In the context of climate change, however, green infrastructure and permeable surfaces have become critically important for sustainable urban development and play a key role in climate adaptation. Green spaces help reduce temperatures, improve air quality, and manage stormwater, offering both ecological and social benefits (Sturiale & Scuderi, 2019).

Objectives

The main objectives of the Living Lab in Tbilisi are:

- to explore the typologies and transformations of open spaces within residential microdistricts, with a particular focus on Block VI;
- to co-create sustainable design solutions together with residents, local stakeholders, and municipal representatives;
- to test the Living Lab methodology as an instrument for participatory urban development in a post-Soviet context.

Expected Results

The expected results of the project include the development of strategies for more effective use and protection of green spaces, the creation of pilot interventions in Block VI, and practical recommendations for municipalities and local communities. Moreover, the project aims to foster long-term collaboration between researchers, residents, and local authorities, while generating transferable knowledge that can be applied to other post-Soviet housing districts.

Fig. 1. Living Lab "The Green Superblock" in the Vaja-Pshavela microdistrict, Block VI, in Tbilisi, 2024. Photo and scheme by author.

Project Structure

The Green Superblock Living Lab in Tbilisi was designed as an applied research project integrating international scholarly debates on Living Labs with context-specific experimentation in a post-socialist urban environment. In the academic literature, various operational frameworks for urban Living Labs have been proposed; among them, the Four-Phase Model (Aquilué, Caicedo, Moreno, Estrada, & Pagès, 2021) provided the main conceptual structure for our activities. This framework encompasses initiation, co-design, prototyping, and evaluation phases, each of which was systematically adapted to the conditions of the Vaja-Pshavela Block VI microdistrict.

During the initiation phase, participatory assessment methods (Moser & Stein, 2011; Geekiyanage et al., 2021) were employed to analyze existing conditions and challenges of green and public spaces. These included walking tours, community mapping, and roundtable discussions, enabling the research team to capture spatial perceptions and everyday experiences of residents, as well as to identify local priorities. The co-design phase introduced collaborative tools for developing proposals and future scenarios. Workshops with residents, children, municipal actors, and students facilitated creative exchanges, producing a range of conceptual and analytical inputs. Public exhibitions and academic presentations served both as dissemination platforms and as mechanisms for stakeholder feedback. The prototyping phase translated selected design ideas into temporary interventions, using the principles of tactical urbanism (Lydon & Garcia, 2015). Pilot projects were co-constructed together with students and residents, often employing low-cost and movable materials such as wooden pallets. This allowed flexible testing of alternative spatial arrangements and provided opportunities for real-time adjustments based on resident feedback. The evaluation and reflection phase combined participatory assessment techniques with empirical measurements. In particular, the Wellbeing Map method (Kyttä, Broberg, Haybatollahi & Schmidt-Thomé, 2016) was implemented to gather residents' subjective perceptions of comfort, safety, and desired changes in the neighborhood. Mapping workshops and surveys generated valuable data linking spatial conditions with wellbeing outcomes.

Overall, the methodological design of the Green Superblock Living Lab combined established Living Lab frameworks with participatory planning tools, tactical urbanism interventions, and experience-based mapping techniques. This multi-layered approach ensured both theoretical alignment with current research on urban Living Labs and practical responsiveness to the local context of post-socialist housing estates.

Results

The Green Superblock Living Lab in Tbilisi generated a range of practical and analytical results across its four phases of implementation.

Community Priorities and Problem Identification

Participatory assessments revealed several pressing concerns in Block VI, including the dominance of cars in public spaces, insufficient regulation of land use, and the degradation of green areas. At the same time, residents emphasized the importance of existing greenery, shaded courtyards, and community gardens as critical assets for neighborhood wellbeing.

Collaborative Design Proposals

Through workshops, roundtables, and exhibitions, residents, students, and professionals co-developed design scenarios that reimagined everyday spaces. Key proposals included the transformation of informal parking zones into green corridors, the creation of permeable surfaces, and the enhancement of accessibility. Public exhibitions both validated these ideas and fostered a sense of collective ownership over future changes (Fig. 2).

Fig. 2. Roundtable Discussion, 2024.
Photo by author.

Pilot Interventions and Prototyping

The international student workshop in autumn 2024 resulted in the co-construction of temporary installations on a neglected open space near Building #2. Using low-cost, movable materials, the intervention reorganized parking areas, introduced greenery, and added communal furniture. These objects were designed to be easily movable, allowing for flexible spatial arrangements and the exploration of various usage scenarios for the site (Fig. 3). As a result of this testing process, a preferred configuration was selected: an organized spatial layout aimed at mitigating uncontrolled car use and enhancing greenery (Fig. 4). Although initially conceived as temporary, the site remains well-preserved months later, with residents voluntarily restricting car access and maintaining vegetation and street furniture.

Fig. 3. Different test scenarios proposed by students for the pilot project site, 2024.
Photo by author.

Fig. 4. Workshop site near Building #2, Vazha-Pshavela Block VI, before (Sept 27) and after (Oct 6), 2024.
Photo by author.

Wellbeing Mapping Outcomes

The application of the Wellbeing Map method collected more than 100 resident contributions, identifying green, red, and yellow zones within the neighborhood. After the pilot intervention, areas previously perceived as unsafe or uncomfortable shifted from “red” to “green,” indicating a tangible improvement in residents’ spatial experiences. Other zones not directly addressed remained unchanged, highlighting the specific impact of localized interventions (Fig. 5).

Fig. 5. Wellbeing Map before and after the pilot project, 2024.
Photo by author.

Community Engagement and Ownership

The Living Lab fostered new forms of local engagement: volunteer groups emerged to care for shared spaces, while residents articulated priorities more clearly and engaged in constructive dialogue with municipal representatives. These outcomes suggest an increased sense of ownership and trust, essential for long-term sustainability. Taken together, these results demonstrate the capacity of participatory and experimental approaches to generate concrete improvements in post-socialist housing estates, both in terms of physical environment and social cohesion.

Discussion

The experience of the Green Superblock Living Lab highlights both the opportunities and challenges of applying Living Lab methodologies in a post-socialist urban context.

Value of Participatory and Experimental Approaches

The project demonstrated that even small-scale, low-cost interventions can significantly influence residents’ perceptions of their environment. Temporary installations, co-designed with community members, effectively shifted attitudes toward public spaces, transforming “red zones” into areas perceived as safe and comfortable. This confirms scholarly arguments that tactical urbanism and bottom-up design approaches (Patti & Polyak, 2017) can catalyze broader urban transformation by creating immediate, tangible improvements.

Institutional Barriers and Cultural Legacies

At the same time, the project revealed systemic barriers to sustainable implementation. Weak institutional support, fragmented responsibilities, and a cultural legacy of passive public ownership limit the capacity of grassroots initiatives to achieve long-term change. The lack of consistent municipal engagement in particular underscores the dependency of Living Labs on external academic or donor frameworks. This raises questions about continuity once funding cycles or research projects conclude.

Balancing Divergent Interests

The co-creation process brought to light the complexity of balancing diverse stakeholder interests. Conflicts emerged around parking, green space allocation, and the use of semi-public areas, illustrating the contested nature of everyday urban life. These negotiations are not merely technical but also social and political, requiring tools for mediation and compromise.

Contribution to Scholarship and Practice

From an academic perspective, the project contributes to ongoing debates on the adaptability of Living Lab models outside Western European contexts. It shows that while theoretical frameworks such as the Four-Phase Model provide useful guidance, they must be flexibly adjusted to local realities. Practically, the project offers a replicable model for universities, municipalities, and civil society actors seeking to address the challenges of modernist housing estates through participatory experimentation. In sum, the Green Superblock Living Lab underscores the dual potential of Living Labs: as vehicles for incremental, community-driven improvements and as experimental platforms that can inform urban policy. Yet their success depends on embedding such initiatives within supportive institutional structures and ensuring long-term ownership by residents and local authorities.

Outlook

The Green Superblock Living Lab in Tbilisi demonstrated the transformative potential of participatory and experimental approaches in addressing the challenges of post-socialist housing estates. However, the long-term impact of such initiatives requires careful attention to sustainability and institutional integration.

Scaling and Replication

The methods tested in Block VI — including participatory assessments, co-design workshops, tactical urbanism interventions, and wellbeing mapping — provide a transferable toolkit that can be applied in other neighborhoods of Tbilisi and beyond. These approaches are particularly relevant for large-scale modernist housing estates across the post-socialist region, where similar challenges of car dominance, unregulated land use, and neglected green spaces persist.

Institutional Integration and Policy Transfer

To move from temporary experiments to durable transformations, stronger collaboration with municipal authorities and integration into urban policy frameworks is essential. The insights gained from the Living Lab can inform local planning strategies, especially in the fields of green infrastructure, mobility, and participatory governance. Ensuring that residents remain active co-owners of such processes is key to their resilience.

Academic and Educational Perspectives

The project also highlighted the role of Living Labs as educational platforms. For students, it offered a rare opportunity to bridge theory and practice; for researchers, it provided an empirical testing ground to refine models of participatory urbanism. Future research could further explore the intersection of spatial design, community engagement, and climate adaptation in post-socialist contexts.

Future Directions

Looking ahead, the continuation of the Green Superblock initiative will depend on maintaining resident involvement and building institutional partnerships capable of supporting long-term implementation. By combining grassroots engagement with policy alignment, Living Labs can evolve from temporary experiments into sustainable frameworks for urban regeneration. In this sense, the Tbilisi case not only offers local improvements but also contributes to a broader discourse on adaptive, inclusive, and resilient urban development in rapidly changing socio-political environments.

References

Hossain, M., Leminen, S., & Westerlund, M. (2019). A systematic review of living lab literature. Journal of Cleaner Production, 213, 976–988. https://doi.org/10.1016/j.jclepro.2018.12.257

Sturiale, L., & Scuderi, A. (2019). The role of green infrastructures in urban planning for climate change adaptation. Climate, 7(10), 119. https://doi.org/10.3390/cli7100119

Aquilué, I., Caicedo, A., Moreno, J., Estrada, M., & Pagès, L. (2021). A methodology for assessing the impact of living labs on urban design: The case of the FURNISH project. Sustainability, 13(8), 4562. https://doi.org/10.3390/su13084562

Moser, C., & Stein, A. (2011). Implementing urban participatory climate change adaptation appraisals: a methodological guideline. Environment and Urbanization, 23(2), 463-485. https://doi.org/10.1177/0956247811418739

Geekiyanage, D., Fernando, T., & Keraminiyage, K. (2021). Mapping participatory methods in the urban development process: A systematic review and case-based evidence analysis. Sustainability, 13(16), 8992. https://doi.org/10.3390/su13168992

Lydon, M., & Garcia, A. (2015). A tactical urbanism how-to. In Tactical urbanism: Short-term action for long-term change (pp. 171-208). Washington, DC: Island Press/Center for Resource Economics. https://islandpress.org/books/tactical-urbanism

Kyttä, M., Broberg, A., Haybatollahi, M., & Schmidt-Thomé, K. (2016). Urban happiness: Context-sensitive study of the social sustainability of urban settings. Environment and Planning B: Planning and Design, 43(1), 34–57. https://doi.org/10.1177/0265813514565558

Patti, D., & Polyak, L. (2017). From practice to policy: Frameworks for bottom-up urban regeneration. Urban Research & Practice, 10(1), 79–93. https://doi.org/10.1080/17535069.2017.1295093

Reconstructing Durres: Governance, Sustainability, and Livability in Post-Earthquake Urban Transformation

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Abstract

The city of Durres, Albania, a historic waterfront city, suffered significant devastation following the 2019 earthquake, exposing critical vulnerabilities in its urban infrastructure and governance systems. As the city embarks on a reconstruction journey, the recently published masterplan for the marina presents a pivotal opportunity to reimagine Durres as a sustainable, livable, and resilient urban center. However, the process is hindered by governance inefficiencies, limited transparency, and a lack of inclusive participation. This research examines the new marina masterplan through the lens of urban transformation, assessing its alignment with principles of sustainability, climate resilience, and social equity. Using Durres as a case study, this paper explores the tensions between rapid post-disaster reconstruction and long-term urban sustainability. It critically evaluates the governance mechanisms shaping the masterplan, highlights institutional weaknesses, and identifies the absence of participatory processes. The study proposes innovative solutions to enhance livability and resilience by drawing on best practices from cities such as L'Aquila (Italy) and Christchurch (New Zealand). These include the integration of green infrastructure, community-driven initiatives, and digital tools into urban redevelopment strategies. The research contributes to the broader discourse on urban transformation by emphasizing the role of governance in shaping sustainable and livable cities, particularly in contexts of institutional fragility. It also advocates for the establishment of a "sustainability lab" in Durres, —an experimental platform where urban design and governance approaches can be tested in collaboration with local communities, academics, and policymakers. By bridging the gap between theory and practice, this study aims to provide actionable insights for cities undergoing similar transformations, while positioning Durres as a compelling example of the challenges and opportunities in post-disaster urban redevelopment. Additionally, the research assesses how blue-green infrastructure, sustainable urban design, and climate adaptation strategies can transform Durres into a model for resilient waterfront cities. By analyzing international best practices and real-world urban experimentation, this paper provides a framework for leveraging urban digitalization, sustainability labs, and citizen-led initiatives to foster an adaptive and socially just reconstruction process. Ultimately, this study contributes to ongoing discussions on urban governance, mobility, water-sensitive urban design, and climate resilience, offering valuable insights for policymakers, urban planners, and scholars striving to bridge the gap between research and real-world implementation in post-disaster urban development.

Keywords: urban transformation, governance, sustainability, livability, post-disaster reconstruction, Durres

Experimenting for Change: Potential of Employees of Municipal Energy Companies as Local Change Agents in Urban Sustainability Transformations

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Abstract

Exceeding planetary boundaries poses a threat to humanity and demands sustainability transformation, particularly within urban contexts. Municipal energy suppliers are important stakeholders in this and have great potential to contribute to the decarbonization of cities. In order to foster their transformative potential of the employees and therefore also as local change agents, we conducted a series of workshops within a municipal energy company (MEC) in a German city with about 35,000 inhabitants. The workshops, based on the climate action education format #climatechallenge, created spaces for reflection and action: Through two transformation experiments, the employees have not only addressed climate protection in the private sphere but also developed and collectively promoted climate protection measures in their workplace, with impacts that extend into the city. The data presented in this article highlight the potential of such transformative workshop formats and position MEC's employees as local change agents in urban sustainability transformations.

Introduction

The ongoing climate crisis (IPCC, 2023; Coperincus, 2025) and the exceedance of planetary boundaries (Steffen et al., 2015) demand a profound socio-technical transformation towards sustainability – in Germany often referred to as the 'Great Transformation' by the WBGU (2011). Urban contexts are a key arena in this transformation (Kraas et al., 2016). Municipal energy companies (MECs) are important stakeholders when it comes to the decarbonization of cities (Röttger, 2022;), when they implement heating networks in districts, utilizing local energy sources, or produce regional renewable energy in photovoltaic parks, etc. National climate protection (UBA, 2025) and local climate neutrality targets (Ruiz-Campillo, 2021) put these MECs under pressure, because they quickly need to identify, plan, fund, implement and maintain climate measures in their communal sphere. This also comes with the need for change management and a transformation of work culture – to activate professional teams in MECs. Therefore, this article addresses the question, how transformative workshop formats can help to empower employees so they can contribute as change agents (WBGU, 2011) to meeting the climate protection targets of the MECs and the energy transition.

Methods

Research Setting

In order to foster the transformative potential of the employees of an MEC – and therefore also as local change agents – we conducted a workshop series in a MEC a city with about 35,000 inhabitants in the south of Germany. Activities took place in three groups, partially overlapping, from January to June 2024, see Table 1. The activities concluded in a final session in which the experiences and activities of the three groups were reflected together and the continuation was planned.

2023	2024					
Dec	Jan	Feb	Mar	Apr	May	Jun
Group I						
	Group II					
				Group III		
						Final Session

Table 1: Research setting - three groups (with three workshops and Footprint and Handprint Challenge each)

Workshop format

The workshops were based on the climate action education format #climatechallenge (Sippel and Wöhler, 2018; Szaguhn, et al. 2021; Szaguhn, 2024). At its core, the three workshop series of Groups I-III consist of three workshop sessions each, guiding the participants to two transformation experiments that create spaces for reflection and action for its participants – namely the Footprint Challenge and the Handprint Challenge. In addition, these challenges were supported in coaching sessions, as depicted in Table 2.

Table 2: Depiction of #climatechallenge workshop format informing the activities of three groups at the MEC

Starting Session 1	Input on current state of climate crisis, calculate their carbon footprint, discuss individual footprint in the face of current climate protection targets, identify a Footprint Challenge
Footprint Challenge	30-day transformation experiment in which the employees address climate protection in the private sphere, by changing aspects in their everyday life: in the realms of nutrition, mobility and consumption; after 15 days: coaching session to support continuation
Reflection Session 2	Input on 'Great Transformation' and introduction of the handprint-concept; identify and collectively develop a Handprint Challenge in a small group to bring about structural change in the working environment
Handprint Challenge	60-day transformation experiment in which the employees collectively promote climate protection measures in their workplace and strategically work towards implementation; also, with the intention to extend its impact into the city; after approx. 30 days: coaching to support continuation.
Final Session 3	Final reflection of the individual and collective activities in Footprint and especially Handprint Challenges – and decide on the continuation of the Handprint Challenge's activities in the climate protection working group

Accompanying Research Design and Questionnaire

Alongside these activities of the three groups, accompanying research was implemented, using questionnaires to collect data in the Sessions 1-3. The target was to investigate whether employees are empowered through the #climatechallenge workshop format – particularly through their activities in the challenges – and thereby contributing to the transformation of the MECs. The questionnaire consists of four thematic clusters: (1) Environmental and climate protection, (2) footprint related climate action, (3) perceived demand for climate action, (4) handprint related climate action. Due to the small sample size, the data were analyzed with methods of descriptive statistics. The sample consists of a total of 37 participating employees with approx. 80 percent male and 20 percent female participants, with broad functions, including: trainees, CEO, assistance of the CEO, corporate developer, marketing, technical service, water mechanics, portfolio manager, GIS data worker, sales, logistics, IT, etc.

Results

The following Table 3 lists the activities of the participating employees within their Handprint Challenges. The employees got involved in communication and education, process improvement and concept development and actually implementing climate protection measures to bring about structural change. The activities within the Footprint Challenges are not presented in this article.

Table 3: Overview of activities of employees' activities at the MEC within their Handprint Challenges

Handprint Challenge	Description and rationale
Communication and Education	
Communication campaign I: Role model for climate action	Identify best practice for climate action within the company and make hidden champions visible, so they can function as role model for other employees
Communication campaign II: Tip of the day	Send a climate related tip via intranet every day, so participants are made aware of potential climate protective activities at their workplace
Workshops on topics such as photovoltaics	Contribute to education by visiting secondary schools to teach on photovoltaics and present the topics of the MEC practically
Process improvement and concept development	
Better project planning for more efficient procurement	Reduce carbon emission due to insufficient project planning; thereby reducing the need for express deliveries, etc.
Residual emissions and compensation	Determine carbon emissions due to the MECs activities, then offset these emissions internally by financing climate protection projects
Solar invest project	Develop a business model for citizen participation at regional photovoltaics projects
Structural changes	
Reduce electricity consumption through lighting	Install LED lightning, motion detectors, information signs, etc.
e-bikes for employees and covered parking space	Buy e-bikes that can be utilized by employees and build covered parking spaces for bikes

In the following, the results of the questionnaires are presented. As mentioned above, data were collected at three survey points in each group – in four thematic clusters. The results thereby allow a careful assessment of the experiences and developments the participating employees made over the course of the workshop sessions. In the following, the clusters are presented, with figure 1 highlighting the developments of the employees within cluster four.

The first cluster addressed general perspective of the participants on environmental and climate awareness in three items. Three of the four items show an increase, from 73 in the first session to approx. 85 percent in the third workshop session, and thereby suggesting a rise of the relevant awareness by approx. ten percent: The participants are e.g. more convinced that, climate change is the biggest challenge to humanity and the MEC should be more committed in climate protection.

Also, the participating employees state that they are more committed to getting involved themselves after the workshop sessions; including Footprint and Handprint Challenges. Apart from that, there is a decrease from 100 to 95 percent in the statement, the MEC plays an important role in climate protection and transformation – indicating a continuing high approval. Generally, the data show a slight raise on environmental and climate awareness – potentially caused by the participation in the workshop series.

Cluster two addresses the climate related behavior on the footprint level; comprised of six items. The strongest increase is visible with regard to the meat reduction item: over the course of the three workshops approval rises from 35 to 62 percent. Furthermore, there is a slight increase on the statement whether participants prefer to consume quality goods from 51 to 57 percent. However, all the other items show a decrease ranging from ten to two percent. The data in this cluster is ambiguous – thereby reflecting the diverse composition of the sample, comprising different ages, gender and interests in the topic of climate protection. Despite this, nutrition seems to be a topic that leads to deep reflection and change for many people.

Cluster number three, consists of one item – addressing the perceived demand for action in the individual working environment of the participants. Data were collected at two data collection points: in the second session after the Footprint Challenge and then in the third session, after the Handprint Challenge. Data show an increase from 67 to 81 percent, underlining the sensitization of the participating employees for the implementation of climate protection measures at their workplaces.

Finally, in cluster four, six items were utilized in order to investigate the change of handprint related activities. In this cluster, all items show a steep increase at data collection point 3 after the Handprint Challenge. The self-assessment statement shows that participating employees experience an increase in contact to colleagues (41 to 86 percent), proposed a climate protection measure (24 to 52 percent), contributed in implementation efforts (38 to 62 percent), analyzed a specific climate protection measure (27 to 71 percent), reflected on hindering or supporting framework conditions for transformation (35 to 48 percent), and became part of a working group (14 to 74 percent). Combined with the data on the actual Handprint Challenges in Table 3, this indicates the impact and potential of the #climatechallenge workshop format in companies – to create spaces for reflection and action; and to empower employees so that they can contribute to transformation of the MEC and its urban sphere.

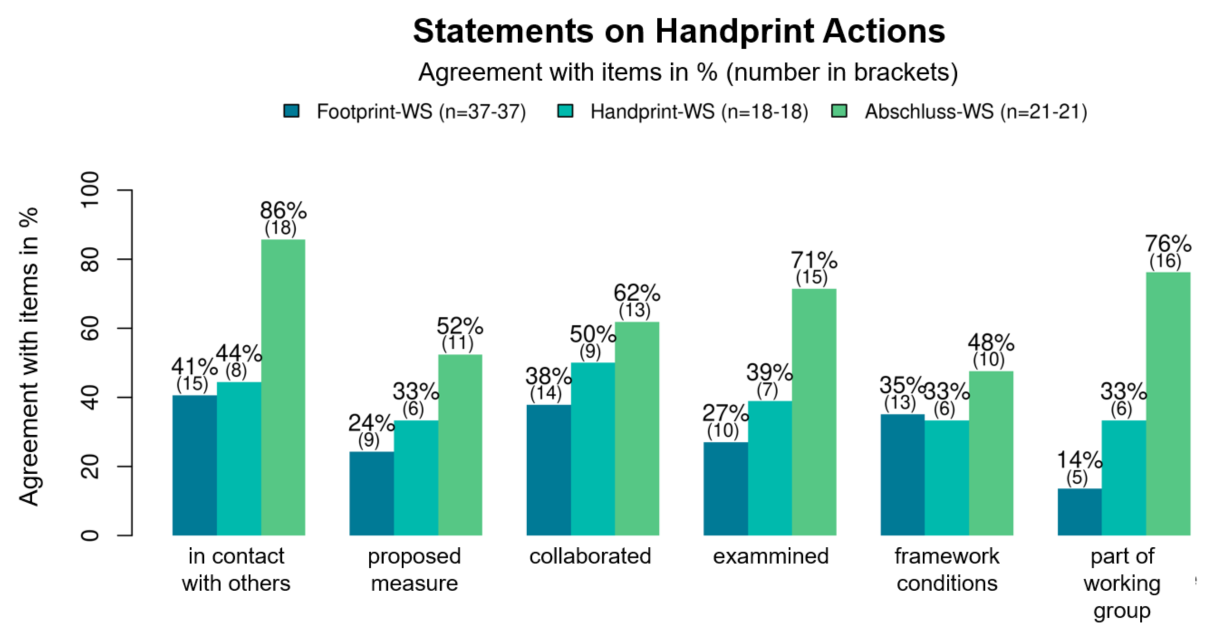

Figure 1: Handprint related behavior over the course of the three workshop sessions and two challenges

Conclusion

The data presented in this article illustrate the opportunities offered by such formats as #climatechallenge – including transformation experiments; for the MECs, but also for the transformation of urban contexts. The activities of the employees, particularly in the Handprint Challenges have given an impulse to the transformation in the MEC examined in this article. In these Challenges, the participants developed collective approaches in the realms of communication, education, process improvement and structural change – thereby often getting involved in transformative processes for the first time. Admittedly, this is merely a small survey with a limited sample size; and also, the survey period only ranged over half a year with no long-term data collected. This limits the findings but points out further research. The activities are continued in the climate action working group, which has been constituted in the final session – in which the participants of all three groups came together to reflect on their experiences. However, the results presented on handprint activities highlight the great potential of these workshop formats for the use in MEC, also to create spaces for reflection and action for the employees – so that they can become local change agents in urban sustainability transformations.

References

Copernicus. (2025). Global Climate Highlights 2024. Copernicus: 2024 is the first year to exceed 1.5°C above pre-industrial level.

IPCC. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. (First). Intergovernmental Panel on Climate Change (IPCC).

Kraas, F., Leggewie, C., Lemke, P., Matthies, E., Messner, D., Nakicenovic, N., ... & Wanner, M. (2016). Der Umzug der Menschheit: Die transformative Kraft der Städte. WBGU-German Advisory Council on Global Change.

Röttger, L. J. (2023). Dekarbonisierung: Pilotprojekt mit Vorbildcharakter: Maßgeschneiderte Zukunftsstrategie für die Energieversorgung in Uelzen. Transforming cities, 8(2), 6-9.

Ruiz-Campillo, X., Castán Broto, V., & Westman, L. (2021). Motivations and intended outcomes in local governments' declarations of climate emergency. Politics and Governance, 9(2), 17-28.

Sippel, M., Wöhler, T.: #climatechallenge - mehr Dynamik für die sozial-ökologische Transformation durch Veränderungsexperimente? In: Jahrbuch Nachhaltige Ökonomie 2018/2019, metropolis Verlag (2018)

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. science, 347(6223), 1259855.

Szaguhn, M. (2024). Transformatives Lernen im Selbst- und Realexperiment: Wie das Format #climatechallenge neue Perspektiven auf Klimaschutz ermöglicht. In Lernziele und Kompetenzen im Bereich Nachhaltigkeit (pp. 25-48). Berlin, Heidelberg: Springer Berlin Heidelberg.

Szaguhn, M., Sippel, M., & Wöhler, T. (2021). 'Mit #climatechallenge zu mehr CSR? Ein innovatives Lernformat für Verantwortungsübernahme in der großen Transformation'. In CSR und Hochschullehre, In: Management-Reihe Corporate Social Responsibility. 237–51. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-62679-5_12.

UBA. (2025). Umweltbundesamt. Treibhausgasminderungsziele Deutschlands. https://www.umweltbundesamt.de/daten/klima/treibhausgasminderungsziele-deutschlands

WBGU (Hrsg.). (2011). Welt im Wandel: Gesellschaftsvertrag für eine Große Transformation; [Hauptgutachten] (2., veränd. Aufl). Wiss. Beirat der Bundesregierung Globale Umweltveränderungen (WBGU)

Insulating the Future – The Fiber That Unites Energy Efficiency and Recycling

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Abstract

In the context of global climate challenges and increasing resource scarcity, the construction sector is a significant source of environmental emissions. This study systematically compares six fiber-based insulation materials regarding their building physics properties and their ecological, economic, and socio-cultural sustainability. Mineral fibers offer advantages due to their low thermal conductivity, but show significant environmental weaknesses. The analysis reveals that wood fibers, despite their natural origin, also present notable sustainability deficits. In contrast, low-processed natural materials such as wood shavings and straw demonstrate clear ecological, economic, and social benefits, which can compensate for their lower building physics performance. These findings highlight the potential of such straightforward, locally sourced materials to promote more sustainable construction practices and underscore their specific relevance for urban transformation processes.

1. Introduction

Reducing global warming requires a substantial decrease in greenhouse gas emissions [Umweltbundesamt, 2021a]. Beyond direct operational emissions, the embodied emissions generated throughout the entire life cycle of building materials are gaining increasing significance. Consequently, the selection of appropriate and sustainable materials has become crucial [Deutsche Umwelthilfe e.V., 2022].
However, the growing diversity of available building materials complicates this decision-making process, particularly given the complex and often conflicting requirements for sustainability and functionality. While technological and material innovations can optimize structural performance, they frequently result in higher energy and resource consumption, as well as increased embodied emissions. Moreover, advances in functionality do not necessarily translate into improvements in economic or socio-cultural aspects. [Holm et al., 2014]
Although sustainability certification systems provide a framework for assessing buildings at the systemic level [Weller et al., 2012], there is no comparable approach for individual materials. A nuanced evaluation of materials is crucial to facilitate rapid transformation within the urban context. Biogenic raw materials, especially for insulation purposes, offer significant potential [Dorsch et al., 2017]. However, their market share remains low [Treml et al., 2023].
The study aims to develop a systemic sustainability assessment for insulation materials to identify criteria for quantifying holistic sustainability.
The paper first explains the methodology, followed by a multidimensional analysis of six fiber insulation materials with a particular focus on thermal comfort. Subsequently, the results are presented and discussed. The paper concludes with an outlook on future research.

2. Materials and methods

To develop a systemic sustainability assessment of building materials, an integrative analysis was conducted on six fiber-based insulation materials: mineral fiber [Saint-Gobain, 2025], wood fiber [Steico, 2025], wood shavings [Baufritz, 2022], wood-clay composite [Holz-Lehmhaus, 2022], cellulose [Steico, 2025], and construction straw [Sonnenklee, 2025].

Fig. 1: Samples of insulation materials: mineral fiber, wood fiber, wood shavings, wood-clay composite, cellulose, and straw [© Widmann]

A uniform thermal transmittance coefficient of U = 0.11 W/(m²K) was defined as a target value, reflecting the standards for highly insulated roof assemblies. Insulation thickness was adjusted according to the specific thermal conductivity of the respective materials, while maintaining a consistent layer structure.
Building physics analysis encompassed thermal, moisture, acoustic, and fire protection characteristics based on manufacturer specifications. The economic evaluation of investment and disposal costs utilized market-relevant pricing data from spring 2025, with usage and maintenance costs assumed to be equivalent across all materials. The ecological performance was assessed through material-specific life cycle analyses based on environmental product declarations. Socio-cultural sustainability was primarily evaluated in terms of thermal comfort, using phase shift as a key indicator for summer heat protection. Due to limited manufacturer data, the phase shift was determined through a combination of analytical calculation, simulation, and empirical measurement. Additionally, potential exposure to dust or pollutants during installation was evaluated.
All findings were integrated using a multi-criteria decision analysis to facilitate an integrative overall assessment of the insulation materials.

3. Results

3.1. Building physics

Owing to its low thermal conductivity (λ), mineral fiber insulation achieves the highest insulation efficiency with minimal material usage. To achieve the specified thermal transmittance requirement (U = 0.11 W/(m²K)), only 24 cm of mineral fiber insulation is required, compared to 28 cm of wood fiber and 32 cm of construction straw. This variation in required thickness directly influences the surface weight of the construction, as shown in Table 1.

Insulation material	λ_D [W/(mK)]	λ_B [W/(mK)]	ρ [kg/m³]	c_p [J/(kgK)]	fire behaviour DIN EN 13501	required insulation thickness [m]	construction weight [kg/m²]
mineral fiber	0,034	0,035	30 - 40	1030	A1	0,24	8,40
wood fiber	0,038	0,040	35 - 45	2100	E	0,28	11,20
wood shavings	0,040	0,042	75 - 80	2100	E	0,30	23,25
wood-clay composite	0,043	0,044	70 - 90	2100	E	0,30	24,00
cellulose	0,038	0,040	38 - 57	2100	E	0,28	13,30
straw	0,043	0,047	90 - 105	2000	E	0,32	31,20

Tab. 1: Building physics characteristics of manufacturer-specific fiber insulation materials [Saint Gobain, 2025; Steico, 2025; Baufritz, 2022, Holz-Lehmhaus, 2022; Sonnenklee, 2025]

Biogenic fiber insulation materials possess good thermal storage capacity thanks to their high bulk density (ρ) and specific heat capacity (c_p), which leads to improved thermal protection in summer. Their open-pored structure also promotes moisture transport, reducing the risk of condensation and creating a balanced indoor climate. In terms of sound insulation, there are no significant differences between the insulation materials. For fire protection, only mineral fiber achieves the highest classification A1, while bio-based insulation materials are classified as E ‘normally flammable’. However, in construction, the fire protection properties of the room-enclosing layers are primarily decisive, so the classification of the insulation materials is of secondary importance [Künzel & Holm, 2013].

3.2. Economics

The specified cost indicators are derived from manufacturer data collected in spring 2025 and may be subject to variation due to inflationary trends. For the economic evaluation, not only material prices but also compaction and the insulation thickness required to achieve the desired energy performance were considered (Fig. 2).

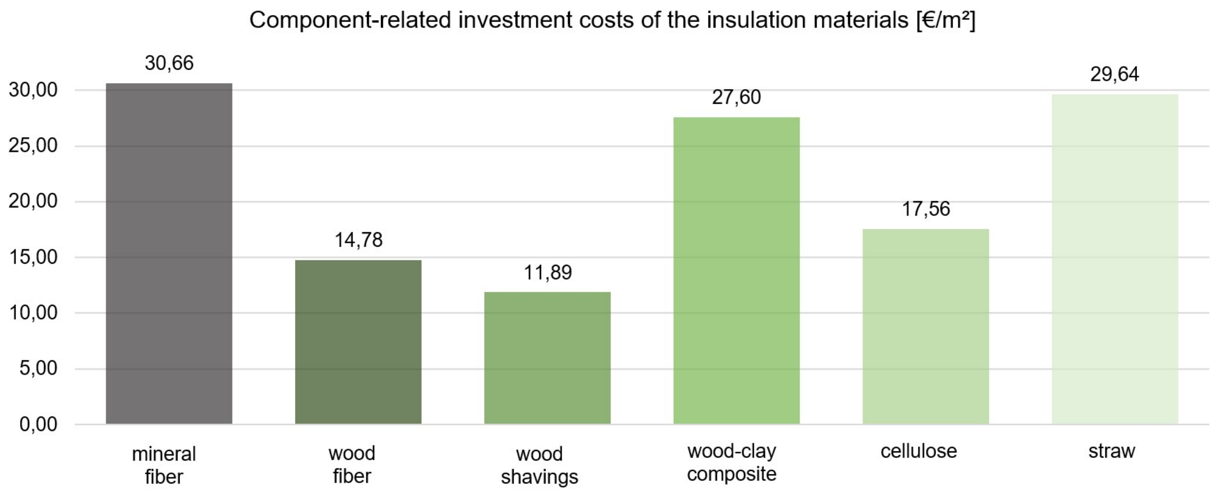

Fig. 2: Economic comparison of component-specific investment costs for insulation materials in €/m² [Saint Gobain, 2025; Steico, 2025; Baufritz, 2022, Holz-Lehmhaus, 2022; Sonnenklee, 2025]

Although nearly twice the quantity of straw is required compared to other materials, the investment costs for constructions insulated with straw and mineral fibers are comparable. Wood shavings are identified as one of the most cost-effective insulation options, primarily because they are a by-product of wood processing and are not subject to a standardized marketing structure. Therefore, their cost based on direct discussions with the manufacturer [Baufritz, 2022].

Additionally, disposal constitutes a significant aspect of the overall economic assessment. For untreated, natural fiber insulation materials such as wood shavings or straw, free composting is theoretically feasible [Dorsch et al., 2017] but is not commonly practiced due to the need for selective dismantling and labor-intensive separation. As a result, natural fiber insulations are typically disposed of as mixed construction and demolition waste, currently incurring average disposal costs of approximately 300 €/t [Rieger, 2025; Osterried, 2025].

In contrast, synthetic insulation materials such as mineral fiber must be treated as hazardous waste and disposed of in special big bags due to potential contamination. Disposal costs, ranging from approximately 700 €/t to 1,000 €/t, are substantially higher for mineral fiber compared to biogenic alternatives and are subject to regional variation [Rieger, 2025; Osterried, 2025].

3.3 Ecology

As part of the material-specific life cycle assessment, primary energy demand and key environmental impacts, including greenhouse gas emissions, acidification, and eutrophication, were quantified for both the manufacturing (A1–A3) and disposal (C3–C4) phases. The recycling potential (D) is presented for informational purposes but was excluded from the overall assessment as required by normative accounting standards [DIN EN 15805:2022].

Greenhouse gas potential was chosen as a representative indicator due to its political and regulatory relevance. Emissions during the manufacturing phase are chiefly affected by the degree of processing and the origin of the material. For example, wood shavings, which are by-products of woodworking processes and require minimal additional processing, exhibit particularly low emissions. Furthermore, renewable raw materials such as wood and straw sequester atmospheric CO_2 through photosynthesis during their growth phase [Holzmann et al., 2012]. This CO_2 assimilation is reflected as a negative contribution within the carbon balance of the materials (Fig. 3).

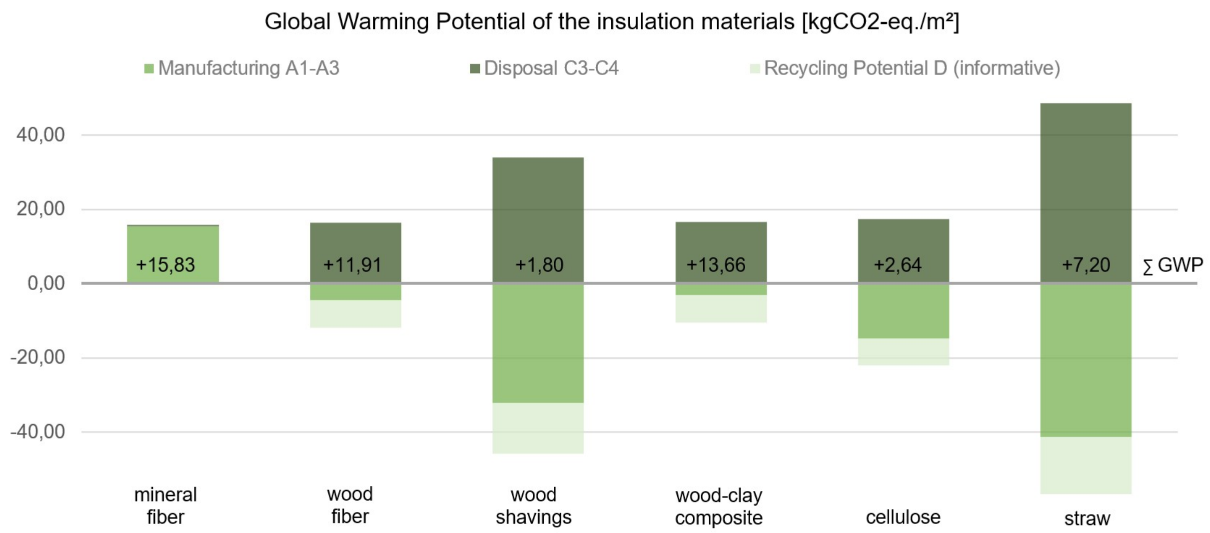

Fig. 3: Ecological comparison of the Global Warming Potential (GWP) of insulation materials in kgCO2-eq/m² [Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen, 2025]

However, an ecological dilemma emerges during the disposal phase: biogenic insulation materials are generally destined for thermal recovery, which results in the re-emission of the previously sequestered CO_2 into the atmosphere. Consequently, cascading use, meaning material recycling before energy recovery, should be prioritized to maximize ecological benefits [Graubner & Reiche, 2000]. In contrast, mineral fiber insulation materials generate minimal direct greenhouse gas emissions during landfilling. However, they persist indefinitely in landfill sites, thereby contributing to land use and resource depletion without being reintegrated into material or energy cycles [Wissenschaftliche Dienste des deutschen Bundestages, 2022].

An analysis of non-renewable primary energy demand reveals that natural materials are not inherently more ecologically sustainable than conventional alternatives. For instance, despite its biogenic origin, wood fiber insulation exhibits a primary energy demand comparable to that of mineral fiber, primarily due to the energy-intensive manufacturing process. The breakdown of the wood structure necessitates substantial mechanical and thermal energy input, particularly during drying at temperatures up to 200 °C. While technological advancements aimed at reducing energy consumption are under development, they have not yet achieved widespread implementation [Michanickl & Barth, 2021]. In contrast, less processed products such as wood shavings, straw, and secondary materials like cellulose demonstrate greater resource efficiency.

3.4. Sociocultural

As people spend approximately 90% of their time indoors [Braune & Rudolphi, 2021], the quality of the indoor environment is crucial to occupant well-being. In Central Europe, the issue of summer overheating is becoming increasingly significant [Umweltbundesamt, 2021b].
Accordingly, phase shift was considered as a key parameter for evaluating summer heat stress. Phase shift refers to the time delay between the peak outdoor temperature and the corresponding temperature at the interior surface of a building component. To minimize the need for active cooling during summer, a high phase shift is desirable for exterior building assemblies. When combined with

natural night-time ventilation strategies, this allows for efficient dissipation of heat accumulated during the day [Ranft & Frohn, 2004]

Due to the frequent absence or limited verifiability of manufacturer data on phase shift, a combination of analytical calculations, simulations, and experimental measurements was employed.
The results for component-specific phase shifts (Fig.4) indicate that biogenic insulation materials such as straw, wood shavings, and wood-clay composite significantly delay heat transfer compared to mineral fiber.

Fig. 4: Sociocultural comparison of thermal comfort based on the determined component-related phase shift of insulation materials in hours [Widmann, 2025]

These values were determined based on the complete roof assembly. Owing to its low bulk density and required thickness, mineral fiber results in a lightweight structure but also exhibits low thermal storage capacity. Consequently, heat penetrates the interior more rapidly, reducing the level of thermal protection [Fachagentur Nachwachsende Rohstoffe, 2024]. This is particularly relevant, as even minor temperature deviations of one Kelvin can impact user performance and well-being by up to 25% [Seppänen & Fisk, 2006]. Additional simulations confirm the relationship between phase shift and thermal perception. However, conventional measures such as shading and targeted ventilation exert a higher influence on indoor temperatures [Feist, 2017]. Beyond evaluating thermal comfort, another focus was given to the social and occupational impacts arising from dust and pollutant exposure during installation. Experimental measurements demonstrated that biogenic insulation materials such as straw and wood shavings generate lower emissions compared to mineral fiber [Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2016].

4. Conclusion

To address the multifaceted nature of sustainability, a multiple criteria decision analysis (MCDA) was conducted. The target criteria equally weighed the four primary domains: building physics, economics, ecology, and social aspects. A point system was developed to capture the distinct characteristics of each criterion. The rating scale was modified in cases of comparable attributes, such as the similar thermal conductivity values of wood fiber and cellulose. The MCDA presented in Figure 5 serves as an exemplary framework and can be adapted flexibly to accommodate different target criteria and weighting schemes [Thokala et al., 2016].

Insulation material			mineral fiber		wood fiber		wood shavings		wood-clay		cellulose		straw	
	target values → possible attributes	weight	Score	partial utility	Score	partial utility	Score	partial utility	Score	partial utility	Score	partial utility	Score	partial utility
building physics	Thermal insulation performance → Thermal conductivity λB [W/(mK)]	10%	4	0,4	3	0,3	2	0,2	1	0,1	3	0,3	0	0
	Construction weight → Roof construction [kg/m³]	10%	5	0,5	4	0,4	2	0,2	1	0,1	3	0,3	0	0
	Fire behaviour DIN EN 13501-1 → Clasifications [A | E]	5%	1	0,05	0	0	0	0	0	0	0	0	0	0
economics	Component-related investment costs → Roof construction [€/m²]	12,5%	0	0	4	0,5	5	0,625	2	0,25	3	0,375	1	0,125
	Disposal costs → [Landfill | Construction waste | Composting pot.]	12,5%	0	0	1	0,125	2	0,25	1	0,125	1	0,125	2	0,25
ecology	Origin of material → [synthetic | natural]	5%	0	0	1	0,05	1	0,05	1	0,05	1	0,05	1	0,05
	Degree of processing → Modul A - PEne [kWh/m²]	10%	0	0	2	0,2	5	0,5	1	0,1	3	0,3	4	0,4
	Recyling potential → Modul D - GWP [kgCO2/m²]	10%	0	0	2	0,2	4	0,4	3	0,3	1	0,1	5	0,5
social	Component-related phase shift → Roof construction [h]	15%	0	0	1	0,15	4	0,6	3	0,45	2	0,3	5	0,75
	Processing (including dust exposure) → impression from experiment [low | medium | high]	10%	0	0	1	0,1	2	0,2	1	0,1	1	0,1	2	0,2
	sum	**100%**		**0,95**		**2,025**		**3,025**		**1,575**		**1,95**		**2,275**

Fig. 5: Multiple criteria decision analysis for the systemic sustainability assessment of various fiber insulation materials [Widmann, 2025]

Among the assessed options, the wood shavings variant achieved the highest overall utility value, scoring 3.025. Physical limitations can be compensated for by the required insulation thickness. However, the material has proven environmental, economic, and social benefits, including its natural origin and minimal industrial processing. Straw insulation follows with 2.275 points and a comparable profile. In contrast, mineral fiber ranks lowest with 0.95 points, as its favorable building physics properties are substantially outweighed by ecological, economic, and social deficits, particularly energy-intensive production and challenging disposal requirements.

In summary, these findings underscore the necessity of a holistic assessment that integrates functional, financial, and ecological considerations. All relevant processes and key data must be iteratively evaluated and balanced. The example of wood fiber demonstrates that not every natural product is inherently more sustainable.
This understanding is particularly crucial for urban transformation, as even small, well-informed actions in material selection can have a significant positive impact on the sustainability of the built environment.

5. Outlook

Future sustainability assessments should place increased emphasis on the reuse and recycling of materials. Alternative disposal strategies, for example, material composability and separability, are essential for advancing circularity in construction. Furthermore, life cycle assessments should incorporate a range of end-of-life scenarios to support more informed decision-making and encourage design for disassembly.

A promising direction for further research lies in the differentiated analysis of how varying insulation thicknesses impact space requirements, economic factors, and socio-cultural dimensions. Additionally, specific environmental effects, such as impacts on biodiversity, warrant more detailed investigation. Expanding the scope of assessment in these ways can further refine the decision-making process and support more sustainable building practices.

References

Baufritz GmbH & Co. KG. (2022). Technisches Datenblatt HOIZ® Hobelspandämmung. URL: https://www.baufritz.com/Dokumente/HOIZ/Datenblatt_HOIZ_web.pdf [retrieved on 26.05.25]

Braune, A., Rudolphi, A. (2023). Kein „Ja, aber…“ mehr. Nachhaltig ist das neue normal (2. Aufl.). DGNB

Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA). (2016). Staub beim Bauen – Risiken und Schutzmaßnahmen. URL: https://www.baua.de/DE/Themen/Arbeitsgestaltung-im-Betrieb/Physikalische-Einwirkungen/Staub/Staub_node.html [retrieved on 26.05.25]

Deutsche Umwelthilfe e.V. (2022). Gebäude bewahren statt abreißen: Klimaschutz durch Sanierung, URL: https://www.duh.de/fileadmin/user_upload/download/Projektinformation/Klima-Geb%C3%A4ude-Check/DUH_Factsheet_Geb%C3%A4ude_Bewahren_Abrisse_Vemeiden_12122022_kr.pdf [retrieved on 20.05.25]

DIN EN 15804:2022-03. Nachhaltigkeit von Bauwerken – Umweltproduktdeklarationen – Grundregeln für die Produktkategorie Bauprodukte (Deutsche Fassung EN 15804:2012+A2:2019). Beuth Verlag

Dorsch, L., Hegger, M., Kellert, R., & Weller, B. (2017). Marktübersicht – Dämmstoffe aus nachwachsenden Rohstoffen. In Fachagentur Nachwachsende Rohstoffe e. V. (Hrsg.), Marktübersicht – Dämmstoffe aus nachwachsenden Rohstoffen (9., überarb. Aufl.).

Fachagentur Nachwachsende Rohstoffe e.V. (FNR). (2024). Wärmeschutz. URL: https://baustoffe.fnr.de/daemmstoffe/bauphysik/waermeschutz [retrieved on 20.05.25]

Feist, W. (2017). Das Passivhaus – Grundlagen, Planung, Ausführung. Springer Vieweg

Graubner, C.-A., & Reiche, K. (2000). Grundlagen der Nachhaltigkeitsanalyse demontierbarer Baukonstruktionen. Bautechnik

Holm, Andreas H.; Sprengard, Christoph; Treml, Sebastian (2014): Dämmstoffe - innovativ, nachhaltig, effizient. In: Bauphysik 36 (1). doi: 10.1002/bapi.201410003

Holz-Lehmhaus GmbH. (2022). Technisches Datenblatt Jasmin® clayfibre Einblasdämmung. URL: https://www.holz-lehmhaus.eu/wp-content/uploads/2024/09/Technisches-Datenblatt-Jasmin-clayfine-mit-CE.pdf [retrieved on 26.05.25]

Holzmann, G., Kaiser, C., Niklasch, W., Schöpgens, H., & Spitzendorfer, J. (2012). Natürliche und pflanzliche Baustoffe: Rohstoff – Bauphysik – Konstruktion (2., überarb. Aufl.). Vieweg + Teubner

Künzel, H. M., & Holm, A. (2013). Bauphysikalische Eigenschaften von Dämmstoffen – Einfluss auf den sommerlichen Wärmeschutz und das Feuchteverhalten. In Energieeffizientes Bauen mit nachwachsenden Rohstoffen. Fraunhofer IRB Verlag

Michanickl, A., & Barth, S. (2021). Entwicklung von Mahlscheiben zur Erzeugung spezifischer Fasergeometrien für Faserverbundwerkstoffe mit geringer Dichte (Schlussbericht, Förderkennzeichen 22012216). Technische Hochschule Rosenheim

Osterried (2025). Osterried Entsorgung GmbH. URL: https://www.osterried.com/downloads [retrieved on 26.05.25]

Ranft, F., & Frohn, B. (2004). Natürliche Klimatisierung. In Energieagentur NRW (Hrsg.), Baupraxis. Birkhäuser

Rieger, A. (2025). REMONDIS SE & Co. KG

SAINT-GOBAIN. (2025). Technisches Datenblatt: InsulSafe® Mineralwolle-Einblasdämmung. URL: https://www.isover.de/documents/technisches-datenblatt/insulsafe.pdf [retrieved on 26.05.25]

Seppänen, O., & Fisk, W. J. (2006). Indoor climate and productivity in offices (Guide Book No. 6)

SonnenKlee GmbH. (2025). Technisches Datenblatt Strohdämmung: Einblasstroh, Bio-Einblasstroh, Bio-Baustrohballen. URL: https://www.sonnenklee.at/wp-content/uploads/2025/04/2025_04_22-Datenblatt-Strohdaemmung-web.pdf [retrieved on 26.05.25]

STEICO SE. (2025). STEICO Einblasdämmung: Holzfaser- und Zellulose-Einblasdämmstoffe – Technisches Datenblatt. URL: https://www.steico.com/fileadmin/user_upload/importer/downloads/4028b6097384810e017496c6dcf14d6f/STEICO_Einblasdaemmung_DEU_de_i.pdf [retrieved on 26.05.25]

Thokala, P., Devlin, N., Marsh, K., Baltussen, R., Boysen, M., Kalo, Z., Longrenn, T., Mussen, F., Peacock, S., Watkins, J., & Ijzerman, M. (2016). Multiple criteria decision analysis for health care decision making—An introduction: Report 1 of the ISPOR MCDA Emerging Good Practices Task Force. Value in Health

Treml, S., Sprengard, C., Albrecht, W., Holm, A. H., & Karrer, C. (2023). Technologien und Techniken zur Verbesserung der Energieeffizienz von Gebäuden durch Wärmedämmstoffe: Metastudie Wärmedämmstoffe – Produkte – Anwendungen – Innovationen (2., aktualisierte Aufl.). Forschungsinstitut für Wärmeschutz e. V. München (FIW München)

Umweltbundesamt (2021a). Treibhausgasemissionen steigen 2021 um 4,5 Prozent. URL: https://www.umweltbundesamt.de/presse/pressemitteilungen/treibhausgasemissionen-stiegen-2021-um-45-prozent [retrieved on 20.05.25]

Umweltbundesamt (2021b). Hitzeschutz in Gebäuden – Maßnahmen und Strategien für den Klimawandel. Dessau-Roßlau: UBA

Weller, B., Albrecht, H., Hegger, M., & Zeumer, M. (2012). Denkmal und Energie. Vieweg + Teubner

Wissenschaftliche Dienste des Deutschen Bundestages. (2022). Studien zu Ökobilanzen von Gebäudedämmstoffen (WD 8 - 3000 - 004/22). URL: https://www.bundestag.de/resource/blob/891140/839fe19dbc21b7e9a5daddcd637dad71/WD-8-004-22-pdf-data.pdf [retrieved on 26.05.25]

Reconstructing Education – Prefabricating the Future of University Buildings

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Abstract

The building sector significantly contributes to greenhouse gas emissions and resource depletion, mainly through the operation of inefficient buildings. The revised Energy Performance of Buildings Directive (EPBD) aims to decarbonise the building stock. The Dutch "Energiesprong" approach, using serial renovations with prefabricated construction and technical elements, is gaining importance for rapid energy modernisation. This study explores its transferability to non-residential buildings, focusing on the building envelope. Based on structural and regulatory requirements, non-residential buildings are categorized according to energy standards to identify suitable typologies with high savings potential. Ecological factors like CO_2 emissions and energy use, along with the economic benefits of prefabrication, are considered. Findings indicate that a simple cubature and structured construction methods are crucial for successful implementation. Reinforced concrete skeleton buildings offers high structural and ecological potential due to their independent load transfer and stored embodied energy. Office buildings from the 1960s to 1980s, often built in Germany using the "university construction method," are particularly suitable for serial refurbishment due to their modular grid. This research identifies key indicators for serial refurbishment, showing strong potential for skeleton buildings using the "university construction method."

Repurposing Urban Parking Space to Green Space for Heat Stress Adaptation: Case Studies of Stuttgart (Germany) and Bhopal (India)

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Abstract

Urban transformation strategies for reclaiming valuable urban land have become crucial for implementing climate actions, such as heat stress adaptation and mitigation measures. Given that a large percentage of urban land is dedicated to parking spaces, the study investigates the repurposing potential of on-street parking spaces to green measures as an alternative use to improve the outdoor thermal comfort. Two case studies were conducted in the city of Stuttgart (Germany) and Bhopal (India). The methodology involves: (i) identifying major causes of heat stress through secondary data analysis, (ii) interviewing city planners and using OpenAI tools to synthesise insights on the feasibility of the case studies, (iii) simulating alternative scenarios of thermal comfort with low, medium and dense vegetation.

The study reveals that repurposing 3-4% of on-street parking with native trees on both sides of the road demonstrated a reduction of mean radiant temperature by 3°C in Stuttgart and 8°C in Bhopal during the daytime. Grass and shrubs showed moderate cooling effects compared to trees during daytime, but they show uniform reduction throughout the day. The output of the multiple scenarios applied highlights the feasibility of repurposing urban space to address climate adaptation actions and ensure sustainability goals. The study framework offers a flexible and scalable approach that can be adapted and replicated to other cities exposed to urban heat stress.

Keywords: Urbanisation, Heat stress, Urban green space, Parking repurposing, Outdoor thermal comfort

1. Introduction

Global climate change results in intense and frequent heat waves, and the risks are further amplified by Urban Heat Islands (UHIs), a phenomenon that causes higher temperatures in urban areas than in surrounding rural areas (Zhao et al., 2018). The temperature caused by the UHI effect results in physical and environmental strain in the cities, which is referred to as urban heat stress (UHS). The main causes of such extreme events are anthropogenic activities and other factors like land use change, increased surface sealing in urban areas, which contribute to UHI, consequently increasing UHS (ICLEI, 2021). Heat waves impose a higher risk to sensitive populations, for instance, older adults, young children, populations with lower income, outdoor workers, and people experiencing health challenges (EPA, 2023).

Considering these challenges, cities must take proactive steps, such as expanding urban green spaces, improving heat-resilient infrastructure, and enhancing public awareness, to adapt to rising temperatures. Small and medium-sized cities are potential candidates as they are highly vulnerable to such events and lack the resources and capacity to tackle the issue (Birkman, 2016). Urban greening measures are widely accepted as efficient mitigation tools. However, rapid urbanisation increases housing demand and the need for parking provisions, leading to a scarcity of green space. This is especially true in India, while German cities face challenges in ensuring equitable access to green spaces across socio-economic neighbourhoods. Therefore, addressing these challenges requires innovative solutions that revitalise existing land for green use while enhancing equitable access (Wendnagel-Beck et al., 2023).

Urban parking spaces occupy a substantial amount of high-value land due to cars remaining idle for most of the day. This growing demand for parking encroaches on space intended for pedestrians, cyclists, and green initiatives, negatively impacting quality of life and the environment (McAslan & Sprei, 2023). Ineffective parking policies can further encourage car ownership and hinder sustainable transportation. A recent study suggests that better parking management, repurposing, and reduction can free up urban areas for crucial green infrastructure and promote a shift towards sustainable mobility (Sprei et al., 2020).

Against this background, this study focuses on the potential for repurposing parking spaces within a city to increase green space. The study is conducted in three steps: first, a comprehensive literature review to understand UHS and the effect of urban green spaces as an adaptation measure; second, interviews with planners and city officials to assess the potential for repurposing parking (on-street and off-street); and finally, analysis of the outdoor thermal comfort provided by urban green spaces in repurposed parking areas to mitigate heat stress.

2. Methods and Data

This section details the methods and data used in each stage of the research process. Figure 1 presents a flowchart of the overall research methodology.

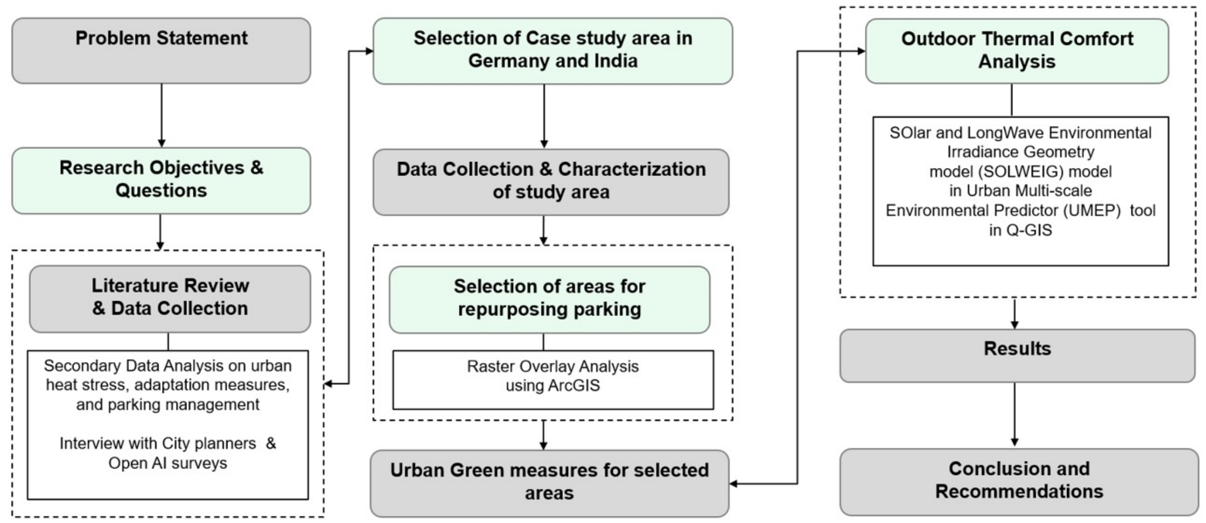

Figure 1: Flowchart of research process. Source: Authors

2.1. Heat stress and the provision of green spaces in Germany and India

A comprehensive literature review to understand the differences in heat stress adaptation and provision of green space in the context of Germany and India, and to establish indicators for site selection analysis. Based on a comprehensive literature review, general factors and indicators for identifying urban areas requiring immediate intervention and detailed heat stress analysis have been categorised and summarised in Table 1.

Factor	Indicators
Climate and Geography	Air temperature, surface temperature, wind speed, direction, elevation, global radiation, relative humidity, and mean radiant temperature.
Urbanisation and Land Cover Change	Impervious surfaces, share/loss of green space, land use (types and distribution), urban growth rate, and road density.
Urban Morphology and Building Characteristics	Built-up area, building height, sky view factor, building and settlement typology, street connectivity, block perimeter, height/width ratio, and aspect ratio
Green Space and Vegetation	Green infrastructure typology, vegetation composition and height, green volume and leaf area index, normalised difference vegetation index, albedo (surface reflectivity), evapotranspiration rates, sensible and latent heat fluxes
Socio-Economic Factors	Age groups, income levels, gender ratio, population, population density and growth, literacy, disability, poverty rates, economic performance, access to social and critical infrastructure, accessibility of green spaces, average household size, migration background, social capital and livelihood

Table 1: Factors and Indicators of heat stress in SMCs. Source: Narváez Vallejo & Schwarz-v.Raumer, 2023; Seeberg et al., 2022; Wendnagel-Beck et al., 2023; Birkmann et al., 2021; Wendnagel-Beck et al., 2021; Ketterer & Matzarakis, 2015; Anupriya & Rubeena, 2023; Azhar et al., 2017; Ghosh, 2019; Barpete & Mehrotra, 2023; Wollschläger et al., 2022; Kabisch et al., 2023; Megahed & Srikantaswamy, 2020; Ojha & Mukherjee, 2024

2.2. Feasibility of repurposing parking spaces in Germany and India

Secondly, semi-structured key informant interviews were conducted with city officials or experts. In the absence of expert interviews, OpenAI tools were used to supplement the research on this topic, aiming to understand current parking policies and strategies in Germany (see Annexure 1A) and India (see Annexure 1B). Effective parking management requires insights from the city, transport, and landscape planners; however, comprehensive decision-making is often challenging due to the need for extensive data collection. To address this, the study introduces open-access GenAI tools, leveraging readily available online data to gather insights, and comparing GenAI-pretrained model-generated answers from OpenAI with expert interview responses to assess reliability (see Annexure 1C & D).

2.3. Case study area in Germany and India

Based on the interviews, study areas in Germany and India were selected. Stuttgart, the capital of Baden-Württemberg, is in the southwestern part of Germany (Landeshauptstadt Stuttgart, 2024). The heat stress is extreme in and around the central part of the city as well as the areas where building density is high or where there is less accessibility to green space (Wendnagel-Beck et al., 2023). From the interview conducted it is understood that although Stuttgart is well connected by public transport the central area experiences high parking demand, resulting in a lack of green space, footpaths or bike lanes.

Similarly, Bhopal, the capital city of Madhya Pradesh, located in central India, has undergone rapid horizontal expansion, altering land use patterns and resulting in high building density and a lack of green space (Barpete & Mehrotra, 2023). Also, the existence of legislation that mandated minimum parking requirements and unregulated on-street parking has caused high traffic density, increased air and noise pollution and rendered it impossible to provide roadside greenery, footpaths or bike lanes.

Furthermore, a GIS-based site selection analysis is performed to select suitable residential areas within the recommended districts/wards in Stuttgart and Bhopal. Seven indicators were selected for the analysis (see Annexure 2), including Land Surface Temperature (LST), Normalised Difference Vegetation Index (NDVI), Sky View Factor (SVF), proximity to public transport stations, accessibility to green space, presence of social and critical infrastructure, and slope. A raster overlay analysis was then carried out, and hotspots within the recommended districts were identified. Subsequently, suitable urban green measures for these areas were selected, taking into account the local context and findings from previous studies.

2.4. Outdoor thermal comfort

Finally, outdoor thermal comfort was assessed for the selected areas using the SOlar and LongWave Environmental Irradiance Geometry (SOLWEIG) model, available in the Urban Multi-scale Environmental Predictor (UMEP) plugin in Q-GIS. Four scenarios were considered: (i) existing situation, (ii) repurposed one side parking with greenery, (iii) repurposed both sides with greenery (iv) every third parking repurposed with greenery.

3. Results

Heat Stress Adaptation Strategies and Planning Priorities: Both Germany and India face significant heat stress, necessitating prioritised adaptation through improved green spaces, infrastructure, and public awareness. The findings indicate divergent approaches to addressing this challenge. German cities prioritise integrated climate-sensitive planning and socio-economic resilience for long-term heat adaptation and mitigation. In contrast, Indian cities focus on basic infrastructure and managing rapid urban growth to protect vulnerable populations from the direct effects of heat stress. These differences reflect varying development stages and resilience priorities. The comprehensive set of factors and indicators for heat stress assessment derived from this study is transferable and applicable to small and medium-sized cities globally.

Repurposing Parking Spaces for Heat Adaptation: In terms of repurposing parking spaces to provide heat adaptation measures, both Germany and India have a positive approach towards repurposing on-street parking for environmental benefits. However, considering the socio-political aspects, the recommendation is to repurpose only a minimal number of parking.

For off-street parking, German city planners suggest the possibility of reducing minimum parking requirements as well as repurposing, but not in combination with repurposing of on-street parking in the same area. In India, due to increasing settlement density and urbanisation rate, city planners were reluctant to adopt policies for replacing off-street parking with green spaces. Consequently, for existing residential areas in Germany and India, it is recommended that off-street parking incorporate green strategies like green roofs, permeable pavement, and green walls without reducing the existing parking spaces.

For new or redeveloped areas, the reduction of minimum parking requirements can be explored to reserve urban land for greenery. Implementing infrastructure programs, such as a well-connected public transport network and car-sharing initiatives, along with incentives for transforming the space into green areas, can enhance the scalability of the approach.

Case Study Sites Selection: The planners recommended six key districts in Stuttgart: West, North, East, South, Mitte, and Bad Cannstatt (Figure 2). For Bhopal, three wards were recommended: Maharana Pratap Nagar (MP Nagar), Arera Colony, and Jawaharlal Nehru Ward (Figure 3). A subsequent GIS-based raster overlay analysis led to the selection of a residential area in Stuttgart West and the vicinity of New Market in Bhopal for more detailed analysis.

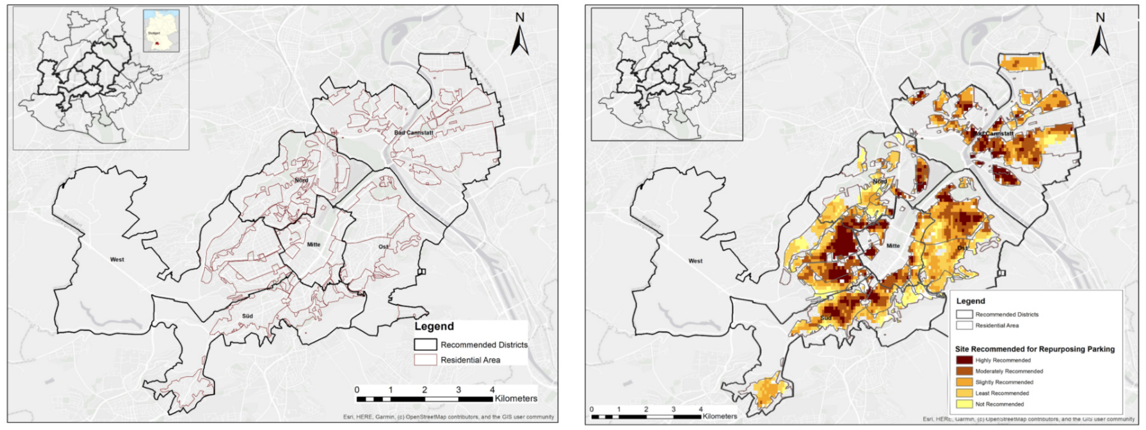

Figure 2: Map showing recommended districts for parking repurpose in Stuttgart and results from GIS-based raster analysis identifying optimal sites (Source: Authors)

Figure 2: Map showing recommended districts for parking repurpose in Stuttgart and results from GIS-based raster analysis identifying optimal sites (Source: Authors)

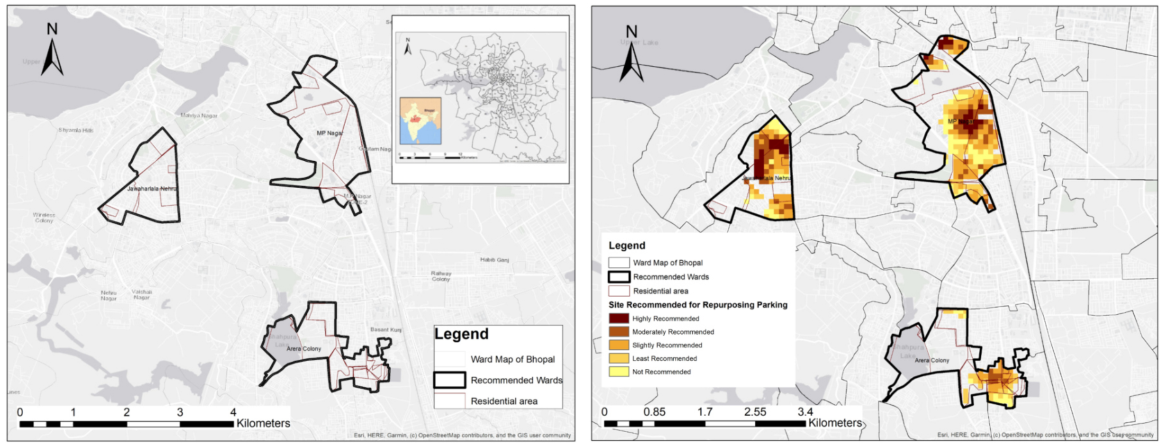

Figure 3: Map showing recommended districts for parking repurposes in Bhopal and results from GIS-based raster analysis identifying optimal sites (Source: Authors)

Comparative Analysis of Expert and AI Tool Responses: The comparative study of the human expert interviews and AI tool responses reveals that OpenAI provided expert-level responses for Stuttgart, drawing on readily available online data. However, for Bhopal, where online information was limited, the AI generated more general, though consistent, responses. This suggests GenAI's potential to accelerate land-use planning, especially in resource-limited contexts, though further GenAI development is needed for accuracy, particularly concerning private land information.

Outdoor Thermal Comfort Analysis: The outdoor thermal comfort analysis, specifically focusing on the Mean Radiant Temperature (T_{mrt}), revealed notable differences between the two study areas. Under existing conditions (Scenario 01), the average T_{mrt} ranged from 27°C to 38.5°C in Stuttgart, and from 32.8 °C to 46°C in Bhopal. Figures 4 and 5 depict the average mean radiant temperature under different scenarios in selected areas in Stuttgart and Bhopal respectively.

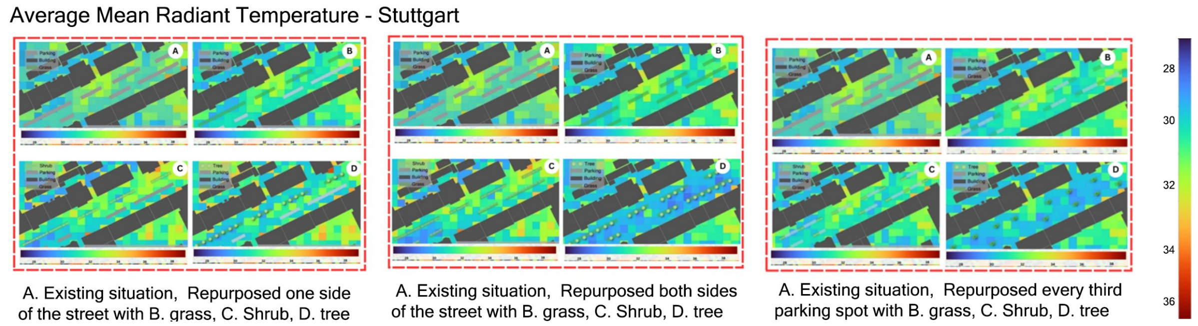

Figure 4: Average Mean Radiant Temperature assessed for Stuttgart

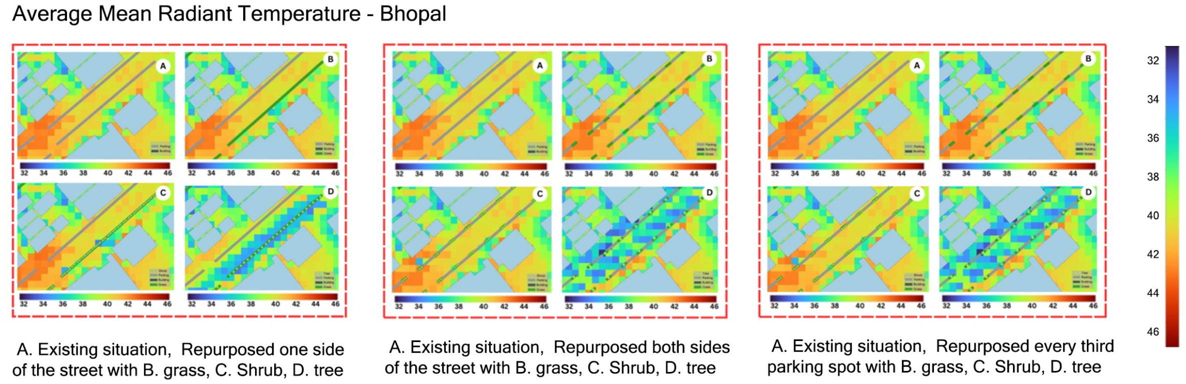

Figure 5: Average Mean Radiant Temperature assessed for Bhopal

Scenario and Green Measures	Reduction in T_{mrt} (°C)		Extent of Cooling Effect
	Stuttgart	Bhopal	
Repurposing one side of the parking with:			
Grass	0.4 to 0.72	0.2 to 2.68	Within 5 m (uniform effect)
Shrub	0.4 to 0.72	0.4 to 2.84	5 -10 m (uniform effect)
Tree	1.4 to 2.55	0.5 to 6.00	5 -15 (uniform effect)
Repurposing both sides of the parking with:			
Grass	0.4 to 0.72	0.2 to 2.68	5 -10 m (uniform effect)
Shrub	0.4 to 0.72	0.4 to 2.84	5 -15 m (uniform effect)
Tree	1.4 to 3.00	0.5 to 8.00	5 -20 m (uniform effect)
Repurposing every third parking with:			
Grass	0.4 to 0.72	0.2 to 2.68	Within 5 m (limited to the presence)
Shrub	0.4 to 0.72	0.4 to 2.84	Within 5 -10 m (limited to the presence)
Tree	1.4 to 1.60	0.5 to 4.00	Within 5 -15 m (limited to the presence)

Table 2: Mean radiant temperature reduction in selected areas in Bhopal and Stuttgart. Source: Authors

Table 2 presents the reduction in mean radiant temperatures relative to the existing condition (Scenario 01) in Bhopal and Stuttgart, following the implementation of green measures in the following configurations: one side (Scenario 02), both sides (Scenario 03), and every third parking space (Scenario 04).

Replacing both sides with native trees (Scenario 03) yielded the largest average temperature reductions: 3°C in Stuttgart and 8°C in Bhopal, with maximum reductions observed during peak hours, but slight increases at dawn/dusk due to canopy effects. While trees offer significant cooling, dense planting can impede wind flow; shrubs generally offer a broader cooling effect than grass. The interview-supported concept of greening every third parking spot showed the least temperature reduction in simulations, suggesting that a pilot program focused on this approach could help assess its real-world effectiveness and scalability.

4. Discussion

This study highlights the need for heat stress adaptation in small and medium-sized cities (SMCs) in Germany and India. The key findings show that converting just 3–4% of on-street parking into green areas, particularly with native trees, can significantly reduce mean radiant temperatures during peak hours, as demonstrated in Stuttgart and Bhopal. Repurposing parking presents a practical, localized solution, especially in space-constrained urban areas. This aligns with recent research suggesting that effective parking management can address broader urban challenges (Selzer, 2021; Sprei et al., 2020).

The thermal analysis results corroborate previous studies emphasizing the microclimatic benefits of urban vegetation. Kirschner et al. (2023) found that street trees influence land surface temperatures within a 60-meter radius, while grass affects a 10-meter radius—findings that support the cooling effects observed in this study. Similarly, Miao et al. (2023) reported that street trees can reduce physiological equivalent temperature (PET) by up to 2°C. Although these studies considered different variables, they validate the outcomes of this research Furthermore, existing literature provides contrasting insights into the effectiveness of large versus small green spaces. For example, Jaganmohan et al. (2016) noted that green spaces under 5.6 ha in Leipzig showed negligible temperature reduction, while a 0.49 ha area in Portugal achieved a 1°C decrease. The present study supports the notion that repurposing small urban areas can still produce moderate thermal benefits.

Despite its strengths, the study acknowledges several limitations. First, the focus on physical and environmental dimensions excludes comprehensive socio-political and economic analyses. Second, exclusive attention to on-street parking omits insights from off-street and shared parking systems due to limited data access. Third, while thermal comfort modelling provides useful theoretical insights, real-world applications may yield varied results, as the study employed standard emissivity, albedo, and average meteorological values. Future research should consider models that better reflect real-time environmental conditions. Finally, the AI component, while innovative, is constrained by current data limitations and lacks contextual nuance in contextual planning judgments, particularly in data-scarce regions like Bhopal.

Future heat stress adaptation planning should include the development of standardised criteria for identifying suitable on-street parking locations for repurposing and fostering inter-departmental coordination and community engagement through incentives and pilot projects. Encouraging public transport and car-sharing can further reduce parking demand and increase public acceptance of greening initiatives (Topp, 1991). Integrating "green parking" concepts into building codes and providing financial support can promote the greening of off-street parking, particularly in rapidly urbanising Indian cities. Future research should also examine social acceptance, legal frameworks, and conduct field validations to refine and implement these localised green infrastructure solutions—enhancing urban resilience and improving quality of life, in alignment with global sustainable development goals.

5. Conclusion and Outlook

This research demonstrates the critical potential of the mobility-related urban land use transformation, in contributing to national climate goals. Repurposing urban parking could be an effective strategic instrument in enhancing not only the thermal comfort but also improving the livability, public health by reducing environmental pollution and encouraging modal shift from private vehicles to sustainable mobility modes such as walking, cycling, and public transport.

Furthermore, the inclusion of digital tools, including GIS-based spatial analysis and GenAI models, underscores the transformative role of digitalisation in urban planning, besides the human-focused approaches of data collection. These tools provide data-driven outputs that can even have the potential to be applied in smart city initiatives and enhance the scalability of climate action strategies. The incorporation of these technologies, alongside experiments carried out in Stuttgart and Bhopal, closely aligns with the objectives of real-world laboratories and the advancement of self-sufficient, robust urban systems.

In conclusion, this study not only enhances the conversation on alleviating UHS but also offers a practical and interdisciplinary research approach for redesigning land use in the urban mobility sector to achieve local and global climate goals. Future planning should integrate these synergies to promote sustainable, climate-adaptive, and people-centric urban environments.

References

Anupriya, R. S., & Rubeena, T. A. (2023). Spatio-temporal urban land surface temperature variations and heat stress vulnerability index in Thiruvananthapuram city of Kerala, India. Geology, Ecology, and Landscapes, 0(0), 1–17. https://doi.org/10.1080/24749508.2023.2182088

Azhar, G., Saha, S., Ganguly, P., Mavalankar, D., & Madrigano, J. (2017). Heat Wave Vulnerability Mapping for India. International Journal of Environmental Research and Public Health, 14(4), Article 4. https://doi.org/10.3390/ijerph14040357

Barpete, K., & Mehrotra, S. (2023). Climate-Informed Planning through Mapping of Urban Thermal Load and Cooling Potential: Case of Tropical City of Bhopal. Journal of the Indian Society of Remote Sensing, 51(7), 1375–1391. https://doi.org/10.1007/s12524-023-01710-3

Birkmann, J., Sauter, H., Garschagen, M., Fleischhauer, M., Puntub, W., Klose, C., Burkhardt, A., Göttsche, F., Laranjeira, K., Müller, J., & Büter, B. (2021). New methods for local vulnerability scenarios to heat stress to inform urban planning—Case study City of Ludwigsburg/Germany. Climatic Change, 165(1), 37. https://doi.org/10.1007/s10584-021-03005-3

Birkmann, J., Welle, T., Solecki, W., Lwasa, S., & Garschagen, M. (2016). Boost resilience of small and mid-sized cities. Nature, 537(7622), 605–608. https://doi.org/10.1038/537605a

Bushra Saba, J. Y. (2021). The politics of green and blue space availability: Case of Bhopal. IOP Conference Series: Earth and Environmental Science

EPA. (2023). Retrieved from https://www.epa.gov/heatislands/heat-island-impacts#:~:text=Heat%20islands%20contribute%20to%20higher,and%20non%2Dfatal%20heat%20stroke

Ghosh, S. (2019). A city growth and land-use/land-cover change: A case study of Bhopal, India. Modeling Earth Systems and Environment, 5. https://doi.org/10.1007/s40808-019-00605-y

ICLEI. (2021, April). Retrieved from https://southasia.iclei.org: https://southasia.iclei.org/wp-content/uploads/2022/01/Heat-Resilience-Toolkit.pdf

Jaganmohan, M., Knapp, S., Buchmann, C. M., & Schwarz, N. (2016). The Bigger, the Better? The Influence of Urban Green Space Design on Cooling Effects for Residential Areas. Journal of Environmental Quality, 45(1), 134–145. https://doi.org/10.2134/jeq2015.01.0062

Jain, S., Kumar, A., Jaiswal, D. R. K., & Nayak, D. T. R. (2019). Land Use Dynamics of Bhopal City Using Free & Open Source Geospatial Techniques.

Kabisch, N., Remahne, F., Ilsemann, C., & Fricke, L. (2023). The urban heat island under extreme heat conditions: A case study of Hannover, Germany. Scientific Reports, 13(1), 23017. https://doi.org/10.1038/s41598-023-49058-5

Ketterer, C., & Matzarakis, A. (2015). Comparison of different methods for the assessment of the urban heat island in Stuttgart, Germany. International Journal of Biometeorology, 59(9), 1299–1309. https://doi.org/10.1007/s00484-014-0940-3

Kirschner, V., Macků, K., Moravec, D., & Maňas, J. (2023). Measuring the relationships between various urban green spaces and local climate zones. Scientific Reports, 13(1), 9799. https://doi.org/10.1038/s41598-023-36850-6

Landeshauptstadt Stuttgart. (2024). Retrieved from Landeshauptstadt Stuttgart: https://www.domino1.stuttgart.de/web/komunis/komunissde.nsf/fc223e09e4cb691ac125723c003bfb31/4e6620005e228f76c12584d300483532/$FILE/bs701_.PDF

McAslan, D., & Sprei, F. (2023). Minimum parking requirements and car ownership: An analysis of Swedish municipalities. Transport Policy, 135, 45–58. https://doi.org/10.1016/j.tranpol.2023.03.003

Megahed, A. S. H., & Srikantaswamy, S. (2020). Study of the Indicators of Climate Change in Mysore District, Karnataka, India. Atmospheric and Climate Sciences, 10(2), Article 2. https://doi.org/10.4236/acs.2020.102008

Miao, C., Li, P., Huang, Y., Sun, Y., Chen, W., & Yu, S. (2023). Coupling outdoor air quality with thermal comfort in the presence of street trees: A pilot investigation in Shenyang, Northeast China. Journal of Forestry Research, 34(3), 831–839. https://doi.org/10.1007/s11676-022-01497-y

MoHUA. (2019). Retrieved from Integrated Research and Action for Development: https://irade.org/Sustainable%20and%20Disaster%20Resilient%20Urban%20DevelopmentFinal%20.pdf

Narváez Vallejo, A., & Schwarz-v.Raumer, H.-G. (2023). Do Green Infrastructure Types Represent Land Surface Temperature? A Case Study of Stuttgart. Wichmann Verlag. https://doi.org/10.14627/537740012

NIDM. (2021). HEALTH ADAPTATION AND RESILIENCE TO CLIMATE CHANGE AND RELATED DISASTERS. Retrieved from https://nidm.gov.in/PDF/pubs/NIDM_HealthAdaptation.pdf

Ojha, S. K., & Mukherjee, M. (2024). Assessing the potential of heat stress mitigation in asymmetrical street conditions of Bhopal city. Theoretical and Applied Climatology, 155(9), 8825–8842. https://doi.org/10.1007/s00704-024-05175-3

Rinke, R., Kapp, R., Reuter, U., Ketterer, C., Fallmann, J., Matzarakis, A., & Emeis, S. (2016). Pilot Actions in European Cities – Stuttgart (pp. 281–303). https://doi.org/10.1007/978-3-319-10425-6_10

Seeberg, G., Hostlowsky, A., Huber, J., Kamm, J., Lincke, L., & Schwingshackl, C. (2022). Evaluating the Potential of Landsat Satellite Data to Monitor the Effectiveness of Measures to Mitigate Urban Heat Islands: A Case Study for Stuttgart (Germany). Urban Science, 6(4), Article 4. https://doi.org/10.3390/urbansci6040082

SKMCCC. (2023). Bhopal City Climate Action Plan. Retrieved from https://epco.mp.gov.in/uploads/media/Bhopal_ES.pdf

Sprei, F., Hult, C., Hult, Å., & Roth, A. (2020). Review of the Effects of Developments with Low Parking Requirements. Sustainability, 12(5), Article 5. https://doi.org/10.3390/su12051744

Topp, H. (1991). Parking policies in large cities in Germany. Transportation, 18, 3–21. https://doi.org/10.1007/BF00150556

UMEP. (2018). httpsumep-docs.readthedocs.io/projects/tutorial/en/latest/Tutorials/IntroductionToSolweigNYC.html.

Wendnagel-Beck, A., Jamshed, A., Iqbal, N., Ravan, M., McMillan, J., & Birkmann, J. (2023). Exploring the link between socio-economic and physical structure in cities to inform heat adaptation options: The case of Stuttgart. 2023 Joint Urban Remote Sensing Event (JURSE), 1–4. https://doi.org/10.1109/JURSE57346.2023.10144129

Wendnagel-Beck, A., Ravan, M., Iqbal, N., Birkmann, J., Somarakis, G., Hertwig, D., Chrysoulakis, N., & Grimmond, S. (2021). Characterizing Physical and Social Compositions of Cities to Inform Climate Adaptation: Case Studies in Germany. Urban Planning, 6(4), 321–337. https://doi.org/10.17645/up.v6i4.4515

Wollschläger, N., Zinck, F., & Schlink, U. (2022). Sustainable Urban Development for Heat Adaptation of Small and Medium Sized Communities. Land, 11(9), Article 9. https://doi.org/10.3390/land11091385

WRI. (2023). Retrieved from https://www.wri.org/insights/future-extreme-heat-cities-data

Zhao, L., Oppenheimer, M., Zhu, Q., Baldwin, J. W., Ebi, K. L., Bou-Zeid, E., Guan, K., & Liu, X. (2018). Interactions between urban heat islands and heat waves. Environmental Research Letters, 13(3), 034003. https://doi.org/10.1088/1748-9326/aa9f73

Annexures

Annexure 1A -Summary of the result of the interview with officials conducted in different cities of Germany

On- Street Parking	Stuttgart	Mannheim	Karlsruhe	Ludwigshafen
Factors in planning on-street parking	Existing street space, Conflict with other requirements, Availability of Public Transport and off-street spaces, Desired use of the street.	Demand for other modes of transport - walking or cycling, Number of residential units and its type, Availability of Public Transport.	Number of Residential units and building type, Mixed land use, Resident parking permit request, duration and fee	Number of Residential units and building type, Mixed land use, Resident parking permit request, duration and fee
Green concepts in parking policies	Tree Planting and pervious pavement	Tree Planting	Tree planting, green curbs, or buffers	Rain Gardens, Tree planting, Green curbs or buffers
Changes in on-street parking regulations	Reduced the number of parking spaces and duration. Increased parking fee Included green concept	Reduced the number of parking spaces. Increased parking fee	Reduced the number of parking spaces, Included green concepts, Dismantling or reallocation for other uses such as bicycle parking	Reduced parking duration, Introduced or increased parking fee
Recommendation for reducing on-street parking for green spaces	Recommended	Mixed Opinion on Repurposing	Yes, highly recommended	Recommended
Suggested areas for repurpose parking spaces	Mitte, Nord,Ost, West, Süd, Badcanstatt	Innenstadt/Jungbusch	Innenstadt-Ost, Innenstadt-West, Weststadt, Nordweststadt, Oststadt, Mühlburg	Nord/Hemshof, Oggersheim, Mitte
Issues caused by on-street parking in residential areas	Lack of space for green concepts/ footway/bike lane	Lack of space for green concepts/ footway/bike lane, High Heat stress due to more sealed surfaces	Lack of space for green concepts/ footway/bike lane	Lack of space for green concepts/ footway/bike lane, Noise or Air Pollution
Concepts recommended for repurposing parking	A combination of green space and parking	A combination of green space and parking	A combination of green space and parking	A combination of green space and parking

Off-Street Parking	Stuttgart	Mannheim	Karlsruhe	Ludwigshafen
Minimum parking requirements per housing unit	1 or less than 1 per housing unit	1 parking spot per housing unit	1 parking spot per housing unit	1 or 1 -2 per housing unit
Reduction factors for off-street parking requirements	Depends on location and public transport availability. Most residential areas are exempt from the 30% reduction, but new developments already include it.	Reduction of 0.8 per house examined but lead to political controversy	Reduction based on public transport accessibility	Reduction based on public transport accessibility
Recommendation for reducing off-street parking for green spaces	Yes, possible only in new/ renovated developments, but it is recommended to keep as it already suggested to include green measures.	Not recommended	Yes, recommended only in new/renovated developments	Yes, recommended in existing, new/renovated developments
Suggested housing areas/neighbourhoods	Mitte, Nord,Ost, West, Süd, Badcanstatt		Innenstadt-Ost, Innenstadt-West, Weststadt, Oststadt, Mühlburg	Mitte, west, Süd
Differences in parking rules for new/renovated units	Yes, reduced the Minimum parking requirements and included green concepts	Yes, reduced the Minimum parking requirements	Yes, reduced the Minimum parking requirement	No changes, but included green concepts
Green concepts in off-street parking policies	Pervious Pavement and Green roof	Pervious Pavement and Green roof	Pervious Pavement and Green roof	Pervious Pavement and Green roof

Annexure 1B Summary of the result of the interview with officials conducted in different cities of India

On- Street Parking	Bhopal	Thiruvananthapur-am	Ernakulam	Mysuru
Factors in planning on-street parking	No of residential units Building type Mixed Land use	No of residential units Building type, Mixed Land use	No of residential units Building type Mixed Land use Parking duration and fee	No of residential units Building type Mixed Land use Parking duration and fee
Green concepts in parking policies	No green concepts included	Tree Planting but mostly no green concepts	No green concepts included	No green concepts included
Changes in on-street parking regulations	No change proposed	Reduced the number of parking spaces, Included green concepts, Introduced or increased parking fees	No change proposed	No change proposed
Recommendation for reducing on-street parking for green spaces	Highly Recommended	Mixed opinions	Highly Recommended	Recommended
Suggested areas for repurpose parking spaces	New Market area, MP Nagar, Arera colony	Thampanoor, Overbridge, Kazhakoottam, Pattom	Panampilly Nagar, Deshabhimani road, Kasturba Nagar Kakkanad, Thripunithura, Paliyam road, Gandhinagar road	Kuvempu Nagar, J P Nagar and Lakshmipuram
Issues caused by on-street parking in residential areas	Lack of space for green concepts/ footway/ bike lane, High heat stress, Air pollution, Higher emissions	Lack of space for green concepts/ footway/ bike lane, Noise and air pollution	Lack of space for green concepts, High heat stress	Lack of space for green concepts, High heat stress Noise and Air Pollution and Higher emission
Concepts recommended for repurposing parking	A combination of green and parking	A combination of green space and parking	One side of the road	A combination of green space and parking

Off-Street Parking	Bhopal	Thiruvananthapuram	Ernakulam	Mysuru
Minimum parking requirements per housing unit	1 per 100-150 sq.m	1 per 100-150sq.m	1 per 100-150sq.m	1 per 100-150sq.m An additional 10% of the total parking supply must be allocated for visitors.
Reduction factors for off-street parking requirements	N/a	30% reduction	30% reduction	N/a
Recommendation for reducing on-street parking for green spaces	Yes, recommended only in new/renovated developments	Mixed opinions	Not recommended	Yes, recommended only in new/renovated developments
Suggested housing areas/neighbourhoods	Kolar Road, Bhopal, private housing colonies	Reduced MPR in some places	Not possible in congested cities like Kochi	Areas in the city's historical core
Differences in parking rules for new/renovated units	No change proposed	Yes, Adopted Parking Maximums	Reduced the MPR	No changes

Annexure 1C - Summary of the comparison of on-street parking interview results between OpenAI and officials

On-street Parking	Stuttgart		Bhopal	
	Human	GenAI Agent	Human	GenAI Agent
Factors in planning on-street parking	Existing street space, Conflict with other requirements, Availability of Public Transport and off-street spaces, Desired use of the street.	Number of residential units, Building type, Availability of public transportation options, Presence of nearby off-street parking, Mixed land use, Resident parking permit requests, Parking duration and parking fees	No of residential units Building type Mixed Land use	Number of residential units, building type, Availability of public transportation options, Presence of nearby off-street parking, Mixed land use, Resident parking permit requests, Parking duration and parking fee.
Green concepts in parking policies	Tree Planting and pervious pavement	Tree Planting and pervious pavement	No green concepts included	Tree planting, permeable pavements, no green concept included in most established areas.
Changes in on-street parking regulations	Reduced the number of parking spaces and duration. Increased parking fee Included green concept	Introduction or increase of parking fees	No change proposed	No major reductions in parking spaces have been proposed so far.
Recommendation for reducing on-street parking for green spaces	Recommended	Highly Recommended	Highly Recommended	Recommended
Suggested areas for repurpose parking spaces	Mitte, Nord,Ost, West, Süd, Bad Cannstatt	Stuttgart-Mitte, Stuttgart-West, Stuttgart-Ost, Bad Cannstatt, Vaihingen	New Market area, MP Nagar, Arera colony	MP Nagar, Arera Colony, Kolar Road, Shahpura, Hoshangabad Road
Issues caused by on-street parking in residential areas	Lack of space for green concepts/ footway/bike lane	Lack of space for green concepts, High heat stress due to sealed surfaces, Noise and air pollution	Lack of space for green concepts/ footway/ bike lane, High heat stress and emissions, Air pollution	Lack of space for green concepts, High heat stress due to sealed surfaces, Noise and air pollution
Concepts recommended	A combination of green space and parking	A combination of green space and parking	A combination of green space and parking	A combination of green space and parking

Annexure 1 D - Summary of the comparison of off-street parking interview results between OpenAI and officials

Off-street Parking	Stuttgart		Bhopal	
	Human	GenAI Agent	Human	GenAI Agent
Minimum parking requirements per housing unit	1 or less than 1 per housing unit	1 parking spot per housing unit is typically required	1 per house	1-2 parking spots per housing unit
Reduction factors for off-street parking requirements	Depends on location and public transport availability. Most residential areas are exempt from the 30% reduction, but new developments already include it.	In cases where alternative mobility options are available, a reduction of up to 50% of the required parking spaces may be applied.	N/A	Reduction of up to 30% is possible in areas with good access to public transportation or shared mobility options.
Recommendation for reducing on-street parking for green spaces	Yes, possible only in new/renovated developments, but it is recommended to keep as it already suggested to include green measures.	Yes, recommended, especially in new or renovated developments.	Yes, recommended only in new/renovated developments	Yes, recommended in new/renovated developments.
Suggested housing areas/neighbourhoods	Mitte, Nord,Ost, West, Süd, Bad Cannstatt	Stuttgart-Mitte, Stuttgart-West, Bad Cannstatt, Vaihingen, Zuffenhausen	Kolar Road, Bhopal, private housing colonies	MP Nagar, Arera Colony, Kolar Road, Shahpura, Hoshangabad Road
Differences in parking rules for new/renovated units	Eliminated MPRs and included green concepts	Reduced minimum parking requirements, Adoption of parking maximums	No change proposed	No change proposed
Green concepts in off-street parking policies	Pervious Pavement and Green roof	Pervious Pavement and Green roof	No concepts included	No concepts included

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Annexure 2 : Indicators, normalized and reclassified values for the site selection analysis

Sl no	Indicators	Stuttgart	Bhopal	Normalized values	Reclassification (5 being the highest and 1 the lowest)
1	Land Surface Temperature (LST in °C)	26-30	28 to 33.5	less than 0.2	1
		30-34	33.5-39	>0.2-0.4	2
		34-38	39 - 44.5	>0.4-0.6	3
		38-42	44.5-50	>0.6-0.8	4
		42-47	50-55.4	>0.8-1	5
2	Normalized Difference Vegetation Index (NDVI)	0 to 0.2	0 to 0.18	less than 0.2	5
		0.2 to 0.4	0.18 to0.28	>0.2-0.4	4
		0.4-0.6	0.28 to 0.38	>0.4-0.6	3
		0.6-0.8	0.38 to 0.48	>0.6-0.8	2
		0.8- 0.9	0.48 to 0.60	>0.8-1	1
3	Sky View Factor (SVF)	0 to 0.15	0 to 0.2	less than 0.2	1
		>0.15-0.30	>0.2-0.4	>0.2-0.4	2
		>0.30-0.45	>0.4-0.6	>0.4-0.6	3
		>0.45-0.60	>0.6-0.8	>0.6-0.8	4
		>0.6- 0.80	>0.8-1	>0.8-1	5
4	Slope (%)				
		less than 5	0 to3	less than 0.2	5
		>5-10	3 to 6	>0.2-0.4	4
		>10-15	6 to 9	>0.4-0.6	3
		>15-20	9 to 12	>0.6-0.8	2
		>20-26	12 to 16	>0.8-1	1
5	Proximity to Public Transport stations (m)	100	100	less than 0.2	5
		200	200	>0.2-0.4	4
		300	300	>0.4-0.6	3
		400	400	>0.6-0.8	2
		500	500	>0.8-1	1
6	Proximity to Social and critical infrastructure (m) (School, Hospital, Kindergarten, Nursing home)	100	100	less than 0.2	5
		200	200	>0.2-0.4	4
		300	300	>0.4-0.6	3
		400	400	>0.6-0.8	2
		500	500	>0.8-1	1
7	Proximity to green areas (m) (Parks, Forest)	100	100	less than 0.2	1
		200	200	>0.2-0.4	2
		300	300	>0.4-0.6	3
		400	400	>0.6-0.8	4
		500	500	>0.8-1	5

Examining Race and Class Disparities in Urban Heat in Australia: Towards Environmental Justice in Urban Planning

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Abstract

Environmental (in)justice driven by climate change and urbanization leads to unevenly distributed impacts, disproportionately affecting marginalized communities. While studies in the United States highlight greater heat exposure among low-income and ethnic minority groups within a single municipality, similar studies are limited for other countries. This knowledge gap restricts a holistic understanding of environmental (in)justice in cities and hinders the development of effective urban planning policies. This research integrates social and environmental sciences to explore the relationship between extreme heat and socio-economic disparities in Australia. Using satellite-derived land surface temperature and Census data from the Australian Bureau of Statistics, the study assesses varying heat exposures within one municipality across different socio-economic groups including education levels, age distribution, and foreign-born populations. Additionally, it examines various urban-planning parameters such as population density, NDVI, and albedo to analyze their distribution among different segments of society. Australia presents a pertinent case study due to its diverse socio-economic landscape and Indigenous communities. By identifying the unequal distribution of urban heat and its disproportionate effects on vulnerable groups, this study underscores the need for governance frameworks and planning strategies that prioritize environmental justice. It highlights the role of participatory and interdisciplinary approaches in shaping equitable urban policies. Addressing these disparities through innovative urban governance and sustainable planning is critical for fostering climate resilience and social equity. The findings offer insights not only for Australia but also serve as a blueprint for analyzing environmental justice aspect in urban heat disparities globally.

1. Introduction

Urban areas are increasingly experiencing the impacts of climate change, with urban heat emerging as a growing environmental and public health threat. As cities expand and densify, natural landscapes are often replaced by impervious surfaces and structures, altering land cover and reducing vegetation. This intensifies heat absorption and retention, leading to significantly warmer conditions in urban environments compared to their rural surroundings — a phenomenon known as the urban heat island (UHI) effect (Oke, 1973; Pappalardo et al., 2023). Using satellite imagery to study Land Surface Temperature (LST) provides extensive spatial coverage, even in areas lacking ground-based measurements. Over the past years, these data have been commonly employed for analyzing Surface Urban Heat Islands (SUHI) (Krikau and Benz, 2025). However, comparability is better during nighttime than daytime and one must note that both temperature metrics represent different, but related physical parameters (Naserikia et al., 2024).

In Australia, the impacts of rising temperatures are alarming. Since 1910, average temperatures have increased by 1.47±0.24,°C, and further warming is projected in the coming decades (Bureau of Meteorology, 2025). Heatwaves are becoming more frequent and severe, posing serious risks to both public health and economic stability (Zhang et al., 2020). Elevated temperatures are attributed to cause over 100 deaths annually in Sydney alone (Chaston et al., 2022). The 2009 heatwave in southeastern Australia resulted in over 300 excess deaths, highlighting the deadly consequences of

extreme heat (Loughnan et al., 2012; World Health Organization and World Meteorological Organization, 2015).

The intra-city variability in urban heat is increasingly recognized as a concern for environmental justice. Not all communities are affected equally by elevated temperatures. Numerous studies, particularly from the United States, show that marginalized and disadvantaged communities — such as low-income groups and racial minorities are often more exposed to higher urban temperatures (Mitchell and Chakraborty, 2018; Benz and Burney, 2021; Hsu et al., 2021). A holistic understanding of environmental justice in terms of urban heat still lacks for most countries of the world including Australia, hindering equitable urban planning and policies.

Through this study, we seek to address the key gap by analyzing disparities in nighttime land surface temperatures (LST) across 36 Significant Urban Areas (SUAs) in Australia. By integrating satellite-derived temperatures with spatial demographic information, the research investigates whether urban heat exposure correlates with socioeconomic and demographic factors such as nationality, education, age, and Indigenous identity — and to what extent these disparities can be explained by income. The study also explores the role of urban characteristics — specifically vegetation, surface reflectivity, and population density in shaping these heat exposure patterns.

2. Data and Methods

2.1 Socioeconomic and demographic data

To analyze their disparate exposure to heat, it is essential to study the spatial distribution of various population groups, particularly disadvantaged sections of society such as foreigners, Indigenous, elderly, populations with low level of education and low-income groups. Census data for 2021 were obtained from the Australian Bureau of Statistics (ABS) at the Statistical Area 2 (SA2) level of census data division. SA2 are medium-sized neighborhoods which represent a community (Australian Bureau of Statistics, 2021a). Each SA2 is located within a Significant Urban Area (SUA), allowing aggregation of the SA2-level information within each SUA. Each SUA represents an urban center or a group of urban centers with an urban population more than 10,000 (Australian Bureau of Statistics, 2021b). This study focuses on SUAs that comprise at least four developed SA2 regions, covering a total of 36 SUAs (see figure 1 top left) including Sydney, Melbourne, Brisbane and Perth.

The following socioeconomic and demographic variables were retrieved for the year 2021 for each analyzed SA2-level:

- Income: The median weekly income of households in AU$. • Share of foreigners: calculated as the percentage of foreign born population compared to the total population of each respective SA2.
- Share of educated: calculated as the percentage of population with at least 12 years of schooling compared to the total population of each respective SA2.
- Share of elderly: calculated as the percentage of population aged 75 and over (i.e. sum of population aged 75–84 years and those aged 85 years and over) compared to the total population of each respective SA2.
- Share of Indigenous: calculated as the percentage of people who identified themselves as Indigenous population compared to the total population of each respective SA2.
- Population density for each SA2: calculated by dividing the total population by the area of the urban and built-up lands of respective SA2.

2.1.1 Land Surface Temperature

Land Surface Temperature (LST) data were obtained from the MODIS Terra Land Surface Temperature and Emissivity Daily Global 1 km product MOD11A1 Version 6.1 (Wan, 2021), processed through Google Earth Engine (Gorelick et al., 2017). To ensure data quality, contaminated pixels were removed using the MOD11A1 quality assurance (QA) flags. Cloud-free pixels with an associated error

< 2K were aggregated for the summer months (December to February) for the years surrounding the year of the census (1 Dec 2019 to 28 February 2023), and for the corresponding periods in the subsequent two years. 90th percentile of daily LST was computed, for both daytime (around 10 am.) and nighttime (around 10 pm.) observations.

Many SA2 contain not only built up areas but also surrounding rural areas. Hence, to gather LST only where people live, the MODIS Landcover dataset MCD12Q1 Version 6.1 (NASA EOSDIS Land Processes DAAC, 2023) was used to retain only the pixels classified as urban and built-up lands (class 13) in the International Geosphere-Biosphere Programme (IGBP) classification. Urban LST values were extracted by spatially averaging across each SA2 and exported as a csv file.

2.1.2 Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) was used as a proxy for vegetation cover and urban greenness. We used monthly NDVI data from the MODIS Terra Vegetation Indices product (MOD13A3, 6.1) (Didan, 2021), accessed via Google Earth Engine. To ensure data quality, only pixels flagged as good or marginal quality (i.e., reliability values of 0 or 1) were retained using a quality assurance (QA) mask. Non-vegetated areas were excluded by masking NDVI values below 0.1. We calculated 90th percentile of NDVI over the same data range (i.e. summers for the years December 2019 to February 2023) as LST, taking again the spatial mean over all urban and built-up areas within each SA2.

2.1.3 Black-Sky Albedo

Black-Sky Albedo data were obtained from the MODIS MCD43A3 Version 6 product (Schaaf and Wang, 2021), accessed via Google Earth Engine (GEE). Although Albedo tends to exhibit low seasonal variability, the 90th percentile mean albedo (QA-filtered for good/marginal pixels) was combined only for summer months December 2019 to February 2023 to ensure temporal consistency with both NDVI and LST datasets. Similarly it was aggregated spatially by taking the mean of all urban and built-up areas only for each SA2.

2.2 Data Analysis

2.2.1 Calculating Intensity

In order to be able to compare physical parameters between the individual SUAs in spite of them being located in vastly different climates, we rescaled the temperature and urban planning parameters (LST, NDVI, albedo and population density) of all SA2s to center around the respective SUAs average. We call the resulting parameters intensities which are comparable across Australia, irrespective of their geographical location and local circumstances, as the normalized values represent a deviation from their respective local (SUA) mean.

More precisely, e.g., the LST data at SA2 level was aggregated to compute the mean daytime and nighttime LST for each SUA level. This SUA-level mean LST was then used to get the meancentered LST values for each SA2 and calculate what we call LST intensity. The mean-centered LST was calculated using the following equation:

$$LST_{intensity,SA2} = LST_{SA2} - LST_{SUA} \quad (1)$$

where $LST_{intensity,SA2}$ is the mean-centered LST for an SA2, LST_{SA2} is the original LST value

for the SA2, and LST_{SUA} is the mean LST of the corresponding SUA.

Similarly, mean-centering was done for NDVI as well as Black-Sky Albedo to get NDVI intensity, BSA intensity and population density (PD) intensity, thus controlling for local variation.

2.2.2 Calculating Disparities

The methodology for our study is adapted from (Benz and Burney, 2021). For each SUA, all areas were divided into four quartiles based on each studied socioeconomic and demographic variable (income, share of foreigners, share of educated, share of elderly and share of Indigenous). For each variable and quartile, mean daytime and mean nighttime LST intensities were calculated. To check for any existing disparities, the LST intensity difference (Δ LST intensity) of the highest and lowest quartiles (temperature of Quartile 4 minus temperature of quartile 1) was calculated for daytime and nighttime. A two-sample t-test with a significance value of $P < 0.05$ was performed to find SUAs with statistically significant disparities in LST intensity across quartiles. As nighttime LST shows a higher correlation to air temperature (U.S. Geological Survey, 2021), and is thus more relevant for human well-being, the statistical significance is only shown for nighttime disparities.

To determine whether observed disparities are primarily economic or also influenced by racial and demographic factors, we controlled for income. Controlling for a variable removes its influence, allowing us to observe the independent effects of other variables.

We also analyzed the distribution of key urban planning drivers of surface heat variation and urban heat retention — specifically, Normalized Difference Vegetation Index (NDVI) intensity, Blacksky Albedo (BSA) intensity, and population density (PD) intensity — across the first (Q1) and last (Q4) quartiles for different socioeconomic and demographic groups. Understanding the distribution of these drivers is critical for interpreting whether heat disparities are systematic and reflect inequitable spatial planning.

3. Results and Discussion

3.1 Calculating Disparities in Heat

We analyzed the distribution of urban heat across different population groups by plotting the mean LST intensity for daytime and nighttime across quartiles of various socioeconomic and demographic variables for all SUAs. In the case of Sydney (figure 1), the highest income quartile (Q4) exhibits a 4.45°C lower daytime and 0.82°C lower nighttime LST intensity compared to the lowest income quartile (Q1), suggesting that lower-income communities are disproportionately exposed to higher urban heat. In Brisbane and Perth patterns are similar at daytime but more complex at night, in Melbourne high income locations have very slightly elevated temperatures compared to low income location at nighttime (approx. 0.15°C difference).

Conversely, the quartile with the highest share of foreigners (Q4) in Sydney experiences 3.24°C higher daytime and 0.98°C higher nighttime LST intensities relative to the quartile with the lowest share of foreigners (Q1), indicating greater heat exposure among migrant populations. Similar patterns emerge in Brisbane and Perth but are more complex in Melbourne.

Overall, in Sydney we see a consistent pattern of heat exposure disparities across socioeconomic and demographic groups (figure 1): More educated communities live in cooler neighborhoods at daytime and nighttime, and Indigenous communities are disproportionately affected by daytime urban heat. We do not find any indication that the elderly are disproportionally exposed to elevated LST intensity. On the contrary: Areas with a high share of elderly (Q4) have 3.09°C lower daytime and 0.72°C lower nighttime LST intensity, suggesting that elderly populations are likely residing in suburban areas with lower exposure to urban heat. However, individual SUAs show varying extends of disparities.

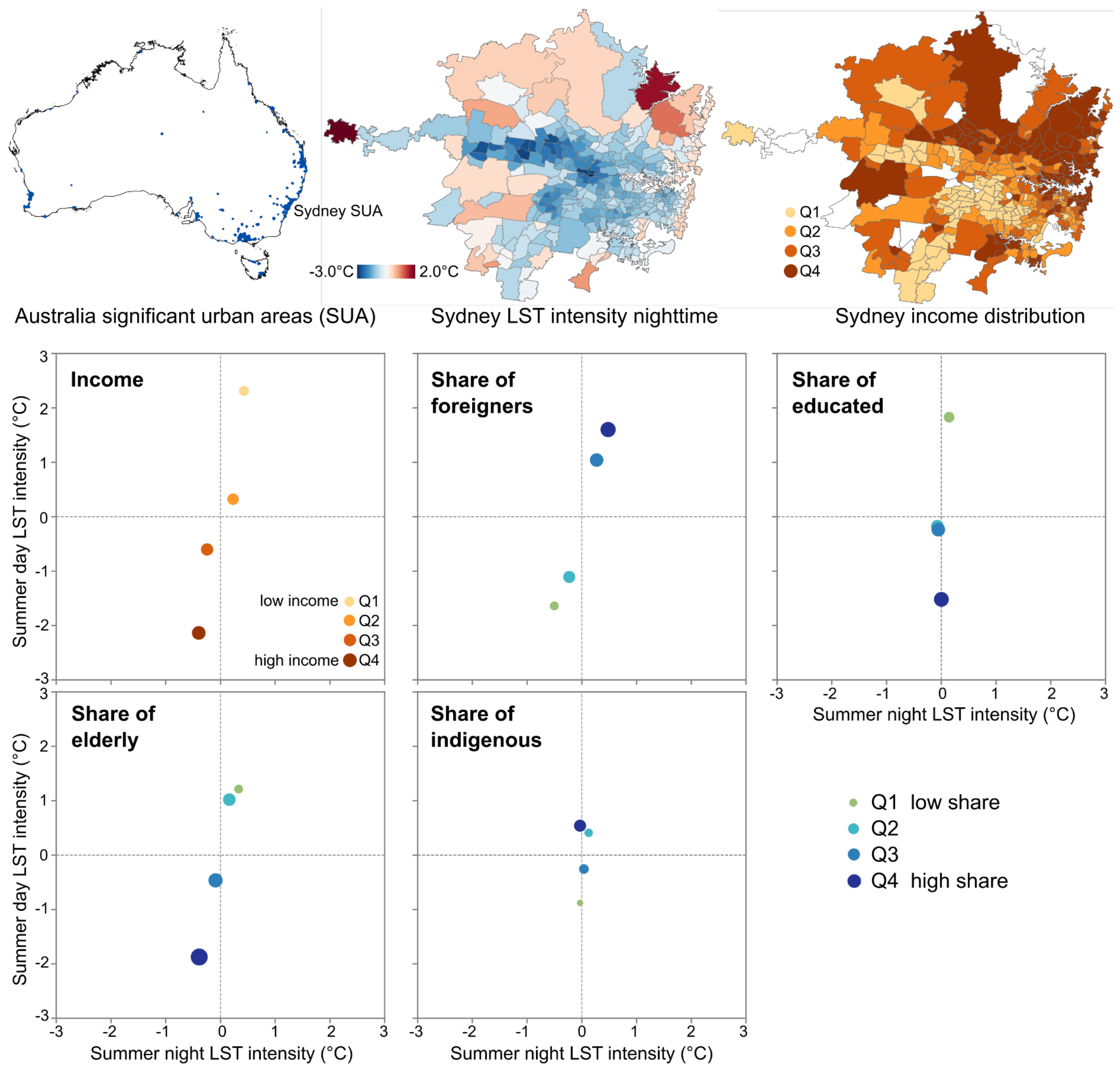

Figure 1: Significant Urban Area (SUA) in Australia - shown by the blue color on the top-left map. The top-middle map shows LST intensities within the significant urban area (SUA) of Sydney, blue represents SA2s with cooler temperatures, red with hotter temperatures as compared to the SUA mean. The top-right map shows income distribution, Q1 (light yellow) representing lowincome households, Q4 (brown) representing high-income households. The second row presents mean daytime and nighttime temperatures across income, share of foreigners, and share of educated population, grouped by quartiles. The third row shows the corresponding temperature distributions for the share of elderly and Indigenous populations, with Q1 represented in light green and Q4 in dark blue.

Extending the analysis to all 36 SUAs in Australia with at least four developed SA2s, the difference in LST intensity between the highest and lowest quartile (Q4-Q1) for all analyzed socioeconomic and demographic data is given in figure 2). To assess statistical significance of these differences, we applied a two-sided Mann–Whitney U test, suitable for small and potentially non-normally distributed samples. This test was conducted only for the subset of 17 SUAs where both the highest and lowest quartiles (Q4 and Q1) contained at least four data points each. We show the percentage of these SUAs exhibiting statistically significant disparities ($P < 0.05$) in either direction, (i.e. disadvantaged communities live in hotter or colder areas) for nighttime LST intensities. The results indicate that in Australia, 29.4 % of all SUAs show significant negative disparities in income which depicts that low-income populations face higher LST at nighttime. In only one SUA (Launceston) low-income

populations face significantly lower heat exposure at nighttime than their high-income neighboring communities.

Furthermore, in 29.4 % of SUAs, areas with a higher share of foreigners are exposed to significant higher nighttime LST than neighboring communities with a higher share of Australian-born populations. However, in 35.3 % of SUAs, areas with higher percentage of educated experience significantly greater heat exposure, indicating that populations with lower education level experience less heat. This may be due to highly educated populations working and living more often in densely populated city centers while populations with a lower education level often work e.g. in farming and live in more rural areas. Similarly, 23.5 % of SUAs with higher Indigenous populations experience significantly lower heat exposure at nighttime, potentially reflecting their location in less urbanized or cooler peripheral areas.

In 23.5 % of SUAs (e.g. Melbourne, Perth) nighttime heat exposure is significantly elevated in SA2s with a higher percentage of elderly populations. At the same time only one (i.e. Sydney) of all analyzed SUAs has significantly elevated nighttime LST in locations with a low share of elderly; As age correlates to risk of heat related illnesses (Faurie et al., 2022; Wang et al., 2012; Vaneckova et al., 2010), this is particularly concerning for the SUAs with positive disparities. However, children are equally at risk including concerning their education-successes (Sugg et al., 2016; Grubenhoff et al., 2007) implying that in Sydney, where elderly live in significantly cooler areas may be at risk of disadvantaging the opposite population group. One reason for the different exposures based on age may be the diverse correlation of age and wealth. Hence in the next step we test how much of the observed disparities are caused by the correlation of income and other sociodemographic variables.

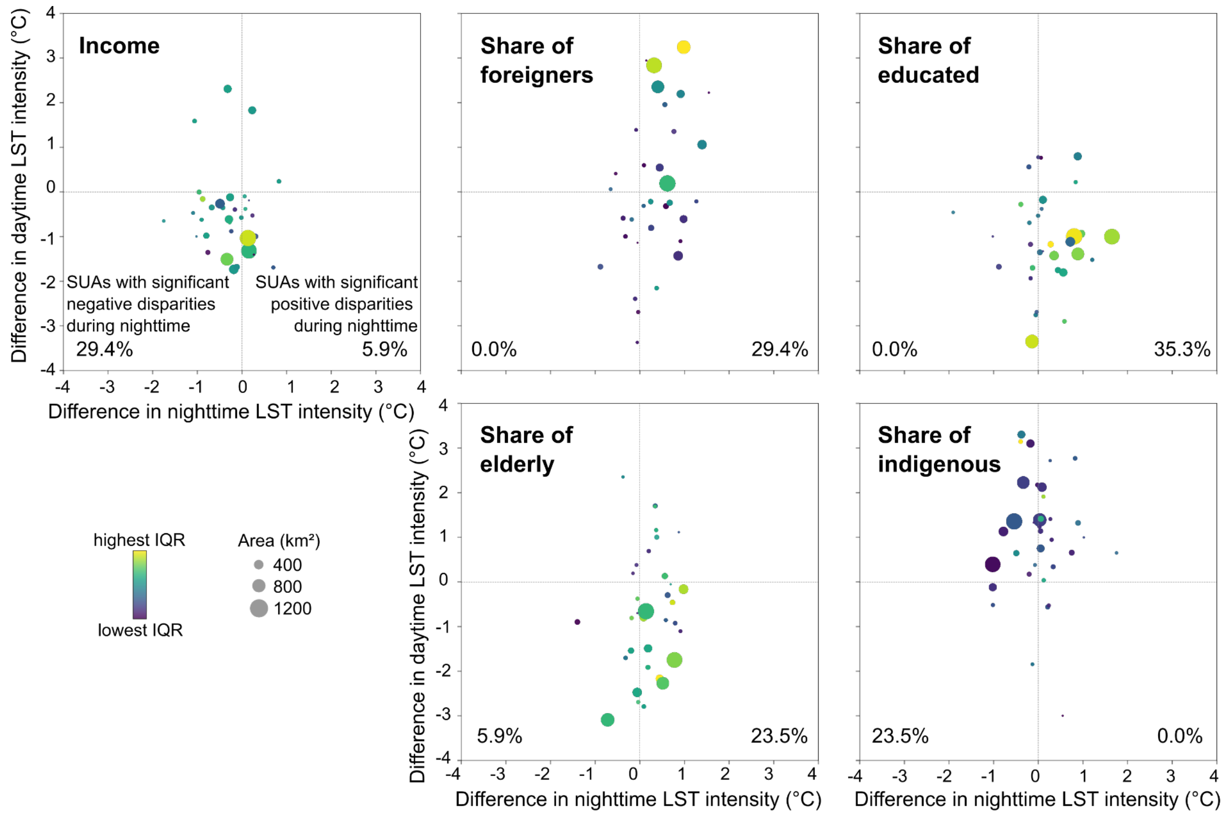

Figure 2: Difference in nighttime and daytime LST intensities (Q4-Q1) for all 36 SUAs based on socio-economic variables. Each dot represents the value of an LST intensity difference between first and last quartile in one SUA, the size of dot being proportional to the SUA area. The color represents the interquartile range (IQR) of the respective socio-economic variable. In the plots, the percentages on the bottom left show significant negative disparities and percentages on the bottom right show significant positive disparities calculated for 17 SUAs using Mann Whitney U test with a threshold at $P < 0.05$

3.2 Disparities after controlling for income

We assumed a linear relationship between income and LST intensity, the deviations between the predicted and the observed value are then calculated to get residuals which are again averaged over each quartile for the studied socio-demographic variables. They now represent true disparities associated with socio-demographics explicitly exuding any economic influence.

After controlling for income, (figure 3) the proportion of SUAs exhibiting significant disparities increased for several groups. Significant disparities in nighttime LST exposure related to the share of foreigners rose to 35.3 %, and those associated with the share of educated increased to 47.1 %, indicating that factors beyond income — such as racial and social — contribute to the differential heat exposure experienced by these groups. For Indigenous populations, the proportion of SUAs where they reside in significantly cooler areas decreased slightly to 17.6 %, suggesting that income explains part of the disparities, but additional non-economic factors likely contribute to the heat exposure inequalities faced by Indigenous communities.

In contrast, disparities related to the share of elderly did not change at all, suggesting that heat exposure disparities affecting elderly populations are predominantly driven by economic, class-based factors rather than racial or demographic characteristics.

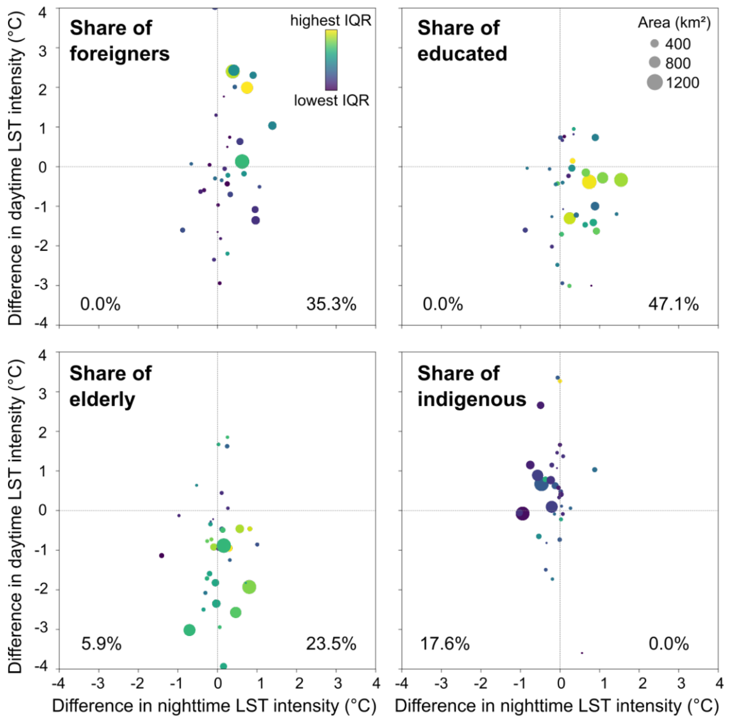

Figure 3: Difference in nighttime and daytime LST intensity (Q4-Q1) for all 36 SUAs based on socio-demographic variables, after controlling for income. Each dot represents the value of LST intensity difference between first and last quartile for one SUA, the size of dot being proportional to the SUA area. The color represents the interquartile range (IQR). In the plots, the percentages on the bottom left show significant negative disparities and percentages on the bottom right show significant positive disparities positive disparities calculated for 17 SUAs using Mann Whitney U test with a threshold at $P < 0.05$

3.3 Drivers of heat disparities

Various factors influence urban heat exposure, many of which are shaped by urban planning decisions. We analyzed the distributions of Normalized Difference Vegetation Index (NDVI) intensity, Blacksky Albedo (BSA) intensity, and population density (PD) intensity, focusing on the areas with the lowest (Q1) and highest (Q4) socio-economic and demographic quartiles across all SA2s in Australia. The distributions are studied prior to controlling for income.

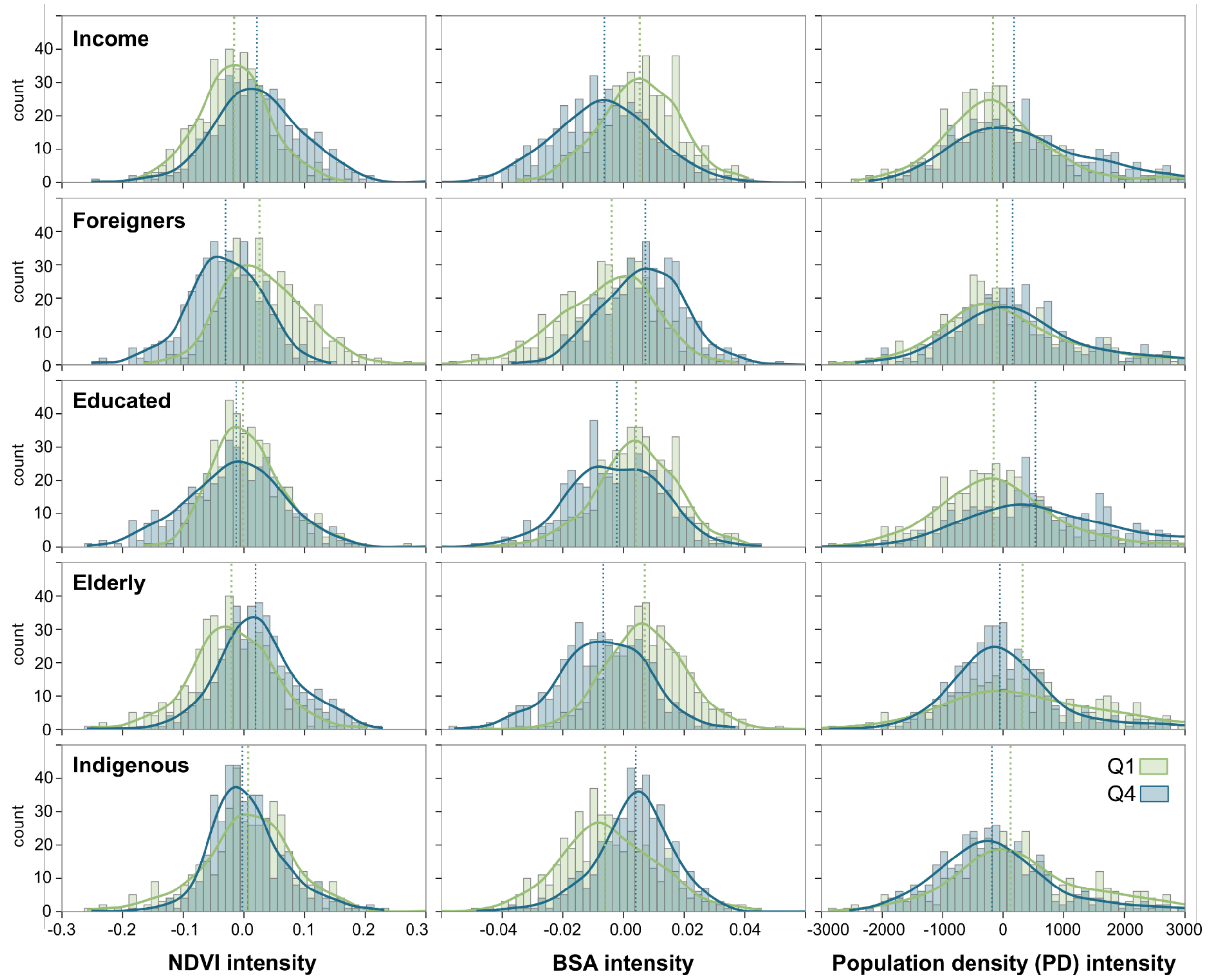

Figure 4: Distribution of drivers of heat disparities for areas with Q1 (light green) and Q4 (blue) quartiles across all SA2 in Australia for socio-economic and demographic variables. Each row represents the socioeconomic variable and columns represent the respective drivers namely NDVI intensity, BSA intensity and population density (PD) intensity. The bars show the histogram of the true data for the two groups, the curves represent the Kernel Density Estimation. The vertical dotted lines in the plots represent the median values of the two groups.

Figure 4 shows distribution for all studied census variables and urban design parameters. NDVI intensity is considerably less for low-income groups (0.04), areas with high share of foreigners (0.06), and areas with low share of elderly (0.04). For education and Indigenous quartiles, NDVI intensity does not show considerable variability. This implies that particularly the heat disparities foreign born population experience may be triggered by less vegetation in their neighborhood and can thus be corrected by urban planing decisions.

Unlike NDVI intensity, BSA intensity shows distinct patterns. Specifically, the median BSA intensity is higher for low-income groups (0.012), areas with a higher share of foreigners (0.010), low share of highly educated population (0.006), areas with lower elderly populations (0.013), and higher share of Indigenous populations (0.010). Since higher BSA indicates more reflective surfaces and less heat absorption, these results suggest that BSA intensity does not align with the elevated heat exposure typically experienced by these groups. Although the magnitude of these BSA intensity differences is relatively small, even minor average variations across large spatial scales can have meaningful effects on urban heat dynamics; however, localized impacts may be limited. Interestingly, socioeconomic groups that are generally more heat-exposed, such as low-income populations, exhibit slightly positive median BSA intensity values — indicating more reflective surfaces relative to their SUA averages. This counterintuitive pattern suggests that BSA intensity alone does not effectively capture the spatial inequalities in urban heat, and that other studied physical drivers — such as NDVI intensity and population intensity — appear to better explain the observed variations in heat exposure across different demographic groups.

PD intensity shows notable differences for all census variables with share of foreign born population leading to the lowest differences. Generally, high income populations live in more densely populated regions (difference of medians is 500 people per km²). This implies that generally population density and with it high building density is not the main driver of economic heat disparities, however this may still be the case in individual SUAs. A high share of foreign born populations however relates to a slightly higher population density (around 250 people per km² difference) which may also contribute to the high share of SUAs where these communities experience significantly higher nighttime LST. The difference in population density is highest when separating by share of highly educated. The median for highly educated is 800 people per km² more than the median for least highly educated. As there are no disparities in NDVI intensity for this group it implies that highly educated communities live in fact in the city center and are thus exposed to more urban heat, however they have generally no disadvantage in NDVI. Our analysis also reveals that locations with a high share of elderly are often in less densely populated areas (differences of medians is 700 people per km²), the same is true for Indigenous populations (390 people per km²), implying that exposure to urban heat is generally not the main driver of nighttime LST disparities for this sociodemographic variable. It is important to note that the situation in individual SUAs may vary.

4. Conclusion and Outlook

The findings contribute to the understanding of inequalities in urban heat exposure linked to socioeconomic and demographic factors in Australia. Foreign-born, educated and low-income populations are disproportionately exposed to higher nighttime temperatures. The results point to the need for equitable urban planning interventions that prioritize green infrastructure especially for vulnerable and marginalized neighborhoods to mitigate the unequal burden of urban heat.

This study also highlights the need for similar understanding of environmental justice globally for the development of a resilient future. However, our study also has certain limitations; first, we use LST, which is not directly experienced by humans but as it is statistically correlated with air temperature, particularly during nighttime, it works well as an indicator. Second, while NDVI is a widely used proxy for vegetation, it does not account for the accessibility, quality, or usability of green space. Furthermore, different types of green infrastructure may vary in their effectiveness at reducing urban heat.

Future research should investigate the temporal dynamics of these disparities - whether they are the result of natural climatic processes or systematic outcomes of urban policy and planning. A detailed understanding is essential for designing actionable, equity-driven responses to climate change.

5. Acknowledgement

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References

Australian Bureau of Statistics (2021a). Australian statistical geography standard (asgs): Edition 3 main structure and greater capital city statistical areas, july 2021 to june 2026 – statistical area level 2 (sa2). https://www.abs.gov.au/ statistics/standards/australian-statistical-geography-standard-asgs-edition-3/ jul2021-jun2026/main-structure-and-greater-capital-city-statistical-areas/ statistical-area-level-2. Accessed: 2025-05-26.

Australian Bureau of Statistics (2021b). Australian statistical geography standard (asgs): Edition 3 – significant urban areas, urban centres and localities, section of state, july 2021 to june 2026. https://www.abs.gov.au/statistics/standards/ australian-statistical-geography-standard-asgs-edition-3/ jul2021-jun2026/ significant-urban-areas-urban-centres-and-localities-section-state. Accessed: 2025-05-26.

Benz, S. A. and Burney, J. A. (2021). Widespread race and class disparities in surface urban heat extremes across the united states. Earth's Future, 9:e2021EF002016.

Bureau of Meteorology (2025). State of the climate. http://www.bom.gov.au/ state-of-the-climate/. Accessed: 2025-05-28.

Chaston, T. B., Broome, R. A., Cooper, N., Duck, G., Geromboux, C., Guo, Y., Ji, F., PerkinsKirkpatrick, S., Zhang, Y., Dissanayake, G. S., Morgan, G. G., and Hanigan, I. C. (2022). Mortality burden of heatwaves in sydney, australia is exacerbated by the urban heat island and climate change: Can tree cover help mitigate the health impacts? Atmosphere, 13(5):714.

Didan, K. (2021). Modis/terra vegetation indices monthly l3 global 1km sin grid v061. Accessed via Google Earth Engine.

Faurie, C., Varghese, B. M., Liu, J., and Bi, P. (2022). Association between high temperature and heatwaves with heat-related illnesses: A systematic review and meta-analysis. Science of the Total Environment, 852:158332.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., and Moore, R. (2017). Google earth engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202:18–27.

Grubenhoff, J. A., du Ford, K., and Roosevelt, G. E. (2007). Heat-related illness. Clinical Pediatric Emergency Medicine, 8(1):59–64.

Hsu, A., Sheriff, G., Chakraborty, T., and Manya, D. (2021). Disproportionate exposure to urban heat island intensity across major us cities. Nature Communications, 12:2721.

Krikau, S. and Benz, S. A. (2025). Temporal and spatial patterns of heat extremes in hesse, germany. Environmental Research Communications, 7(5):051001.

Loughnan, M. E., Nicholls, N., and Tapper, N. J. (2012). Mapping heat health risks in urban areas. International Journal of Population Research, 2012:1–12.

Mitchell, B. C. and Chakraborty, J. (2018). Exploring the relationship between residential segregation and thermal inequity in 20 us cities. Local Environment, 23(8):796–813.

NASA EOSDIS Land Processes DAAC (2023). Mcd12q1 modis/terra+aqua land cover type yearly l3 global 500 m sin grid v061. https://doi.org/10.5067/MODIS/MCD12Q1.061. Accessed 202505-28.

Naserikia, M., Nazarian, N., Hart, M. A., Sismanidis, P., Kittner, J., and Bechtel, B. (2024). Multicity analysis of satellite surface temperature compared to crowdsourced air temperature. Environmental Research Letters, 19(12):124063.

Oke, T. R. (1973). City size and the urban heat island. Atmospheric Environment (1967), 7(8):769– 779.

Pappalardo, S. E., Zanetti, C., and Todeschi, V. (2023). Mapping urban heat islands and heatrelated risk during heat waves from a climate justice perspective: A case study in the municipality of padua (italy) for inclusive adaptation policies. Landscape and Urban Planning, 238:104831.

Schaaf, C. and Wang, Z. (2021). Modis/terra+aqua brdf/albedo daily l3 global - 500m v061. Accessed via Google Earth Engine.

Sugg, M. M., Konrad, C. E., and Fuhrmann, C. M. (2016). Relationships between maximum temperature and heat-related illness across north carolina, usa. International journal of biometeorology, 60:663–675.

U.S. Geological Survey (2021). Monitoring and assessing urban heat island variations and effects in the united states. Fact Sheet 2021-3031, U.S. Geological Survey. Accessed: 2025-05-29.

Vaneckova, P., Beggs, P. J., and Jacobson, C. R. (2010). Spatial analysis of heat-related mortality among the elderly between 1993 and 2004 in sydney, australia. Social science & medicine, 70(2):293–304.

Wan, Z. (2021). Modis/terra land surface temperature/emissivity daily l3 global 1km sin grid v061. Accessed via Google Earth Engine.

Wang, X. Y., Barnett, A. G., Yu, W., FitzGerald, G., Tippett, V., Aitken, P., Neville, G., McRae, D., Verrall, K., and Tong, S. (2012). The impact of heatwaves on mortality and emergency hospital admissions from non-external causes in brisbane, australia. Occupational and environmental medicine, 69(3):163–169.

World Health Organization and World Meteorological Organization (2015). Heatwaves and health: Guidance on warning-system development. Technical report, World Health Organization, Geneva. Accessed: 2025-05-28.

Zhang, Y., Beggs, P. J., McGushin, A., Bambrick, H., Trueck, S., Hanigan, I. C., Morgan, G. G., Berry, H. L., Linnenluecke, M. K., Johnston, F. H., et al. (2020). The 2020 special report of the mja–lancet countdown on health and climate change: lessons learnt from australia's "black summer". Medical Journal of Australia, 213(11):490–492.

Diurnal Patterns and Drivers of Urban Fog in Milan

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Abstracts

The goal of this study is to detect and analyze local and large-scale drivers of urban fog dissipation using satellite data. In urban areas the heat island effect is often associated with a suppression or an accelerated dissipation of fog. This can be explained by night-time urban warming that lifts the cloud base, while day-time solar radiation may contribute to fog "burnoff" in the morning hours due to enhanced heating of the surface and the air above. However, the processes determining the urban fog life cycle are not yet fully understood. To better understand determinants of fog life cycle in urban areas, meteorological conditions associated with urban fog dissipation are analyzed in Milan using a variety of data sources. This study utilizes data from the SEVIRI (Spinning Enhanced Visible Infra-Red Imager) satellite to study urban fog patterns. Additionally, data from METAR (Meteorological Aerodrome Report), urban weather stations, and ERA-5 reanalysis is used to investigate both the local and large-scale characteristics of urban fog. As a result distinct meteorological patterns are identified that favor fog dissipation in Milan on particular days and the preceding nights. These observed changes in urban fog patterns have implications for the future climate and the population in many European cities, as they influence the urban energy budget and, consequently, heat stress in urban environments. Not only will this study help better understand future developments of the urban climate, the results will also set a basis for improved urban modeling and planning.

Predicting Heat-related Risk Using Multi-source Remote Sensing Data on a Regional Scale

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Karlsruhe Institute of Technology (KIT)

Abstract

Excessive heat is a major health hazard, worsened by climate change. Urban Heat Islands (UHIs), characterized by elevated temperatures compared to surrounding areas, exacerbate this threat, especially in densely populated regions. However, high-resolution data for effective risk reduction is lacking. This study develops a heat risk framework, defining risk as the product of hazard, exposure, and social vulnerability for the region of Hesse, Germany. A machine learning model estimates heat-related risks where local data is missing, achieving an R^2 of 0.93 on the validation dataset and 0.81 on the test dataset. Our findings demonstrate that proxy variables, such as Land Surface Temperature (LST), can effectively identify areas prone to the risk of heat stress, but not always heat stress itself. Despite its regional focus, this study is a first step toward improving public health interventions and urban planning in data-sparse areas.

1. Introduction

Although heat poses a significant hazard to human health (Semenza et al. 1996; Anderson and Bell 2009; Yadav et al. 2023), with vulnerable populations such as the elderly and children being particularly affected (Shafiei Shiva, Chandler, and Kunkel 2022), there is a notable lack of measurement data necessary for effective risk assessment and mitigation in spatially heterogeneous urban areas. Mitigating the threat of heat requires climate adaptations by targeted urban planning approaches and public health interventions (Mavrakou et al. 2018). Different parts of a city can have vastly different environmental conditions, such as building density, vegetation cover, and surface materials, which influence the local micro climate. Local Climate Zones (LCZ) (Demuzere et al. 2022), classify these urban and natural landscapes based on their microclimatic characteristics at a 100 m scale. Since many cities lack high-resolution meteorological data in both spatial and temporal dimensions, LCZs offer an initial insight into the probable microclimatic conditions of different urban areas. However, for successful implementation of intervention strategies it is essential to not only identify the heat hazard but also assess the exposure and vulnerability of the population to target areas of high risk.

Various approaches have been developed to assess heat risk in urban areas, commonly integrating the components of hazard, exposure, and vulnerability. For example Sabrin, Karimi, and Nazari (2022) developed a heat risk index for a case study in Alabama, USA, at the district level, defining risk as the product of exposure and vulnerability, while Cheval et al. (2023) applied a risk matrix approach on a national scale, using Land Surface Temperatures (LST) as the hazard component in a pixel-wise assessment. Similarly (Zhou et al. 2021; Ferreira et al. 2021) used LST as a proxy for heat exposure when approximating heat risk via LCZs. In the absence of detailed air temperature data LST are frequently used as a substitute to meteorological air temperature (Ta) measurements (Diem et al. 2024; Pena Acosta et al. 2023; Sismanidis et al. 2023; Karimi et al. 2021; Lin, Wei, and Guan 2024; Chakraborty and Lee 2019) due to their height spatial coverage, however this relationship has been previously challenged Naserikia et al. (2024; Krikau and Benz 2025). There is a notable lack of distinction between LST and Ta in heat risk models, often leading to their interchangeable use. This is

problematic, as it may lead to the misclassification of urban areas into incorrect risk categories, resulting in misdirected interventions and inefficient allocation of resources.

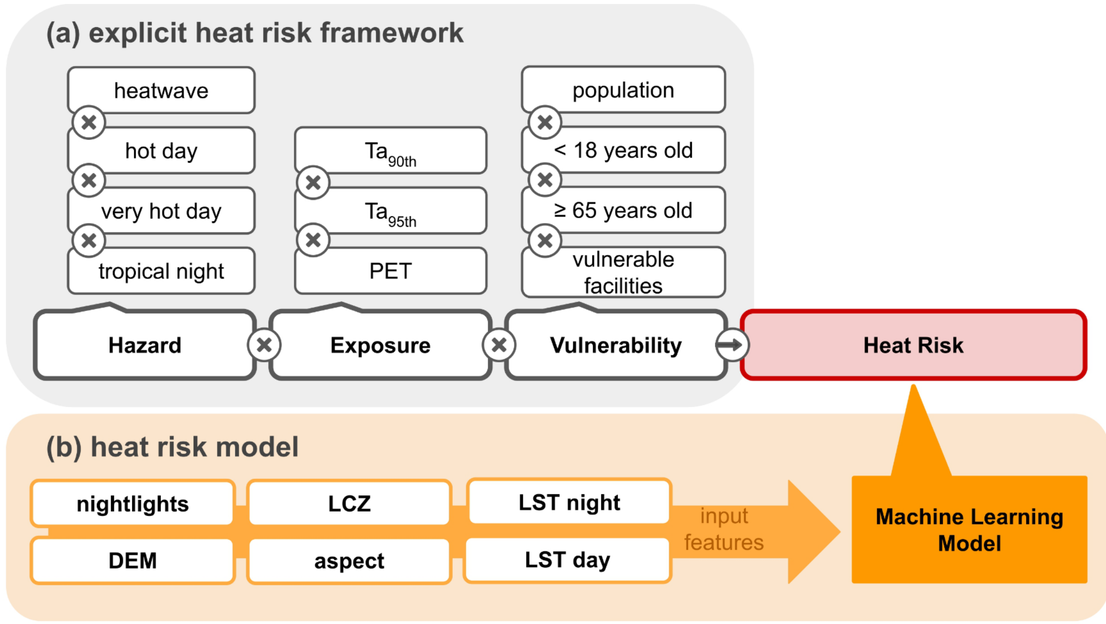

Figure 1: Framework for the risk calculation (a) and components of the model for predicting heat risk (b).

In this study, we develop a) a risk framework to predict heat-related risks at the example of Hesse, Germany where data is available. Additionally, the relationship between LST and the various heat-related components is examined. To estimate these risks in regions lacking local data, we employ b) a machine learning framework that utilizes the calculated risk as the target variable and globally available satellite-derived indicators (such as nightlights, LST, LCZ, digital elevation model (DEM), and aspect) as input features.

2. Methodology

2.1 Explicit Heat Risk Calculation

Following Cardona et al. (2012) we assess heat related risk (figure 1(a)) as the product of hazard, exposure, and vulnerability (equation 1). Here, the hazard component encompasses different temperature related metrics, including heat waves and hot days. Exposure is assessed based on simulated thermal comfort data and measurement data, while the social vulnerability is evaluated based on demographic factors. The spatial resolution of all datasets is 1 km, or they have been downsampled to this resolution if originally available at higher resolutions.

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability} \quad [1]$$

A heat **hazard** describes an event that is potentially harmful to human health and wellbeing due to elevated temperatures. To quantify it we first determine the number of

- heat wave events, defined as periods during which temperatures exceed both the 95th percentile of the local decade-long air temperature distribution and 28 °C for at least three consecutive days,
- hot days, where maximum temperatures exceed 30 °C,

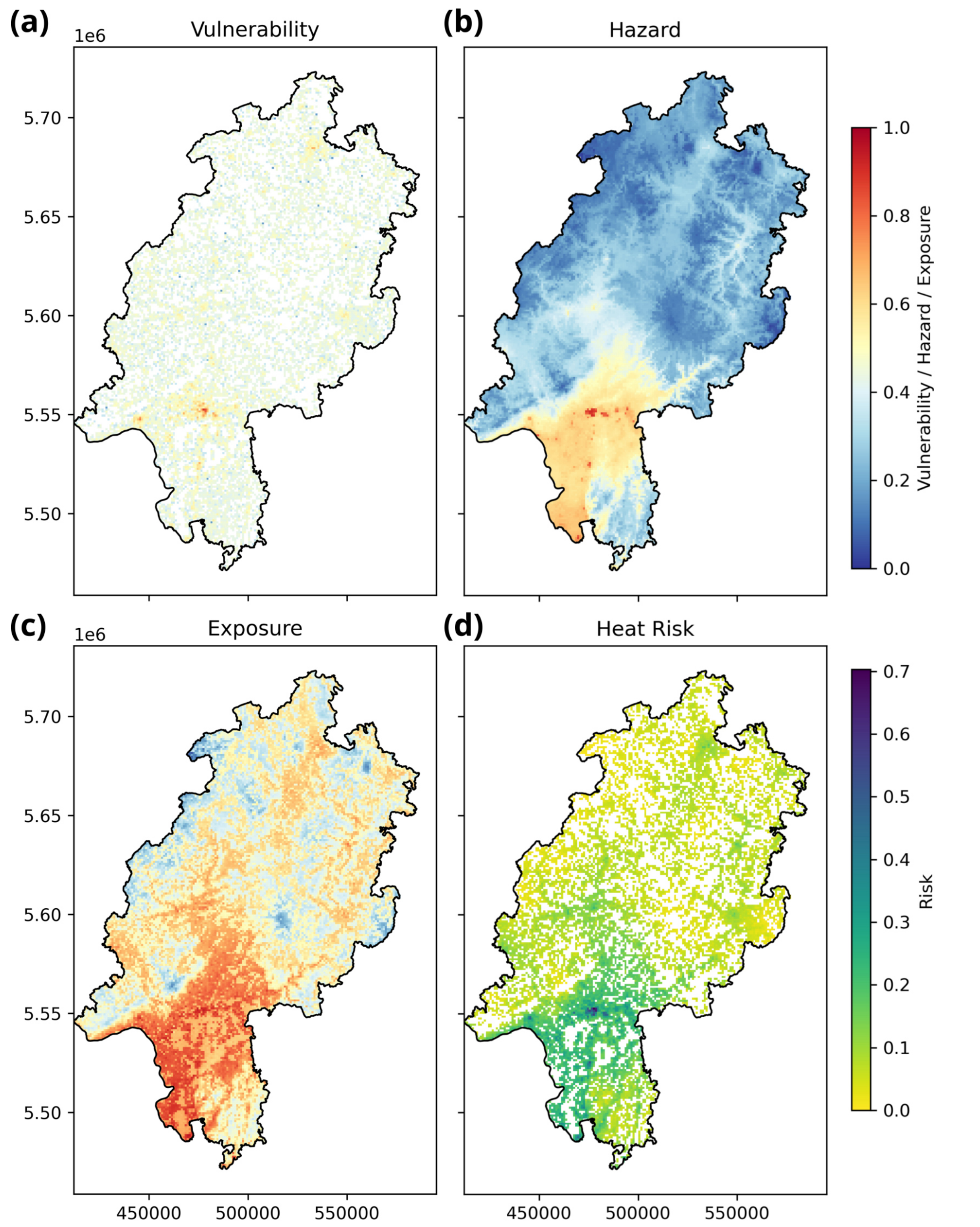

Figure 2: Calculated heat risk (d) in Hesse, Germany, based on vulnerability (a), hazard (b), and exposure (c) components. The southern region experiences the highest levels of heat exposure and hazard.

- very hot days, where maximum temperatures exceed 35 °C, and
- tropical nights, where minimum temperatures exceed 20 °C

within Hesse, Germany (see figure 1(a)) for the summer month (June-August) of the 10-year period 2011 to 2020. All this is derived from the "HOchaufgelöste STündliche RAsterDAtensatz" (HOSTRADA) dataset (Krähenmann et al. 2018) from the German Weather Service (DWD), and determined using the code of Krikau (2025). All input variables are first normalized from 0 (no occurrence) to 1 (high probability of event occurrence) range and then averaged per pixel for each risk component. Pixel with no data values are excluded from the final risk calculation where the components are multiplied according to equation 1.

Heat **exposure** is given by the intensity of heat experienced in a given region. Here we quantify it by first scaling, then multiplying the following variables given also in figure 1(a). Physiologically Equivalent Temperature (PET) (Höppe 1999) from a 'Flow over Irregular Terrain with Natural and Anthropogenic Heat sources' (FITNAH) model for a a heat-intensive artificial day on an August 1st at 14:00 by (Ketterer et al. 2022). As air temperature alone does not determine thermal exposure, instead solar radiation, wind speed, and humidity modify how hot or cold the environment feels to the human body, therefore this dataset is used within the exposure component. Additionally, the 90th and 95th percentiles of air temperature based on the 10-year summer HOSTRADA dataset are included to represent the overall distribution of air temperature.

The social **vulnerability** component captures the population's sensitivity to heat stress. based on the 2011 census data (Bundes und der Länder 2011) It includes general population density, socioeconomic indicators such as the proportion of elderly (over 65 years) and children (under 18 years). The presence of vulnerable facilities like schools and care homes within the area based on the points of interest dataset from the German Federal Office for Cartography and Geodesy Bundesamt für Kartographie und Geodäsie (BKG) (2023).

2.2 Risk Estimation in Regions with Limited Data Availability

To estimate risk in data-sparse regions, a machine learning model using a random forest regressor is implemented with the following parameter after hyperparameter tuning: n_estimators=300, max_depth=15, max_features="log2", min_samples_split=3, and min_samples_leaf=3. The western 40% of the bounding box of Hesse is allocated for testing, while the remaining valid data is divided into 70% for training and 30% for validation. Model performance is assessed using root mean square error (RMSE) and R^2, while Shapley Additive Explanations (SHAP) values provide insights into feature importance. The input features include the 2018 Local Climate Zone (LCZ) dataset (Demuzere et al. 2022), daytime and nighttime LST from MODIS Terra (Wan, Hook, and Hulley 2015) (overpass time 10:30 and 22:30 at equator) and Aqua (overpass times 01:30 and 13:30) (Wan, Hook, and Hulley 2021) (10-year mean of summer months), nightlights (often used for an approximation of population density e.g. Benz, Davis, and Burney (2021)) Elvidge et al. (1997), DEM Survey (2010) and the derived aspect. Target variable is the previously explicitly calculated heat risk (figure 1(b)).

3. Results

3.1 Mapped Risk in Hesse in Relation to LST

Figure 2 shows the three heat risk components (social vulnerability, hazard and exposure) along with the resulting explicitly calculated heat risk map. The southern region of Hesse, near the Rhine Valley and influenced by a Mediterranean climate, experiences the highest hazard levels. Meanwhile, exposure and vulnerability are greatest in urban areas, particularly around Frankfurt and Kassel. Risk values reach from 0.00 to 0.70 with mean values of 0.09 over the whole region. The table 1 shows the correlation of the available LST datasets with different heat extreme events and the parameters of the heat risk framework.

Table 1: Pearson correlation of the LST data to the occurrence of heat extreme events and the components of the risk framework. For each parameter, the highest correlation with the LST time step is marked in bold.

Parameter	LST (01:30)	LST (10:30)	LST (13:30)	LST (22:30)
risk	0.69	0.78	0.79	**0.80**
hazard	0.63	0.73	0.73	**0.77**
exposure	0.39	0.81	**0.83**	0.52
vulnerability	0.2	0.24	**0.25**	0.23
hot days	0.6	0.73	0.73	**0.75**
very hot days	0.58	0.72	0.72	**0.73**
heat wave events	0.54	**0.69**	0.68	0.68
tropical nights	**0.55**	0.28	0.28	0.54

Although LST from MODIS Aqua (overpass times 01:30 and 13:30) aligns more closely with the observed minimum and maximum LST values (8.9°C and 37.7°C, respectively) than MODIS Terra (10.1°C and 35.8°C), air temperature as well as the calculated heat hazard show the strongest correlation with nighttime observations from MODIS Terra (table 1). A similar pattern is observed in the correlations with the number of hot and very hot days. Nighttime LST shows the strongest correlation with tropical nights, while correlations with heatwave events are comparable across all LST products, though the peak values are generally lower. Daytime LST exhibits a strong correlation with the exposure component, whereas social vulnerability consistently shows weak correlations with all LST products.

3.2 Predicting the Heat risk in Data-sparse Regions

The fully predicted risk map for the bounding box of Hesse (figure 3) shows high-risk areas in the urban regions of Frankfurt and Wiesbaden, while outside the region of interest, elevated risk is observed in urban areas around Mannheim and Würzburg. For the validation dataset, the model achieves an RMSE of 0.021 and a R^2 score of 0.93. On the test dataset (northern Hesse), the R^2 score is 0.81, with a RMSE of 0.024 and a mean absolute error of 0.017 (figure 4). Largest differences between true and predicted risk are observed in the area of the city of Kassel. SHAP analysis (figure 5) reveals that DEM followed by LST 22:30 and 13:30 is the most influential factor in predicting heat-related risk.

4. Discussion

While the model demonstrates strong performance based on validation metrics, its predictive capability on unseen data may be limited by the underrepresentation of high risk areas in the training set. As a non-extrapolative method, the random forest model may fail to capture extreme risk zones not well represented during training. However, in the current case, the model tends to overestimate thermal stress in urban areas such as Kassel. This may be partly due to the high influence of elevation (DEM) which could bias predictions in other low lying areas with inherently lower risk. Expanding the dataset to include more regions with elevated thermal risk would likely enhance the model's reliability and generalizability.

Additionally it is important to note that census data reflects where people are officially registered rather than their actual locations throughout the day, such as workplaces. While facilities like schools and care homes are included in the dataset, future research could incorporate movement patterns, as explored by (Sun et al. 2024), to account for population shifts between urban and suburban areas. Since daily mobility between workplaces and residences influences heat exposure, developing a dynamic population risk assessment index could improve the accuracy of heat risk evaluations. While the focus here is on social vulnerability, other vulnerable aspects such as biodiversity should also be included in a comprehensive heat risk model.

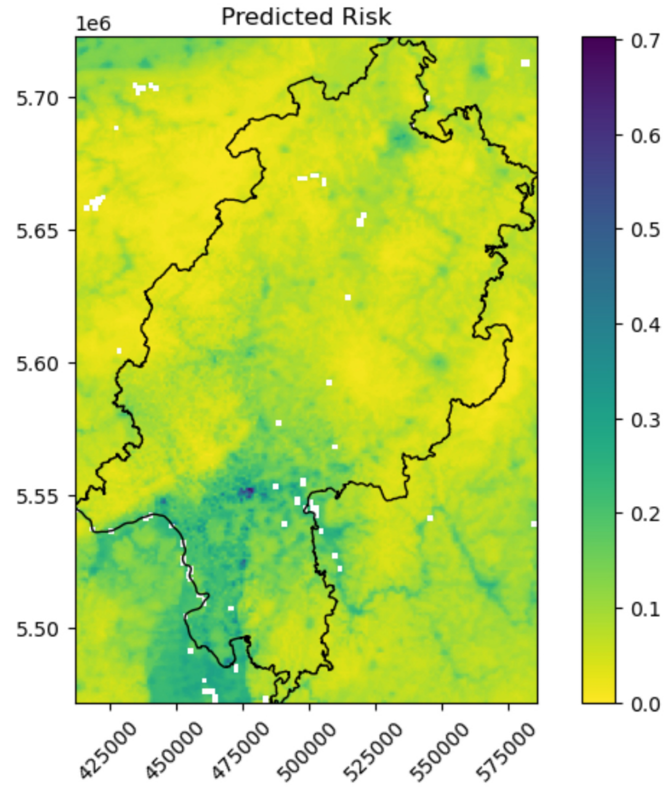

Figure 3: The predicted heat risk within the bounding box of Hesse, Germany, shows that high-risk areas are primarily located in the southern region.

0 1 2 3 4 5 6 7

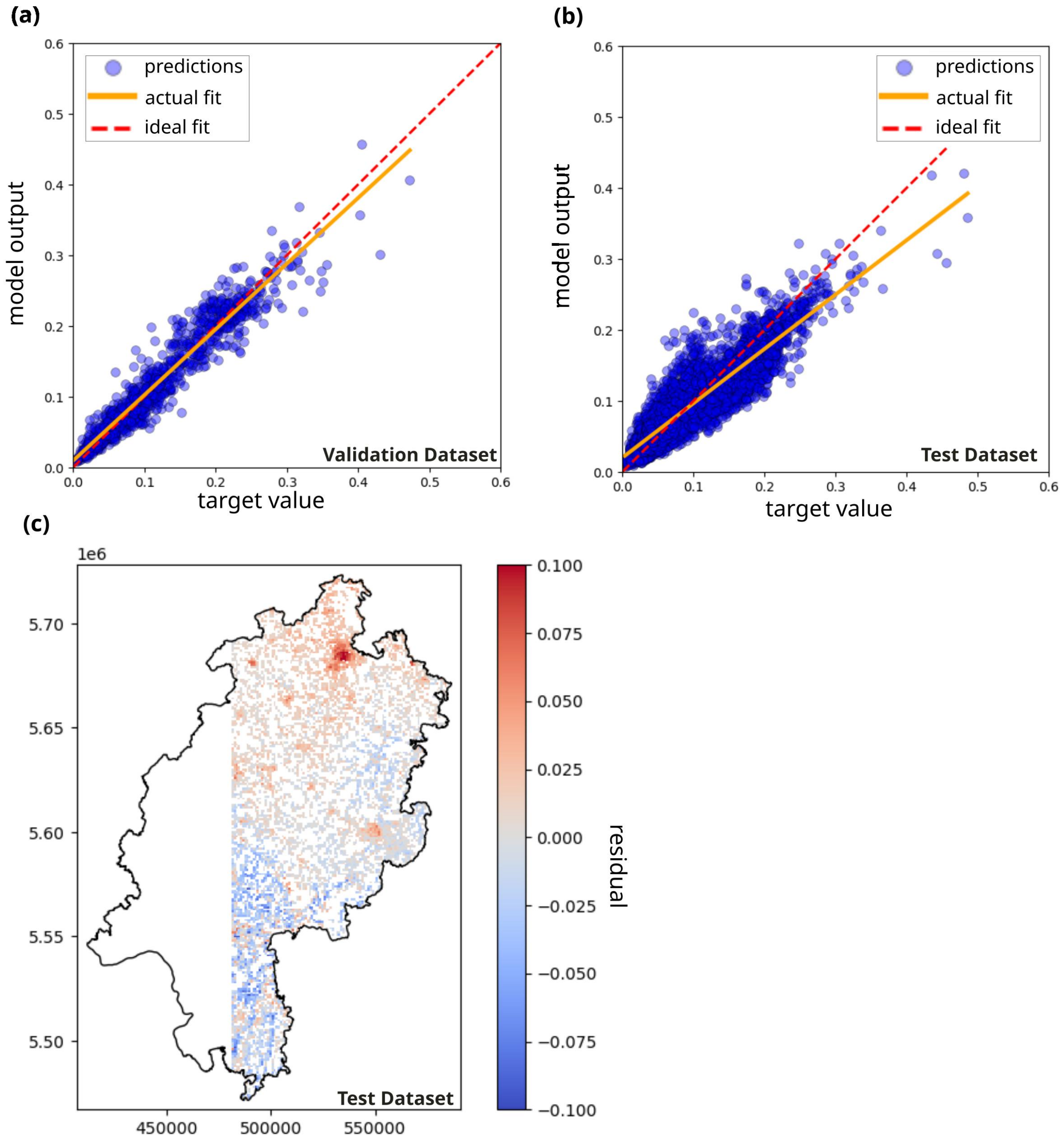

Figure 4: The performance of the model on the validation dataset (a) achieves a R² score of 0.93 with a RMSE of 0.02 while the performance on the test dataset (northern Hesse) achieves a R² score of 0.81 with a RMSE of 0.02 (b). Prediction errors for the test dataset (c) are highest in the urban area of Kassel.

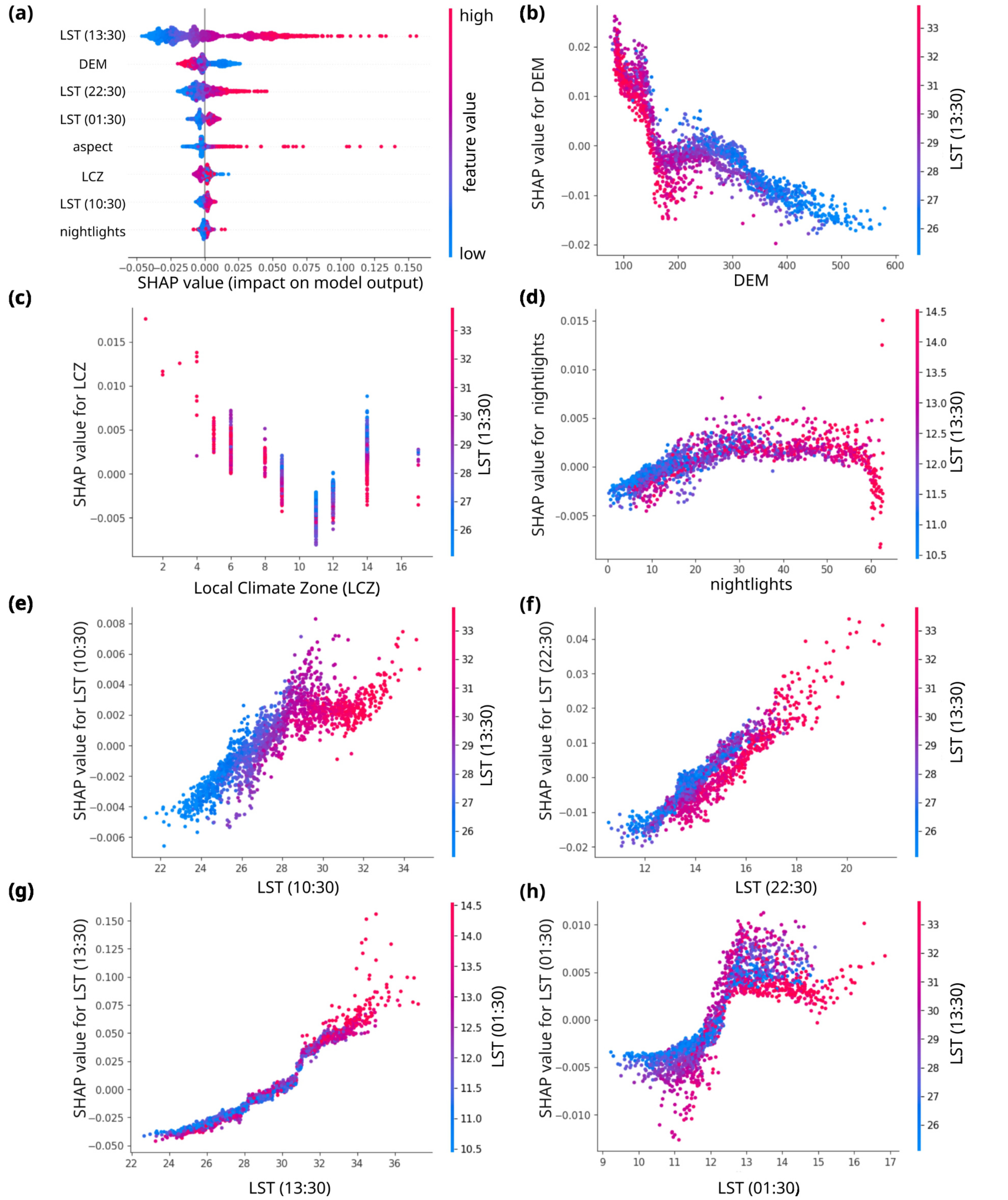

Figure 5: Shapley values (a) for the heat risk prediction parameters indicate that the elevation (DEM), has the strongest positive influence on the model's output (b), followed by the LST data at 22:30, 13:30, 20:30 and 13:00.

Additionally, higher-resolution data is essential for capturing the highly heterogeneous nature of urban landscapes, enabling more effective prioritization of interventions. As higher-resolution remote sensing products are available, future studies can build upon these findings to enhance spatial precision and applicability.

The correlation analysis showed that not all hazard components align closely with the patterns of the aggregated LST data. LST and Ta describe different physical characteristics and often diverge, with variations across the diurnal cycle (Nazarian et al. 2024). Here, LST shows stronger correlations with both the exposure component (during daytime) and the overall calculated heat risk. This is likely because human thermal discomfort is influenced not only by elevated temperatures, but also by factors such as solar radiation, wind, and humidity. While substituting Ta with LST due to limited data availability may risk under- or overestimating heat stress in certain areas, the developed model demonstrates that, when combined with additional parameters than Ta alone, LST can be a valuable proxy for identifying areas of elevated heat risk.

5. Conclusion

This study presents a method for predicting heat-related risk in data-sparse regions by combining hazard, exposure, and vulnerability components and the explicit calculated heat risk with a machine learning model based on random forest regression. Although LST is often used as a proxy for Ta to identify urban areas in need of intervention, our data reveal that the relationships between LST and different heat risk components vary significantly. LST cannot be used as a direct replacement for Ta measurements. During the daytime, the spatial pattern of heat exposure is highly correlated with LST, while the correlation with heat hazard is lower, although more consistent across the diurnal cycle. The occurrence of (very) hot days is strongly correlated with LST, whereas there is little to no relationship with heatwave events and tropical nights. Note that this is valid for a 1-km resolution over a largely rural area and not necessarily for high resolution data in dense urban environments. The developed machine learning model uses LST from MODIS Terra and Aqua along with DEM, aspect, nightlights and LCZ as input features. The model shows predictive performance, with an R^2 of 0.81 and an RMSE of 0.02 on the test dataset. However, its accuracy is limited by the scarcity of high-risk locations in the training data. Expanding the training dataset to encompass regions with higher thermal stress could enhance the model's generalizability, particularly given that SHAP analysis indicates that elevation data currently has a significant impact on the model's performance. SHAP feature analysis indicates further that nighttime LST at 22:30 followed by daytime LST at 13:30 has the strongest influence on the heat risk predictions.

For urban planning, LST should therefore not be used as a direct substitute for Ta, as our results demonstrate considerable variability in how LST relates to different aspects of heat risk. Although LST shows a strong correlation with daytime heat exposure, its relationship with heat hazard is less consistent, and it does not adequately capture critical events such as heatwaves and tropical nights when analysed at the aggregated 1-km resolution. To accurately identify and prioritize heat risk hotspots, it is essential to incorporate additional geospatial features into the analysis. To mitigate urban heat islands, various strategies such as increasing urban greenery and reducing surface sealing are commonly recommended, as outlined in initiatives like the "Klimprax-Stadtklima" (Hessisches Landesamt für Naturschutz, Umwelt und Geologie (HLNUG) 2025) project. However, selecting the most effective measures for a specific area remains challenging due to the diversity and complexity of available data. Therefore, we are currently working on developing a simplified system to support decision-making. Adaptation efforts should also address exposure and vulnerability by, for example, ensuring access to shaded areas and cooling opportunities, thereby reducing the impact of heat hazards on urban populations.

Future research should prioritize heat risk extremes at higher spatial and temporal resolutions to target the heterogenous urban landscape and incorporate human mobility patterns to better capture the complex dynamics of urban heat risk. This study represents the first step in demonstrating how LST can be used to quantify heat risk and can aid in the selection of targeted urban planning and mitigation strategies, even in regions lacking dense air temperature monitoring networks.

Acknowledgment

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References

Anderson, Brooke G., and Michelle L. Bell. 2009. "Weather-Related Mortality: How Heat, Cold, and Heat Waves Affect Mortality in the United States." Epidemiology (Cambridge, Mass.) 20 (2): 205–13. https://doi.org/10.1097/EDE.0b013e318190ee08.

Benz, Susanne A., Steven J. Davis, and Jennifer A. Burney. 2021. "Drivers and Projections of Global Surface Temperature Anomalies at the Local Scale." Environmental Research Letters 16 (6): 064093. https://doi.org/10.1088/1748-9326/ac0661.

Bundes und der Länder, Statistische Ämter des. 2011. "INSPIRE Dataset Feed: Zensusatlas 2011 – Bundesweite Kleinräumige Daten (1 Km²-Raster) Der Amtlichen Statistik Zu Bevölkerung, Gebäude Und Wohnungen."

Bundesamt für Kartographie und Geodäsie (BKG). 2023. "Points of Interest Open (POI-Open)." https://gdz.bkg.bund.de/index.php/default/points-of-interest-open-poi-open.html; BKG.

Cardona, Omar-Dario, Maarten K. Van Aalst, Jörn Birkmann, Maureen Fordham, Glenn McGregor, Rosa Perez, Roger S. Pulwarty, et al. 2012. "Determinants of Risk: Exposure and Vulnerability." In Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, edited by Christopher B. Field, Vicente Barros, Thomas F. Stocker, and Qin Dahe, 1st ed., 65–108. Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.005.

Chakraborty, T., and X. Lee. 2019. "A Simplified Urban-Extent Algorithm to Characterize Surface Urban Heat Islands on a Global Scale and Examine Vegetation Control on Their Spatiotemporal Variability." International Journal of Applied Earth Observation and Geoinformation 74 (February): 269–80. https://doi.org/10.1016/j.jag.2018.09.015.

Cheval, Sorin, Alexandru Dumitrescu, Vlad Amihăesei, Adrian Irașoc, Monica-Gabriela Paraschiv, and Darren Ghent. 2023. "A Country Scale Assessment of the Heat Hazard-Risk in Urban Areas." Building and Environment 229 (February): 109892. https://doi.org/10.1016/j.buildenv.2022.109892.

Demuzere, Matthias, Jonas Kittner, Alberto Martilli, Gerald Mills, Christian Moede, Iain D. Stewart, Jasper van Vliet, and Benjamin Bechtel. 2022. "A Global Map of Local Climate Zones to Support Earth System Modelling and Urban-Scale Environmental Science." Earth System Science Data 14 (8): 3835–73. https://doi.org/10.5194/essd-14-3835-2022.

Diem, Phan Kieu, Can Trong Nguyen, Nguyen Kieu Diem, Nguyen Thi Hong Diep, Pham Thi Bich Thao, Tran Gia Hong, and Thanh Noi Phan. 2024. "Remote Sensing for Urban Heat Island Research: Progress, Current Issues, and Perspectives." Remote Sensing Applications: Society and Environment 33 (January): 101081. https://doi.org/10.1016/j.rsase.2023.101081.

Elvidge, Christopher D, K. E. Baugh, E. A. Kihn, H. W. Kroehl, and E. R. Davis. 1997. "Mapping City Lights With Nighttime Data from the DMSP Operational Linescan System." Photogrammetry and Remote Sensing 63 (6): 727–34.

Ferreira, Fabiana Lourenço E Silva, Enio Bueno Pereira, André Rodrigues Gonçalves, Rodrigo Santos Costa, and Francisco Gilney Silva Bezerra. 2021. "An Explicitly Spatial Approach to Identify Heat Vulnerable Urban Areas and Landscape Patterns." Urban Climate 40 (December): 101021. https://doi.org/10.1016/j.uclim.2021.101021.

Hessisches Landesamt für Naturschutz, Umwelt und Geologie (HLNUG). 2025. “KLIMPRAX Stadtklima.” KLIMPRAX Stadtklima. https://www.hlnug.de/themen/klimawandel-und-anpassung/projekte/klimprax-projekte/klimprax-stadtklima.

Höppe, P. 1999. “The Physiological Equivalent Temperature – a Universal Index for the Biometeorological Assessment of the Thermal Environment.” International Journal of Biometeorology 43 (2): 71–75. https://doi.org/10.1007/s004840050118.

Karimi, Alireza, Pir Mohammad, Sadaf Gachkar, Darya Gachkar, Antonio García-Martínez, David Moreno-Rangel, and Robert D. Brown. 2021. “Surface Urban Heat Island Assessment of a Cold Desert City: A Case Study over the Isfahan Metropolitan Area of Iran.” Atmosphere 12 (10): 1368. https://doi.org/10.3390/atmos12101368.

Ketterer, Christine, Jost Nielinger, Markus Hasel, and Rainer Röckle. 2022. “Erstellung Einer Landesweiten Klimaanalyse/ Kaltluftströmungssituation Unter Berücksichtigung Des Klimawandelbedingten Temperaturanstiegs.” Abschlussbericht. Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Wohnen.

Krähenmann, S., A. Walter, S. Brienen, F. Imbery, and A. Matzarakis. 2018. “High-Resolution Grids of Hourly Meteorological Variables for Germany.” Theoretical and Applied Climatology 131 (3): 899–926. https://doi.org/10.1007/s00704-016-2003-7.

Krikau, Svea. 2025. “Spatio-Temporal Analysis of Heat Extremes.” Zenodo. https://doi.org/10.1088/2515-7620/adce59.

Krikau, Svea, and Susanne A Benz. 2025. “Temporal and Spatial Patterns of Heat Extremes in Hesse, Germany.” Environmental Research Communications, April. https://doi.org/10.1088/2515-7620/adce59.

Lin, Jinyao, Keqin Wei, and Zifeng Guan. 2024. “Exploring the Connection Between Morphological Characteristic of Built-up Areas and Surface Heat Islands Based on MSPA.” Urban Climate 53 (January): 101764. https://doi.org/10.1016/j.uclim.2023.101764.

Mavrakou, Thaleia, Anastasios Polydoros, Constantinos Cartalis, and Mat Santamouris. 2018. “Recognition of Thermal Hot and Cold Spots in Urban Areas in Support of Mitigation Plans to Counteract Overheating: Application for Athens.” Climate 6 (1): 16. https://doi.org/10.3390/cli6010016.

Naserikia, Marzie, Negin Nazarian, Melissa A Hart, Panagiotis Sismanidis, Jonas Kittner, and Benjamin Bechtel. 2024. “Multi-City Analysis of Satellite Surface Temperature Compared to Crowdsourced Air Temperature.” Environmental Research Letters 19 (12): 124063. https://doi.org/10.1088/1748-9326/ad8be4.

Nazarian, Negin, Benjamin Bechtel, Gerald Mills, Melissa Anne Hart, Ariane Middel, E. Scott Krayenhoff, Gaby S. Langendijk, Lei Zhao, Andy Pitman, and Winston Chow. 2024. “Integration of Urban Climate Research Within the Global Climate Change Discourse.” PLOS Climate 3 (8): e0000473. https://doi.org/10.1371/journal.pclm.0000473.

Pena Acosta, Monica, Faridaddin Vahdatikhaki, João Santos, and Andries G. Dorée. 2023. “A Comparative Analysis of Surface and Canopy Layer Urban Heat Island at the Micro Level Using a Data-Driven Approach.” Sustainable Cities and Society 99 (December): 104944. https://doi.org/10.1016/j.scs.2023.104944.

Sabrin, Samain, Maryam Karimi, and Rouzbeh Nazari. 2022. “Modeling Heat Island Exposure and Vulnerability Utilizing Earth Observations and Social Drivers: A Case Study for Alabama, USA.” Building and Environment 226 (December): 109686. https://doi.org/10.1016/j.buildenv.2022.109686.

Semenza, J. C., C. H. Rubin, K. H. Falter, J. D. Selanikio, W. D. Flanders, H. L. Howe, and J. L. Wilhelm. 1996. “Heat-Related Deaths During the July 1995 Heat Wave in Chicago.” The New England Journal of Medicine 335 (2): 84–90. https://doi.org/10.1056/NEJM199607113350203.

Shafiei Shiva, Javad, David G. Chandler, and Kenneth E. Kunkel. 2022. “Mapping Heat Wave Hazard in Urban Areas: A Novel Multi-Criteria Decision Making Approach.” Atmosphere 13 (7): 1037. https://doi.org/10.3390/atmos13071037.

Sismanidis, Panagiotis, Benjamin Bechtel, Iphigenia Keramitsoglou, Zihan Liu, and Wenfeng Zhan. 2023. “The Intensity of Surface Urban Heat Islands in the Global North During the COVID-19 Lockdowns.” In 2023 Joint Urban Remote Sensing Event (JURSE), 1–4. https://doi.org/10.1109/JURSE57346.2023.10144159.

Sun, Zhaobin, Xiaoling Zhang, Ziming Li, Yinglin Liang, Xingqin An, Yuxin Zhao, Shiguang Miao, Ling Han, and Demin Li. 2024. “Heat Exposure Assessment Based on High-Resolution Spatio-Temporal Data of Population Dynamics and Temperature Variations.” Journal of Environmental Management 349 (January): 119576. https://doi.org/10.1016/j.jenvman.2023.119576.

Survey, U. S. Geological. 2010. “GMTED2010: Global Multi-resolution Terrain Elevation Data 2010 Courtesy of the U.S. Geological Survey.”

Wan, Zhengming, Simon Hook, and Glynn Hulley. 2015. “MOD11A1 MODIS/Terra Land Surface Temperature/Emissivity Daily L3 Global 1km SIN Grid V006.” NASA EOSDIS Land Processes Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MOD11A1.006.

Wan, Zhengming, Simon Hook, and Glynn Hulley. 2021. “MODIS/Aqua Land Surface Temperature/Emissivity Daily L3 Global 1km SIN Grid V061.” NASA EOSDIS Land Processes Distributed Active Archive Center. https://doi.org/10.5067/MODIS/MYD11A1.061.

Yadav, Namita, Kushagra Rajendra, Amit Awasthi, Charan Singh, and Bibhuti Bhushan. 2023. “Systematic Exploration of Heat Wave Impact on Mortality and Urban Heat Island: A Review from 2000 to 2022.” Urban Climate 51 (September): 101622. https://doi.org/10.1016/j.uclim.2023.101622.

Zhou, Yi, Guoliang Zhang, Li Jiang, Xin Chen, Tianqi Xie, Yukai Wei, Lin Xu, Zhihua Pan, Pingli An, and Fei Lun. 2021. “Mapping Local Climate Zones and Their Associated Heat Risk Issues in Beijing: Based on Open Data.” Sustainable Cities and Society 74 (November): 103174. https://doi.org/10.1016/j.scs.2021.103174.

Urban Infrastructures under Climate Pressure – Exploring Benefits of Transformation Concepts for Long-term Change

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Abstract

Despite their role in public services, urban infrastructures—social, technical, and blue-green—often lack an integrated governance approach. This research examines characteristics and governance challenges across the lifespan of urban infrastructures. A literature review and expert workshop identified key governance adjustments, including resource availability, evolving requirements, and conflicting objectives. Since no single theory fully addresses these challenges, three theoretical approaches—the Long-term Governance Framework, Multi-level Perspective, and Change Management—are assessed for their contributions. The findings show that elements from each theory help address governance issues, supporting decision-making frameworks for sustainable urban development. A first practical testing of this theoretical research is executed in studying the transition of urban heating systems in two mid-sized European municipalities.

1. Introduction

By 2050, more than two thirds of the world's population are expected to be living in cities, making it essential to prepare urban spaces for current and future challenges (UN-Habitat 2022). Urban areas are particularly vulnerable to climate change impacts such as drought, flooding, heat stress, water supply or the urban heat island effect (UHI) due to their concentration of people, services and infrastructures (Albers et al. 2015, Elmqvist et al. 2019, Bloch et al. 2012). Mitigating climate change is equally as important as adapting to its impacts. While the necessity for climate adaptation is widely recognized (Field et al. 2012, UNEP 2013), many municipalities still lack strategic climate adaptation plans, instead reacting to damage from extreme weather events (Castán Broto and Bulkeley 2013). Adaptation and mitigation measures must be considered and implemented holistically to prevent conflicts between them (Libbe et al. 2010). However, there are target trade-offs in urban governance between targets of climate mitigation and adaptation as well as other (traditional) targets of public service provision (Viguié and Hallegatte 2012).

Urban areas are densely populated human settlements with built and infrastructural environments, defined as social-ecological-technical systems (SETS) (Depietri and McPhearson 2017). They are a system of systems in which the different sub-systems, e.g. social or ecological, interact with each other (Cutter 2021). Within this urban system exists a conglomerate of various infrastructures which are natural or designed and managed spatial systems (Andersson et al. 2022), including railways, heating networks, wastewater systems or urban trees. These facilities and installations with individual and collective benefits influence, ensure, and maintain the economic development, social coexistence and the ecologically sustainable development of an area (Schmidt and Monstadt 2018). Additionally, they are an important part of public services (Grabski-Kieron and Boutet 2023, Schmidt and Monstadt 2018). Compared to non-urban infrastructures, urban infrastructures exhibit high density and parallelism, where multiple infrastructures coexist and interact within limited space, creating complexity (Saidi et al. 2018, Andersson et al. 2022). Density and parallelism of urban infrastructures mean the high number of different infrastructures which exist and operate side by side, at many times also interacting, per unit of area – above or below ground. For instance,

underground spaces accommodate water and sewage pipes, heating networks, fiber optic cables, power lines, and tree roots competing for space.

Climate pressures on urban infrastructures like flooding or heat stress necessitate additional capacities for water retention, increased demand for cooling or in the worst case even lead to infrastructure damage or failure. A more comprehensive overview of climate risks and their effects on infrastructure such as railways or various energy infrastructures is available in OECD (2024). Addressing urban infrastructure challenges requires an interdisciplinary research perspective across disciplines like for example traffic planning, hydraulic engineering, landscaping, and land-use planning. The design of urban infrastructure focuses increasingly on responding to the challenges posed by future climates (Ürge-Vorsatz et al. 2018). However, a holistic view of urban infrastructures and their reciprocal influence is lacking concerning climate mitigation and adaptation.

In contrast to big cities, small- and medium-sized towns (SMSTs) are very much underrepresented in research (Servillo et al. 2017, Kern 2023). SMSTs combine the number of small towns (5,000 – 20,000 inhabitants) and medium-sized towns (20,000 – 100,000 inhabitants) (Berescu et al. 2011). Approximately 38 % of European citizens live in cities with 5,000 – 100,000 inhabitants (Berescu et al. 2011) showing the big lever of SMSTs in contributing to climate mitigation and the high number of people affected by impacts of climate change that cities need to adapt to. These impacts of climate change such as severe weather events make urban areas particularly vulnerable and therefore underline the importance of climate adaptation in SMSTs (Hoppe et al. 2016). Also, guiding documents on EU and European level like the new Leipzig-Charter (EU 2020) or the Ljubljana Agreement (EU 2021) as foundation for the EU's Urban Agenda put an emphasis on the consideration of small- and medium-sized towns. Therefore, this research focuses on climate mitigation and adaptation of infrastructures in SMSTs.

2. Methodology

This research aims to link the three theoretical concepts of the Long-term Governance Framework (Scheer et al. 2025), the Multi-level Perspective (Rip and Kemp 1998, Geels 2002) and Change Management (Lewin 1947, Kotter 1996) in addressing areas of adjustment in municipal infrastructure governance, focusing on the heating infrastructure in SMSTs. The theory used in this research was built through a literature review and a subsequent workshop with scientific experts. To test this theoretical heuristic framework as further explained in chapter 3, case studies are conducted on small- and medium-sized European cities, as there is an evident research and data gap considering climate mitigation and adaptation practices in municipalities with less than 100,000 inhabitants (Kern 2023). Therefore, one German and one Danish mid-sized municipality are chosen as cases. A Danish municipality is chosen because Denmark is well progressed in their heating transition which already started in the 1980s (Petrović and Karlsson 2014). Additionally, a German municipality is chosen because as part of the German Heat Planning Act, municipalities with less than 100,000 inhabitants must complete their respective heating plans by June 30th 2028, giving them a rather tight time frame to decarbonize their heating networks (BBSR 2024). Within each of the cases, an in-depth study is carried out through expert interviews with municipal administration as well as other stakeholders involved in the respective municipal heating transition. Additionally, municipal documents regarding the heating transition will be analyzed to complete the picture. The aim of this in-depth analysis of two mid-sized cities and their respective heating transition as case studies is to examine what went well in these cases and what didn't in order to foster learning across cities (Banerjee and Petersen 2023).

3. Municipal Levers in Theory and Practice

As climate change pressures urban areas and infrastructures, ensuring their future resilience is essential. However, infrastructure planning and its strong traditions can lead to hiding “assumptions and simplifications and may reinforce existing ‘solutions’ rather than explore alternatives when the urgency of climate change calls for innovation” (Andersson et al. 2022). As a backbone of fossil technology chains, some existing infrastructure may stabilize the fossil regime, leading to climatedamaging carbon lock-ins due to their longevity (Erickson and Tempest 2015). This also applies to municipal heating networks, requiring a respective transition towards decarbonization.

Key characteristics of urban infrastructures were identified through a literature review and a scientific expert workshop. The identified characteristics represent different potential areas of adjustment where changes can be made to the system of urban infrastructures through municipal governance. These characteristics can be summarized under eight topics: resources, requirements, expectations, responsibilities, path dependency, objectives, justice, and care and maintenance. Resources include financial, human, and temporal constraints affecting municipal infrastructure management, according to both, the literature review and the expert workshop. Requirements encompass external demands from higher political levels or from climate change as a necessity to adapt. Expectations reflect the demands of interest groups, such as civil society or businesses, regarding infrastructure functionality and participation, which may differ between groups and vary over time. Responsibilities refer to the complex, multi-level governance decision-making processes, requiring collaboration and interdisciplinarity. Path dependency describes the inertia of established infrastructures that hinders innovation and adaptation. Objectives capture the diverse goals of infrastructures, which may complement or conflict with one another due to their diversity and parallelism. Justice addresses equal access to infrastructures and to participation in decision-making. Care and maintenance involve managing aging infrastructures and overcoming departmental silos for comprehensive maintenance.

The eight topics identified vary in relevance throughout the lifespan of an urban infrastructure. Thus, the identified topics can be assigned to the different stages of a heuristic three-stage model representing such lifespan (Figure 1). Depicting the lifespan of urban infrastructures helps to get a comprehensive picture of the various infrastructures within a city, from vision to end-of-life, and to support municipal decision-making in identifying areas of action for climate mitigation and adaptation across these lifespans. This can enhance collaboration, innovation and resilience in municipal governance. The lifespan of an infrastructure involves its entire existence from vision to planning, implementation, monitoring, evaluation, and – if necessary – removing, dismantling, and disposing. Therefore, the three-stage model begins with a long-term vision for climate protection and adaptation in urban infrastructures. Cross-sectoral planning and implementation follow to realize this vision, identifying and executing necessary measures. Monitoring and evaluation ensure continuous assessment. This process is iterative rather than linear, allowing for adjustments. Therefore, the proposed three-stage model is not a one-size fits all model in which the mechanisms creating change are identical and predictable. It rather serves as a conceptualization of nonlinear pathways by suggesting the different characteristics of urban infrastructures as various potential areas of adjustment for municipal governance.

To address the different topics of characteristics as areas of adjustment for the governance of urban infrastructures, a linkage of three theories is proposed (Figure 2). The Long-term Governance Framework (Scheer et al. 2025), the Multi-level Perspective (Rip and Kemp 1998, Geels 2002) and Change Management (Lewin 1947, Kotter 1996) are matched with the characteristics which are sorted into the three stages of the heuristic model (Figure 1). The matching is carried out through a comprehensive analysis of the approaches and their individual elements with consideration of the identified characteristics. As the identified characteristics represent different areas of adjustment where changes can be made to the system of urban infrastructures through municipal governance, the theoretical approaches show possibilities of pursuing these respective changes. Each characteristic is then matched with the approach whose individual elements are most suitable to address the respective challenges and to drive change.

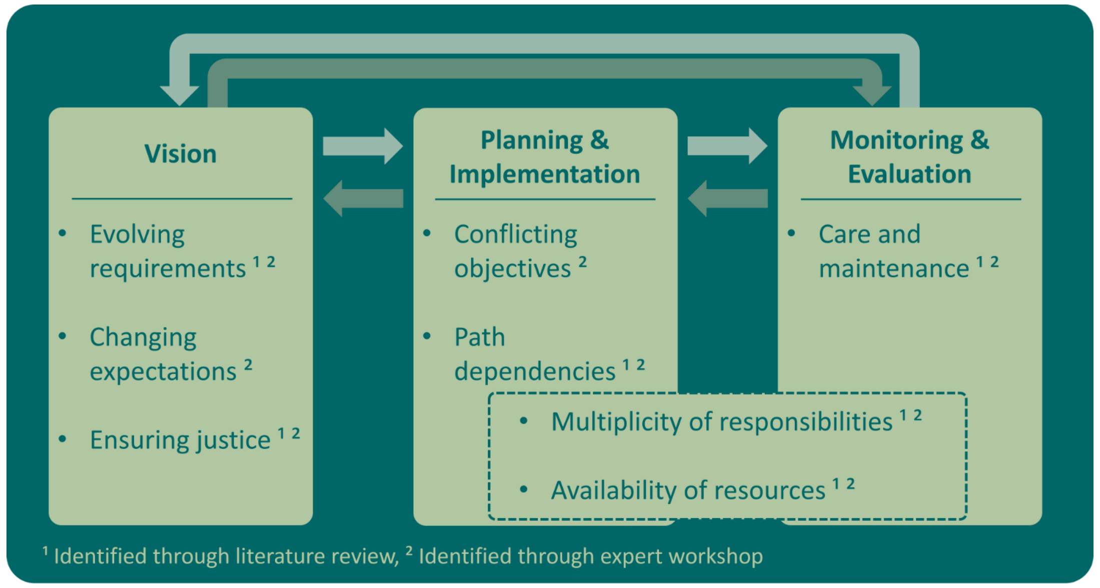

Figure 1: Identified potential areas of adjustment in climate protection and adaptation throughout the lifespan of urban infrastructures, assigned to the different stages of a three-stage model. Own elaboration.

Characteristics by stage	Vision			Planning & Implementation				
						Monitoring & Evaluation		
Approaches	Evolving requirements	Changing expectations	Ensuring justice	Conflicting objectives	Path dependencies	Multiplicity of responsibilities	Availability of resources	Care and maintenance
LTG Framework		X	X					X
MLP	X				X	X		
CM		X		X			X	

Figure 2: Matching of identified issues with the three approaches of the Long-term Governance Framework, the Multi-level Perspective and Change Management. Own elaboration.

These theoretical findings need to be tested for practical applicability in municipalities. This is done in an explorative analysis of municipal heating transition processes in two European medium-sized cities in Germany and Denmark to assess the key success factors and transferable insights informing the development of effective, long-term urban energy governance strategies. Particularly in the case of the municipal energy and therefore also heating transition, there are many complementary measures involving a number of different actors with varying interests, objectives and ideas at different levels and in different sectors (Czada and Radtke 2018). Therefore, the case studies examine the different actor constellations, decision-making processes, and local governance formats in shaping the success or challenges of the respective municipal heating transitions. Furthermore, the employment of innovative approaches, technologies, and governance instruments is investigated. This helps to achieve the adjustment and validation of the existing heuristic framework for analyzing municipal levers in the lifespan of infrastructures.

4. Discussion and Conclusion

This study set out to investigate the complex interrelations between urban infrastructures and climate change governance in SMSTs, with a particular focus on municipal heating systems, drawing on the theoretical integration of the Long-term Governance Framework, the Multi-level Perspective, and Change Management. The cases illustrate that while the context matters, many of the identified levers—such as addressing justice, enabling collaborative governance, and embedding change management—are widely transferable and scalable across municipalities. The heuristic model developed and tested in this study proves valuable as both an analytical and strategic tool. It not only facilitates a structured understanding of infrastructure-related governance challenges but also enables municipalities to identify and prioritize actions for climate-resilient development. Importantly, the model acknowledges the non-linear, evolving nature of infrastructure systems and the necessity of dynamic governance responses.

In conclusion, this research contributes to closing the knowledge gap on climate governance in SMSTs and provides actionable insights for municipal actors navigating the heating transition. The focus on the complete lifespan of urban infrastructures allows for a better understanding and shaping of municipal governance to advance a climate resilient urban transformation. Future research should expand the empirical base, refine the heuristic framework across different infrastructure sectors, and explore how institutional learning can be fostered across municipalities facing similar challenges. Ultimately, equipping SMSTs with robust, adaptive governance tools is essential for a just and effective climate transition at the urban scale.

References

Albers, R. A. W., Bosch, P. R., Blocken, B., van den Dobbelsteen, A. A. J. F., van Hove, L. W. A., Spit, T. J. M., van de Ven, F., van Hooff, T. & Rovers, V. (2015). Overview of challenges and achievements in the climate adaptation of cities and in the Climate Proof Cities program. Building and Environment, 83, 1–10. https://doi.org/10.1016/j.buildenv.2014.09.006

Andersson, E., Grimm, N. B., Lewis, J. A., Redman, C. L., Barthel, S., Colding, J. & Elmqvist, T. (2022). Urban climate resilience through hybrid infrastructure. Current Opinion in Environmental Sustainability, 55, 101158. https://doi.org/10.1016/j.cosust.2022.101158

Banerjee, P., & Petersen, S. (2023). Learning in Cities from Within and Across Cities: A Scoping Review. Triple Helix, 1–38. https://doi.org/10.1163/21971927-bja10044

BBSR (Ed.) (2024). Wärmewende in Deutschland: Status quo der Kommunalen Wärmeplanung.

Berescu, C., Vranken, J. & Querrien, A. (2011). Cities of tomorrow. Challenges, visions, ways forward. https://doi.org/10.2776/41803

Bloch, R., Jha, A. K. & Lamond, J. (2012). Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. https://doi.org/10.1596/978-0-8213-8866-2

Castán Broto, V., & Bulkeley, H. (2013). A survey of urban climate change experiments in 100 cities. Global Environmental Change, 23(1), 92–102. https://doi.org/10.1016/j.gloenvcha.2012.07.005

Cutter, S. L. (2021). Urban Risks and Resilience. In W. Shi, M. F. Goodchild, M. Batty, M.-P. Kwan, & A. Zhang (Eds.), Urban Informatics (pp. 197–211). Springer. https://doi.org/10.1007/978-981-15-8983-6_13

Czada, R., & Radtke, J. (2018). Governance langfristiger Transformationsprozesse. Der Sonderfall „Energiewende“. In J. Radtke & N. Kersting (Eds.), Energiewende: Politikwissenschaftliche Perspektiven (S. 45–75). Springer Fachmedien. https://doi.org/10.1007/978-3-658-21561-3_3

Depietri, Y., & McPhearson, T. (2017). Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.), Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice (pp. 91–109). Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5_6

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K. & Folke, C. (2019). Sustainability and resilience for transformation in the urban century. Nature Sustainability, 2(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Erickson, P., & Tempest, K. (2015). Keeping cities green: Avoiding carbon lock-in due to urban development.

EU (European Union) (Ed.). (2020). The New Leipzig Charter. The Transformative Power of Cities for the Common Good.

EU (European Union) (Ed.). (2021). Ljubljana Agreement. Urban Agenda for the EU.

Field, C. B., Barros, V., Stocker, T. F., Dahe, Q., Dokken, D. J., Ebi, K. L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S. K., Tignor, M. & Midgley, P. M. (Eds.) (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. https://doi.org/10.1017/CBO9781139177245

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Grabski-Kieron, U., & Boutet, A. (2023). Kleine und mittlere Städte – Lage, Entwicklung und Perspektiven in verschiedenen Raumtypen. In E. Gustedt; U. Grabski-Kieron; C. Demazière; D. Paris (Eds.), Städte und Metropolen in Frankreich und Deutschland (pp. 87-109). Forschungsberichte der ARL 22.

Hoppe, T., Van der Vegt, A., & Stegmaier, P. (2016). Presenting a Framework to Analyze Local Climate Policy and Action in Small and Medium-Sized Cities. Sustainability, 8(9), Article 9. https://doi.org/10.3390/su8090847

Kern, K. (2023). Cities in EU multilevel climate policy: Governance capacities, spatial approaches and upscaling of local experiments (S. 113–128). https://doi.org/10.4337/9781789906981.00019

Kotter, J. P. (1996). Leading Change: Wie Sie Ihr Unternehmen in acht Schritten erfolgreich verändern. Verlag Franz Vahlen. http://d-nb.info/1002403197/04

Lewin, K. (1947). Frontiers in Group Dynamics: Concept, Method and Reality in Social Science; Social Equilibria and Social Change. Human Relations, 1(1), 5–41.

Libbe, J., Köhler, H., & Beckmann, K. J. (2010). Infrastruktur und Stadtentwicklung: Technische und soziale Infrastrukturen - Herausforderungen und Handlungsoptionen für Infrastruktur- und Stadtplanung. Deutsches Institut für Urbanistik.

OECD. (2024). Infrastructure for a Climate-Resilient Future. OECD. https://doi.org/10.1787/a74a45b0-en

Petrović, S., & Karlsson, K. (2014). Danish heat atlas as a support tool for energy system models. Energy Conversion and Management, 87, 1063–1076. https://doi.org/10.1016/j.enconman.2014.04.084

Rip, A., & Kemp, R. (1998). Technological change. In Human choice and climate change: Vol. II, Resources and Technology (pp. 327–399). Battelle Press.

Saidi, S., Kattan, L., Jayasinghe, P., Hettiaratchi, P., & Taron, J. (2018). Integrated infrastructure systems—A review. Sustainable Cities and Society, 36, 1–11. https://doi.org/10.1016/j.scs.2017.09.022

Scheer, D., Venghaus, S., Sardo, S., Stark, S., Kuppler, S., Schmidt, M., & Hoyer-Klick, C. (2025). No easy way out: Towards a framework concept of long-term governance. Energy, Sustainability and Society, 15. https://doi.org/10.1186/s13705-025-00513-3

Schmidt, M., & Monstadt, J. (2018). Infrastruktur. In ARL (Ed.), Handwörterbuch der Stadt- und Raumentwicklung (pp. 975–988).

Servillo, L., Atkinson, R., & Hamdouch, A. (2017). Small and Medium-Sized Towns in Europe: Conceptual, Methodological and Policy Issues. Tijdschrift Voor Economische En Sociale Geografie, 108(4), 365–379. https://doi.org/10.1111/tesg.12252

UNEP (United Nations Environment Programme) (Ed.). (2013). PROVIA Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change. Consultation Document. United Nations Environment Programme.

UN-Habitat (Ed.). (2022). World Cities Report 2022: Envisaging the Future of Cities.

Ürge-Vorsatz, D., Rosenzweig, C., Dawson, R., Sanchez-Rodriguez, R., Bai, X., Barau, A. S., Seto, K., & Dhakal, S. (2018). Locking in positive climate responses in cities. Nature Climate Change, 8. https://doi.org/10.1038/s41558-018-0100-6

Viguié, V., & Hallegatte, S. (2012). Trade-offs and synergies in urban climate policies. Nature Climate Change, 2, 334–337. https://doi.org/10.1038/nclimate1434

Mobility and Urban Space

Exploring the Potential of Mobility Hubs to Enhance Intermodal Private Transport Choices - A Stated Choice Approach in the Surroundings of Karlsruhe

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Abstract

The current car-dependent transport system in industrialized countries such as Germany not only exceeds ecological planetary boundaries but also creates unequal mobility opportunities and burdens for various groups of people (Mattioli et al., 2020). For example, individuals in suburban and rural areas often face limited access to public transportation, making them more reliant on cars, while low-income urban residents might suffer from higher exposure to air pollution due to traffic congestion. Additionally, people with disabilities may encounter significant challenges in accessing car-dependent infrastructure, further exacerbating mobility inequalities (Mindell et al., 2024).
This urges the need for a spatially adapted solution to reduce environmental burdens alongside social challenges and to especially focus on the connection between urban and rural area. In recent years, the provision of mobility hubs has emerged as a potential solution for enhancing the compatibility of intermodal transport options in comparison to motorized individual transport Arnold et al. (2023). A mobility hub, also known as a shared mobility hub, is defined as "a location where multiple sustainable transport modes come together at one place, providing a seamless connection between modes and offering besides public transport several shared mobility options, but also potentially including other amenities, ranging from retail, workplaces, to parcel pick-up points like lockers" (Blad et al., 2022).

Regarding its potential uptake, Xanthopoulos et al. (2024) reach the conclusion that without the introduction of additional push measures, the enhancement of sustainable modes of transport through mobility hubs would be negligible. Rongen et al. (2022) provide qualitative evidence that policies such as road pricing and parking restrictions have a strong positive influence on the uptake of mobility hubs.

Consequentaly, this study aims to explore the interplay between the provision of mobility hubs and car-restrictive policies and their joint impact on choosing intermodal routes instead of private cars. Furthermore, the potential of mobility hubs to enhance accessibility for specific social groups, including elderly individuals and those residing in rural areas, will be a key focus area. To investigate these interactions I will conduct a survey with a stated choice experiment, which is a commonly used method to investigate the behavioral impact of new concepts and technologies in transport research (Rose and Bliemer, 2009).

The survey will be part of the project "Country to City Bridge", funded by the German Federal Ministry for Digital and Transport. The aim of the project is to research an attractive mobility service with a high level of social acceptance as an alternative to the private car for connecting the countryside to the city, based on new, automated vehicle concepts and their networked operation in a ridepooling fleet. At mobility stations on the outskirts of the city, it will be possible to switch to conventional public transport or other alternative means of transport such as hire bikes.
The geographical focus of this project is on the greater Karlsruhe area, where the planning of possible mobility hubs is also taking place. The participants should therefore be representative of the city and district of Karlsruhe. One main advantage is that collected data will be comparable to the MiD (Mobilität in Deutschland). This is to be ensured by drawing a sample from the population register or via a market research institute. The invitation to the survey will be sent by post and the survey itself will be conducted online.

The survey is structured in the following manner: First, respondents are asked to provide information regarding their socio-economic factors, including age, gender and household income. This is followed by an inquiry into their mobility behaviour, with particular emphasis on the most frequently utilized means of transportation. These responses subsequently serve as a status quo alternative in the subsequent choice experiments. Furthermore, respondents are prompted to disclose information regarding their available mobility resources, such as the availability of personal vehicles or bicycles, membership status of the Deutschlandticket or car-sharing services. Additionally, the quality of public transport will be assessed by investigating accessibility and frequency of connections of individuals. The provision of socio-economic information, combined with knowledge about respondents' mobility behaviour and available mobility resources, will be used to pre-group respondents and assign them to different choice task designs. For example, respondents residing in urban areas and who frequently use a car will receive different choice tasks than rural inhabitants who do not do so.
The objective of the present study is to examine people's propensity to utilize intermodal transportation options. To this end, each choice task will comprise at least one such option. To ensure the creation of realistic scenarios, each choice task will present a genuine route within the Karlsruhe region, with the respondent tasked with selecting a suitable mode of transport. These routes will be further differentiated in terms of distance and spatial structure of route origin and destination. For example, one route choice includes a medium distance and leads from the suburban area of Karlsruhe into the city centre. Given its intermediate distance, the alternative of walking is rendered unfeasible.

In order to circumvent the occurrence of respondent fatigue or inundation, the number of alternatives for each choice task will be curtailed to a maximum of three, constituting a subset of all alternatives. In addition to the intermodal transport options, one option will encompass the status quo mode that respondents previously reported on using.

The impact of car-restrictive policies and incentives to use intermodal transport options will be reflected in the attributes of the mode choice tasks. The following main attributes will be included: costs, access and travel time, as well as the number of necessary interchanges per trip. Furthermore, to study the impact of being collected at home by an autonomous bus on people's choice behavior, with this will be included as a scenario description in some choice tasks. Further scenario descriptions will facilitate an investigation into the impact of the provision of amenities and co-working opportunities at mobility hubs. Additionally, this study will examine the impact of reporting estimated costs per mode and month instead of trip-wise. The latter will allow for an analysis of whether respondents' decision-making behavior is influenced by the presentation of costs.

Refernces

Arnold, T., Frost, M., Timmis, A., Dale, S., and Ison, S. (2023). Mobility hubs: review and future research direction. Transportation Research Record, 2677(2):858–868.
Blad, K., de Almeida Correia, G. H., van Nes, R., and Annema, J. A. (2022). A methodology to determine suitable locations for regional shared mobility hubs. Case Studies on Transport Policy, 10(3):1904–1916.
Mattioli, G., Mattioli, G., Roberts, C., Steinberger, J. K., and Brown, A. (2020). The political economy of car dependence: A systems of provision approach. Energy research and social science, 66:101486–.
Mindell, J. S., Amin, S., Mackett, R., Taylor, J., and Yaffe, S. (2024). Disability and travel. In Advances in Transport Policy and Planning. Advances in transport policy and planning.
Rongen, T., Tillema, T., Arts, J., Alonso-Gonz´alez, M. J., and Witte, J.-J. (2022). An analysis of the mobility hub concept in the Netherlands: Historical lessons for its implementation. Journal of Transport Geography, 104:103419.
Rose, J. M. and Bliemer, M. C. (2009). Constructing efficient stated choice experimental designs. Transport reviews, 29(5):587–617.
Xanthopoulos, S., van der Tuin, M., Azadeh, S. S., de Almeida Correia, G. H., van Oort, N., and Snelder, M. (2024). Optimization of the location and capacity of shared multimodal mobility hubs to

maximize travel utility in urban areas. Transportation Research Part A: Policy and Practice,179:103934.

Networking Frontrunner Cities: the aspern.mobil LAB "Städte-Dialog "

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Abstract

Aspern Seestadt is one of Europe's largest urban development areas, and aims to create a dense, urban, and sustainable district modelled around the 15-minute-city with a focus on an innovative, low-car mobility concept. In this context, the aspern.mobil LAB tends to support a sustainable mobility culture in this urban development area and to pass on innovative solutions to other stakeholders. Therefore, the LAB launched the Städte-Dialog (Cities Dialogue). This exchange connects pioneers in planning low-car neighbourhoods. It uses expert contributions and examples to present new approaches and establish new solutions and alliances in the city administrations through workshops. The Cities-Dialogue poses essential questions to the lab: How can knowledge from the urban mobility lab be successfully imparted on a higher level, and what can the network between cities contribute to our neighbourhood-oriented urban mobility lab?

1. The aspern.mobil LAB in aspern Seestadt

Aspern Seestadt – Vienna's urban laboratory – is one of Europe's largest urban development areas. Around 25,000 residents and up to 20,000 jobs will be here by the 2030s. The aim is to combine urbanity and periphery through an innovative concept that includes building groups, high-quality public spaces, and a sustainable mobility system. The urban development is based on the guiding principles of the. The design follows the principle of "life first, then the urban space, then the buildings" (Gehl Architects, 2009, p. 18).

A dense network of footpaths and cycle paths creates internal and external connections and promotes active mobility. Before the residents moved in, the underground had already travelled to Seestadt. Six neighbourhood car parks with around 1,900 parking spaces organise motorised traffic. (Wien 3420 aspern Development & Stadt Wien MA 18, 2018, p. 30) A mobility fund, financed by contributions from the car park operators, contributes to innovative mobility solutions such as a bicycle rental system, a car sharing system or a delivery service (Wien 3420 aspern Development, n.d.) For the aspern.mobil LAB, this offers many opportunities for research and development.

The lab is based on the Reallabor-Approach (living lab). It addresses the following aspects: As a mediating body, it contributes to improving the quality of life in the urban development area and thus contributes " to transformation in socially relevant problem areas" (Haus, 2025, p. 468). The core of the lab is to "close the gap between research and practice" (Haus, 2025, p. 466) and to develop new practical mobility offers in processes of cross-stakeholder collaboration. The aspern.mobil LAB fulfils all criteria according to Parodi (2024, p. 217); the long duration of over ten years, the claim to transformation and the intensive integration of residents, administration and business in the sense of transdisciplinarity should be emphasised. With its broad range of methods, the lab addresses three categories of social change: social and individual change, governance change and structural change (Kreß-Ludwig et al., 2024, p. 13).

2. Innovation corridors

The aspern.mobil LAB focuses on neighbourhood-related mobility in aspern Seestadt, including its origin and destination traffic. Three-quarters of all journeys usually begin and end at the residential location, which mobility innovations can therefore influence. (Löster, 2022)

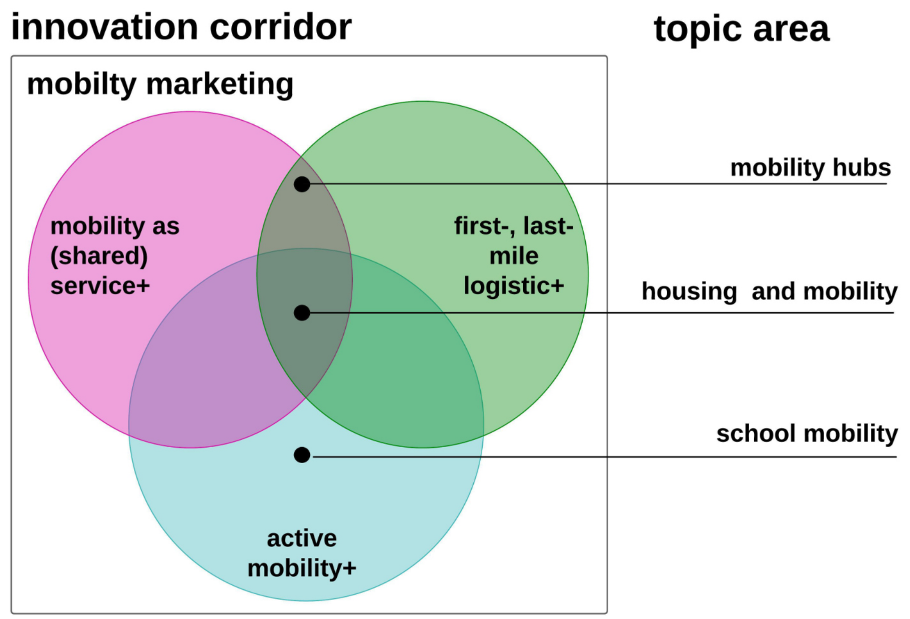

Fig. 1: Innovation corridors of aspern.mobil LAB and corresponding topics (own illustration).

One of the lab's goals is to transform the mobility culture in Seestadt so that residents can travel more often on foot, by bike, or with sharing services. Mobility culture is understood as a perceived consensus within local social networks on further developing the local mobility system (Bamberg et al., 2020, p. 3). The local mobility culture is reflected in peer-to-peer car sharing initiatives, ideas competitions on mobility in Seestadt, comprehensive mobility advice and decentralised cargo bike sharing, among other things.

Corresponding innovation corridors of the aspern.mobil LAB integrate modes, operators and infrastructures into the mobility system to enable seamless intermodal travel chains. However, the corridors are not solely focused on mobility; other services extend them. This Plus (see figure 1) links the corridors with cross-sectors and refers in the field of active mobility to the interaction with health and sport; in first/last mile logistics it considers the neighbourhood as a central; in the area of Mobility as a (Shared) Service it is primarily aimed at linking services outside of mobility with mobility-related ones. The mobility consultancy, aspern Seestadt, creates advisory, marketing, and communication services to raise awareness of innovative mobility solutions. With the topics of mobility hubs, housing, and mobility, as well as school mobility, it is possible to achieve a strong practical relevance from local problems.

3. Structure

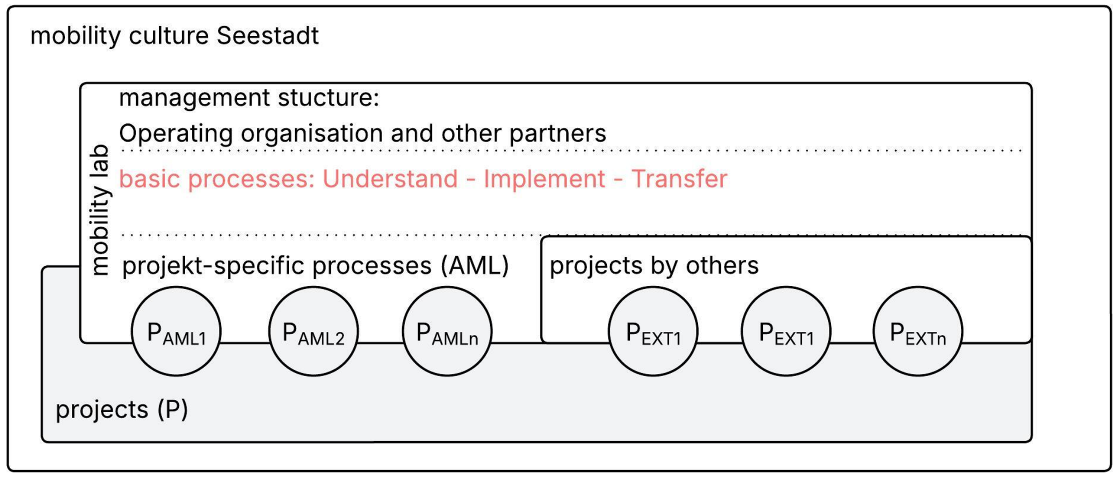

Fig. 2: Embedding and structure of the aspern.mobil LAB (own illustration).

The aspern.mobil LAB is operated by TU Wien, in particular by the research units Transportation System Planning (MOVE) and Law (Faculty of Architecture and Spatial Planning) as well as the research unit Artifact-Based Computing and User Research (Faculty of Computer Science). There is an exchange with other mobility laboratories from the research field. There is close co-operation with the administration (Wien 3420) and the Vienna Business Agency. A particularly close partner is the city's innovation agency, Urban Innovation Vienna (UIV), responsible for the city network (see section 5). There is intensive contact with residents via neighbourhood management, an instrument of the City of Vienna that supports new urban development areas (Gebietsbetreuung Stadterneuerung, n.d.) and its formats.

The laboratory works in a three-part structure that is embedded in the mobility system of the City of Vienna, the mobility culture, and the local projects (see figure 2). The lab comprises its organisation, the basic processes, and project-specific processes. The lab organisation, to which the other processes are linked, includes content and financial management, the space used for projects, meetings, events, and the existing technical infrastructure and social networks. Within the laboratory, the basic processes of understanding, implementing, and passing on are the central working concept (see section 4). The projects link their activities to these basic processes and are thus embedded in the laboratory. The innovation projects draw various processes from the aspern.mobil LAB. For example, the mo.hub project was supported in the co-creative design and location finding of mobility stations – a topic that also met with great interest in the "Städte-Dialog" (Cities Dialogue).

4. Basic processes

The basic processes are value propositions for various stakeholders in the lab's ecosystem. They function independently of the projects and are divided into understanding, implementing, and passing on.

Understanding: The basis for successful mobility innovations is a differentiated understanding of the diverse mobility needs of different user groups in Seestadt. For example, the aspern Seestadt mobility survey - a long-term study on mobility behaviour in the neighbourhood - provides high-resolution and socially differentiated mobility data (aspern.mobil LAB, n.d.). The resulting knowledge enables better target group-oriented planning of mobility offers and is part of the indicators for evaluating urban development(Wien 3420 aspern Development, 2024, p. 19).

Implementing: In close cooperation with users, administration and local stakeholders, ideas are accompanied from conception to implementation in the real-world laboratory according to the "design thinking" principle. The realisation of the Pocobo fine dust sensor in the form of a bicycle drinking bottle, which was developed from a lab's formats and used in various application contexts by multiple stakeholders, was supported.

Passing on: Thanks to its practical approach, the lab acts as a bridge between the administration and innovation stakeholders. Systemic consulting imparts tried and tested methods for overcoming technical and organisational hurdles. The instruments for this are events such as the "Tage des offenen Reallabors" and public relations. At the same time, aspern.mobil LAB promotes knowledge transfer between cities and neighbourhoods with similar challenges and goals, as described in the following section.

5. Transfer to neighbourhoods and the city network format

Learning about processes is essential "to translate successful urban innovation projects into broader transformation" (Evans et al., 2021, p. 179). The format Städte-Dialog directly addresses sharing and learning. Various innovative mobility solutions have already been realised in Seestadt aspern, including at the interface between urban development, public space, and housing. A vital partner here is Urban Innovation Vienna, which has developed guidelines and recommendations for action in this area for the City of Vienna (Urban Innovation Vienna, 2019).

Since 2023, the aspern.mobil LAB has developed a regular exchange on local innovations in the field of low-car district planning: the Cities Dialogue "Planning low-car neighbourhoods". The dialogue aims to gain a common understanding of success factors and barriers to innovation and to discuss these in a joint framework.

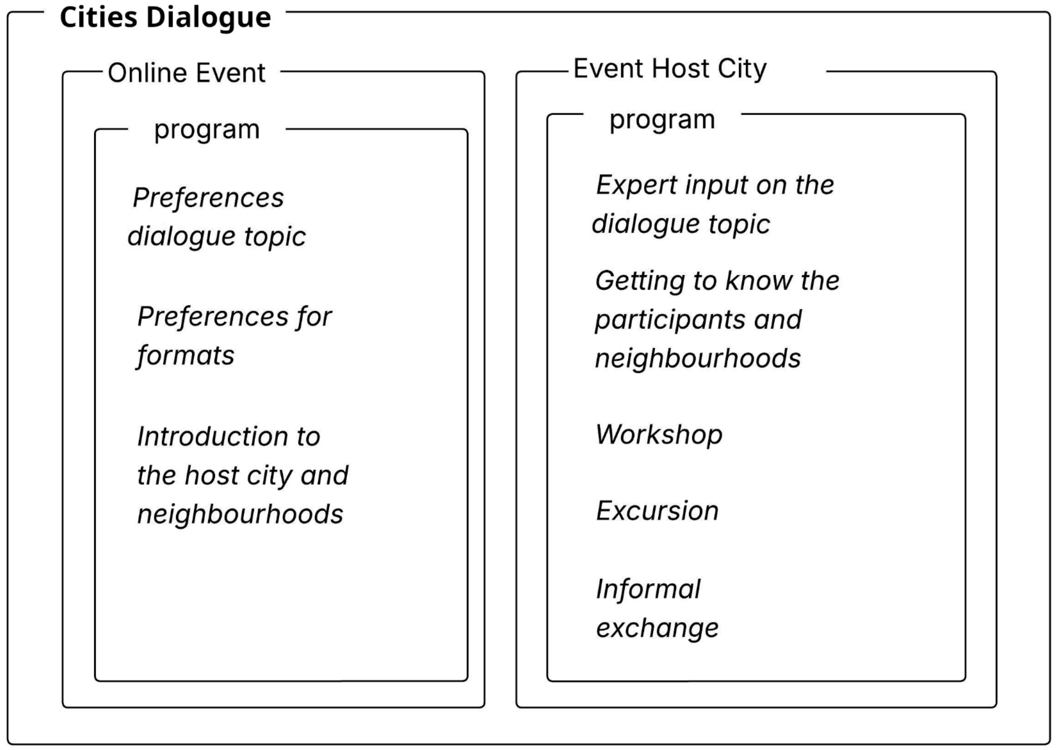

Fig. 3 Structure of the Cities Dialogue "Planning low-car neighbourhoods" (own illustration).

Evans et al. emphasise the importance of research institutions in passing knowledge to city administrations (2021, p. 179). This is also where aspern.mobil LAB and its processes enable activities that have not yet emerged from the city administrations.

The format, which provides for an annual meeting, has occurred twice, in October 2024 and October 2025. Each Cities Dialogue has a host city and is dedicated to an overarching topic. Vienna kicked things off with a focus on neighbourhood car parks, followed by Heidelberg in 2025. In preparation for each exchange, there is an online meeting at which the participants are asked for their methodological and content-related priorities. This also strengthens the motivation for participation in the Cities Dialogue by allowing participants to get to know each other and contribute their topics and questions.

The online preparatory meeting follows the Cities Dialogue with an on-site event. The exchange (see figure 3) addresses all three learning settings identified by Glaser et al.(Glaser et al., 2022, pp. 632–635) (networks, study visits, workshops):

1. Joint visits to the innovative neighbourhoods and the implemented solutions on site,
2. expert input on the dialogue topic on site from participants of the event, and
3. Workshops on various issues and solutions brought to the event by the participants.

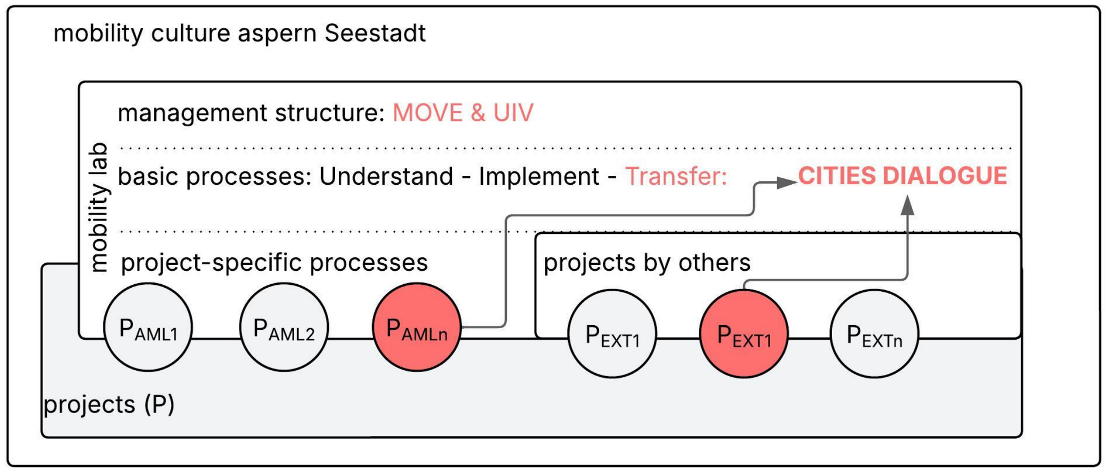

Fig 4: Integration of projects in the basic process of passing on, using the example of the Cities Dialogue (own illustration).

The Cities Dialogue benefits from the diverse processes and projects implemented as part of the aspern.mobil LAB and beyond (see figure 4). For example, through the aspern Seestadt mobility survey (see section 4), it can be shown that the neighbourhood car parks achieve their intended effect. The distance travelled by people who park their cars in the garages is the same as the distance to the bus stop. Findings from the mo.hub project, which investigated the co-creative development of mobility, could be taken up in the urban dialogue, for example, in workshops.

6. Outlook

The aspern.mobil LAB in Vienna's aspern Seestadt urban development district is a mobility laboratory for promoting a sustainable mobility culture. The integrated working methods and associated synergies of the mobility lab could be demonstrated using the urban dialogue "Planning low-car neighbourhoods" as an example. The dialogue, which focuses on obstacles, innovations and solutions in mobility and urban development, has established a new learning structure between city administrations. The aspern.mobil LAB is currently organising the urban dialogue. Still, with funding for the lab ending, the question arises as to whether and how this network can be carried forward into the future. Further dissemination initiatives could address other target groups such as politicians, active citizens, planning offices, and companies. The formats of the city dialogue would need to be adapted for this. The commitment of the participating cities and the positive feedback on the one

hand, and the easily comprehensible and straightforward structure on the other, which has also focused on personal responsibility, show that this learning format is gaining importance for cities.

This article was translated with the help of deepl.com.

References

aspern.mobil LAB. (n.d.). Die Mobilitätserhebung aspern Seestadt. Aspern.Mobil LAB. Retrieved 20 June 2025, from https://www.mobillab.wien/mobilitaetspanel/

Bamberg, S., Rollin, P., & Schulte, M. (2020). Local mobility culture as injunctive normative beliefs – A theoretical approach and a related measurement instrument. Journal of Environmental Psychology, 71, 101465. https://doi.org/10.1016/j.jenvp.2020.101465

Evans, J., Vácha, T., Kok, H., & Watson, K. (2021). How Cities Learn: From Experimentation to Transformation. Urban Planning, 6(1), 171–182. https://doi.org/10.17645/up.v6i1.3545

Gebietsbetreuung Stadterneuerung. (n.d.). Was wir tun. GB*Stadtteilmanagement. Retrieved 20 June 2025, from https://www.stadtteilmanagement.wien/was-wir-tun/

Gehl Architects. (2009). Partitur des öffentlichen Raums (Wien 3420 aspern Development & Stadt Wien MA 18, Eds.). https://www.aspern-seestadt.at/jart/prj3/aspern/data/downloads/PartiturdesffentlichenRaums_2017-07-12_1607953.pdf

Glaser, M., Bertolini, L., Te Brömmelstroet, M., Blake, O., & Ellingson, C. (2022). Learning through policy transfer? Reviewing a decade of scholarship for the field of transport. Transport Reviews, 42(5), 626–644. https://doi.org/10.1080/01441647.2021.2003472

Haus, J. (2025). Transdisziplinäre Experimentierräume als Forschungsstrategien in der Mobilitätswende. In W. Canzler, J. Haus, A. Knie, & L. Ruhrort (Eds.), Handbuch Mobilität und Gesellschaft (pp. 465–484). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-37557-7_27

Kreß-Ludwig, M., Marg, O., Schneider, R., & Lux, A. (2024). Lessons from transdisciplinary urban research to promote sustainability transformation in real-world labs: Categories, pathways, and key principles for generating societal impact. GAIA - Ecological Perspectives for Science and Society, 33(1), 10–17. https://doi.org/10.14512/gaia.33.S1.3

Löster, N. (2022, January 13). Drei Viertel aller Wege beginnen oder enden vor der eigenen Haustür. https://www.vcd.org/artikel/wohnen-und-mobilitaet-klimaschutz-im-verkehr

Parodi, O., Ober, S., Lang, D. J., & Albiez, M. (2024). Reallabor versus Realexperiment: Was macht den Unterschied? GAIA - Ecological Perspectives for Science and Society, 33(2), 216–221. https://doi.org/10.14512/gaia.33.2.4

Urban Innovation Vienna. (2019). Werkstattbericht Leitfaden Mobilitätsmaßnahmen im Wohnbau (Stadt Wien – Stadtteilplanung und Flächenwidmung, Ed.).

Wien 3420 aspern Development. (n.d.). Mobilität gemeinsam weiterentwickeln. aspern die Seestadt Wiens. Retrieved 20 June 2025, from https://www.aspern-seestadt.at/lebenswelt/mobilitaet/mobilitaet_gemeinsam_weiterentwickeln

Wien 3420 aspern Development. (2024). EVA: Evaluierung, Zwischenbilanz und Zielsystem für aspern Seestadt.

Wien 3420 aspern Development & Stadt Wien MA 18 (Eds.). (2018). Fortschreibung Masterplan.

THE IMPACT OF SMART MOBILITY ON URBAN SPATIAL STRUCTURE

-- Comparing cities in China and Germany

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1. Introduction & Research Problem

- **Urban Form and Transportation Technology**
  Urban spatial structure has evolved with each transport era—from horsecars to highways—each reshaping the urban form.
- **New Transport Era**
  Smart mobility, driven by ICT, automatic driving, and Mobility as a Service (MaaS), represents a new paradigm in urban transport.
- **From Movement to Morphology**
  Smart mobility not only changes how people move but also reshapes lifestyles and travel behavior, thereby influencing land use, accessibility, and urban morphology.
- **Artificial Intelligence as a Methodological Catalyst**
  AI techniques like computer vision and machine learning now enable large-scale analysis of spatial and behavioral data.
- **Research gap**
  Despite the growing prominence of smart mobility, its spatial implications remain underexplored, particularly within cross-cultural and institutional contexts.
- **Research goal**
  This study combines Artificial Intelligence (AI) and Structural Equation Modeling (SEM) to analyze the bidirectional relationship between smart mobility, travel behavior, and spatial structure across Chinese and German urban regions. It further explores how behavioral factors mediate these effects and how socio-cultural and institutional differences shape the adoption and spatial consequences of smart mobility. Through this integrated framework, this approach seeks to inform data-driven and culturally adaptive urban planning strategies that support sustainable and equitable mobility transitions.

2. Key Research Questions

→ **How does Smart Mobility influence urban spatial structure, both directly and indirectly?**

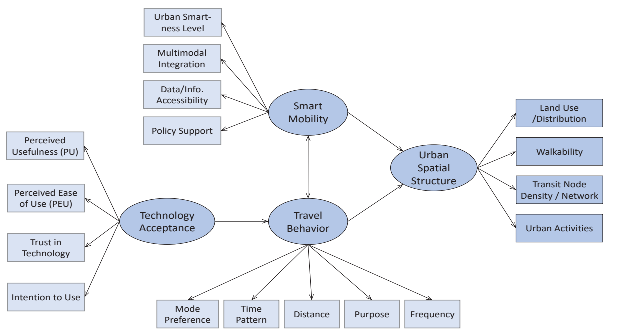
→ **To what extent are those effects mediated by behavioral change, and how do behavioral mechanisms vary across different socio-cultural and institutional contexts?**

→ **How can these complex, multidimensional relationships be measured and modeled using an integrated AI–SEM framework?**

3. Theoretical Framework

- **Socio-technical shaping of urban space**
  Early technological determinism viewed technology as an autonomous driver of spatial change, while the SCOT framework emphasizes its cultural, institutional, and social embeddedness.
- **Behavioral perspectives on mobility decisions**
  TPB explains travel choices via attitudes, control, and norms. TAM extends this by linking perceived usefulness and ease of use to technology adoption—key to understanding smart mobility uptake.
- **Subjective influences on travel mode choice**
  Recent studies highlight how lifestyle, risk perception, adaptability, and environmental attitudes shape mobility behavior, particularly in response to emerging transport options.
- **Spatial-structural constraints and affordances**
  Time geography, space syntax, and TOD theories stress how spatial form and accessibility shape behavior, reinforcing structure–behavior feedback mechanisms.

4. Conceptual framework of the structural equation model

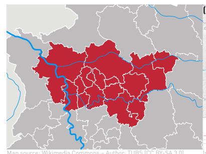


The interaction between smart mobility, travel behavior, and urban spatial structure is understood as a complex feedback system characterized by multidimensional and bidirectional causal paths. These interactions are mediated by both structural forces, such as spatial form and policy frameworks, and subjective drivers like perception, attitude, adaptability and cultural background.

The model integrates latent variables and AI-derived spatial indicators to capture the co-evolutionary dynamics between digital mobility systems, user behavior, and spatial organization in both Chinese and German metropolitan regions.

6. Case Study Regions & Comparative Design

Ruhe Area



Map source: Wikimedia Commons – Author: TUBS (CC BY-SA 3.0)

Chengdu–Chongqing urban agglomeration (CCUA)

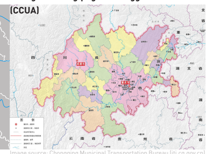


Image source: Chongqing Municipal Transportation Bureau (jtj.cq.gov.cn)

	Ruhr Area (Germany)	CCUA (China)
Area	Approx. 4.435 Km2	Approx. 54.000 Km2
Population	5 million	80 million
Urban Morphology	Polycentric, post-industrial	Polycentric megaregion, developing
Population Density	Medium	High - Lower in peripheral areas
Industrial Characteristics	Former coal and steel base, now transitioning to services and tech	Fast-growing manufacturing, digital economy, and green industries
Digital Economy Foundation	Well-developed ICT, logistics, and R&D network; focus on "Industry 4.0"	Rapidly growing; strong focus on smart mobility and AI-based urban governance
Transport Infrastructure	Dense rail, road, light rail networks; integrated regional fare system	Rapid expansion of high-speed rail, metro systems, and BRT lanes
Smart Mobility Facilities	Existing smart bus dispatching, integrated transfer hubs, shared bike systems	Multi-platform mobility (e.g., Didi, Amap), facial recognition ticketing, smart traffic lights
Smart Mobility Policies	EU-supported MaaS, autonomous driving, and sustainable transport initiatives	National-level smart city and green mobility pilot programs (e.g., Chengdu, Chongqing)
National Strategic Role	Historically strategic industrial core	Key driver in Western Development strategy
Data Availability	High	Medium–High

7. Contribution

- **Contribution to Urban Transformation**
  - This study reveals how smart mobility technologies reshape urban spatial structure, both directly and indirectly.
  - It integrates behavioral and spatial perspectives into a unified urban modeling framework.
  - It offers cross-cultural comparative insights by examining both Chinese and German metropolitan contexts.
- **Practical Impact and Policy Relevance**
  - The findings support integrated spatial and mobility planning for more adaptive urban strategies.
  - It informs behavior-sensitive smart mobility policies grounded in user perception and lifestyle.
  - The AI-enhanced framework enables data-driven urban monitoring and governance.
  - It promotes context-sensitive policy design by considering socio-cultural diversity.

5. Data & Methodology

DATA COLLECTION

Statistics Data
Source: Gov. open plattforms
Content: Smart Mobility infrastrcture, population, economic, etc.
Tools: python, Excel

Survey Data
Content: Travel habits, TAM, TPB constructs
Tools: LimeSurvey

Satellite Images
Sources: Google Earth, National Open Platforms
Temporal Coverage: 2010–2025, 2–3 year intervals

AI PROCESSING

Computer Vision / ML
Tasks: Urban form feature extraction (e.g., block size, density, land use patterns)
Material: Satellite Images
Tools: python

Spatial Analysis
Tasks: GIS overlay, Urban Change De tection, Spatial Trend Analysis, Indicator Extraction.
Temporal Coverage: 2010–2025 2–3 year intervals
Tools: ArcGIS, python

SEM MODELING

Hybrid SEM Framework
Constructs: Smart Mobility, Travel Beha vior, Urban Spatial Structure, Technology Acceptance
Latent variables: TAM/TPB components, subjective evaluation
AI Integration: Capture non-linear relationships and spatial complexity
Cross-cultural Analysis: Modeling Cultural Variation in Mobility–Space Causality
Tools: python, Smart PLS, R

FINAL OUTPUTS

Data-driven spatial model
Uses multi-source data such as statistical, survey, and remotely sensed data to model smart mobility's impact on urban spacial structure.

Culturally adaptive planning insights
Offers evidence-based planning strategies sensitive to cultural and behavioral differences.

Integrated methodological framework (AI + SEM)
An AI-integrated SEM framework to analyze complex, multi-directional causal relationships among key constructs.

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Diesel Bans and Urban Air Quality: A Causal Study of NO2 Emissions in Germany Using Synthetic Control

Narek Mirzoyan
Karlsruhe Institute of Technology (KIT)

Abstract

Urban air pollution is a growing public health and environmental issue. This study investigates the effectiveness of diesel traffic bans in reducing nitrogen dioxide emissions in four German cities: Berlin, Darmstadt, Hamburg, and Stuttgart, from 2012 to 2022. Each city has implemented similar policies to comply with the European Union's emission standards.

Using the synthetic control method, we evaluate the effects of policies restricting diesel traffic on selected streets, street segments, and urban areas. Our results indicate that the implementation of diesel traffic bans led to significant reductions in nitrogen dioxide emissions per capita in Darmstadt and Stuttgart. However, the policy appeared to have a limited effect in Berlin and Hamburg.

The study suggests that policy effectiveness is influenced by factors such as city size, pre-existing traffic patterns and the extent of diesel restrictions. In addition, our findings highlight the importance of tailoring policies to local conditions and underscore the value of using rigorous research methods when assessing the effectiveness of environmental policies.

Bridging Home Care Services and Female Migrant Laborers by Electrical Two-Wheels

Prof. Haixiao Pan
Tongji University Shanghai

Abstract

At present, China is facing an increasing age. According to the national census, people aged 60 and above account for 18.7% of the population, including many disabled elderly people. Due to the birth control policy applied many years ago, nowadays, the empty nest family is increasing. Old people prefer to stay home instead of choosing nursing home services. Taking care of old parents and their descendants will be more challenging. New models of home care have sprung up. The Chinese government has launched many related policies, such as "Guidance on Expanding the Pilot Program of Long-term Care Insurance System" to support home care. The local government in less developed areas where the migrant home care workers come from has also carried out a training program to improve the capacity of those willing to join the nursing service to get their earnings.

The home care workers are primarily female migrants from less-developed rural areas. Their income is dependent on the number of families they can serve. The families they serve evaluate their service. Their mobile phones count the check-in time. To serve more families, they always work more than 12 hours daily at great intensity. Their work depends on reliable, flexible, physical strength-saving, and easy-parking travel modes.

To understand their service activity and living conditions, we surveyed 213 home care workers face-to-face. With a navigation App, we obtained the travel times by walking, bus, metro, and car between served families. It has been found that electrical two-wheelers are widely adopted and indispensable tools for home care workers to meet the demands of an aging society. It is concluded that central urban areas with high built environment density have a dense distribution of service points, caregivers' service travel time is shorter, service efficiency is high, and have a higher earning; suburban areas with low built environment density have a dispersed distribution of service points, caregivers' service travel time is high, service efficiency is low, the number of work orders is small, and their wages are relatively low. Electrical two-wheels enable the low-educated middle-aged female migrants from rural areas to become an adequate labor force in a mega city. Facing the aging society, holistic policies should be further explored.

Promoting Sustainable Urban Mobility through Quadruple Helix Collaboration: A Case Study on Ridesharing in Ried, Austria

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Abstract

Urban congestion and Scope 3 emission accountability drive the need for sustainable mobility. (EcoHedge, 2024; Machado et al., 2018). Ridesharing offers potential but often fails to scale (Shoshany-Tavory et al., 2022). This study examines how a multi-stakeholder approach, based on the Quadruple Helix framework, can promote ridesharing.

A case study in Ried, Austria, used the DOMINO app (https://domino-app.at) during European Mobility Week 2024 to launch a collaborative ridesharing initiative. The app combined multimodal routing, data tracking, and point-based rewards.

Results show that collaboration among companies, nonprofits, the city, and academia led to active engagement. Promotional efforts resulted in an initial increase in usage and shared rides. However, activity declined after the incentive phase ended, underlining the need for sustained engagement. Despite appealing rewards, participation remained below expectations, suggesting that behavioural change requires long-term commitment and targeted strategies to maximize impact.

Keywords: ridesharing, shared mobility, MaaS, living lab approach, behavioural change, multi-stakeholder collaboration, quadruple helix framework, corporate sustainability, scope 3 emissions

Introduction

Traffic congestion, air pollution, and limited urban space are growing challenges in urban areas, intensified by increasing transport demand (Darbanian et al., 2024; Lazarus et al., 2021). To address these issues, sustainable mobility solutions are needed, particularly those that optimize the use of existing transport resources. One such solution is ridesharing, where travelers with similar routes share a vehicle and associated costs (Furuhata et al., 2013; Mitropoulos et al., 2021; Pigalle & Aguiléra, 2023; Shaheen & Cohen, 2019).

Austria aims to reduce individual motorized transport from 61% in 2018 to 42% by 2040 (BMK, 2023a). However, vehicle occupancy has steadily declined—from 1.85 persons per car in 1960 to 1.15 in 2017, and only 1.08 for commuting—meaning just one in thirteen cars carries more than one person (BMK, 2023b; VCÖ, 2018).

Considering commuting (as reason for travel) the value drops to 1,08 persons in a vehicle. This means in only every 13th car there is a second person (BMK, 2023b; VCÖ, 2018). Increasing occupancy rates can significantly reduce total vehicle kilometers. The Federal Ministry for Climate Action projects a 2.5% reduction in domestic road traffic by 2030 compared to 2022 (BMK, 2023b).

This shift is also being driven by corporate sustainability obligations. As of 2025, large companies (under conditions) in Austria must report Scope 3 emissions, including those from employee commuting (Scope 3, Category 3.7)(Radonjič & Tompa, 2018; Schwochow). Under the Corporate Sustainability Reporting Directive (CSRD), this will extend to SMEs by 2026 (Green Vision Solutions, 2024).

Despite strong policy goals, many ridesharing initiatives remain small-scale and fail to scale up (Shoshany-Tavory et al., 2022).

This paper explores how and if multi-stakeholder collaboration within a quadruple helix framework—bringing together government, industry, academia, and civil society/community—can support ridesharing adoption. A case study in Ried, Austria, serves as the empirical basis.

Methods

This section explains the method used for the research.

Quadruple Helix Framework

Driving sustainable innovation requires collaboration across sectors. The Quadruple Helix framework, frequently applied in smart city contexts, emphasizes cooperation between government, industry, academia, and community/civil society (GRRIP, 2020b; Marchesani & Ceci, 2025). It aims to align innovation with societal needs, enhancing relevance and inclusivity. (Carayannis & Campbell, 2010; Encyclopedia, 2022).

Case Study Ried

A case study approach enables an in-depth examination of complex real-world phenomena (Goodman, 2011). This research applied the Quadruple Helix framework to the city of Ried, Austria, which faces congestion and parking challenges. At the same time, local companies seek to reduce emissions and support sustainable commuting for employees.

As of 2021, Ried had 12,404 residents, with 62,268 in the surrounding district (Brinkhoff, 2025). The region is car-dominated: in 2022, 74.3% of trips were made by motorized individual transport, 5.4% by public transport, 5.6% by bicycle, 13.4% on foot, and 1.2% were multimodal see Figure 1 ((Pfeiffer, 2022).

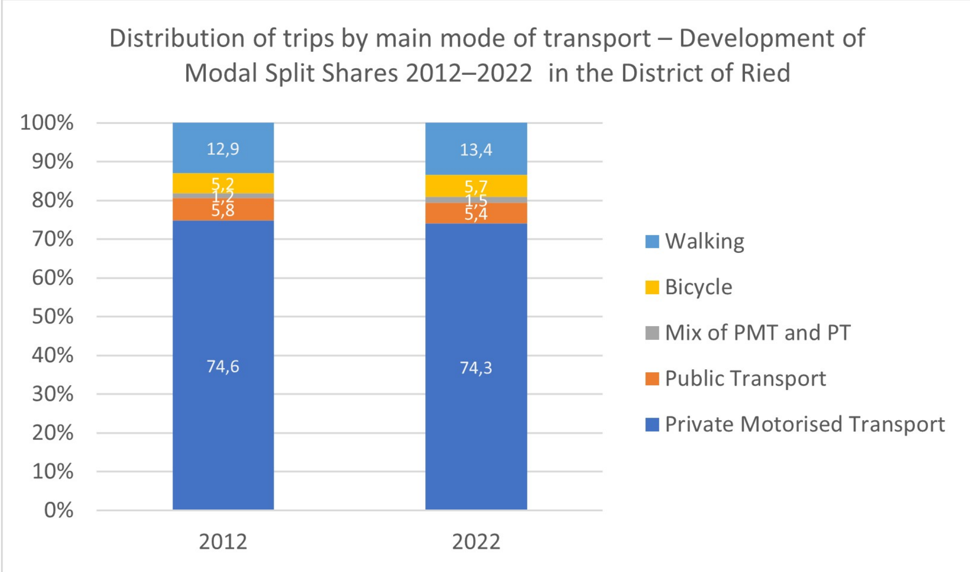


Figure 1: Modal split shares in Ried, FHOÖ & Land OÖ (Pfeiffer, 2022), 2025

Digital ride sharing infrastructure – DOMINO

To explore ridesharing potential, this study utilized the DOMINO app, developed through an R&D project by MobiLab and Fluidtime. Unlike conventional ridesharing tools, DOMINO integrates route planning for public transport, private vehicles, cycling, and walking. It allows for the creation of private communities, fostering trust and enabling incentive-based participation through a points system. The platform also enables behavioral data collection, supporting detailed analysis of ridesharing patterns.

Data Analysis

A dashboard was developed to visualize user behavior over a defined period. While the DOMINO Management Portal (Fluidlife) provides general user data, it lacks detail on ridesharing activities. To address this, data was extracted, processed, and enriched using a Python-based program integrating the OpenRouteService API. This generated shortest-path routes between trip origins and destinations, simulating actual journeys. The goal was to estimate distances travelled by drivers and passengers and calculate potential CO_2e savings, using the GLEC Framework (Global Logistics Emissions Council, 2023). Figure 2 illustrates the data processing and visualization workflow.

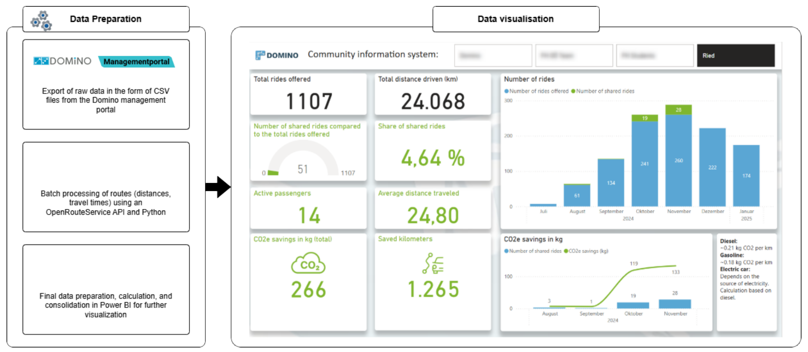


Figure 2: Schematic representation of data processing and visualisation, Müller, 2025

Results

This chapter presents the main findings of the case study in Ried, Austria, structured along the key methodological steps.

Quadruple helix framework – formation of the core team

The initiative was led by a local non-profit organization and the regional development agency, forming the backbone of the quadruple helix collaboration. Together, they engaged the City of Ried, seven major companies with emission reduction goals, and the University of Applied Sciences Upper Austria to provide scientific support, access to the technical infrastructure (DOMINO app) and impact measurement. Regular meetings allowed for joint decision-making and coordination.

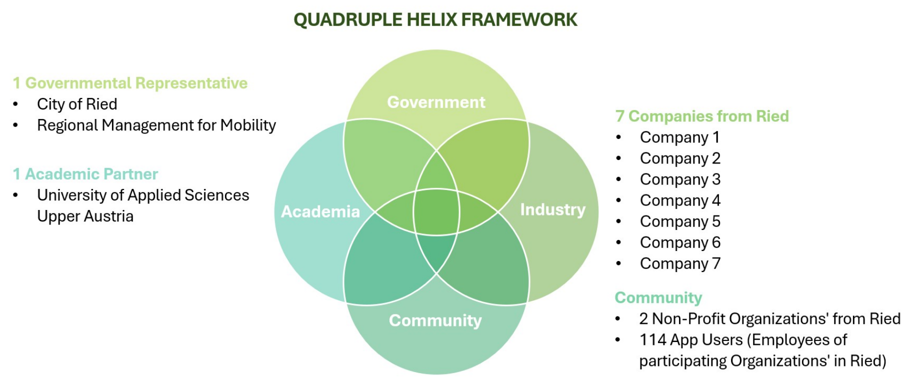


Figure 3: Quadruple Helix Framework including all actors of the DOMINO project in Ried, (GRRIP, 2020a) Reindl, 2025

Campaign launch and promotion

The European Mobility Week 2024 served as the campaign launchpad, branded as “Ried Rides”. From September to November, eleven partners promoted the DOMINO app, including through local press (Wiesbauer, 2024) and online-presence (Europäische Mobilitätswoche, 2024) and newsfeed over the app see Figure 4, Figure 5 and Figure 6.

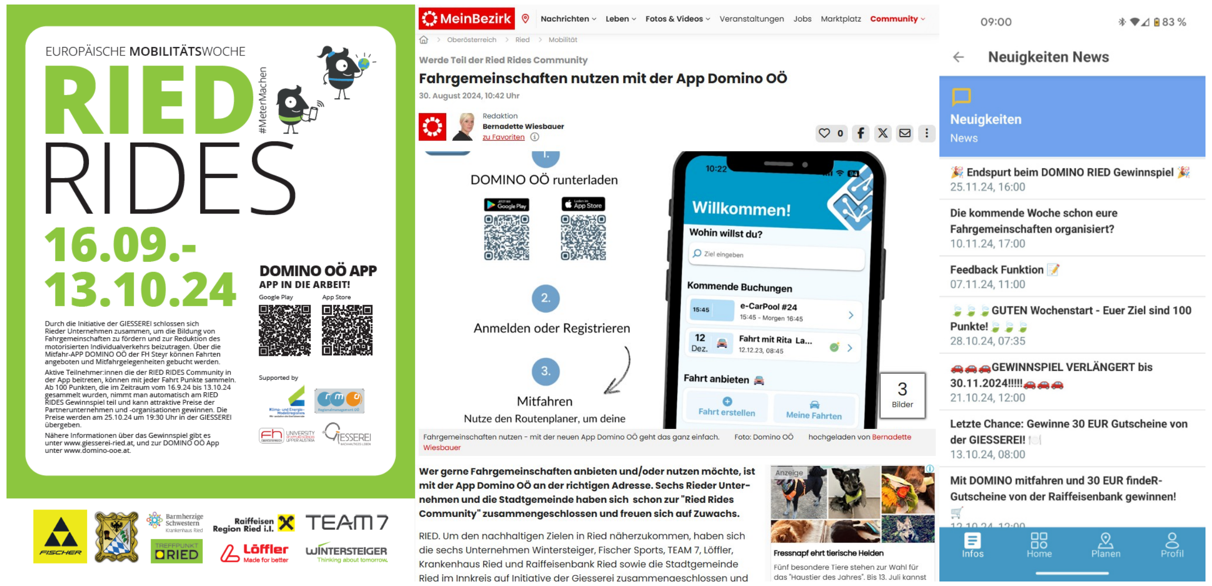


Figure 4: Ried Rides Campaign, Gieserei (Europäische Mobilitätswoche, 2024), 2024

Figure 5: Local Newspaper about DOMINO, Reindl (Wiesbauer, 2024), 2024

Figure 6: Newsfeed in the DOMINO App, Reindl, 2024

Implementation and Engagement

During this period the partners from industry, non-profit organizations and the city of Ried promoted the app via word of mouth, information within the own organizations, within the DOMINO app and so forth. Various communication channels were used to promote the campaign (see Table 1).

Table 1: Channels used in the course of the DOMINO campaign

Channels	Ried Rides promoted through	Details
E-Mail	✔	E-Mail to employees
Events & Conferences	✔	Price award ceremony
In App Promotion	✔	17 Articles in DOMINO app
Influencer & Partner Collaboration	-	
Intranet	✔	Intranet advertisement for Domino in the organizations of the project partners
Press	✔	Article in newspaper
Printed Material	✔	Flyer for mobility week
SEO & Online Advertising	-	
Social media	✔	DOMINO Instagram and TikTok
TV & Radio	-	
Word of mouth	✔	in organizations of the project partners

Incentivation

Participants earned points by offering or joining shared rides:

+1 point per offered ride

+15 points per completed shared ride (driver or passenger)

Reaching 100 points qualified users for a prize draw, which included rewards contributed from the project partners such as sports gear, gift baskets, and vouchers. The draw was extended from 4 to 11 weeks due to initially low participation: by mid-October, only 14 shared rides had occurred, with few users meeting the entry threshold of 100 points.

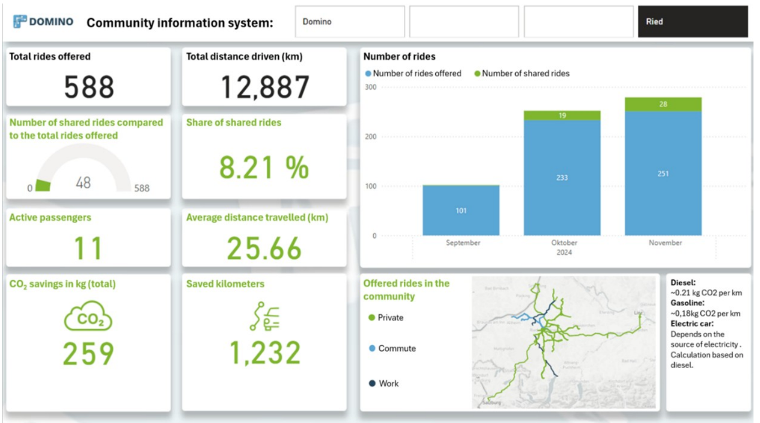
Data Collection

Early onboarding led to 42 users before the campaign began mid-September. By late September, 59 users had joined, offering 101 rides (after the official launch), with 1 shared ride.

In October, user numbers rose to 91 (+54%), and 234 rides were offered, 19 of which were shared.

By end of November, the community grew to 103 users (+13%). Users posted 253 rides and 28 of them were shared with passengers in the end. Over the entire incentive period (Sept 16–Nov 30), users offered 588 rides, resulting in 48 shared rides. That saved over 1200km with an estimated equivalent of 259 kg CO_2 savings (see Figure 7).

Figure 7: Results of DOMINO during period of prize draw from 16.09.2024-.30.11.2024, Müller & Reindl, 2025



After the prize draw ended, activity decreased sharply. Although users continued to offer rides, no shared rides were recorded in the weeks that followed.

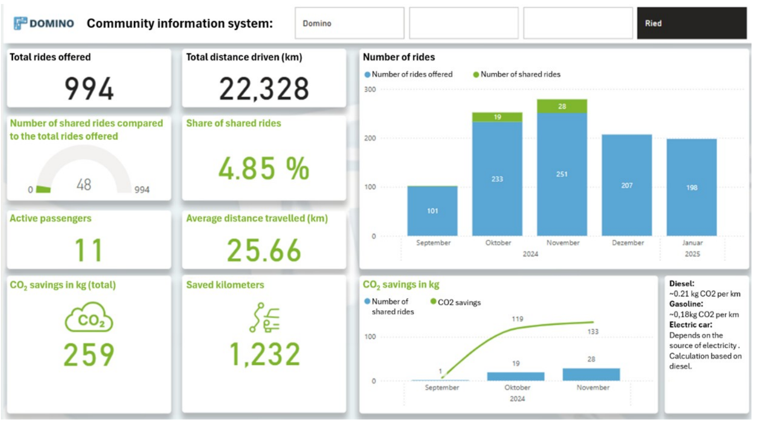


Figure 8: Results DOMINO in period after prize draw

Discussion

Team formation

The quadruple helix approach proved effective in aligning diverse stakeholders around a shared mission. Appointing a dedicated contact person within each partner organization ensured internal communication and ownership. Regular coordination meetings supported transparency and progress. However, partners' differing institutional backgrounds led to varied expectations, especially regarding timelines. Scaling the initiative will require broader engagement, where also small businesses should join the mobility movement. To embed the project as a long-term urban initiative, the city of Ried must work towards a stronger leadership role, while the academic partner transitions from coordination to support.

Campaign launch and promotion

As reflected in the data, an initial increase in user registrations was observed following the official launch. Media coverage and active involvement of partners with strong local networks - notably the city administration and non-profits - were crucial in reaching potential. Future campaigns could benefit from expanding media outreach to include TV, radio, and digital marketing, which were excluded here due to budget constraints.

Implementation and engagement

Key individuals within companies played a central role in promoting the app internally. Continuous communication and regular reminders were vital for maintaining engagement. The data suggests that sustained promotional effort is needed to foster long-term behavioral change.

Incentivization

While environmental benefits such as reducing CO_2 emissions alone did not motivate significant behavioral shifts, the prize draw proved to be a strong incentive. The extension of the campaign period was necessary, as user engagement developed more slowly than expected. After the incentive phase ended, ride-sharing activity dropped sharply, indicating that external motivators are essential to encourage participation. Future research should examine which incentive types work best for different user groups.

Data Collection

All partners showed a high interest in the results, underlining the need for comprehensive data tracking. The use of a Power BI dashboard was valuable, but future iterations should tailor visualizations more closely to stakeholder needs.

Future steps should include identifying which data points are most relevant to users and organizations and thus tailor the dashboard to their needs and to deepen the data analytics towards identifying route overlaps or shared rides between employees from different companies.

Conclusion and Outlook

The RIED Rides initiative illustrates the potential of digital platforms like the DOMINO app to foster sustainable mobility through an integrated approach combining carpooling, public transport, and shared resources. Cross-sector collaboration—spanning companies, government, academia, and civil society—proved vital for aligning goals and harnessing complementary strengths. Transparent data presentation emerged as a key enabler, particularly for companies seeking to communicate environmental progress to employees. Monitoring key performance indicators supports the quantification of environmental benefits and enables comparisons across communities. While nearly 600 rides were offered, actual ridesharing uptake was around 8%, resulting in over 1,200 kilometres saved and an estimated reduction of 250 kg CO_2e. The significant rise in users after the incentive phase highlights the importance of sustained motivational strategies to sustain engagement. A major milestone was the project's recognition with the "Klimabündnis" award for the European mobility week, which not only validated its impact but also increased regional visibility. To scale the impact further, efforts should focus on expanding the user base and shifting from one-time prize draws toward a continuous, user-driven incentive model. Companies could offer rewards of varying value, allowing users to redeem points at their discretion. Additional ideas include reserving parking spaces exclusively for carpools or enabling point redemption for monthly parking access—linking ridesharing with smart parking management. Future research should examine strategies to promote ridesharing among specific target groups by addressing behavioural motivators and barriers. Long-term success will depend on the integration of digital infrastructure with strategic communication, community engagement, and continuous support.

References

BMK. (2023a). Mobilitätsmasterplan 2023. https://www.bmk.gv.at/themen/mobilitaet/mobilitaetsmasterplan/mmp2030.html

BMK. (2023b). Sharing Strategie und Mitfahren. https://www.bmk.gv.at/themen/mobilitaet/alternative_verkehrskonzepte/sharing_strategie.html

Brinkhoff, T. (2025). Städte und Gemeinden in Ried (Oberösterreich, Österreich) - Einwohnerzahlen, Grafiken, Karte, Lage, Wetter und Web-Informationen: Citypopulation. https://citypopulation.de/de/austria/oberosterreich/412__ried_im_innkreis/

Carayannis, E. G., & Campbell, D. F. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation and the Environment Relate To Each Other? International Journal of Social Ecology and Sustainable Development, 1(1), 41–69. https://doi.org/10.4018/jsesd.2010010105

Darbanian, F., Juppe, M., Schildorfer, W., Tockner, R., Rudloff, C., & Seer, S. (2024). Ridesharing as a part of modal shift: An Austrian Pilot case study. In AHFE International, Advances in Human Factors of Transportation. AHFE International. https://doi.org/10.54941/ahfe1005245

EcoHedge. (2024). Employee Commuting Emissions: Scope 3 Category 7 Explained. https://www.ecohedge.com/blog/employee-commuting-emissions-scope-3-category-7-explained/

Encyclopedia. (2022). Quadruple and Quintuple Innovation Helix (Q2IH) Framework. https://encyclopedia.pub/entry/35805

Europäische Mobilitätswoche. (2024). RIED RIDES – APP in die Arbeit - Europäische Mobilitätswoche. https://www.mobilitaetswoche.at/event/ried-rides-app-in-die-arbeit/

Furuhata, M., Dessouky, M., Ordóñez, F., Brunet, M.-E., Wang, X., & Koenig, S. (2013). Ridesharing: The state-of-the-art and future directions. Transportation Research Part B: Methodological, 57, 28–46. https://doi.org/10.1016/j.trb.2013.08.012

Global Logistics Emissions Council. (2023). Global Logistics Emissions Council: Framework: V3.1. https://smart-freight-centre-media.s3.amazonaws.com/documents/GLEC_FRAMEWORK_v3_UPDATED_04_12_24.pdf

Goodman, V. D. (2011). A brief overview of qualitative research. In Qualitative Research and the Modern Library (pp. 7–31). Elsevier. https://doi.org/10.1016/B978-1-84334-644-9.50001-9

Green Vision Solutions. (2024). CSRD: Die neue EU-Richtlinie und die Kennzahlen Scope 1, 2 und 3 | Aktueller Überblick. https://greenvisionsolutions.de/neue-eu-richtlinie-csrd/

(2020a).

GRRIP. (2020b). Why is Quadruple Helix engagement so important? – GRRIP Project. https://grrip.eu/why-is-quadruple-helix-engagement-so-important/

Lazarus, J. R., Caicedo, J. D., Bayen, A. M., & Shaheen, S. A. (2021). To Pool or Not to Pool? Understanding opportunities, challenges, and equity considerations to expanding the market for pooling. Transportation Research Part a: Policy and Practice, 148, 199–222. https://doi.org/10.1016/j.tra.2020.10.007

Machado, C. A. S., Salles Hue, N. P. M. de, Berssaneti, F. T., & Quintanilha, J. A. (2018). An Overview of Shared Mobility. Sustainability, 10(12), 4342. https://doi.org/10.3390/su10124342

Marchesani, F., & Ceci, F. (2025). A quadruple helix view on smart city: Exploring the effect of internal and external open innovation on public services digitalization. Technovation, 139, 103141. https://doi.org/10.1016/j.technovation.2024.103141

Mitropoulos, L., Kortsari, A., & Ayfantopoulou, G. (2021). A systematic literature review of ride-sharing platforms, user factors and barriers. European Transport Research Review, 13(1), 61. https://doi.org/10.1186/s12544-021-00522-1

Pfeiffer, B. (2022). Ergebnis der Oö. Verkehrserhebung 2022: Das Mobilitätsverhalten der Wohnbevölkerung und das Verkehrsaufkommen im Bezirk RIED / I. https://www.land-oberoesterreich.gv.at/Mediendateien/LK/Ergebnis%20der%20O%C3%B6.%20Verkehrserhebung%202022_Ried.pdf

Pigalle, E., & Aguiléra, A. (2023). Ridesharing in all its forms – Comparing the characteristics of three ridesharing practices in France. Journal of Urban Mobility, 3, 100045. https://doi.org/10.1016/j.urbmob.2023.100045

Radonjič, G., & Tompa, S. (2018). Carbon footprint calculation in telecommunications companies – The importance and relevance of scope 3 greenhouse gases emissions. Renewable and Sustainable Energy Reviews, 98, 361–375. https://doi.org/10.1016/j.rser.2018.09.018

Schwochow, A. Betriebliche CO2-Bilanz – Scopes leicht erklärt. https://klimaschutz-wirtschaft.de/greenhouse-gas-protocol-scopes-leicht-erklaert/

Shaheen, S., & Cohen, A. (2019). Shared ride services in North America: definitions, impacts, and the future of pooling. Transport Reviews, 39(4), 427–442. https://doi.org/10.1080/01441647.2018.1497728

Shoshany-Tavory, S., Trop, T., & Shiftan, Y. (2022). A cross-cultural study of nonprofit self-organized ridesharing. Transportation, 1–41. https://doi.org/10.1007/s11116-022-10347-z

VCÖ. (2018). Autoverkehr in Österreich hat sich binnen 30 Jahren verdoppelt - Mobilität mit Zukunft. https://vcoe.at/presse/presseaussendungen/detail/20181206-autoverkehr-oesterreich-30-jahre

Wiesbauer, B. (2024). Werde Teil der Ried Rides Community: Fahrgemeinschaften nutzen mit der App Domino OÖ. https://www.meinbezirk.at/ried/c-motor/fahrgemeinschaften-nutzen-mit-der-app-domino-ooe_a6869806

Effects of Sociodemographic Characteristics and Travel Behavior on Urban Neighborhood Satisfaction

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Abstract

Urban public space in densely populated neighborhoods is a limited resource, with competing demands for its use. Historically, urban planning has focused on car oriented development but concerns about climate change and sustainable mobility have prompted a reevaluation. Street experiments have become a popular method to test new ideas and engage local communities, though they often face mixed reactions. This study examines neighborhood satisfaction in Munich's Dreim¨uhlenviertel, a densely populated urban area, focusing on the relationship between neighborhood satisfaction, sociodemographic characteristics, and travel behavior. The results show no significant differences in neighborhood satisfaction based on sociodemographic factors, but significant effects by car ownership and usage, with car usage having the stronger impact. Residents who own or frequently use cars report higher satisfaction with livability, urban green space, and bike parking, but are more dissatisfied with car parking compared to those who do not own or rarely use cars. These findings emphasize the need to involve residents in urban transformation projects and consider their needs when implementing transformative projects like street experiments.

Keywords: neighborhood satisfaction, travel behavior, urban transformation, livability

1. Introduction

Urban public space is a limited resource in densely populated neighborhoods, where various demands compete for space– such as car parking, transport infrastructure, and spaces for relaxation and recreation, like green areas. For many decades, urban planning has been dominated by car-oriented development. However, rising concerns over climate change effects, quality of life, and the need for eco-friendly mobility have spurred a rethinking of how public space is allocated. This paradigm shift marks a transformation of urban spaces, focusing on implementing measures for climate protection and adaptation, promoting sustainable and active mobility, and improving the overall quality of public spaces. Street experiments have emerged as a popular strategy in this context. By implementing temporary measures cities are able to test new approaches and engage local residents and businesses in the transformation process. These experiments help make urban changes more tangible, but they also encounter varying reactions. Some residents embrace these changes, while others are concerned about the loss of convenience, potential economic impacts, or the disruption of the status quo. Understanding and addressing the concerns of both proponents and skeptics is crucial. By integrating opposing perspectives into the planning process, cities can minimize resistance and encourage broader acceptance, which increases the chances of successfully implementing transformative urban projects. This study focuses on neighborhood satisfaction in Munich's Dreim¨uhlenviertel. We explore the factors that contribute to differing levels of satisfaction among residents regarding various aspects of their neighborhood, such as livability, urban green spaces, and parking conditions for both bicycles and cars. The paper is structured as follows: First, we provide a literature review on different aspects of transformation projects and neighborhood satisfaction. Next, we describe the data and methodology used in our study. We then present and discuss our results, followed by the overall conclusions.

2. Literature Review

Bertolini (2020) demonstrates that city street experiments– ranging from simple re-markings to the repurposing of entire streets– can drive systemic changes in urban mobility. However, as Grunwald (2019) cautions, the acceptance of such changes may be hampered by unforeseen burdens that are unevenly distributed across society. In this context, Lanzendorf et al. (2024) highlight that measures are more likely to be accepted when the benefits for local residents are tangible, although acceptability can vary by population group. Moreover, effective urban planning, including transformational street experiments, relies on the active participation and involvement of stakeholders, as emphasized by Lindenau and B¨ohler-Baedeker (2014). Street experiments aim to enhance livability and optimize the use of urban space, often by reallocating street space for greener and more pedestrian-friendly environments. These changes directly influence how residents perceive their neighborhoods, particularly in terms of urban green spaces and overall quality of life. In terms of urban livability and green spaces, Oviedo et al. (2022) report that car users often perceive higher livability, while Wu et al. (2023) confirm that urban greenness contributes positively to life satisfaction. Bahr (2024) further notes that greener neighborhoods are particularly associated with higher life satisfaction among older residents. Neighborhood satisfaction, however, shows mixed relationships with urban density. Howley et al. (2009) find no direct connection between density and satisfaction, whereas Mouratidis (2018) suggests that higher density may actually enhance neighborhood satisfaction. Taken together, these studies underscore the complexity of urban residents' perceptions of urban space and set the stage for investigating the factors that contribute to differing satisfaction levels with the neighborhood environment. This study investigates these dynamics in Munich's Dreim¨uhlenviertel.

3. Data and Methodology

This study was part of the transformation project Bestandsquartier der Zukunft, conducted in Munich's Dreim¨uhlenviertel in 2023. This historic neighborhood, near the city center, is home to approximately 6,300 residents within a compact area of 37 hectares. Its dense urban fabric and lack of parking garages result in a high share of public space occupied by on-street parking. Initiated by the Mobile Zukunft M¨unchen alliance– comprising the City of Munich's Mobility Department, the Bavarian State Ministry of Housing, Building, and Transport, and other partners– the project aimed to develop and test mobility transition measures to improve quality of life, promote climate-friendly transportation, and address climate change impacts (Mobile Zukunft M¨unchen, 2024). A key component was a participatory street experiment involving local residents and businesses. The data used in this study comes from a survey based on the so-called 'travel skeleton' concept developed by von Behren et al. (2018), which was conducted in Dreim¨uhlenviertel from August to November 2023. This method provides a structured yet flexible approach for capturing travel behavior and psychographic information, including transportation modes, norms, and attitudes, offering a multidimensional view of respondents' travel patterns. Unlike conventional trip diaries, which can be burdensome for respondents, the 'travel skeleton' collects travel data for a typical week, reducing response effort while enabling a broader survey scope. The survey has been applied in numerous cities worldwide, either covering entire urban areas (Magdolen et al., 2019; von Behren et al., 2022) or focusing on specific districts (Puhe et al., 2024; von Behren et al., 2018). It provides a detailed understanding of residents' mobility patterns and, when applied at the district level, also assesses the suitability and acceptance of mobility transformation measures in the neighborhood. We included four questions on their perceptions and satisfaction with the neighborhood, covering livability, urban green spaces, and the parking situation to reflect local conditions and focus on topics relevant to residents. Given the prominence of parking issues in the quarter the survey separately examined parking availability and conditions for motorized and non-motorized vehicles. Satisfaction was rated on a 5-point Likert scale, from 'unsatisfied' to 'satisfied'. Respondents were recruited via posters throughout the neighborhood and outreach at community events, workshops and social media. In total, 162 residents volunteered to complete the survey, representing 2.5% of Dreim¨uhlenviertel's population. However, the sample is not fully representative due to an underrepresentation of both younger and older age groups, a high proportion of highly educated respondents, and overrepresentation of employed individuals. To examine factors influencing satisfaction with the neighborhood environment, we applied a combination of statistical tests to assess significance and correlations. Given the sample size and data characteristics, we employed statistical methods suited for categorical and ordinal data. To enable meaningful comparisons while ensuring sufficient group sizes, we categorized 3 respondents into groups based on nominal and ordinal data:

- Sociodemographic characteristics: sex (male/female), age (20-29/30-39/40-49/50-59/≥60 years), education level (no A-level equivalent/A-level/university), and the presence of young children (0-6 years) in the household (no/yes).

- Car ownership: whether the household possesses a private motorized vehicle, such as a car, motorbike and camper van (no/yes).

- Private car usage: whether the respondent uses a private motorized vehicle on at least a weekly basis (no/yes).

The satisfaction with the neighborhood environment includes the aspects of livability, urban green spaces, parks and trees (hereafter green spaces), parking situation for bicycles and e-scooters (hereafter bike parking situation) and parking situation for motorized vehicles (hereafter car parking situation). To explore relationships between these four aspects and assess group differences in satisfaction with the neighborhood environment, we apply three statistical methods. We use Polychoric Correlation Analysis to examine the relationships between the four different aspects of satisfaction with the neighborhood environment. Given the small sample size, we use Fisher's Exact Test with Monte Carlo simulation to assess whether significant differences in satisfaction with the neighborhood environment exist between the defined groups. A p value below 0.05 indicates a significant difference in satisfaction, highlighting group variables for which a deeper analysis is promising. We apply Bayesian Ordinal Regression to further investigate significant group differences identified by Fisher's Exact Test. This method explores the relationships between satisfaction and potential influencing factors, allowing us to determine which factors impact satisfaction and the direction of these effects while accounting for uncertainty in the results. A positive estimate indicates a positive effect, and a 95%-credible interval not including zero is strong evidence that the predictor significantly influences satisfaction.

4. Results and Discussion

The Polychoric Correlation Analysis reveals moderate to strong positive correlations between satisfaction with livability, green spaces, and the bike parking situation. Conversely, a moderate negative correlation is found between satisfaction with green spaces and satisfaction with the car parking situation. No significant correlation is observed between satisfaction with the parking situation for cars and bikes, nor between satisfaction with livability and the car parking situation. These results suggest that satisfaction with livability, green spaces, and the bike parking situation are interrelated and could be considered as one factor, whereas satisfaction with the car parking situation appears to be independent. Fisher's exact test reveals no significant differences in satisfaction across age groups and across education levels. However, significant differences in satisfaction with the neighborhood environment were observed between the genders (bike parking situation) and between respondents with and without children in the household (livability). Additionally, significant

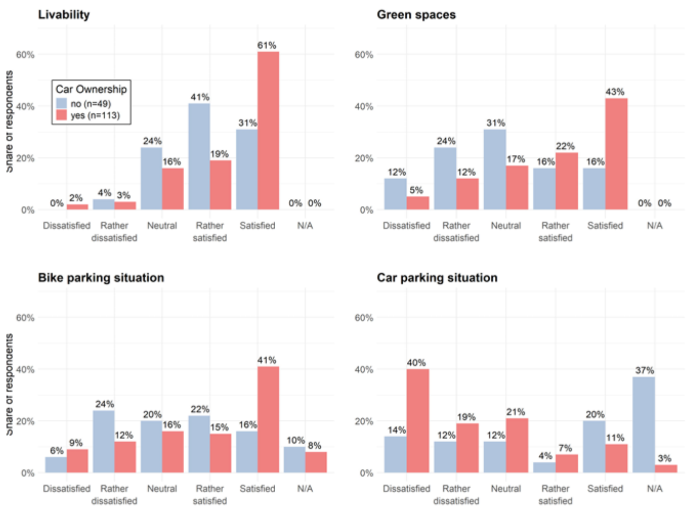

Figure 1: Neighborhood satisfaction by car

ownership differences in satisfaction with livability, green spaces, and the bike parking situation were found between respondents with and without car in the household. However, no significant difference was observed for satisfaction with the car parking situation. When respondents were grouped by weekly and non-weekly usage of private cars, significant differences emerged across all four aspects of satisfaction with the neighborhood environment. These results suggest that further investigation into the differences related to sex, the presence of children in household, and the possession and usage of a motorized vehicle is promising. Bayesian Ordinal Regression reveals no significant effects for sex or the presence of children in the household (0-6 years) on any of the four aspects of satisfaction. However, the results show that satisfaction with the status quo of the neighborhood environment in Dreim¨uhlenviertel varies based on car ownership and usage: both the possession of a car and its frequent usage show significant effects on all satisfaction aspects (see Figure 1 and Figure 2). The estimated effect of frequent car usage on satisfaction is higher for all four neighborhood aspects compared to car ownership, suggesting that travel behavior has a stronger association with neighborhood satisfaction than car ownership. Individuals who own or use a private car tend to be satisfied with livability, green spaces and the bike parking situation. This group may be less likely to see a need for changes in these areas. In contrast, those without car ownership or weekly private car usage are more likely to be

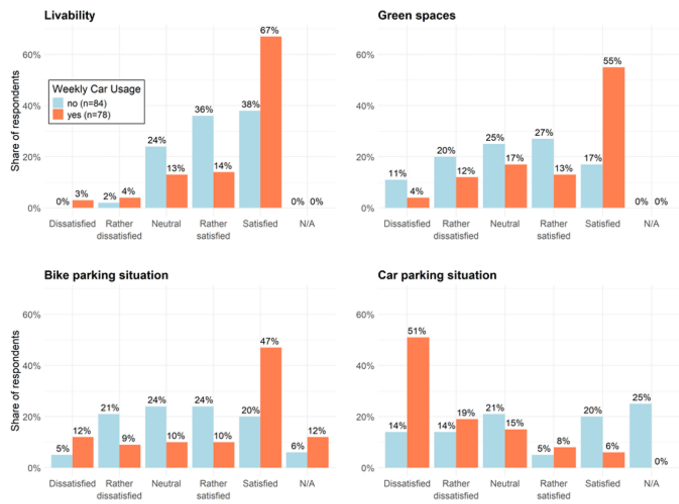

Figure 2: Neighborhood satisfaction by car

usage dissatisfied with livability, green spaces and the bike parking situation, making them more open to changes aimed at improving these aspects. The perception of car parking follows an opposite pattern. Car owners and frequent car users are more likely to be dissatisfied with the car parking situation, while those without a car are more likely to be satisfied it. The effect of weekly car usage on satisfaction with the car parking situation is approximately 1.45 times that of car ownership. This may be because frequent car users are regularly confronted with the challenge of finding parking, whereas individuals who own cars, regardless of their usage frequency, likely encounter this issue less often which may influence their satisfaction levels. This highlights differing needs and expectations among Dreim¨uhlenviertel's residents regarding the public space of their neighborhood. In Dreim¨uhlenviertel, differing satisfaction with urban space is– most likely due to the omnipresence of the issue– particularly evident in the car parking situation. While we also observe differences and statistical effects in livability, green spaces, and bike parking, the causal links are not explored. However, these findings should be interpreted with caution, as there is a potential for strategic responses where residents may overstate satisfaction to avoid triggering changes. In particular, residents who own or regularly use cars might report higher satisfaction with livability, green spaces, or bike parking situation if they believe that acknowledging low satisfaction could lead to measures that would, in turn, reduce parking spaces for their own vehicles– especially since the project was conducted in cooperation with the city administration. It is important to note that we cannot verify whether such strategic responses actually occurred.

5. Conclusion

The study examines neighborhood satisfaction of residents in a dense urban quarter by exploring the relationship of stated satisfaction with sociodemographic characteristics and individual travel behavior. We group residents and apply three statistical methods to identify significant differences in satisfaction among these groups, as well as to determine the factors that influence neighborhood satisfaction and the direction of these effects. The results from Dreim¨uhlenviertel suggest a differentiated consideration of various aspects of neighborhood satisfaction, with livability, green spaces, and the bike parking situation being interrelated, while the car parking situation should be considered separately. The results also indicate that satisfaction with the urban neighborhood environment differs based on car ownership and usage, with the effect of car usage being stronger than that of car ownership. These findings underscore the importance of involving residents to achieve broad acceptance for urban transformation projects, given that individual needs and perceptions of neighborhood characteristics differ. Consequently, it is advisable to investigate the specific needs and perceptions of urban areas where projects, such as street experiments, are conducted. Future research should refine and expand survey questions on neighborhood satisfaction to better understand its relationship with travel behavior. In urban transformation projects, such as street experiments, surveys before and after interventions would help measure changes in residents' attitudes and satisfaction. Overall, more research is needed to support conflictfree transformations of public urban spaces.

References

Bahr, S. (2024). The relationship between urban greenery, mixed land use and life satisfaction: An examination using remote sensing data and deep learning. Landscape and Urban Planning, 105174. https://doi.org/10.1016/j.landurbplan.2024.105174 Bertolini, L. (2020). From "streets for traffic" to "streets for people": Can street experiments transform urban mobility? Transport Reviews, 40(6), 734–753. https://doi.org/10. 1080/01441647.2020.1761907

Grunwald, A. (2019). Das Akzeptanzproblem als Folge nicht ad¨aquater Systemgrenzen in der technischen Entwicklung und Planung. In C. Fraune, M. Knodt, S. G¨olz, & K. Langer (Eds.), Akzeptanz und politische Partizipation in der Energietransformation: Gesellschaftliche Herausforderungen jenseits von Technik und Ressourcenausstattung (pp. 29–43). Springer Fachmedien. https://doi.org/10.1007/978-3-658-24760-7 2 7

Howley, P., Scott, M., & Redmond, D. (2009). Sustainability versus liveability: An investigation of neighbourhood satisfaction. Journal of Environmental Planning and Management, 52(6), 847–864. https://doi.org/10.1080/09640560903083798 Lanzendorf, M., Baumgartner, A., & Klinner, N. (2024). Do citizens support the transformation of urban transport? Evidence for the acceptability of parking management, car lane conversion and road closures from a German case study. Transportation, 51(6), 2073–2101. https://doi.org/10.1007/s11116-023-10398-w

Lindenau, M., & B¨ohler-Baedeker, S. (2014). Citizen and Stakeholder Involvement: A Precondition for Sustainable Urban Mobility. Transportation Research Procedia, 4, 347360. https://doi.org/10.1016/j.trpro.2014.11.026

Magdolen, M., von Behren, S., Chlond, B., Hunecke, M., & Vortisch, P. (2019). Combining Attitudes And Travel Behavior: A comparison of urban mobility types identified in Shanghai, Berlin and San Francisco. 98th Annual Meeting of the Transportation Research Board. https://doi.org/10.5445/IR/1000093783

Mobile Zukunft M¨unchen. (2024). Bestandsquartier der Zukunft– Dreim¨uhlenviertel. https: //www.mzm-allianz.net/projekte/bestandsquartier-der-zukunft-dreimuehlenviertel/ Mouratidis, K. (2018). Is compact city livable? The impact of compact versus sprawled neighbourhoods on neighbourhood satisfaction. Urban Studies, 55(11), 2408–2430. https://doi.org/10.1177/0042098017729109

Oviedo, D., Sabogal, O., Villamizar Duarte, N., & Chong, A. Z. (2022). Perceived liveability, transport, and mental health: A story of overlying inequalities. Journal of Transport & Health, 27, 101513. https://doi.org/10.1016/j.jth.2022.101513

Puhe, M., Burger, L., Hupfer, C., & Rall, A. (2024). Quartiersgaragen als L¨osung f¨ur die Parkproblematik in Bestandsquartieren? Internationales Verkehrswesen, 76(4), 2227. Retrieved February 27, 2025, from https://elibrary.utb.de/doi/abs/10.5555/ iv202440022

von Behren, S., Chlond, B., & Vortisch, P. (2022). Exploring the role of individuals' attitudes in the use of on-demand mobility services for commuting– A case study in eight Chinese cities. International Journal of Transportation Science and Technology, 11(2), 229–242. https://doi.org/10.1016/j.ijtst.2021.03.008

von Behren, S., Minster, C., Magdolen, M., Chlond, B., Hunecke, M., & Vortisch, P. (2018). Bringing travel behavior and attitudes together: An integrated survey approach for clustering urban mobility types. 97th Annual Meeting of the Transportation Research Board. https://doi.org/10.5445/IR/1000093811

Wu, W., Tan, W., Wang, R., & Chen, W. Y. (2023). From quantity to quality: Effects of urban greenness on life satisfaction and social inequality. Landscape and Urban Planning, 238, 104843. https://doi.org/10.1016/j.landurbplan.2023.10484

Intermodality and Urban Mobility: User Acceptance and Spatial Planning Implications for Autonomous Ridepooling in Hamburg

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Abstract

As transport and urban planners face the challenges of climate change and transport related issues, new mobility solutions must be explored. Intermodal solutions, especially autonomous ridepooling, present a viable option in this context. To investigate the occurrence of intermodality and the potential for implementing an autonomous ridepooling service within Hamburg's existing transportation system, we analyzed a mobility survey conducted in Hamburg with 2,815 participants. We found that intermodal behavior is not limited to specific urban contexts, but varies across different spatial settings. Even among current non-users, there is a notable openness to intermodal options when presented with hypothetical scenarios.

Keywords: intermodality; autonomous ride-pooling; survey data

1. Introduction

Intermodal transport—especially the combination of public transport (PT) with various first and last mile options—is gaining increasing importance, as it can help address transport-related challenges. These challenges include, among others, CO_2 emissions, traffic congestion, and insufficient parking space. To mitigate these issues, new solutions are being sought. In particular, approaches that complement intermodality, such as (autonomous) ridepooling (RP, ARP), have the potential to enhance urban mobility by offering a flexible and efficient extension to the existing transport system.

However, the successful implementation of these concepts requires a comprehensive understanding of their spatial integration across different regions, since both travel behavior and the structure of existing transport systems can vary. Based on these insights, it is crucial to identify gaps where RP or ARP could be integrated into current transport networks. This leads to a twofold research purpose: What is the current state of intermodal behavior in and around our study area in Hamburg? And what potential emerges from these findings for expanding the intermodal system through ARP?

2. Literature Review

The impact of intermodal mobility, defined as the sequential use of multiple modes of transport within a single journey, has been explored increasingly in urban transport studies (Teixeira, Rocha, & Couto, 2025). A common example of intermodal mobility is combining cycling with public transport (PT), such as biking to a station and then switching to PT (Santos, Mendes, & Julião, 2023). This approach not only enables access to a wider range of destinations, but also allows for greater flexibility in journey planning, such as more adaptable timing (Santos et al., 2023). However, this increased complexity also extends to implementation, requiring close cooperation between planners, policymakers, and transport operators (Teixeira et al., 2025).

Given this context, it becomes apparent that the understanding of intermodal behavior is twofold: One the one hand, it must be understood how to organize the supply side: infrastructures and means of transport (Costescu & Roman, 2023). A study by Frank et al. explored this topic by modeling accessibility improvements by locating mobility hubs in different areas allowing for smoother intermodal journeys. They found that these multimodal hubs must be strategically placed and tailored depending on whether certain points-of-interest or working spaces should be reached (Frank, Dirks, & Walther, 2021). On the other hand, understanding the demand side is crucial: without knowing how and why users choose intermodal journeys, it is impossible to optimize networks or promote intermodal behavior among non-users (Meyer-Hollatz, Kaiser, Keller, & Schober, 2024; Wang, Li, & Jiang, 2024).

To address such obstacles in intermodal networks, some cities have already expanded their systems with new mobility solutions such as RP. Alongside the public transport company HOCHBAHN, the RP service MOIA has been active in Hamburg since 2019 (Kostorz, Fraedrich, & Kagerbauer, 2021). Today, RP is entering a new stage with the prospect of becoming autonomous. For cities like Hamburg, integrating ARP into existing mobility platforms may help reach new user segments and reduce car dependency (Dolins, Karlsson, Smith, & Strömberg, 2025).

3. Methodology

To achieve the objectives of this paper, we analyzed the travel patterns and intermodal behavior of urban residents (with primary and secondary residences) within the administrative area of Hamburg and its surroundings. The data used stems from a survey in 2024 conducted within the project ALIKE in Hamburg, overall aiming at the implementation of public, ARP vehicles on Hamburg's streets by 2026. Participants were recruited via Hamburg's PT provider (Hamburger Hochbahn), the RP provider MOIA and an access panel—each contributing roughly one-third of the final cleaned sample (n = 2,815). The 20–30 min survey included questions on mobility tools, RP, autonomous driving and a Stated-Choice-Experiment (SCE) with mono- and intermodal options.

First, we analyzed various variables related to intermodal behavior by examining their distributions within the sample as well as potential statistical influences. The frequency of use was visualized with maps to provide a clearer understanding of the spatial distribution within the study area. An overlay with supply-side elements—such as different train stations (including S-Bahn, U-Bahn, regional trains, and A-Bahn) and bus stops within Hamburg—served as a reference point for identifying areas with a mismatch between supply and demand. This step provided the basis for identifying participants who can be classified as non-users of intermodal transport options. The reasons why these individuals do not use such options were examined in a subsequent step using distribution analyses and statistical methods. For further insights, we conducted a low-threshold analysis of the results from the SCE. All analyses were carried out using R Studio and QGIS.

4. Intermodality in Hamburg: Distributions and Spatial Analysis

Firstly, we used the survey question: "Do you regularly combine different modes of transport for a single trip in your daily life?" offering the following options: (almost) daily, 1-3 times a week, 1-3 times a month, less than once a month and never. As can be seen in table 1 nearly one-third of our sample consists of non-users, who should be investigated further in this study. Doing so, it may not only provide valuable insight into the reasons behind their non-use of intermodal options, but also they may represent a potential target group for future actions such as the expansion of the transport system through ARP.

Table 1: Distribution of Intermodal Usage Frequencies

Intermodal usage	Absolute frequency	Relative frequency
(Almost) daily	395	14%
1–3 times per week	441	16%
1–3 times per month	453	16%
Less than once per month	657	23%
Never	869	31%

Based on these insights, we mapped the distribution of the three usage categories—weekly ((almost) daily and 1-3 times per week), monthly (1-3 times per month and less than once per month), and never—at the postal code level. In the maps, only postal code areas containing a minimum of five participants were included. As a result, some areas appear blank in the maps (see Figure 1, 2, 3) due to insufficient data density. For each postal code, the percentage share of each of the three intermodal usage categories, daily / weekly, monthly and never, was calculated. The resulting maps confirm the tendencies of the initial analysis: intermodal mobility appears to be an occasional behavior, mostly on a monthly basis. When examining postal code areas with shares between 20–40%, it is noticeable that several areas consistently maintain this range across all three maps. This indicates that participants from these areas are relatively evenly distributed across all three usage categories. Notably, these areas include both locations within Hamburg's administrative boundaries and peripheral areas in the surrounding region. However, this somewhat balanced picture is broken up by areas of 40–60% and even 60–100%, in which the proportion of monthly users is higher than that of weekly or never users. Moreover, these high shares are distributed with no clear spatial pattern across all three categories. Considering weekly and never users, some tendencies, however, might be observed: postal code areas with higher proportions (above 40%) tend to be located on the urban fringe. Interestingly, in the case of non-users, several areas with similarly high proportions are also found near the city center. This suggests a fragmented spatial pattern, where urban fringe areas demonstrate a dual character: in some places, intermodal transport is used intensively, while in others it is avoided.

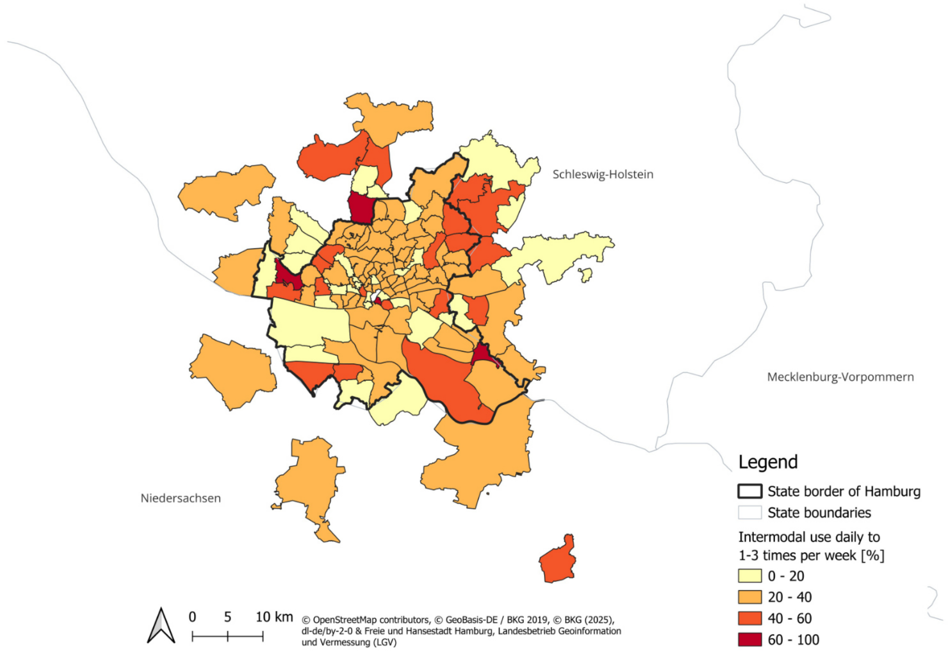

Figure 1: The percentage distribution of intermodal, daily / weekly usage across postal codes in and around Hamburg

To gain a deeper understanding of these patterns, the maps were overlaid with infrastructure

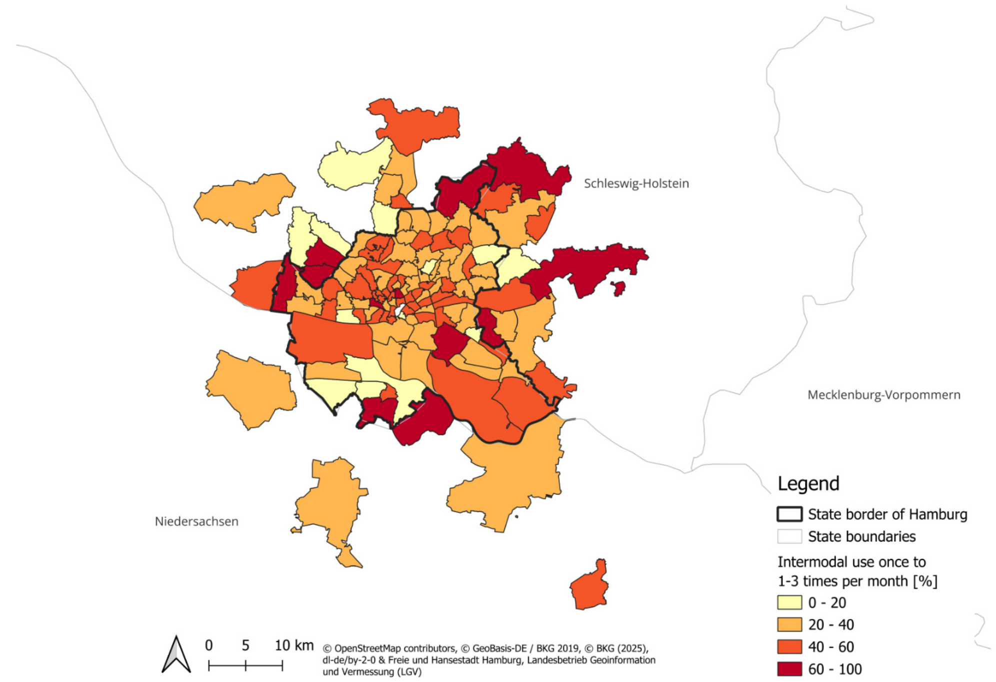

Figure 2: The percentage distribution of intermodal, monthly usage across postal codes in and around Hamburg

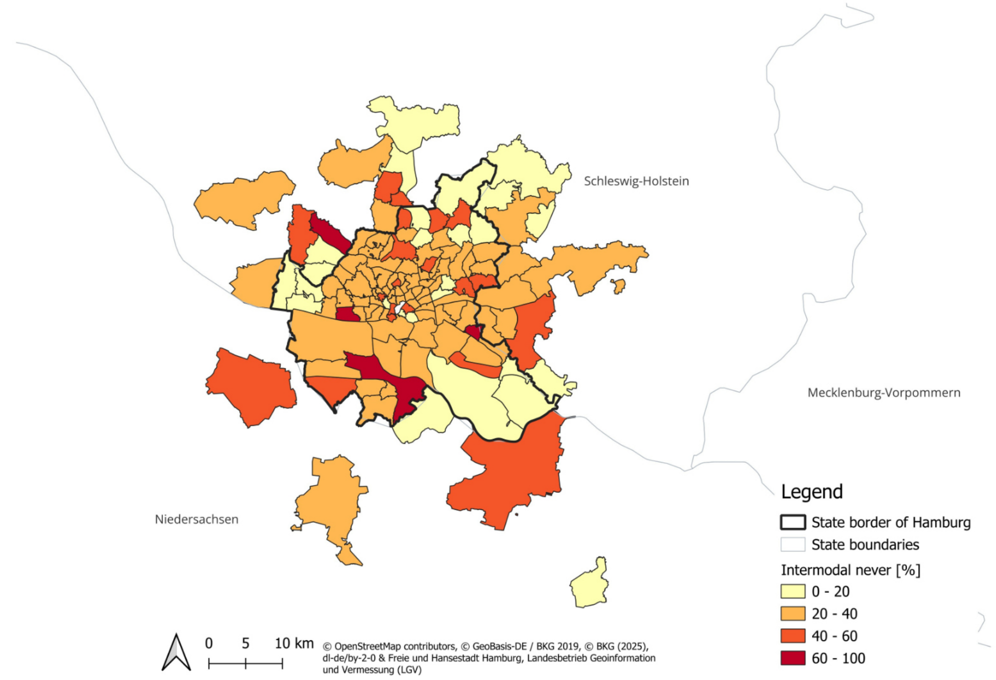

Figure 3: The percentage distribution of non-intermodal usage across postal codes in and around Hamburg

supply data for the city of Hamburg. This included various rail stations as well as bus stops. The resulting overlay shows that, at the postal code level, the PT network, especially the bus network, appears to be broadly and evenly distributed. However, more fine-grained map insights could not be obtained due to the coarseness of the polygons in the supply data.

Overall, the map overlay analysis suggests that the mere availability of PT infrastructure (especially buses) is not sufficient to ensure intensive intermodal usage, as there is a need for the will to do so. This can be seen in areas that are well developed and accessible within or close to the city center, yet still contain non-users. For planning, this implies that, in addition to more fine-grained spatial analyses, demand-oriented solutions are essential. Special attention should be given to non-user groups, particularly those residing in well served areas. Given this insight, and the fact that further map-based analysis at the postal code level would not yield more detailed results due to limited participant density in some areas, the focus was then shifted toward analyzing behavioral patterns.

4.1 No intermodal usage

In the following section, we took a closer look at non-users in order to identify specific strategies for potentially converting them into users of intermodal transport. We began with a descriptive analysis of the 869 individuals in this group (Table 2). In summary, the non-user group in our sample appears to be relatively balanced in terms of gender distribution (excluding non-binary individuals, due to the limited number of responses). It is, however, predominantly composed of older individuals aged 51 and above with a high level of car ownership. The combination of retired and employed individuals suggests that both commuting and leisure-related mobility patterns may be relevant within this group.

Next, we analyzed the frequency of use of various monomodal modes of transport to gain a more nuanced understanding of their travel behavior. The high level of car ownership was also reflected in the high proportion of daily / weekly car use. 31% did not answer the question, presumably due to the lack of access to a private vehicle or the absence of a pooling account. In contrast, bicycle usage was more mixed, even though main usage occurs on a monthly basis. PT usage was similarly rare. These results underline a barrier when aiming to shift from no-usage to intermodal usage. The combination of high car ownership and usage as well as little PT, bike and RP usage not only may represent a structural and mental barrier but also prevent a low-threshold access point to intermodality by using the bike (e.g. bike + PT).

To figure out whether non-users differ significantly from users of intermodality, we used a logistic regression. The results suggest that women tend to be non-users more often than men (Table 2). Also, with each additional year of age, the odds of being a non-user increase by approximately 1.6%. The same direction applies for the amount of cars per household (HH). Conversely, HHs with fewer individuals tend to be non-users compared to bigger HHs. In terms of occupation, individuals working full-time, part-time or pursuing an educational purpose were less likely to be a non-user compared to those currently not employed. Homemakers and retirees were found not to be significant at the p-value = 0.05 level.

We also looked at the attitude towards autonomous driving. Even among non-users, many expressed a positive attitude toward autonomous driving. When exploring this even further, we analyzed the responses given by non-users to the question regarding their personal expectations for mobility in the event that the current PT system was to be expanded by ARP (Figure 4). The key finding is that in all positively-framed answer categories, non-users indicated agreement. In particular, the statement "improved accessibility" symbolizes that non-users are open to being more intermodal when ARP is an alternative. This finding suggests a discrepancy, as it depicts non-users being indirectly open to an intermodal system. Consequently, it indicates a classic intention–behavior gap, given they reported not to be intermodal but are indirectly considering it if circumstances change. This presents an important potential for planning, as this target group is not resistant per se and may be a potential new user group for autonomous RP, especially if aiming at its intermodal usage.

Table 2: Distributions of different variables on non-users of intermodality

Variable	Distribution	Estimate ß	p-value
Gender	men: 50%, women: 49%, non-binary: 1%	0.307	< 0.001
Age	11–30: 8%, 31–40: 16%, 41–50: 20%, 51–60: 29%, 61+: 27%	0.016	< 0.001
Car per HH [cars]	1: 28%, 2: 48%, 3: 19%, 4+: 5%	0.239	< 0.001
HH size [individuals]	1: 33%, 2: 42%, 3: 13%, 4+: 12%	-0.157	< 0.001
Occupation: full-time	52%	-0.51	0.009
Occupation: part-time	14%	-0.543	0.012
Occupation: retired	21%	-0.302	0.177
Occupation: unemployed	6%	reference	reference
Occupation: education	4%	-0.773	0.007
Occupation: homemaker	3%	0.434	0.230
Car usage	daily/weekly: 53%, monthly: 15%, never: 1%, no answer: 31%	–	–
Bike usage	daily/weekly: 27%, monthly: 49%, never: 24%	–	–
RP usage	daily/weekly: 4%, monthly: 37%, never: 1%, no answer: 58%	–	–
Autonomous driving attitude	positive: 49%, neutral: 28%, negative: 22%	–	–
SCE	47% selected an intermodal option in at least 1 of 6 choice situations. 26% in at least 2, 13% in 3, 4% in 4, 1% in 5.	–	–

To support this statement even further, we analyzed our SCE to figure out whether reported non-users chose intermodal alternatives in the SCE. In our SCE, intermodal options included bike + PT, RP + PT, ARP + PT and PT + ARP and were presented in different choice situations differing in time of day, trip purpose and type of ARP. Interestingly, we found that out of 6 choice situations, almost half of the non-user group chose one intermodal alternative. More than one quarter of all non-users even chose an intermodal alternative in 2 out of 6 choice situations.

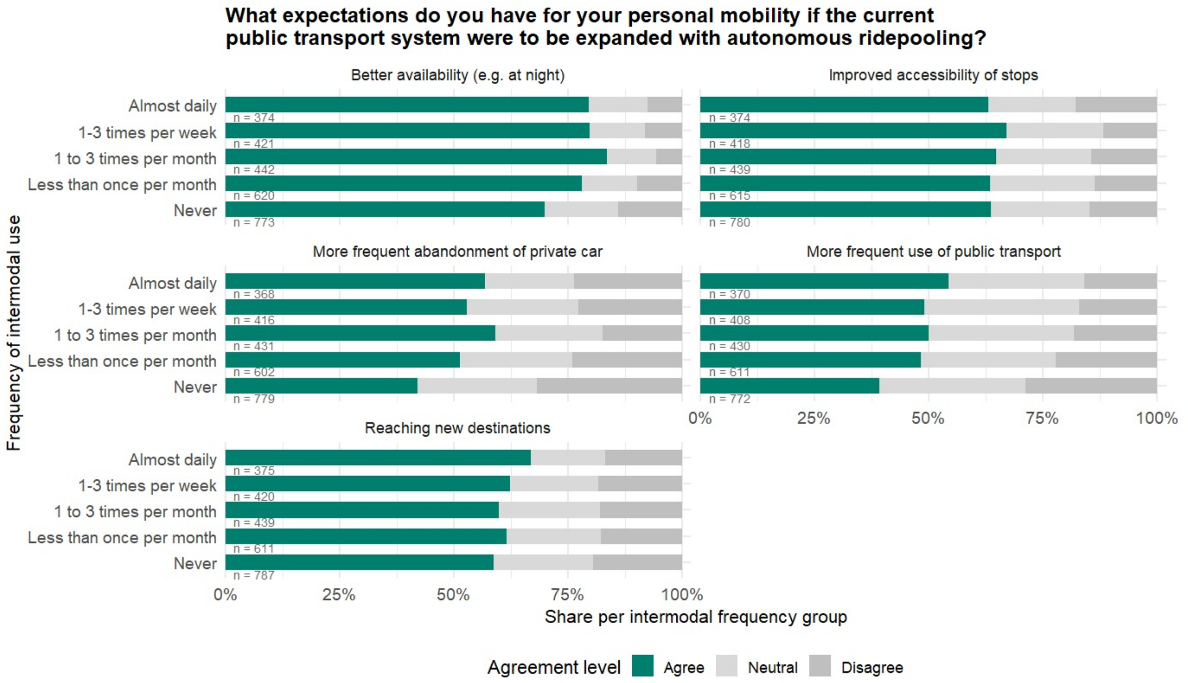

Figure 4: Expectations of Non-Users on the Integration of ARP into PT

Overall, the results call for tailored interventions such as demand-responsive services, the expansion of multimodal hubs and behavioral campaigns. Strengthening intermodality requires not only infrastructure, but also inclusive planning that considers the social and demographic diversity of mobility needs.

5. Conclusion

In conclusion, intermodal behavior cannot be categorized as a strictly urban or suburban phenomenon. Monthly usage represents a widespread strategy that most of the participants tend to follow. Urban fringes further show ambivalence as both high and no usage coexist and even in well-served inner-city areas, non-use exists - possibly also because intermodal travel is not perceived as necessary where sufficient direct connections are already available. Looking at the supply side, infrastructure alone does not fully explain intermodal behavior, which is why individual behavioral factors must be considered. Non-users tend to be older, car-ownership-oriented and living in single or 2- person households. Nonetheless, a considerable proportion of this group was shown to not only have a positive attitude towards ARP but also to be open towards intermodal alternatives in certain, hypothetical choice situations. Interpreting these findings within the term "urban transformation", the findings support a shift away from viewing urban mobility as static infrastructure toward a dynamic, user-centered approach that accounts for diverse mobility behaviors—an essential component in developing sustainable and resilient urban environments. Hence, it can be concluded that there is a great potential for intermodal service planning through targeted mobility solutions such as ARP.

References

Costescu, D., & Roman, E. A. (2023). Challenges in the development of urban intermodal mobility systems. In Handbook of research on promoting sustainable public transportation strategies in urban environments (pp. 98–119). IGI Global.

Dolins, S., Karlsson, M., Smith, G., & Strömberg, H. (2025). Riding with strangers: profiling potential users and refusers of shared autonomous vehicles in swedish cities. Transportation, 1–22.

Frank, L., Dirks, N., & Walther, G. (2021). Improving rural accessibility by locating multimodal mobility hubs. Journal of transport geography, 94, 103111.

Kostorz, N., Fraedrich, E., & Kagerbauer, M. (2021). Usage and user characteristics—insights from moia, europe's largest ridepooling service. Sustainability, 13(2), 958.

Meyer-Hollatz, T., Kaiser, M., Keller, R., & Schober, M. (2024). Understanding information needs for seamless intermodal transportation: Evidence from germany. Transportation Research Part D: Transport and Environment, 130, 104161.

Santos, T., Mendes, R. N., & Julião, R. P. (2023). The potential of integrated transport modes: modelling the combined use of bicycles and train in lisbon, portugal. Cidades. Comunidades e Territórios(47).

Teixeira, J. F., Rocha, H., & Couto, A. (2025). Intermodal mobility: A psychometric and behavioural analysis of public transport users in porto metropolitan area. Travel Behaviour and Society, 40, 101027.

Wang, B., Li, J., & Jiang, F. (2024). Road–rail intermodal travel mode choice behavior considering attitude factors. Sustainability, 16(14), 5955.

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Abbreviations

The following abbreviations are used in this manuscript:

RP = ridepooling

ARP = autonomous ridepooling

PT = public transportation

HH = household

SCE = Stated-Choice-Experiment

Water and Urban Ecology

Advances in Urban Flood Damage Assessment: Understanding Floodwater Transferring from Street into Property (INSIDE)

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Abstract

Urban areas are increasingly vulnerable to flood damage due to climate change, urbanization, and population growth, necessitating accurate flood risk assessment and mitigation strategies. This study focuses on understanding floodwater transfer from streets into buildings, a critical yet often overlooked aspect of urban flooding. A 1:1 scale experimental prototype was developed at the Universitat Politècnica de Catalunya to simulate floodwater interaction with a typical single-family building façade. The setup includes a street section, building exterior, and interior space, enabling precise measurement of floodwater intrusion through doors under controlled conditions. Key findings include the quantification of flow intrusion, the influence of hydrostatic pressure, and detailed water depth profiles. These results provide a numerical framework for predicting floodwater entry into buildings, improving urban flood models, and informing flood resilience strategies. This study advances urban flood damage assessment by bridging the gap between field data limitations and laboratory-based insights, contributing to more effective flood risk management in urban environments.

Keywords: Urban flooding Experimental hydraulics Street-building exchanges model

Introduction

Urban areas are increasingly vulnerable to extensive flood damage due to the concentration of economic and social assets, underscoring the critical need for accurate flood intensity prediction and effective risk mitigation strategies(Schubert & Sanders, 2012). This vulnerability is exacerbated by factors such as climate change, the expansion of impervious surfaces due to urbanization, and population growth, all of which contribute to heightened flood risk. Quantifying flood damage typically involves assessing tangible losses, which are defined as economic damages that can be monetarily appraised. These are further categorized into direct damages, resulting from physical contact with floodwater, and indirect damages, which arise from secondary effects such as business interruptions or infrastructure failures. Between 2011 and 2020, global insured losses due to natural disasters made 217.9 billion USD, with severe convective storms accounting for the largest share, followed by floods (67.3 billion USD) and wildfires (56.2 billion USD). In Europe, floods were the leading cause of insured losses (20.1 billion USD), followed by severe convective storms (15.6 billion USD) (SWISS Re, 2021). Concurrently, there has been a global increase in the number of individuals affected by disasters, including injuries and disruptions to livelihoods, particularly in the agricultural sector. While economic losses have risen, mortality rates have declined, highlighting the need for improved flood resilience measures (CRED & UNDRR, 2020). Given the escalating impacts of urban flooding, the reliability and performance of flood inundation models are of paramount importance (Dottori & Todini, 2012). Developing high-resolution numerical models that accurately replicate the complex interactions between floodwater and urban environments is essential for effective flood risk management (Mignot et al., 2019). For instance, Chen & Leandro (2019) modelled floodwater intrusion into buildings through doorways using the fluid mechanics principles of discharge over a rectangular weir, providing insights into the hydrodynamic behaviour of urban flooding(Martínez-Gomariz et al., 2021). Incorporating building effects into flood models significantly improves their accuracy(Huang et al., 2014), as demonstrated by a synthetic test case featuring a channel and 200 buildings. This study revealed that the presence of buildings reduces peak discharge by 30% and peak water depth by 18% in street networks, while also introducing a temporal lag in the flood hydrograph (Choley et al., 2021).

However, field data for validating flood models—such as aerial imagery, watermarks, or post-event surveys—are often insufficient, ambiguous, or incomplete, particularly for extreme or future scenarios (Neal et al., 2009 To address this limitation, laboratory experiments offer a robust alternative, enabling precise measurement of flow characteristics under controlled and reproducible conditions (Mignot et al., 2019). Laboratory data are particularly valuable for calibrating and validating reducedcomplexity models, which are increasingly used in flood risk assessments (Dottori & Todini, 2012). Focusing on the often-overlooked process of floodwater interaction with building interiors, and recognizing the value of laboratory experiments in addressing data scarcity, a 1:1 scale prototype was developed at the Universitat Politècnica de Catalunya. This experimental setup simulates a typical single-family building façade, including a street section, building exterior, and interior space. The prototype is designed to study the hydrodynamic processes of floodwater entry within buildings, providing critical data for improving urban flood models. By replicating real-world conditions in a controlled environment, this laboratory approach enhances the understanding of floodwater behaviour and supports the development of more accurate predictive models.

Methodology

The methodology has been carefully designed to investigate the interactions between floodwater and the elements of urban buildings, with a particular focus on the ingress of floodwater through building openings such as doors. This section is divided into three stages. Firstly, the laboratory set-up phase, in which the constructed prototype is presented. Secondly, the instrumentation phase, in which the measurement proposal for the study of water intrusion is explained. Finally, the experimental protocol phase, in which the flow entering the building is measured.

Laboratory set up

The prototype experimental setup is designed to represent an interaction of floodwater with a building façade, focusing on water ingress through typical building apertures. The setup (Figure 1) includes a street section (10.0 m long, 1.0 m wide, and 1.8 m high) and a building structure with two consecutive apertures measuring 2.5 m and 1.0 m, respectively. The interior space simulates floodwater intrusion. Water is introduced is through a pipe with 500 mm of diameter, and the structure includes a honeycomb element to ensure flow calming. The experiment includes two outlets: Outlet 1 drains water circulating through the street, with water level controlled by a gate at end of the street. Outlet 2 allows water that enter to inside building to return to the circulation system. At the end of the interior space, a triangular weir is located to measure the flow. The building is adjacent to the street, enabling floodwater to interact with the façade and intrude into the interior space, facilitating the study of water depth.

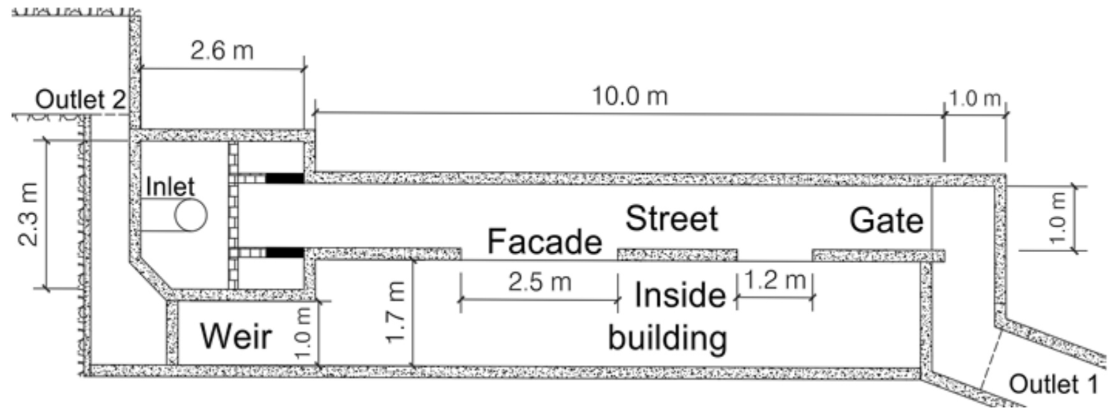

Figure 1. Configuration and dimensions of the experimental set-up.

The prototype possesses the advantage of being real scale (Figure 2), thereby obviating some of the uncertainties that are present at reduced scale. For instance, experimentation with closed doors, where the distances are narrow, such as under the door, could be adequately recreated in this experimental set-up. The controlled environment allows for precise regulation of flow conditions, facilitating reproducible experiments. Flow behaviour is going to be measured through pressure sensors. This configuration offers significant insights into the dynamics of floodwater in urban environments, facilitating understanding of the interaction between floodwater and buildings and leading to improvements in flood urban modelling.

Figure 2. Laboratory setup

Instrumentation

Experimental protocol

The experiment consists of the installation and testing of a carpentry door, a typical door found in unifamilial houses and community buildings in Barcelona (see Figure 3). The protocol commences with the instrumentation stage, during which pressure sensors are installed in front of the door and the space representing the interior of the building. The objective of this stage is to measure water depth in the experiment during floodwater intrusion. Subsequent to this, a calibration process is conducted to establish the relationship between flow rate and water level in the prototype, ensuring accurate measurements. This step is conducted with any open closure. Following this, the installation of enclosures is carried out, integrating the door into the experimental setup with proper sealing and alignment to simulate real-world conditions.

Figure 3. Typical urban door for unifamilial houses in Barcelona

The objective of this study is to measure the flow entering a building in two different scenarios. Firstly, the entering flow will be measured in the absence of a level behind the door. Secondly, the flow will be measured with a level behind the door in order to analyse the influence of hydrostatic pressure on the flow. This protocol ensures precise data collection and reliable results for the study of floodwater interaction with urban building elements.

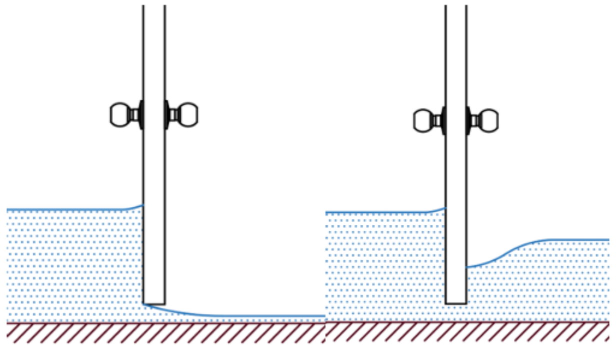

Figure 4. Experimental protocol configuration

Expected Results

The expected results of this study aim to provide a numerical expression that quantifies floodwater intrusion into buildings, focusing on the interaction between floodwater and urban building elements. The experimental setup, designed to simulate real-world conditions, will yield critical insights into the hydrodynamic processes governing floodwater entry through typical building apertures, such as doors.

1. Quantification of Flow Intrusion: The study will establish a numerical relationship between external floodwater levels and the rate of water intrusion into buildings. This relationship will be expressed as a function of water depth across the building façade. The results will provide a flow rate equation for water entering through doors, considering both scenarios: (a) without a water level behind the door and (b) with a water level behind the door (hydrostatic pressure influence).

2. Influence of Hydrostatic Pressure: The experiments will demonstrate how hydrostatic pressure behind the door affects the flow rate of water intrusion. It is expected that higher water levels inside the building will reduce the net flow rate due to increased resistance from the hydrostatic pressure.

3. Pressure and Water Depth Profiles: Pressure sensors installed in front of the door and inside the building will generate detailed pressure and water depth profiles during floodwater intrusion. These profiles will help validate the numerical model and provide empirical data for urban flood simulations. In summary, the expected results will advance the understanding of floodwater transfer from streets into buildings, providing a robust numerical framework for urban flood damage assessment.

Conclusion

This study addresses the critical challenge of understanding floodwater transfer from streets into buildings, a key factor in urban flood damage assessment. Through a 1:1 scale experimental prototype, the hydrodynamic processes of floodwater intrusion through building apertures, such as doors, were systematically investigated. The results provide a numerical expression quantifying floodwater entry, considering both scenarios: (1) without a water level behind the door and (2) with hydrostatic pressure influence. Key findings include: A numerical relationship between external floodwater levels and the rate of water intrusion was established. Influence of hydrostatic pressure inside the building were shown to reduce the net flow rate due to increased resistance. These findings advance the understanding of floodwater behaviour in urban environments, offering a robust framework for improving flood risk assessment and mitigation strategies. By replicating real-world conditions in a controlled laboratory setting, this study bridges the gap between field data limitations and the need for accurate predictive models. The results underscore the importance of incorporating building-floodwater interactions into urban flood models, ultimately contributing to more resilient urban infrastructure and effective flood management practices.

References

Chen, K. F., & Leandro, J. (2019). A Conceptual time-varying flood resilience index for urban Munich https://doi.org/10.3390/w11040830 city. Water (Switzerland), 11(4). Choley, C., Finaud-Guyot, P., Garambois, P.-A., & Mose, R. (2021). An effective urban flood model accounting for street-building exchanges. SimHydro 2021: Models for Complex and Global Water Issues - Practices and Expectations.

https://hal.science/hal-03992011 CRED, C. for R. on the E. of D., & UNDRR, U. O. for D. R. R. (2020). Human Cost of Disasters: An Overview of the Last 20 Years 2000-2019. UN Office for Disaster Risk Reduction. https://books.google.es/books?id=YxcOEAAAQBAJ

Dottori, F., & Todini, E. (2012). Testing a simple 2D hydraulic model in an urban flood experiment.

Hydrological https://doi.org/10.1002/hyp.9370 Processes, 27(9), 1301–1320.

Huang, C. J., Hsu, M. H., Chen, A. S., & Chiu, C. H. (2014). Simulating the storage and the blockage effects of buildings in urban flood modeling. Terrestrial, Atmospheric and Oceanic Sciences, https://doi.org/10.3319/TAO.2014.02.11.01(Hy) 25(4), 591–604.

Martínez-Gomariz, E., Forero-Ortiz, E., Russo, B., Locatelli, L., Guerrero-Hidalga, M., Yubero, D., & Castan, S. (2021). A novel expert opinion-based approach to compute estimations of flood damage to property in dense urban environments. Barcelona case study. Journal https://doi.org/10.1016/j.jhydrol.2021.126244 of Hydrology, 598.

Mignot, E., Li, X., & Dewals, B. (2019). Experimental modelling of urban flooding: A review. In Journal of Hydrology (Vol. 568, pp. 334–342). Elsevier B.V. https://doi.org/10.1016/j.jhydrol.2018.11.001 Schubert, J. E., & Sanders, B. F. (2012). Building treatments for urban flood inundation models and implications for predictive skill and modeling efficiency. Advances in Water Resources, 41, 49–64. https://doi.org/10.1016/j.advwatres.2012.02.012 SWISS Re. (2021). Natural catastrophes in 2020 secondary perils in the spotlight, but don't forget primary-peril risks. https://www.swissre.com/dam/jcr:ebd39a3b-dc554b34-9246-6dd8e5715c8b/sigma-1-2021-en.pdf

Transformative Governance through Embedded Scientific Collaboration

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1. Introduction

Urban areas worldwide are becoming increasingly vulnerable to the various impacts of climate change, such as rising temperatures, altered precipitation patterns, and intensified extreme weather events – along with their cascading physical and societal consequences. Proactive adaptation strategies are required to strengthen urban resilience and to protect urban infrastructure, while maintaining the quality of life for city inhabitants. Municipal administrations play a key role in developing and implementing these climate adaptation initiatives. However, significant barriers to integrating climate adaptation measures into existing urban planning frameworks have been identified, including institutional inertia, limited resources and missing background data as well as fragmented policy landscapes (Boehnke et al., 2023; Boehnke et al., 2022; McClure & Baker, 2018).

To address these challenges, innovative approaches such as Urban Living Labs have emerged as effective platforms for fostering collaboration between researchers, policymakers, and community stakeholders. Urban Living Labs operate as experimental arenas within real-life urban settings, facilitating the co-creation and testing of sustainable, innovative solutions tailored to specific local contexts (Bulkeley et al., 2016; Steen & van Bueren, 2017).

This paper presents a novel transdisciplinary approach, implemented through an embedded collaboration between researchers and municipal planning authorities. Although not formally framed as a real-world laboratory, the setting adheres to the fundamental principles of real-world laboratory research and while adapting to the constraints imposed by the administrative context that hinder innovative transformation. This approach aims to bridge the gap between scientific research and municipal practice, fostering a more resilient and adaptive urban environment.

2. Operationalising Embedded Scientific Collaboration in Urban Planning

This study was developed through a collaborative proposal initiated by two senior researchers in partnership with the municipality's planning department. The involvement of these scientists, one of whom was already well known and trusted within the administration, was a crucial factor in securing institutional support and fostering confidence in the research team's scientific expertise. Their existing relationships paved the way for the integration of a third postdoctoral researcher who worked in and closely with the planning department. This allowed for an unprecedented level of cooperation and insights into the internal dynamics, procedures and routines of municipal planning.

The project's main objective was to incorporate climate adaptation measures into an ongoing large-scale urban development project. To this end, the postdoctoral researcher spent an average of two days per week at the city planning office over a period of one and a half years. They collaborated with city planners and administrative staff from various climate adaptation-related departments (e.g., civil engineering, green spaces and climate protection), as well as external consultants who had been commissioned for the planning task at hand. The senior researchers provided sustained, parallel support throughout the process with their expert knowledge and reputation, e.g. by contributing essential input to relevant meetings and maintaining close contact with senior management and the key figures responsible for urban development planning.

The study focused on two key informal planning phases that preceded the legally binding development plan: the drafting of the local development plan and formulating a comprehensive framework plan for the entire redevelopment area. These phases provided strategic entry points for integrating climate adaptation measures into fundamental planning decisions.

The methodological approach was structured around three iterative stages inspired by adaptation frameworks proposed by Moser and Ekstrom (Moser & Ekstrom, 2010) and Hamin and Gurran (Hamin & Gurran, 2015)

– Assessing Climatic Needs: The researchers conducted an in-depth assessment of climatic vulnerabilities in the planning area. This involved analysing internal municipal reports, climate studies, and other environmental data relevant to identify key adaptation challenges as well as possibilities based on local conditions.

– Developing Adaptation Strategies: A literature review was conducted to compile relevant adaptation measures, which were then refined in consultation with urban planners and external experts. This step ensured that the selected measures aligned with local planning regulations and practical feasibility.

– Integrating Adaptation into Planning Processes: The researchers introduced climate adaptation strategies into municipal decision-making by contributing technical recommendations in meetings, integrating measures into framework planning documents, and facilitating discussions with city council members and the public. Additionally, informal interactions with municipal staff, such as coffee break discussions and routine meetings, helped foster awareness and acceptance of adaptation measures as well as increasing mutual trust between the embedded researcher and the administrative staff.

By embedding a researcher within the city administration, together with the pivotal support of the senior scientists, this project not only facilitated the direct implementation of climate adaptation strategies but also found a way to bridge the gap between research and municipal governance through trust-based and mutually appreciative collaboration.

3. Advancing Municipal Climate Resilience through Research Integration

The integration of the researchers into the city administration yielded several tangible advancements in embedding climate adaptation strategies within urban planning. One of the most far-reaching transformations resulting from the targeted involvement of the researchers was the enhancement of urban ventilation within the existing design concept. Collaborating closely with municipal planners and an external bureau during the drafting of the land-use plan, the researchers recommended targeted modifications to building structures to improve airflow and mitigate heat accumulation. These recommendations were ultimately incorporated into a revised design, directly strengthening the urban climate resilience of the planned district.

Another key outcome was the subsequent commissioning of a heavy rainfall adaptation concept for the planning area—an initiative that would not have been pursued without the researchers' influence. Throughout the project, the embedded researcher employed various strategies to emphasize the critical relevance of this adaptation task: internal expert presentations, the development of two alternative concept proposals for heavy rainfall management, and the consistent introduction of the topic into planning meetings. However, it was not until the flood events triggered by extreme rainfall in Aachen in late 2018 that the urgency of this planning task became fully apparent to all stakeholders, ultimately ensuring its integration into the land-use plan.

Beyond physical planning, the researchers played a key role in climate adaptation advocacy within the municipal decision-making processes. Through participation in internal meetings, council discussions, and public forums, the researchers were able to introduce and support the implementation of targeted climate adaptation measures - beyond urban ventilation and heavy rainfall management. This ensured that climate considerations were integrated into various stages of the planning process, from its conceptualization to stakeholder engagement.

In addition to influencing immediate planning decisions, the approach also included engagement in capacity building within the administration. Through internal presentations and workshops, municipal staff were introduced to climate adaptation principles, expanding their knowledge and sensitivity to these issues. This educational effort is anticipated to foster a more proactive approach to climate considerations in future administrative actions, supporting long-term institutional change.

4. From ULL Ideals to Institutional Realities: Reflecting on Embedded Practice

The following section aims to position the applied method of this study within established research approaches in the social sciences. By comparing our approach with Urban Living Labs (ULLs), reflecting on innovation constraints in planning practice, and aligning our method with principles of transdisciplinary research, the following contributes to a clearer theoretical classification of our research design.

The research design presented shares several structural and conceptual similarities with the Urban Living Lab (ULL) approach. Comparing the key characteristics of ULL described by Voytenko et al. (2016), the methodology i) was placed in a geographical area and “real urban context where the process in focus is taking place”; ii) comprised participation and user involvement of key relevant stakeholders for city governance, such as the planning department and decision makers in charge of the project, external practitioners, other city departments and citizens (only to be informed) and iii) greatly benefited from the leadership of the planning office, which organized routine meetings with various stakeholders as well as proactively supported further meetings, information presentations, etc. that were developed in collaboration with the scientists - ensuring a high level of participation, collaboration and co-design. Similarly, the researchers collaborated with city planners and other administrative staff to integrate climate adaptation strategies and measures into the ongoing urban planning process. In this context, the “co-design” aspect focused on the researchers’ attempts at adaptation integration and the stakeholders’ response to these efforts (integration, concerns, restrictions, further ideas, etc.). This approach fits well with the understanding of ULLs “as a means through which to set up demonstrations and to trial different kinds of intervention in the city” […] “intended to bring together multiple actors that seek to intervene in order to address contemporary urban challenges and foster learning through forms of open and engaged experimentation” (Bulkeley et al., 2016: 13).

However, an important distinction lies in the innovation logic. ULLs are described as typically focusing on the development and piloting of new solutions by co-design between scientists and stakeholders (Voytenko et al., 2016) or on innovation as a development of new products or as the discovery of new solutions (Steen & van Bueren, 2017). In the project presented, however, the emphasis was on applying and integrating pre-existing climate adaptation measures into an ongoing planning process. This nuance aligns with Wirth et al. (2019), who argue that ULLs are also capable of institutionalizing existing innovations through mechanisms such as policy embedding, awareness-building, and especially “experimenting with new ways of engagement and participation” (Wirth et al., 2019: 246). One might even argue that not the measures proposed but the integration of adaptation as a rather new planning concern was innovative at that time. Another distinction lies in the special role citizens are often given in the ULL context, from giving valuable feedback to being collaborative co-creators (Rizzo et al., 2021). In contrast, citizen participation was largely limited to information events, a classic instrument aimed at transparency rather than engagement.

Our findings resonate well with critical reflections by Rizzo et al. (2021), who argue that the institutional culture of urban planning is often not conducive to transformative innovation. From their perspective, the incremental nature of planning, which was very apparent in our study (Boehnke et al., 2023), “hinders a broader understanding of co-produced knowledge-making that challenges conventional public participation” and even “counters the idea of ULL” (Rizzo et al., 2021: 1753). Following their thoughts about traditional living lab settings (:1753), one could even argue that by trying to implement measures into an existing plan and building on compromises in meetings, our approach comprises usual participatory planning workshops as an accompanying tool within the ULL context.

5. Conclusion

This study has introduced and reflected on an embedded scientific collaboration that, while structurally resembling Urban Living Labs (ULLs), followed a markedly different logic of intervention. Rather than co-designing new solutions or testing experimental technologies, the project focused on integrating well-established climate adaptation measures into an ongoing urban development plan—thereby operating at the intersection of applied research and institutional practice. The embedded approach mirrored core ULL elements such as place-based engagement, cross-sectoral collaboration, and iterative dialogue with stakeholders. However, it differed in two significant ways: first, innovation was not located in the generation of novel ideas or tools but in the procedural integration of climate adaptation as a relatively new planning concern; and second, citizen participation was limited to classic information formats, diverging from the idea of citizens being central actors for co-creation as emphasized in ULL theory.

Despite these differences, the approach proved effective in achieving concrete results. The integration of targeted adaptation measures—such as improved urban ventilation and a comprehensive concept for heavy rainfall management—into formal planning instruments highlights the potential of researcher-administration collaboration to shape policy outcomes from within. Moreover, the iterative presence of the embedded researcher contributed to institutional learning, particularly by raising awareness of climate risks, fostering interdepartmental exchange, and supporting the long-term anchoring of adaptation knowledge within the planning administration. In light of often-cited institutional inertia in urban planning (Rizzo et al., 2021; Boehnke et al., 2023), these outcomes underscore the pragmatic potential of embedded scientific collaboration—not as a transformative laboratory in the idealized ULL sense, but as a grounded mechanism for embedding evidence-based climate strategies into the everyday routines and decision-making processes of local governments.

References

Boehnke, D., Jehling, M., & Vogt, J. (2023). What hinders climate adaptation? Approaching barriers in municipal land use planning through participant observation. Land Use Policy, 132, 106786. https://doi.org/10.1016/j.landusepol.2023.106786

Boehnke, D., Krehl, A., Mörmann, K., Volk, R., Lützkendorf, T., Naber, E., Becker, R., & Norra, S. (2022). Mapping Urban Green and Its Ecosystem Services at Microscale—A Methodological Approach for Climate Adaptation and Biodiversity. Sustainability, 14(15), 1–28. https://doi.org/10.3390/su14159029

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., van Steenbergen, F., & Voytenko Palgan, Y. (2016). Urban living labs: governing urban sustainability transitions. Current Opinion in Environmental Sustainability, 22, 13–17. https://doi.org/10.1016/j.cosust.2017.02.003

Hamin, E. M., & Gurran, N. (2015). Climbing the Adaptation Planning Ladder: Barriers and Enablers in Municipal Planning. In W. L. Filho (Ed.), Handbook of Climate Change Adaptation. Springer.

McClure, L., & Baker, D. (2018). How do planners deal with barriers to climate change adaptation? A case study in Queensland, Australia. Landscape and Urban Planning, 173, 81–88. https://doi.org/10.1016/j.landurbplan.2018.01.012

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. Proceedings of the National Academy of Sciences of the United States of America, 107(51), 22026–22031. https://doi.org/10.1073/pnas.1007887107

0 1 2 3 4 5 6 7

Rizzo, A., Habibipour, A., & Ståhlbröst, A. (2021). Transformative thinking and urban living labs in planning practice: a critical review and ongoing case studies in Europe. European Planning Studies, 29(10), 1739–1757. https://doi.org/10.1080/09654313.2021.1911955

Steen, K., & van Bueren, E. (2017). The Defining Characteristics of Urban Living Labs. Technology Innovation Management Review, 7(7). https://timreview.ca/article/1088

Voytenko, Y., McCormick, K., Evans, J., & Schliwa, G. (2016). Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda. Journal of Cleaner Production, 123, 45–54. https://doi.org/10.1016/j.jclepro.2015.08.053

Wirth, T. von, Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: mechanisms and strategies for systemic change through experimentation. European Planning Studies, 27(2), 229–257. https://doi.org/10.1080/09654313.2018.1504895

Changeability for Transformation: a Strategy for Urban Landscapes in the Anthropocene

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Abstract

Urban landscapes have always reflected external changes. Currently, the Anthropocene and the related great acceleration present an increasing challenge to urban transformation. Yet landscape architecture is often conceptualised to be built and remain the same for many years. This paper discusses the relevance and potential of changeability in urban landscapes and explores the need for a revised planning strategy in the context of the Anthropocene. It examines how changeability can be defined in landscape architecture, the approaches that have already been realised and the potential for creating urban landscapes that can anticipate and respond to increasing and accelerating change. To achieve this, built reference projects are analysed to identify important starting points in landscape architecture.

1. Introduction

We are living in a time of uncertainty – driven by human-induced climate change and globalisation. Paul Crutzen and Eugene Stoermer introduced a term for this time, in which every part of the world is influenced by human activity: The Anthropocene (Crutzen and Stoermer, 2000). Although it has not yet been accepted as a geological epoch (ICS, 2025), the term describes the challenges of the Great Acceleration (Steffen et al. 2015) and poses the need to rethink urban landscapes, given that they contain main affected actors such as flora and fauna. The German Advisory Council on Global Change (WBGU) describes urban transformation as "a social search and learning process that requires adaptive development in order to respond to new insights" (WBGU 2016: 142). However, landscape architecture, a profession which, according to the International Federation of Landscape Architects, is responsible for maintaining the stability of ecosystems and social and economic well-being (2020), is often conceptualised to be built and remain the same for many years. Traditional planning assumes that the "external conditions [..] remain relatively constant" (Christiaansen et al. 2014: 1). This paper discusses the relevance and potential of changeability in urban landscapes and the extent to which there is a current need for a revised planning strategy in the context of the Anthropocene. In order to do that, it examines how changeability can be defined in landscape architecture and what the current status of changeable landscape architecture is. Firstly, the relationship between uncertainty and the Anthropocene is reflected upon. Secondly, Anthropocene-related theories and literature on changeability and flexibility in landscape architecture are evaluated. Finally, built reference projects are analysed to identify approaches to changeability that have already been implemented in landscape architecture and where there is potential to increase them. Within this paper, various changeable design approaches in landscape architectural reference projects are evaluated and categorised by processual participation, materiality, objects and vegetation. Validated approaches are highlighted, while aspects with the greatest potential and urgency for change in planning are identified in order to lay the foundation for the development of concrete, transferable guidelines for practice. In order to achieve a sustainable urban transformation, landscape architecture needs to shift its objectives. Consequently, the question is posed as to whether urban landscapes can be designed in such a way that open space becomes a change-welcoming landscape Lab to communicate and create a relationship with people, animals, plants and climate in the Anthropocene.

2. Uncertainty and the Anthropocene

While there is "nothing more bewildering [for planners] than having to deal with uncertainty" (Silva 2016: 1043), urban landscapes are exposed to uncertain impacts caused by several factors which are scientifically proven and predicted to accelerate (e.g. IPPC report 2023). Considering the Great Acceleration, which describes the concurrency of various human-impacted trends (Steffen et al. 2015), levels of uncertainty will even rise in the future, as the extent of inter-trend impacts is unknown. As such, it is urgent to reflect on our current understanding of static urban landscapes. Bruno Latour, an important sociologist who has written extensively on the Anthropocene, wrote in 2005: "The world is not a solid continent of facts sprinkled by a few lakes of uncertainties, but a vast ocean of uncertainties speckled by a few islands of calibrated and stabilised forms" (Latour 2005). In what ways can landscape architects see uncertainty as an opportunity to design and perceive urban landscapes differently? Can "unpredictability become [..] one of the resources of the project", as claimed in Convivial Grounds (Pouzenc, Römer and Constructlab 2023: 133)? However, with optimism and a willingness to embrace uncertainty, it is a great chance to determine design principles which can create landscapes that evolve and change with accelerating trends.

3. Relevant Anthropocene-related Theories and Changeability in Landscape Architecture Literature

Anthropocene-related theories such as Assemblage (Gilles Deleuzes and Felix Guatarri), Actor-Network-Theory (Bruno Latour) or Resonance theory (Hartmut Rosa) offer valuable insights in this context. Within Assemblage theory, Deleuze and Guattari describe the experience of a space as a result of different circumstances that depend on relations and changes (1989: 8). Latour's Actor-Network-Theory emphasises the multidimensionality of a network of relationships (Latour 1996: 370) He also stated that the core of life in the Anthropocene is the fact that all actors share the same shape-shifting fate (Latour 2014, 17). Of particular relevance is Rosa's Resonance theory, as it shows the importance of entering into a relationship with the surroundings and seeing the landscape as an active participating actor in this (Rosa 2019). By shifting understandings of landscape towards an "all-together" — an active, responsive part of a relationship with living beings — new imperatives are revealed in landscape architecture.

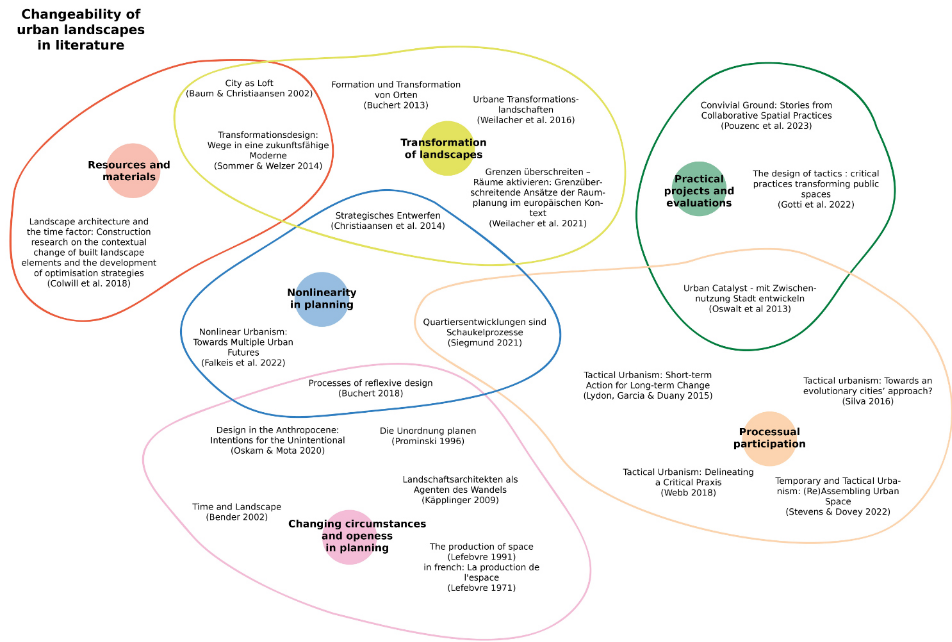

Figure 3.1: Changeability of urban landscapes in literature, graphic: Josefine Siebenand

In landscape architecture literature, a few approaches to changeable landscapes have been discussed and explored. As shown in Figure 3.1, some of this literature can be categorised. Firstly, several books and articles focus on the evaluation of practical projects. Mostly comprised of Tactical urbanism or temporary interventions, these projects are highly relevant to changeability in urban landscapes as they involve local stakeholders in developing spaces and allow open spaces to adapt to changing circumstances with temporary solutions. Another category comprises theoretical discussions of processual participation. A field that has been examined in great detail in relation to changing landscapes is the transformation of landscapes. For instance, Sommer and Welzer's book discusses the 'world of less' and transformation 'by design or by disaster' (Sommer & Welzer 2014: 27). The approach of resources and materials also relates to changeability, often involving the reuse and conservation of existing materials in new designs. Nonlinearity in Planning is a central approach for discussing changeable urban landscapes, as it questions the planning and building process. Another relevant category is concerned with changing circumstances and openness in planning.

Each investigation into changeable landscape architecture offers different perspectives on where to start to create landscapes that actively contribute to the transformation of cities we need in the Anthropocene. In this paper, changeability of urban landscapes is defined as the ability of the built space to allow, prepare and promote different development possibilities. It is thus not about the multifunctionality of surfaces, but about the actual ability to change the space.

4. Built Projects

There are various interesting landscape architecture projects that aim to create changeable urban landscapes. It is worth reflecting on some of these projects and identifying the approaches through which landscape architects have already implemented changeability, as well as the areas where insufficient ideas have been revealed, creating potential for future urban transformation. At the Department of Designing Urban Landscape at Leibniz University Hannover, five approaches to changeability have been developed through work with students: (A) Materials, (B) Furniture and objects, (C) Processual Participation, (C) Vegetation and (E) Anchoring to existing change (Siebenand: submitted). Within these topics, landscape architects can create changeability in their designs from different perspectives in each case. Within four of these approaches, projects were found that already apply aspects of this (Figure 4.1).

(A) Materials

When it comes to changeable materials, paving is particularly relevant, as sealing is the most important consideration for non-human actors. Landscape architects must consider deconstructability and permeability. In terms of the changeability of materials, permeability is a decisive factor, whether through cracks and gaps or porosity. 'You must leave a gap' (Raxworthy, 2016) is also a central idea of the Ecocathedraal project by Louis Le Roy – a gap that allows plants and animals to develop and occupy space. Interesting projects that employ the approach of cracking existing material are the former airfield in Bonames, PARKS, and the Jardin de Joyeux. It is particularly interesting when local stakeholders gradually change the paving material as part of a structured plan, as in PARKS or Ecokathedraal. This makes the landscape more changeable in a way that "encourage[s] a nurturing relationship" and reconnects people and nature (Mathieson 2024). It also raises the question of whether the goal should be to never seal spaces or rather to consider how to remain open and prepare for the possibility of removal when the sealed surface is no longer necessary. It is important to consider how sealed areas that are useful in the current situation could develop with changes in use and other circumstances. This is relevant not only for the surface material, but also for the substructure. Could water, vegetation, and animals permeate in the event of a change? Some aspects that could be considered in future planning are (1) involving gaps and cracks, and (2) preparing the flooring and underground for future openings.

	Landscape architecture project	Approach to changeability
Materials	Former Airfield Bonames Frankfurt a.M., DE GTL Landscape Architects Built: 2002- 2004	- break open of existing material (asphalt and concrete) - design lets water and vegetation take up space - cracks and permeability are the main approach
	Ecokathedraal Mildam, NL Louis le Roy since the late 1960s	- piling up recycled materials, done by the landscape architect and various participants - the main approach is to „leave a gap" for plants and animals
	PARKS Hamburg, DE Hallo e.V., Atelier le Balto since 2020	- participants break open flooring material step by step in a concepted structure - sealed surface stays in used areas and is taken away in other areas to create space for plants, animals and water
Furniture and elements	SUPERBLOCKS Barcelona, ES various landscape architects (e.g. Leku Studio) Built: first 1993, most since 2019	- close streets for cars with movable furniture to create open space - trees and elements can be moved within the superblock
	LEVEL UP street pavillon Rijeka, HR Brett Mahon, Joonas Parviainen, Saagar Tulshan, Shreyansh Sett Built: 2018	- use of scaffolding to create multi-storey open space - design of wooden elements that can be changed within the system - elements can be reused and changed in different contexts
	Stackable Playscapes Amman, JOR Sarah Abdul Majid and Sandra Hiari Built: 2017	- design of simple wooden system that can be joined in various ways to create temporary playgrounds
	Klybeckquai Basel, CH Fontana Landschaftsarchitektur Built: 2013	- movable and temporary objects and furniture along the tracks
Processual participation	Park am Gleisdreieck Berlin, DE Atelier Loidl 2005 provisional park 2013 finalised	- provisional park and temporary use before the competition - participation during the planning process and living lab
	Reallabor Wolbecker Straße Münster, DE Urban Catalyst, Modulorbeat, SHP 2021	- living lab as a participation for future developments
	Park in Progress Hamburg, DE Atelier le Balto competition 2023	- closely attached to PARKS, the existing participation concept that is al-ready established by local actors - defines areas that can be developed by local actors
	Tempelhofer Feld Berlin, DE Grün Berlin, Astoc, Gross.Max 2013	- processual development with defined pionieer areas in which local actors can co-create the space - temporary phases of making the whole space public - long-term provision of defined changeable areas for local actors
	PlatzProjekt Hannover, DE Platzprojekt e.V. since 2013	- definition of a programme -no fixed design for the open space but rules on which projects can take part (charitable, willing to co-create, etc.) - decisions by all participants
Vegetation	Jardin au movement Paris, FR Gilles Clément Built: 1992	- planted initial vegetation and embraces the change of vegetation, not fully controlled by people - composition of vegetation changes over time
	University Campus Toni Areal Zurich, CH Studio Vulkan Built: 2014	- Initially, wooden boxes were stacked with perennials and young shrubs - over time, the vegetation grows, takes up space and destroys the boxes
	Jardin de Joyeux Paris, FR Wagon Landscaping Built: 2016	- the existing material has been broken open and some soil and gravel were brought in - some initial planting and seeding, then the vegetation continues the breaking process of the asphalt and developes the space
	Former Airfield Bonames Frankfurt a.M., DE GTL Landscape Architects Built: 2002- 2004	- break open of existing material (asphalt and concrete) - design lets water and vegetation take up space and transform the space - development of vegetation changes the flooring and sense of space
	Car Park Ring Lübeck, DE	- loosely distributed planting of trees to prepare the space for a longterm development into a public park

Figure 4.1 - Approaches to changeability in built projects, graphic: Josefine Siebenand

(B) Furniture and elements

A close at hand approach to the changeability of open space is furniture – as it can easily be built to be movable and multifunctional. Prominent references are the Superblocks in Barcelona or the Klybeckquai in Basel. Analysing various projects with changeable elements it becomes clear that there are two common approaches: (1) including elements with a fixed use that can be moved or (2) Creating a stock of flexible material from which various objects can be built. The Level Up Street

Pavilion and the Stackable Playscapes both use this approach, providing a system of materials that can be changed and combined according to the circumstances.

(C) Processual Participation

Processual participation is a common method for achieving the integration and co-creation of local human actors, often within a limited timeframe. Examples include the Park am Gleisdreieck or the Living Lab on Wolbecker Straße. There are some examples, however, in which processual participation is not simply a temporary part of the planning process but rather a permanent component of the concept. Particularly interresting within this approach is the Park in progress. Comparing several landscape architecture projects, a few approaches can be identified: (1) Defining areas that can be modified by local stakeholders within a given concept, such as the peripheral areas of Tempelhofer Feld or certain aspects of the Park in Progress. This approach enables the landscape architect to design a specific layout and ensure that certain areas remain unchanged. A much freer approach is (2) designing a guide or programme for co-creating the space, as at Platzprojekt.

(D) Vegetation

In terms of vegetation, an approach to changeability that focuses more on the long-term provision of different development options for unforeseen changes can be found. In built projects, the following approaches are found: (1) enable the plant composition to change. One interesting example is the Jardin au movement, which is based on the idea that plant compositions should be able to change and not be fully controlled by humans (Clément, 2001). (2) Allow the vegetation to transform the space. This approach can be seen in the Toni Areal and the Jardin de Joyeux. In both projects, the concept involves letting the vegetation break up the constructed structure. (3) Plan the vegetation so that it can fit into future developments. An example of this is the Lübeck Car Park Ring, where the city planted trees in unusual configurations in the parking areas to prepare the space for long-term development into a public park.

5. Changeability in Landscape Architecture

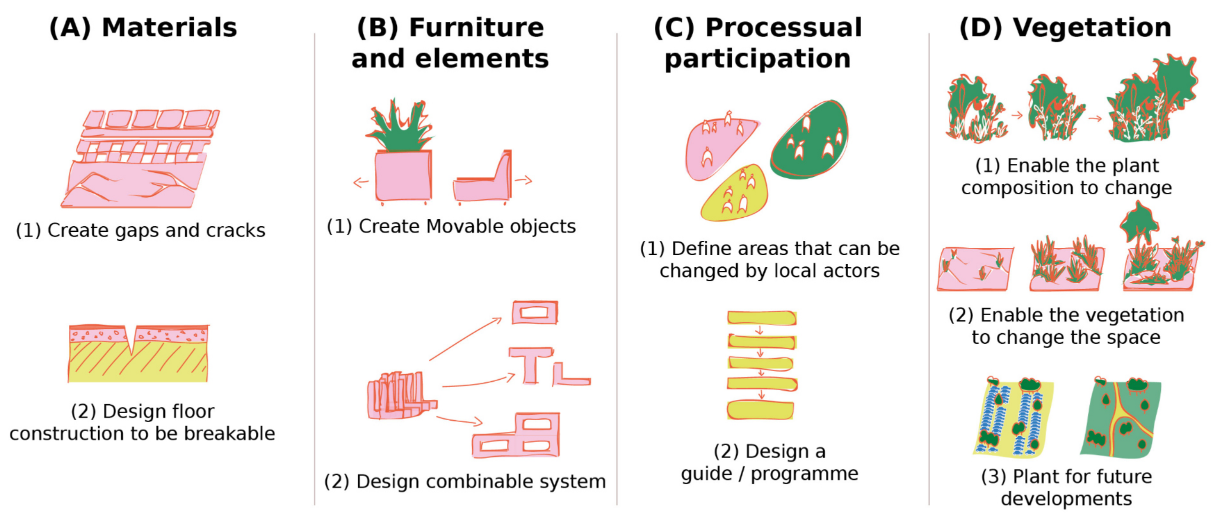

Figure 5.1 - Changeability in Landscape architecture, graphic: Josefine Siebenand

When evaluating built landscape architecture projects, it becomes clear that various approaches to changeable landscapes are already used by practising landscape architects. However, these do not represent the average urban landscape project However, these do not represent the average urban landscape project, even though the Great Acceleration and the Anthropocene with the related uncertainties pose the urgent need to have a high proportion of changeable urban landscapes. Also there is potential for more changeability in each category: In terms of materials, landscape architects should resist defining every centimetre of the ground cover – that could enable non-human actors to take up space and change with the environment and influences. Another important aspect is designing the paving construction of defined areas in such a way as to prepare the space for change, ideally with a plan for future use of the surface material. It would be highly relevant to conduct future research into what kind of paving substructure would be best suitable for various changes. As for the furniture and elements, there are already diverse approaches in built landscape architecture projects - this might be the most obvious way to create changeability. Still there is more potential in most current projects to neglect the fear of vandalism and design a certain percentage of furniture. Many examples in e.g. Switzerland prove the feasibility. Temporary participation is also already part of most landscape architecture projects, but usually limited to the planning process and not as a permanent tool. The few references, that incorporate Processual participation in their long-term design show that it gives spaces the opportunity to develop with changes, however it takes a lot of accompanying and therefore financial resources. In this approach it is especially important to define a framework with fixed design elements to ensure that the planner's main idea does not get lost during the process. Creating changeability with Vegetation is often more of an answer to the question Where can we let go? as plants are constantly developing and trying to take up space. It is also an aesthetic and artistic matter to make succession look like part of the design instead of a neglected space. An approach that differs from the others in this category is the Planting for future developments, as it takes the worth of older trees in future planning into consideration and works with scenarios.

5. Conclusion - What to take away

In summary, this paper demonstrates that the Anthropocene brings increasing uncertainties that require a more changeable perspective on urban landscapes. Theories such as assemblage, actor-network-theory and resonance emphasise the importance of landscape being an actively responsive part of changing circumstances and giving non-human actors the opportunity to co-create the space. While there are various approaches to changeability in the literature and built projects of landscape architecture, this is not reflected in everyday practice. In particular, the preparation of the paving substructure and vegetation of future changes is rarely considered and requires further research. The long-term provision of processual participation can also currently be found in very few projects. The above raises the question whether landscape can actually be built as a finalisable project or rather needs to be accompanied. For a sustainable urban transformation, urban landscapes have the potential to become more actively changing spaces for human and non-human actors. Landscape architects could support that by incorporating changeable approaches in their designs more often.

References

Aouf, R. (2018). Stackable Playscapes System Transforms Empty Lots into Playgrounds. Dezeen (blog). 17. Januar 2018. https://www.dezeen.com/2018/01/17/stackable-playscapes-system-transforms-empty-lots-into-playgrounds-amman-design-week/.

Atelier le Balto. (2023). Park in Progress 1. Platz | Atelier le balto, le blog. 26th January 2023. https://www.lebalto-leblog.eu/park-in-progress-1-platz/.

Bender, B. (2002). Time and Landscape. Current Anthropology 43 (S4): p. 103–12. https://doi.org/10.1086/339561.

Block, I. (2019). Level Up Street Pavilion Provides Multi-Level Hang-out Space for Rijeka. Dezeen (blog). 20th February 2019. https://www.dezeen.com/2019/02/20/level-up-street-pavilion-rijeka/.

Buchert, M. (2013). Formation und Transformation von Orten. In Einfach Entwerfen. Simply Design, p.38–65. Berlin: Jovis.

Buchert, M. (Ed.) (2018). Prozesse reflexiven Entwerfens: Processes of reflexive design. Berlin: Jovis Verlag.

Christiaansen, K. & Baum, M. (2002). City as Loft. Topos 38: p.6–17.

Christiaansen, K., Schüller, N. & Rieniets, T. (2014). Strategisches Entwerfen. ETH Zürich.

Clément, G. (2001). Le Jardin En Mouvement. De La Vallee Au Jardin Planetaire, 4eme Edition. Sens & Tonka.

Colwill, S. (2018). Landscape architecture and the time factor: Construction research on the contextual change of built landscape elements and the development of optimisation strategies (Final Report). Fachgebiet Landschaftsbau-Objektbau. https://doi.org/10.14279/depositonce-9407.

Crutzen, P. & Stoermer, E. (2000). The Anthropocene. IGBP Newsletter 41.

Deleuze, G & Guattari, F. (1989). A Thousand Plateaus: Capitalism and Schizophrenia. Translated by Brian Massumi. Journal of Interdisciplinary History 19 (4): p.657. https://doi.org/10.2307/203963.

Falkeis, A., Shesterikova, A., James, B. & Tingen, M. (2022). Nonlinear Urbanism: Towards Multiple Urban Futures. Birkhäuser. https://doi.org/10.1515/9783035624410.

Gotti, F., Leveratto, J. & Colombo, C. (2022). The design of tactics : critical practices transforming public spaces. Barcelona.

GTL Landscape Architecture. (2025). Alter Flugplatz Bonames | Frankfurt am Main. GTL Landschaftsarchitektur Triebswetter, Mauer, Bruns Partner mbB (blog). Accessed on 23rd June 2025. https://gtl-landschaftsarchitektur.de/projekt/alter-flugplatz-bonames-frankfurt-am-main-bonames/.

Hallo e.V. (2021). „Reflexionsbericht 2020-21 PARKS“. Accessed on 23rd June 2025. https://parks-hamburg.de/mediathek/.

INTERNATIONAL FEDERATION OF LANDSCAPE ARCHITECTS. (2020). Definition (Basierend auf der bestehenden Definition der ISCO/08) des Berufes.

International Commission on Stratigraphy (ICS). (2025). Joint statement by the IUGS and ICS on the vote by the ICS Subcommission on Quaternary Stratigraphy. Accessed on 29th April 2025. https://stratigraphy.org/news/152.

IPPC, Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P., Trisos, C. u. a. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (Eds.)]. Intergovernmental Panel on Climate Change (IPCC). Geneva, Switzerland

Käpplinger, C. (2009). Landschaftsarchitekten als Agenten des Wandels. In System Landschaft - Landscape as a system, p.64–77. Basel Boston Berlin: Birkhäuser.

Latour, B. (1996). On Actor-Network Theory: A Few Clarifications. Soziale Welt 47: p.369–81.

Latour, B. (2005). Reassembling the social: an introduction to actor-network-theory. Clarendon lectures in management studies. Oxford; New York: Oxford University Press.

Latour, B. (2014). Agency at the Time of the Anthropocene. New Literary History 45 (1): p.1–18.

Lefebvre, H. (1997). The Production of Space. Translated by Donald Nicholson-Smith. Reprinted. Oxford: Blackwell.

Lydon, M. & Garcia, A. (2015). A Tactical Urbanism How-To. In M. Lydon & A. Garcia (Hrsg.), Tactical Urbanism: Short-Term Action for Long-Term Change (S. 171–208). Washington, DC: Island Press/ Center for Resource Economics.

Oskam, P. & Mota, J. (2020). Design in the Anthropocene: Intentions for the Unintentional. p.269–79. https://doi.org/10.1007/978-3-030-61671-7_26.

Oswalt, P., Overmeyer, K. & Misselwitz, P. (2013). Urban Catalyst - mit Zwischennutzung Stadt entwickeln. Berlin: DOM Publishers.

Ott, C. (2020). „Superblock of Sant Antoni / Leku Studio“. ArchDaily. 27th April 2020. https://www.archdaily.com/938244/superblock-of-sant-antoni-leku-studio.

Pouzenc, J., Römer, A. & Constructlab. (2023). Convivial Ground: Stories from Collaborative Spatial Practices. Published by Peter Zuiderwijk. JOVIS. https://doi.org/10.1515/9783986120054.

Prominski, M. (1996). Die Unordnung planen. Garten + Landschaft, 1996.

Raxworthy, J. (2016). Building a Wilderness with Louis Le Roy. In The Slow Reader: A resource for design thinking and practice, Published by C. Strauss und A. P. Pais, p.98–109. Amsterdam: Valiz.

Rosa, H. (2019). Resonanz: Eine Soziologie der Weltbeziehung. 8. Aufl. Berlin: Suhrkamp Verlag.

Siegmund, Y. (2021). Quartiersentwicklungen sind Schaukelprozesse. In Grenzen überschreiten – Räume aktivieren: Grenzüberschreitende Ansätze der Raumplanung im europäischen Kontext, p.164–65. Berlin: JOVIS.

Silva, P. 2016. Tactical Urbanism: Towards an Evolutionary Cities' Approach?. In Environment and Planning B: Planning and Design 43 (6): p.1040–51. https://doi.org/10.1177/0265813516657340.

Simon & Marjolijn. (2025). „Ecokathedraal“. Atlas Obscura. 21st June 2025. http://www.atlasobscura.com/places/ecokathedraal.

Sommer, B. & Welzer, H. 2014. Transformationsdesign: Wege in eine zukunftsfähige Moderne. München: oekom verlag GmbH.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O. & Ludwig, C. (2015). The Trajectory of the Anthropocene: The Great Acceleration. The Anthropocene Review, April 2015. https://doi.org/10.1177/2053019614564785.

Stevens, Q. & Dovey, K. (2022). Temporary and Tactical Urbanism: (Re)Assembling Urban Space. 1. Aufl. New York: Routledge. https://doi.org/10.4324/9781003284390.

WBGU (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen). (2016). Der Umzug der Menschheit: Die transformative Kraft der Städte. disP - The Planning Review 54 (1). https://doi.org/10.1080/02513625.2018.1454726.

Webb, D. 2018. Tactical Urbanism: Delineating a Critical Praxis. 2018. https://www.tandfonline.com/doi/epdf/10.1080/14649357.2017.1406130?needAccess=true&role=button.

Weilacher, U., Giseke, U., Neppl, M., Scholl, B., Siedentop, S. & Voigt, A. (2021). Grenzen Überschreiten – Räume Aktivieren: Grenzüberschreitende Ansätze Der Raumplanung Im Europäischen Kontext. Published by Internationales Doktorandenkolleg „Forschungslabor Raum“. 1. Aufl. Berlin: JOVIS.

Weilacher, U., Koch, M., Neppl, M., Schönwandt, W., Scholl, B. & Voigt, A. (2016). Urbane Transformationslandschaften. Published by Internationales Doktorandenkolleg Forschungslabor Raum. Jovis.

Figures

Figure 3.1: Changeability of urban landscapes in literature. Graphic by Josefine Siebenand

Figure 4.1: Approaches to changeability in built project. Graphic by Josefine Siebenand, used photos in the graphic (top-down): Bonames. Photo: Stefan Cop; Ecokathedraal. Photo: Peter Wouda; PARKS. Photo: Hallo e.V.; Superblocks. Photo: Christopher Marco; Level Up Street Pavillon. Photo: Rahul Palagan; Stackable Playscapes. Photo: Rima Sabina Aouf; Klybeckquai. Photo: Fontana; Park am Gleisdreieck. Photo: Joscha Kaiser; Wolbecker Straße. Photo: Modulorbeat; Park in Progress. Graphic: Atelier le Balto; Tempelhofer Feld. Photo: Olebader; Platzprojekt. Photo: Miriam Schwab; Jardin au movement. Photo: Gilles Clément; Toni Areal. Photo: Studio Vulkan; Bonames. Photo: Stefan Cop; Car Park Ring. Photo: Google Street View

Figure 5.1: Changeability in Landscape architecture. Graphic by Josefine Siebenand

The Role of Organic Street Networks in Sustainable Urban Mobility

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Abstract

Organic street networks shape movement patterns and urban experiences, yet their physical characteristics remain underexplored. Their forms are often resistant to modification due to heritage values, historical significance, and geographical constraints. Unlike other street systems, organic networks adapt to the built environment rather than displacing it, preserving natural resources and socio-cultural spaces. This study evaluates the walkability of Tehran's organic street networks—original, integrated, and imitated—analyzing their structural and spatial configurations alongside gendered mobility differences. Using GIS mapping and qualitative methods, including expert interviews and surveys, the research highlights how these networks naturally foster pedestrian movement. The findings underscore their role in sustainable urban development and climate resilience, demonstrating how they maintain urban identity while minimizing environmental disruption.

1. Introduction

Sustainable urban mobility is a growing priority as cities worldwide face increasing challenges related to traffic congestion, pollution, and climate change. Encouraging walking, cycling, and public transit is key to reducing car dependence and enhancing urban livability. Street networks play a foundational role in shaping mobility patterns; their structure directly influences the ease, safety, and attractiveness of pedestrian movement. As such, walkability has emerged as a central indicator in urban planning, linking built form to broader health, environmental, and social outcomes.

Among the various street network typologies, organically developed layouts offer distinct characteristics. Despite their enduring presence and potential benefits, organic street networks have often been overlooked in contemporary urban mobility research. Conventional planning approaches tend to favor geometric regularity and vehicular flow, potentially sidelining the socio-cultural and environmental qualities embedded in organically grown urban forms. There is a pressing need to revisit these networks not as outdated remnants, but as adaptable systems that may hold valuable insights for sustainable urban development. By analyzing their spatial characteristics and how they shape pedestrian experience, the study aims to contribute to a more inclusive understanding of urban mobility that recognizes the value of historic urban forms in meeting contemporary sustainability goals.

2. Literature Review

Organic street networks are urban layouts characterized by irregular geometry, winding streets, and spatial structures that evolved gradually without comprehensive pre-planning (Farid, 1989). These networks typically arise from local adaptation processes, responding to topographical, cultural, and historical influences (Moshhadizadeh Dehaghani, 1994). Common characteristics include narrow streets, numerous cul-de-sacs, and a complex hierarchy of public, semi-public, and private spaces. Organic networks adapt their form naturally to the built and natural environment, preserving local heritage, urban identity, and community cohesion. Their formation is typically incremental, shaped by residents' immediate needs and traditional urban development principles (Azimi et al., 2013). An organic structure is based on the ability and power to own a space, qanat, and water routes (Soltani Mohammad and Yousefi, 2018), Important centers include Emamzadeh, Neighbors' meeting points (Khaleghi, 2024).

The organic street networks emphasize pedestrian scale, creating environments that naturally slow down vehicular traffic and enhance pedestrian comfort and safety. The organic networks' irregular forms provide climatic benefits by offering shade, protection from winds, and maintaining ecological integrity (Boroumand, 2010). Existing literature predominantly evaluates walkability using factors such as connectivity (Shieh, 2009; Amanpour et al., 2015; Mousavi et al., 2016; Yoo and Lee, 2017), accessibility (Habibi, 2007; Sazandeh et al., 2018), pedestrian comfort (Fadaki and Roshani, 2013), safety (Jacobs, 1961; Hillier and Vaughan, 2007; Carmona et al., 2012; Rahmana and Hosseinian, 2014; Amanpour et al., 2015), and Hierarchy of the spaces (Jamei et al., 2021). Earlier studies on organic networks have highlighted their potential advantages (Farid, 1989; Soltanzadeh, 1993; Moshhadizadeh Dehaghani, 1994), including enhanced pedestrian experience, climate adaptability, and cultural preservation.

Similarly, most gender-focused mobility research has been conducted in the context of planned or mixed urban forms, often emphasizing safety, accessibility, and usability concerns for women and other vulnerable groups (Whitzman et al., 2011; Hanson, 2010). These studies consistently highlight that women's mobility is more sensitive to factors such as lighting, visibility, public surveillance, and the presence of mixed land use. In complex organic networks—particularly those with narrow alleys, irregular paths, and low visual connectivity—such concerns may be exacerbated, contributing to perceptions of insecurity and restricted movement, particularly after dark. A study by Collins et al. (2023) examined spatiotemporal gender differences in urban vibrancy, revealing that women and men experience urban spaces differently, influenced by factors such as points of interest and transportation networks.

In the context of Tehran, the Association for Iranian Studies (n.d.) discusses the interplay between gender, sexuality, and urban space in Tehran's historical development, highlighting the unique experiences of women in the city's evolving urban fabric. Additionally, a study by Zareian (2024) emphasizes the importance of gender-responsive planning in Iranian urban public spaces, advocating for designs that consider women's needs and experiences to foster more inclusive environments. These studies collectively suggest that women's mobility is influenced by a complex interplay of spatial configurations, cultural norms, and safety perceptions. In organic street networks, characterized by narrow, winding paths and limited visibility, these factors may be amplified, potentially restricting women's movement and sense of security.

3. Methodology

The study focuses on six neighborhoods in Tehran, each representing a subtype of organic street networks: original (Sanglaj, Chizar), integrated (Qeytariyeh, Dr. Hooshyar, Darous), and imitated (Shahrak-e Qarb) [Fig. 1,2].

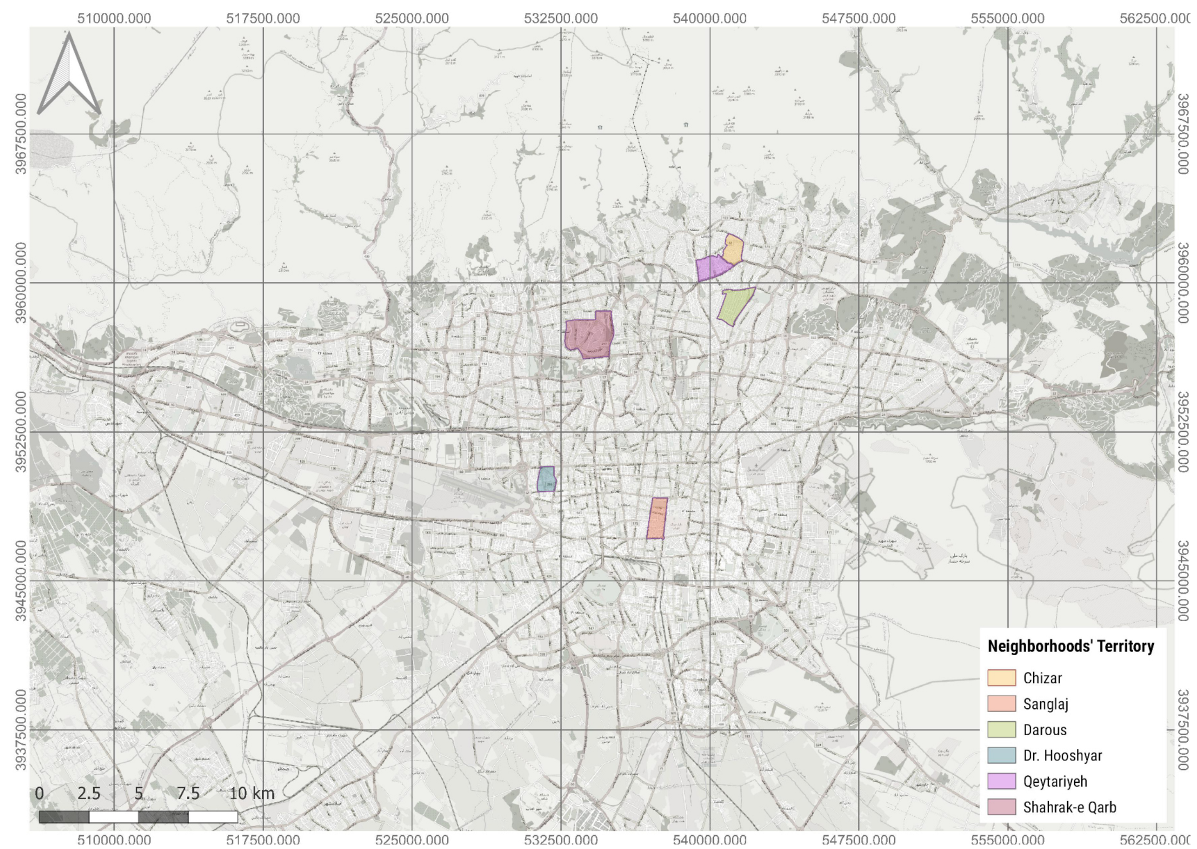

Figure 1. The location of the selected neighborhoods in Tehran (Khaleghi, 2024)

Figure 2. Different organic street network types in Tehran and the location of the qanat routes (Khaleghi, 2024)

These areas range from dense historic quarters with narrow, winding streets to modern developments designed to mimic traditional layouts. GIS-based mapping and spatial analysis were used to assess features such as street width, connectivity, visual access, and the distribution of public spaces. Complementary qualitative methods included expert interviews and resident surveys, capturing perceptions of safety, comfort, usability, and the built environment. Special attention was given to gender differences in mobility experiences, identifying disparities in how men and women navigate and perceive walkability in these networks. Table 2 summarizes the walkability criteria and assessment methods used [Table 1].

Table 1. Walkability assessment factors, elements, indicators, methods, scale in Tehran organic street networks (Khaleghi, 2024)

Factor of walkability	Element of the street network	Indicator	Method	Scale
Safety against moving traffic	The width of the streets	The possibility to separate pedestrian and vehicle spaces; the width of the street more than 6 meters	Mapping based on GIS, Questionnaire	Street
	The form of the streets	Physical and visual barriers due to the form of the street – the topography	Mapping based on Questionnaire	Street
Security against crime and harassment	Hierarchy of spaces	Existing semi-public spaces	Mapping based on Questionnaire	Network
		Accessibility from one street to the others (betweenness)	GIS data	Network
	Street configuration	Eyes on the street - Blind corners, Indefensible spaces	Mapping based on Questionnaire	Network
	The form and height of the streets	Street lighting	Questionnaire data	Network
Accessibility	Number of intersections	Calculating the number of intersections	GIS data	Network
Connectivity	Principle of continuity and connectivity- Physical connectivity	Beta and Eta indexes	GIS data	Network
	Principle of continuity and connectivity- spatial continuity- Visual connectivity	Street and street network landmarks	Mapping based on GIS and Questionnaire	Network
Climate comfort	Contrasting, human scale, orientation, principle of scale of proportion	Constructional elements to consider the climate such as Sabat, roof, specific flooring and using steps because of topography, trees as street elements, and the shadow of the street facades and orientation of the streets inside the network	Mapping based on GIS and Questionnaire data	Network
The quality of the built environment	Human Scale/ Scale and proportion	Creating a sense of proper enclosure by respecting the ratio of height to width	Mapping based on Questionnaire	Network
	Permeability	Number of dead ends	GIS data	Network
		The number of intersections and the small distance between intersections	GIS data	Network
	Readability	The ability to detect branching paths from a street	Questionnaire data	Network
Attractiveness and beauty	View	The level of visibility of the skyline and natural elements	Mapping based on GIS	Network
		Creating shade due to the presence of the roof and sabbat and the narrow width of the path	Questionnaire data	Network
	Greenery	Trees on the streets, old trees	Questionnaire data	Network
	Water	Rivers, Qanats, and water channels	Questionnaire data	Network
	Sounds	Sounds of traffic, water, nature, life	Questionnaire data	Network
	Smell	Smell of nature, water (positive and negative), city	Questionnaire data	Network
	Buildings – Street walls	Old and important neighborhood/city places and buildings, holy and religious places and buildings	Questionnaire data	Network
	Variety/ Principles of contrasting	Visual analysis	GIS data	Network
		Opening and different widths of the streets	Mapping based on GIS	Network
		Proportion between full and empty spaces	GIS data	Network
		A variety of old street elements were used including Sagha Khaneh and Gozar, Kuche- Baq, street roofs, and Sabat and arch	Interview and Questionnaire data	Network

4. Findings and Discussion

Tehran's organic street networks can be grouped into three categories—original, integrated, and imitated—each with unique spatial characteristics that shape walkability, environmental performance, and social experience. These networks illustrate how street form directly impacts sustainable urban mobility and the lived experiences of pedestrians, especially women.

Original organic networks, such as those in Sanglaj (historic core) and Chizar (older neighborhood), are defined by narrow, winding streets, irregular widths, and hierarchical transitions between public and private spaces. Despite their visual complexity and limited vehicular access, these areas support strong pedestrian activity. Factors such as human scale, shaded pathways, and proximity to commercial and religious functions enhance walkability. They also promote environmental resilience, as their spatial density and shading create microclimates that moderate urban heat. However, safety concerns—especially for women—arise due to poor lighting, low visibility, and defensible space issues. Nevertheless, these neighborhoods often maintain strong social ties, which can contribute to a heightened sense of community-based security.

Integrated organic networks, including grid-organic (Qeytariyeh), tributary-organic (Dr. Hooshyar), and grid-tributary-organic (Darous), emerge from the blending of planned and organic forms. These areas vary in their spatial logic but generally benefit from greater visual connectivity and accessibility. Grid-tributary examples offer improved navigation and openness, which women in particular associate with enhanced safety and comfort. These networks provide a promising framework for balancing heritage preservation with modern functionality. However, their effectiveness depends on how successfully organic principles are retained alongside added infrastructure.

In contrast, imitated organic networks—such as Shahrak-e Qarb—seek to replicate the visual form of historic neighborhoods but often lack their socio-cultural depth. While they feature curvilinear layouts and tree-lined paths, their wide roads, controlled layouts, and car-oriented designs reduce pedestrian interaction and informal social surveillance. As a result, walkability is lower, and users report diminished connection to place, particularly in the absence of vibrant street life or neighborhood cohesion.

Across all network types, gender-based mobility experiences reveal key disparities. Women consistently reported higher sensitivity to street lighting, path visibility, and public activity. Integrated networks with better visual openness and mixed-use frontages tended to be more inclusive. Original networks, though less visually transparent, sometimes compensate with stronger social familiarity. Imitated networks, however, often lack both physical safety measures and a sense of communal trust.

Environmentally, the original and integrated networks demonstrate resilience through their ability to adapt to topography and climate, offering natural shading, ventilation, and ecological continuity. Culturally, they preserve traditional forms and foster neighborhood identity. These strengths position them as valuable models for sustainable urban transformation—if maintained and adapted carefully.

Ultimately, this study shows that organic street networks—especially those that evolved historically or blend organically with modern elements—can support sustainable mobility through walkability, environmental responsiveness, and socio-cultural continuity. However, their success in practice hinges on inclusive design, especially gender-sensitive interventions, and thoughtful management that enhances usability without compromising heritage. These insights offer both a critique of car-centric planning and a framework for reimagining historic urban forms as active, adaptable elements in contemporary city-making.

5. Conclusion

This study has demonstrated the critical role of organic street networks in promoting sustainable urban mobility within the complex urban fabric of Tehran. Through structural and spatial analysis of original, integrated, and imitated organic networks, the research highlighted their inherent potential to support walkability, pedestrian safety, environmental responsiveness, and socio-cultural continuity. Key findings revealed that original organic networks, despite spatial irregularities, foster strong pedestrian activity due to their human scale and environmental adaptability. Integrated networks offer a balanced configuration that combines traditional qualities with enhanced connectivity, while imitated networks reflect modern attempts at replication but often fall short in functionality and inclusivity.

From a policy and planning perspective, the research underscores the importance of preserving and enhancing the unique qualities of organic networks. Urban development strategies should prioritize the protection of historic textures and integrate pedestrian-focused interventions that are sensitive to local culture, topography, and user diversity. Retrofitting efforts in older neighborhoods must maintain spatial integrity while improving lighting, accessibility, and security, particularly from a gender-inclusive lens. Furthermore, planning frameworks should recognize organic networks not as outdated remnants but as adaptive systems that offer valuable lessons for contemporary urban design, particularly in regions facing climate stress and cultural erosion.

For future research, deeper investigation into the dynamics of gendered mobility in various urban typologies could enrich understanding of inclusivity in mobility planning. Expanding comparative studies across other cities with similar organic patterns could also validate and refine the walkability evaluation framework developed here. Moreover, interdisciplinary approaches that incorporate behavioral psychology, environmental data, and urban economics may offer new insights into how organically evolved spaces can meet the evolving demands of 21st-century urban life while preserving their historic essence.

References

1. Amanpour, S., Hosseini Shahparian, N., Maleki, S. (2015). Spatial analysis of the levels of urban services in Ahvaz metropolis with an emphasis on social justice. Urban Planning Geography Research; 4(3): 495-517.
2. Association for Iranian Studies. (n.d.). Gender and urban space in Tehran. https://www.associationforiranianstudies.org/content/gender-and-urban-space-tehran
3. Azimi, N., Azadeh, S.R., Zare Roudbezani, M. (2013). Geographical analysis of urban form patterns in Iran. Urban Studies Quarterly, 7th issue.
4. Boroumand, M. (2010). Urban fabric pattern and its role in reducing earthquake damage. Case example: Gharb and Derkeh settlement, Zagros landscape geography and urban planning quarterly. third year, number 7.
5. Carmona, M., Heath, T., Oc, T., Tiesdell, S. (2012). Public places - urban spaces, Routledge.
6. Collins, J., Nolasco, C., Wu, H., Wu, M., & Xu, H. (2023). Spatiotemporal gender differences in urban vibrancy. arXiv. https://arxiv.org/abs/2304.12840
7. Fadaki, E. H., Roshani, P. (2013). providing sustainable design solutions in a hot and dry climate; A case study of Yazd. National conference of architecture, urban planning and sustainable development with a focus on native architecture to sustainable city. Khavaran Institute of Higher Education. Mashhad. Iran.
8. Farid, Y. (1989). "Geography and Urbanism", Tabriz, Tabriz University.
9. Habibi, S.M. (2007). Urban spaces and civic life. Fine Arts 14. 7.
10. Hanson, S. (2010). Gender and mobility: New approaches for informing sustainability. Gender, Place & Culture, 17(1), 5–23.
11. Hillier, B., Vaughan, L. (2007). The city as one thing. Progress in Planning, 67, 205-230.
12. Jacobs, J. (1961). The Death and Life of Great American Cities. New York: Random House.
13. Jamei, E.; Ahmadi, K.; Chau, H.W.; Seyedmahmoudian, M.; Horan, B.; Stojcevski, A. (2021). Urban Design andWalkability: Lessons Learnt from Iranian Traditional Cities. Sustainability; 13, 5731. https://doi.org/10.3390/su13105731
14. Khaleghi, N. (2024). Assessing the walkability of Tehran organic street networks: Based on the network's form = Die Auswertung der Fußgängerfreundlichkeit der Teherans organische Straßennetzwerke: Basierend auf der Form des Netzwerks [Doctoral dissertation, Karlsruhe Institute of Technology (KIT); Tehran University]. KITopen. https://doi.org/10.5445/IR/1000174027
15. Mashhadizadeh Dehaghani, N. (1994). An analysis of urban planning features in Iran. Iran Science and Industry Publications. Tehran. Iran.
16. Mousavi, M., Majdi, H., Habib, F. (2016). Recognizing the physical and spatial features of the old fabric of the city in Iran. Hoviyat Shahr Magazine; number 28, 10th year.
17. Rahnama, M.R., Hosseinian, N. (2014). The effect of physical components on the feeling of security in public spaces (Abkouh neighborhood, Mashhad). Research Journal of Great Khorasan, 6(18): 61-79.

18. Sazandeh, M., Yazdanfar, S. A., Faizi, M. (2017). The components of urban landscape continuity on increasing the desire to walk in urban parks (case study: urban parks of Shiraz). Scientific and research quarterly of research and urban planning, 9(34), 93-104.
19. Shieh, I. (2009) Ba Shahr va Mantaghe dar Iran [City and Region in Iran]; University of Science and Technology: Tehran, Iran.
20. Soltani Mohammadi, M., Yousefi, Y. (2018). Recognizing the effect of aqueducts on settlements in the central region of Iran (case study: Mohammadieh Nayin village); Housing and Village Environment; 37 (164): 101-114.
21. Whitzman, C., Legacy, C., Andrew, C., Klodawsky, F., Shaw, M., & Viswanath, K. (2011). Women's safety and everyday urban life: A research agenda. Urban Studies, 48(10), 2007–2022.
22. Yoo, Ch., Lee, S. (2017). When Organic Urban Forms and Grid Systems Collide: Application of Space Syntax for Analyzing the Spatial Configuration of Barcelona, Spain, Journal of Asian Architecture and Building Engineering, 16:3, 597-604, DOI: 10.3130/jaabe.16.597
23. Zareian, R. (2024). Gendered approaches to urban public spaces in Iran: An analytical study. The 3rd International Conference on New Approaches in Engineering and Basic Sciences. Belguim.

Towards a Smart Circular Urban Future: Water Management Visions in Amsterdam and Busan

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1. Introduction

Amid growing global concerns over climate change, environmental degradation, and unsustainable resource consumption, the integration of circular economy principles into urban systems has emerged as a crucial strategy for sustainability (von Hauff, 2023). Urban areas—with their high densities of infrastructure, institutions, and consumption—offer fertile ground for implementing circular strategies that aim to minimize waste and extend the lifecycle of materials and products (Aceleanu et al., 2019). However, achieving these goals requires overcoming complex coordination challenges among sectors with divergent material flows and institutional logics (Fromhold-Eisebith, 2024).

In parallel, the advent of smart city technologies—such as Big Data, IoT, and AI—has opened new possibilities for enhancing the efficiency and adaptability of circular urban systems (Ramesohl et al., 2022). These technologies enable data-driven approaches to recycling, waste management, and secondary materials markets, while also fostering new behavioural norms and business models. This convergence has given rise to the concept of the Smart Circular City, wherein digital innovation supports the transformation toward more regenerative, resilient, and inclusive urban systems.

Anchored in this evolving paradigm, this study investigates how Smart Circular City visions are formulated and operationalized within the specific socio-technical and spatial contexts of Amsterdam (Netherlands) and Busan (Republic of Korea). By focusing on the domain of urban water management, the paper examines how such visions function as socio-epistemic practices—that is, as frameworks that not only guide planning and investment but also shape institutional dynamics, public discourse, and governance structures. Methodologically, the study combines Vision Assessment (VA) and Critical Discourse Analysis (CDA) to analyze the ways in which smart and circular urban futures are co-constructed, legitimized, and contested across these two city contexts.

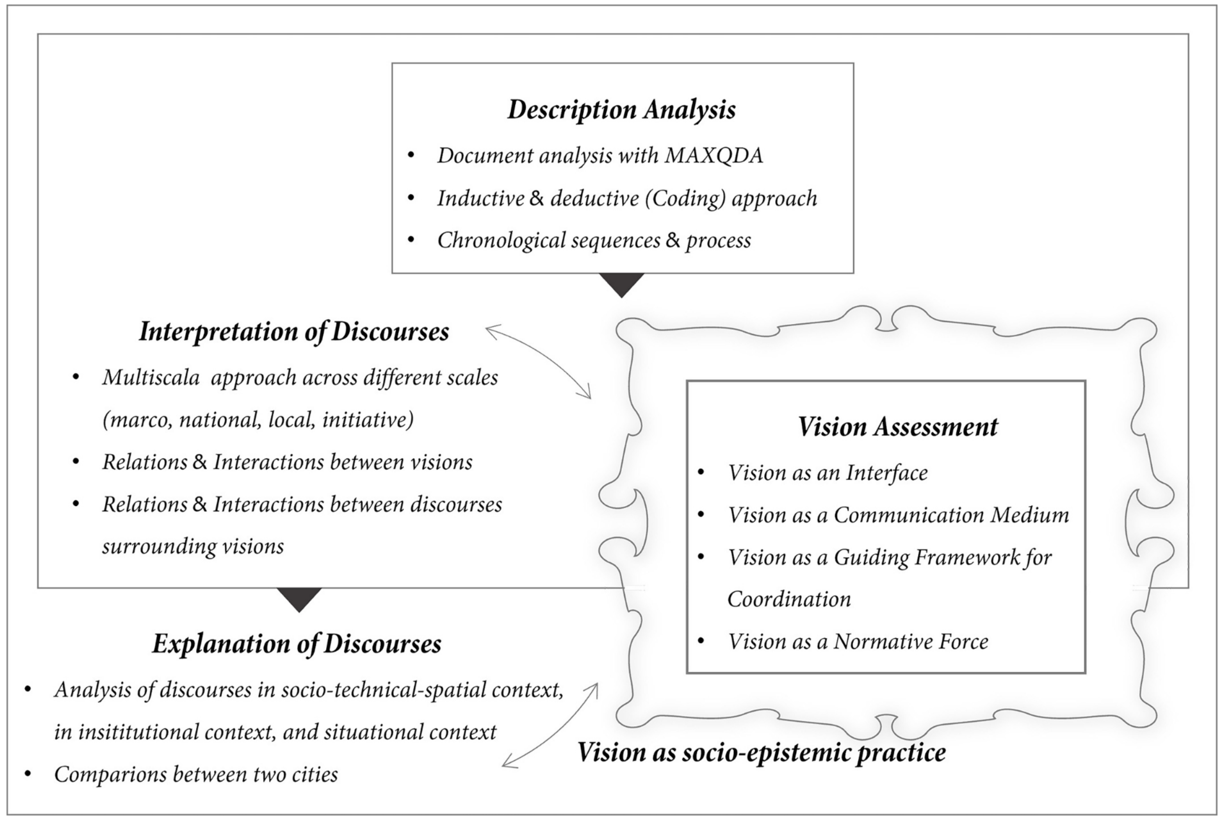
2. Case Introduction

While academic interest in Smart Cities and Circular Cities continues to grow, the integrated concept of the Smart Circular City remains relatively underexamined and lacks extensive empirical grounding due to its recent emergence. Within this context, the Netherlands and South Korea stand out as innovators, having advanced national agendas on smart urban development through distinct institutional pathways. Amsterdam represents a decentralized and inclusive model, characterized by multi-stakeholder governance and adaptive urban experimentation. In contrast, Busan exemplifies a centralized and state-led model, where smart water initiatives are driven by national priorities aligned with Korea's Fourth Industrial Revolution strategy.

Both cities place strong emphasis on circularity in urban water management, a sector critical to climate adaptation and infrastructural resilience. Despite their differing planning traditions and climatic conditions, Amsterdam and Busan have implemented smart water circulation systems to address urban flooding and seasonal water stress. Their selection for this study reflects their contrasting governance architectures: Amsterdam's iterative, bottom-up approach fosters policy flexibility, while Busan's top-down model emphasizes technological coherence and strategic scalability. These divergent cases reveal how socio-technical-spatial configurations shape the formation and enactment of smart circular city visions.

3. Analytical Framework

Figure 1 :A multidimensional analysis approach in the context of Vision Assessment and Fairclough's CDA



Note. created by the author, 2025

This study adopts an integrated analytical framework combining Vision Assessment (VA) and Critical Discourse Analysis (CDA) to examine how Smart Circular City visions shape urban transformation processes (Lösch, 2022; Fairclough, 1992). VA identifies four key functions of visions: (1) interfaces, which link current challenges with future aspirations; (2) communication media, through which diverse actors negotiate meaning, expectations, and institutional roles; (3) guiding frameworks for coordination, enabling alignment across sectors and governance levels; and (4) normative forces, which define what is desirable and legitimate, shaping behaviours and institutional commitments. These functions highlight how visions not only articulate urban futures but also influence planning strategies, institutional dynamics, and policy implementation.

To complement this macro-perspective, Fairclough's CDA offers a micro-level analysis of how visions are discursively constructed, legitimized, and embedded in institutional contexts. Its three-dimensional model—focusing on textual features, discursive practices, and social practices—enables the deconstruction of language to uncover how ideologies and power relations inform smart circular narratives (Fairclough, 2001; Wodak & Meyer, 2001). CDA reveals how specific rhetorical framings and lexical choices reinforce or challenge dominant urban imaginaries.

By combining these approaches, the study offers a multidimensional lens for analyzing the performative power of smart circular city visions. While Vision Assessment explains how visions structure transformation at a systemic level, CDA exposes how discourse constructs and stabilizes these visions within particular socio-political realities. Together, they allow for a critical interrogation of the socio-epistemic functions of urban futures and the governance architectures through which they are operationalized.

4. Findings

Amsterdam: Institutional Experimentation and Systemic Constraints

Figure 2: Visualization of Circular Buiksloterham

Note. by DELVA Landscape Architects/Urbanism, 2019

In Amsterdam, the integration of Smart Circular City principles within urban water management reflects a decentralized, multi-stakeholder governance approach. The city has pioneered several flagship projects, such as Circular Buiksloterham and RESILIO's smart blue-green roof initiative, which emphasize co-creation and technological experimentation. These initiatives have been supported by EU policies such as the Horizon 2020 program and the European Green Deal, positioning Amsterdam as a model for scalable, data-driven sustainability interventions. The city's water management strategy is embedded within a broader multiscalar circular economy framework, linking waste reduction, energy efficiency, and climate resilience from the EU level down to local governance.

Through digitalization and data-driven analytics, Amsterdam has enhanced its ability to monitor and optimize water flows, preventing excessive water consumption and reducing the risk of flooding. Amsterdam's role as a lighthouse city within the EU's smart circular strategy underscores its function as a testbed for cutting-edge urban sustainability initiatives. As one of the European Innovation Partnership's (EIP) Smart Cities and Communities projects, Amsterdam serves as an experimental ground where policies and technologies are refined before broader EU-wide implementation. The city's ability to integrate research, governance experimentation, and private sector investment has allowed it to set precedents for smart circular urbanism at an international scale. However, this role as a policy frontrunner also comes with significant challenges, as Amsterdam must continuously align its local priorities with overarching EU directives, which may not always be fully adaptable to localized urban conditions. However, the reliance on public-private partnerships (PPPs) and external funding sources presents governance asymmetries, where institutional priorities and market-driven imperatives shape project trajectories.

While Amsterdam's model promotes flexibility and stakeholder inclusion, it also faces challenges in achieving long-term systemic transformation, as scaling pilot initiatives requires sustained financial and regulatory support. Despite these challenges, Amsterdam's iterative governance approach has enabled continuous learning and adaptation, allowing the city to serve as a living lab for smart circular innovation. Through policy experimentation, cross-sectoral collaboration, and technological integration, Amsterdam's water management framework continues to evolve, offering valuable insights for cities seeking to implement smart circular principles at scale. By maintaining its position as a leading case study in EU-driven sustainability policies, Amsterdam demonstrates how smart circularity can be institutionalized within a multi-level governance system, ultimately reinforcing its role as a global benchmark for urban sustainability.

Busan: State-Oriented Innovation and Participatory Limitations

Figure 3: Visualization of Busan Eco Delta Smart City

Note. By Ministry of Land, Infrastructure and Transport of Korea, 2018

Busan's Smart Circular City vision is deeply embedded within South Korea's centralized urban policy architecture, reflecting a top-down model driven by national ambitions. Anchored by the Korean New Deal and the Ministry of Land, Infrastructure and Transport, Busan's water strategy emphasizes large-scale digital infrastructure—including AI-powered flood forecasting, IoT-based sewage grids, and smart reuse systems—as tools for enhancing urban resilience and economic competitiveness.

The Busan Eco Delta City (EDC), envisioned as a smart water city, embodies this vision. It integrates advanced technologies into green urban development while promoting Busan as a prototype for global smart city exports. Yet, despite its technological sophistication, the governance structure behind these developments remains rigidly hierarchical. The state, rather than local communities, sets the vision, allocates resources, and determines implementation mechanisms. Citizen participation is invited, but largely within predetermined parameters—such as public design competitions and curated living labs—which often instrumentalize public input rather than foster genuine co-production.

Busan's emphasis on digital efficiency risks overshadowing social inclusivity. The smart circular narrative is used to reinforce economic development strategies, especially in real estate and infrastructure sectors. Although the EDC promotes "living labs" and collaborative innovation, these are typically framed within market-friendly and state-coordinated structures that limit opportunities for grassroots experimentation. Additionally, heavy investment in high-tech systems raises long-term concerns about cybersecurity, maintenance costs, and data governance.

The city's ability to replicate or adapt its model in other Korean contexts remains constrained by path dependency and centralized institutional logics. Despite discourse around openness and innovation, urban transformation remains tightly controlled by national agencies and elite actors. Local knowledge systems, environmental justice concerns, and decentralized governance models remain marginalized. In this way, Busan's smart circular vision, while rhetorically aligned with global sustainability goals, functions more as a strategic tool of state-led modernization than as a genuinely inclusive vision of urban regeneration.

To evolve beyond its current limits, Busan must expand participatory governance structures, diversify stakeholder agency, and foster locally grounded imaginaries of urban sustainability that extend beyond technological determinism.

5. Conclusion

This study has critically examined how Smart Circular City visions function as socio-epistemic practices in shaping contemporary urban water governance, focusing on the contrasting cases of Amsterdam and Busan. Through a comparative lens, the research demonstrates that while smart circularity presents a promising paradigm for integrating technological innovation with sustainability imperatives, its realization is deeply embedded in the socio-technical and political contexts of each city.

Amsterdam exemplifies a multi-scalar, experimental governance approach, where smart circular visions are co-produced through the interplay of municipal leadership, EU policy alignment, and collaborative living lab initiatives. The projects like RESILIO and Circular Buiksloterham showcase the city's capacity to act as a testing ground for scalable innovation. However, this leadership role is accompanied by structural limitations. Reliance on EU funding, the dominance of public-private partnerships, and centralized decision-making within institutions like Waternet challenge the sustainability and inclusivity of these initiatives. Despite strong rhetoric around participatory governance, citizen involvement often remains secondary to technocratic priorities and economic feasibility. Moreover, digitalization raises ethical concerns related to data ownership, surveillance, and transparency, which remain under-addressed in current governance frameworks.

In contrast, Busan reflects a state-coordinated model of smart circular urbanism, deeply rooted in South Korea's national economic strategy and technological modernization agenda. The integration of circular principles into Busan's water management system is largely driven by top-down initiatives such as the Korean New Deal and national smart city legislation. The city's infrastructure emphasizes AI-based monitoring, IoT networks, and predictive systems to improve water resilience and urban efficiency. While these technologies enhance operational capacities, they also reinforce a technocratic governance paradigm that limits the role of civil society and suppresses locally-driven alternatives. Public engagement is often instrumentalized through curated platforms and competitive funding mechanisms, rather than facilitating genuine co-production of urban futures.

Both cases reveal that Smart Circular City visions are far from neutral or universally enabling. They function as performative frameworks that not only guide policy and infrastructure development but also shape power relations, define governance boundaries, and embed normative expectations about urban transformation. Whether embedded in Amsterdam's EU-aligned living lab model or Busan's state-directed innovation system, these visions mediate the relationship between sustainability and digitalization in highly contextual ways—often privileging institutional actors and predefined agendas over inclusive, pluralistic urban futures.

This research contributes to a growing body of literature that views urban visions as discursive instruments and strategic governance tools rather than purely technical roadmaps. However, several limitations remain. The focus on two case studies—while methodologically robust—limits the generalizability of findings across diverse urban and political environments. Finally, the analysis draws primarily from policy discourse and secondary sources; future studies would benefit from empirical fieldwork, stakeholder interviews, and longitudinal tracking of project impacts.

In sum, for Smart Circular City visions to meaningfully contribute to urban sustainability, they must transcend technocratic models and embrace inclusive, adaptive, and context-sensitive governance. Only by critically interrogating the visions that shape our cities can we ensure that their futures are not only smart and circular—but also just, democratic, and genuinely transformative.

References

Aceleanu, M. I., Serban, A. C., & Burghelea, C. (2019). The circular economy—An opportunity for a sustainable development. Romanian Economic Journal, 22(71), 43–58.

Fairclough, N. (1992). Discourse and social change. Polity Press.

Fairclough, N. (2001). Language and power (2nd ed.). Longman.

Lösch, A. (2022). Visions in technological futures: The function of expectations in innovation governance. Science and Public Policy, 49(2), 220–231. https://doi.org/10.1093/scipol/scab079

Ramesohl, S., Baedeker, C., & Parodi, O. (2022). Smart and circular cities: Integrating digitalization with resource efficiency. Journal of Cleaner Urbanism, 28(4), 203–218.

von Hauff, M. (2023). Circular economy in practice: A systems perspective. Springer.

Wodak, R., & Meyer, M. (Eds.). (2001). Methods of critical discourse analysis. Sage.

Exploring Synergies of Urban Greening for Wildlife in Cities

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Abstract

Cities worldwide are increasingly allocating significant resources to innovative urban landscape designs, aiming to address societal needs and adapt to the impacts of climate change. For this, the co-design of nature-based solutions and green infrastructures can act as transformative solutions in urban green planning that have significant potential to not only help mitigate the climate crisis but also combat biodiversity loss within urban environments. Existing greening initiatives primarily focus on urban forestry, such as the management of trees, vegetation structures, and parks within urban neighborhoods. These initiatives aim to improve habitat connectivity, enhance human health, provide socio-ecological benefits, and ensure equal habitat quality for residents. Here, the current understanding of the specific green features needed to support wildlife (i.e., fauna) species diversity is largely based on assumptions rather than solid scientific evidence which ultimately creates a significant gap in our holistic approach to urban biodiversity management. Focusing on this, I present a conceptual review of existing knowledge on synergies of urban greening for wildlife in cities. The assessment is planned under the project "CitiesForALL: Co-designing Future Cities for Humans and Wildlife" project, based at the Institute of Technology Assessment and System Analysis in KIT. Here, I discuss how the spatial patterns and ecological processes of wildlife occurrences across cities varies, and how the spatial configuration of different green features in built-up areas can potentially contribute to the changing wildlife patterns in urban environments.

Numerous studies have shown that urban areas can act as refuges for wildlife. Overall species diversity tends to decline as areas are increasingly built-up, however, species-specific consequences may differ in the urban matrix. Generalist species, that are behaviourally flexible, benefit from anthropogenic food sources, artificial nesting facilities and reduced predation due to the altered three-way trophic dynamic system of predator-prey-human interactions across urban areas (Gallo et al., 2019; Moura, Clucas and Furnas, 2022). For example, the abundance of European Rabbits (Oryctolagus cuniculus) is increasing in urban areas due to an altered meta-population dynamic (Ziege et al., 2020), and Stone Martens (Martes foina), Red Fox (Vulpes vulpes) can persist remarkably well in urban areas compared to rural areas (Luniak, 2004; Rodewald and Gehrt, 2014; Peerenboom et al., 2020). On the other hand, habitat-specialist species such as the European Hedgehog (Erinaceus europaeus) become increasingly rarer towards urban centres due to the increasing build-up density causing a loss of green patches (Taucher et al., 2020). Different dimensions in spatial configuration in urban matrix might also affect wildlife diversity differently across cities in the developed countries. For example, in Germany and the USA, there has been a long-standing trend towards the spatial expansion of built-up areas outside the central urban areas, promoting urban sprawl. This urban growth pattern has often included highly dispersed built-up areas leading to additional filtrations in wildlife diversity due to the loss of forest/agricultural areas.

In general, suburban areas, compared to urban and rural areas, support the highest variety of species, due to the presence of higher heterogeneity in green habitat patches and vegetation structures, and mixed land use intensities (Leveau and Leveau, 2020; Sultana, Corlatti and Storch, 2021). This phenomenon follows the ‘intermediate disturbance hypothesis’ which suggests that species diversity peaks at intermediate level of urbanisation. In conjunction with this, the ‘Luxury effect’, i.e., better habitat quality in the vicinity of communities with high socio-economic values (with better perception of wildlife), may also promote coexistence of greater variety of species in suburban matrices (Strohbach, Haase and Kabisch, 2009; Sultana et al., 2022). To date, while these factors are acknowledged as driving factors of biodiversity, existing studies have rarely taken an interdisciplinary approach to evaluating spatial configuration in built-up areas and their impacts on wildlife diversity in cities.

It is further important to note that urban areas typically consist of green habitats with varying levels of integrity, ranging from large nature reserves to small, isolated patches with scattered trees, which can benefit different taxonomic groups in different ways. Most of the existing studies have highlighted the role of flora and insects, with some attention given to birds, and rarely, mammals. Generally, it is reported that wildlife diversity increases as the size of green patches increases, following the species-area relationship (SAR) theory (Ferenc, Sedláček, and Fuchs, 2014; Leveau et al., 2019; Di Pietro, Mantoni, and Fattorini, 2021). For instance, while the presence of red foxes (Vulpes vulpes) tends to decline with increasing urbanization, foxes show a positive response to greater urban intensity when the proportion of green space exceeds 20% (Fidino et al., 2021). This has led to the development of the SLOSS (Single Large or Several Small) theory (Fahrig et al., 2022), which suggests that small green patches can act as stepping stones and corridors for animal movement, making them valuable resources in urban settings (Soanes et al., 2018). However, the design and distribution of green patches and trees in urbanized areas are still limited and their purposes vary across different urban gradients.

While many studies have identified driving factors behind urban wildlife patterns, inter- and transdisciplinary research focusing on this in cities remains scarce. Despite calls for transformative actions in urban green space research, existing socio-ecological frameworks for co-designing nature-based solutions and green infrastructures do not adequately address wildlife management. The current body of urban wildlife knowledge is often also limited to a few cities and common species, leaving substantial gaps in development practices. For example, there is limited research on how various biological components, such as trees, insects, birds, and mammals, interact in urban environments. Additionally, there are notable spatial and temporal gaps in our understanding of urban greening and the factors driving wildlife diversity in both developed and developing countries (Knapp et al., 2021; Sultana et al., 2023), hindering wildlife-inclusive urban planning globally.

Bridging this gap will require large-scale experiments conducted in cities from diverse regions. While this issue is gaining attention (Magle et al., 2012, 2019), progress is hindered by challenges related to data availability and current ecological knowledge regarding various terrestrial vertebrate groups (e.g., mammals) across large spatial scales and regions, which hinders the development of a unified understanding of how green infrastructure supports wildlife (Fidino et al., 2021; Knapp et al., 2021; Sultana, Corlatti, and Storch, 2023). Most studies have focused on well-known cities, such as Munich, or common species like the red fox (Vulpes vulpes) (König, 2008; Janko et al., 2012; Kimmig et al., 2020). To fill this gap, recent years have seen an increase in broad-scale, multi-city collaborations to enhance our understanding of animals and to promote wildlife-inclusive urban design. However, such initiatives are predominantly concentrated in North America (Magle et al., 2012, 2019; Magle and Fidino, 2018; Fidino et al., 2021, 2022). Comparable studies remain rare in other developed countries, such as Germany, where medium-sized cities may exhibit different urban configurations and designs that could influence urban wildlife differently. As a consequence, there is lack of consistent knowledge of how varying spatial design in built-up and green features is shaping overall wildlife diversity and generalist vs. specialist species across urban areas. More empirical assessments connecting multiple cities from Europe and North America, who are pioneer in green infrastructure practices, would significantly contribute with unified knowledge of required thresholds of different green features for wildlife management in urban areas.

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References

Di Pietro, S., Mantoni, C. and Fattorini, S. (2021) 'Influence of urbanization on the avian species-area relationship: insights from the breeding birds of Rome', Urban Ecosystems, 24(4), pp. 779–788. doi: 10.1007/s11252-020-01081-4

Fahrig, L. et al. (2022) 'Resolving the SLOSS dilemma for biodiversity conservation: a research agenda', Biological Reviews, 97(1), pp. 99–114. doi: 10.1111/brv.12792

Ferenc, M. et al. (2014) 'Are cities different? Patterns of species richness and beta diversity of urban bird communities and regional species assemblages in Europe', Global Ecology and Biogeography, 23(4), pp. 479–489. doi: 10.1111/GEB.12130.

Fidino, M. et al. (2021) 'Landscape-scale differences among cities alter common species' responses to urbanization', Ecological Applications, 31(2), pp. 1–12. doi: 10.1002/eap.2253.

Fidino, M. et al. (2022) 'Integrated species distribution models reveal spatiotemporal patterns of human-wildlife conflict', Ecological Applications. doi: 10.1002/eap.2647

Gallo, T. et al. (2019) 'Urbanization alters predator-avoidance behaviours', Journal of Animal Ecology, 88(5), pp. 793–803. doi: 10.1111/1365-2656.12967.

Janko, C. et al. (2012) 'Space use and resting site selection of red foxes (Vulpes vulpes) living near villages and small towns in Southern Germany', Acta Theriologica, 57(3), pp. 245–250. doi: 10.1007/s13364-012-0074-0.

Kimmig, S. E. et al. (2020) 'Beyond the landscape: Resistance modelling infers physical and behavioural gene flow barriers to a mobile carnivore across a metropolitan area', Molecular Ecology, 29(3), pp. 466–484. doi: 10.1111/MEC.15345

Knapp, S. et al. (2021) 'A Research Agenda for Urban Biodiversity in the Global Extinction Crisis', BioScience. Oxford University Press, pp. 268–279. doi: 10.1093/biosci/biaa141.

König, A. (2008) 'Fears, attitudes and opinions of suburban residents with regards to their urban foxes: A case study in the community of Grünwald - A suburb of Munich', European Journal of Wildlife Research, 54(1), pp. 101–109. doi: 10.1007/s10344-007-0117-z

Leveau, L. M. and Leveau, C. M. (2020) 'Street design in suburban areas and its impact on bird communities: Considering different diversity facets over the year', Urban Forestry and Urban Greening, 48. doi: 10.1016/J.UFUG.2019.126578

Leveau, L. M. et al. (2019) 'A global consistent positive effect of urban green area size on bird richness', Avian Research, 10(1), pp. 1–14. doi: 10.1186/S40657-019-0168-3/TABLES/3.

Luniak, M. (2004) 'Synurbization: Adaptation of animal wildlife to urban development', Proceedings 4th International Urban Wildlife Symposium, pp. 50–55

Magle, S. B. and Fidino, M. (2018) 'Long-term declines of a highly interactive urban species', Biodiversity and Conservation, 27(14), pp. 3693–3706. doi: 10.1007/s10531-018-1621-z.

Magle, S. B. et al. (2012) 'Urban wildlife research: Past, present, and future', Biological Conservation, 155, pp. 23–32. doi: 10.1016/j.biocon.2012.06.018

Moura, C. W., Clucas, B. and Furnas, B. J. (2022) 'Humans Are More Influential Than Coyotes on Mammalian Mesopredator Spatiotemporal Activity Across an Urban Gradient', Frontiers in Ecology and Evolution, 10(June), pp. 1–18. doi: 10.3389/fevo.2022.867188.

Peerenboom, G. et al. (2020) Wildtiermanagement im Siedlungsraum Siedlungsraum – Ein Handbuch für Kreise und Kommunen in Baden-Württemberg.

Rodewald, A. D. and Gehrt, S. D. (2014) 'Wildlife Population Dynamics in Urban Landscape', in Urban Wildlife Conservation: Theory and Practice, pp. 117–147. doi: 10.1007/978-1-4899-7500-3.

Strohbach, M. W., Haase, D. and Kabisch, N. (2009) 'Birds and the city: Urban biodiversity, land use, and socioeconomics', Ecology and Society, 14(2). doi: 10.5751/ES-03141-140231

Sultana, M. et al. (2022) 'Neighboring Green Network and Landscape Metrics Explain Biodiversity within Small Urban Green Areas—A Case Study on Birds', Sustainability, 14(11), p. 6394. doi: 10.3390/su14116394

Sultana, M., Corlatti, L. and Storch, I. (2021) 'The interaction of imperviousness and habitat heterogeneity drives bird richness patterns in south Asian cities', Urban Ecosystems, 24(2), pp. 335–344. doi: 10.1007/S11252-020-01037-8/FIGURES/2

Sultana, M., Corlatti, L. and Storch, I. (2023) 'Are the same factors determining biodiversity in cities across different regions? Comparing drivers of urban bird richness patterns in Southern Asia vs. Western Europe', Urban Ecosystems 2023, pp. 1–13. doi: 10.1007/S11252-023-01404-1

Taucher, A. L. et al. (2020) 'Decline in distribution and abundance: urban hedgehogs under pressure', Animals, 10(9), pp. 1–22. doi: 10.3390/ani10091606.

Ziege, M. et al. (2020) 'population genetics of the european rabbit along a rural-to-urban gradient', Scientific Reports, 10(2448), p. 12. doi: 10.1038/s41598-020-57962-3.

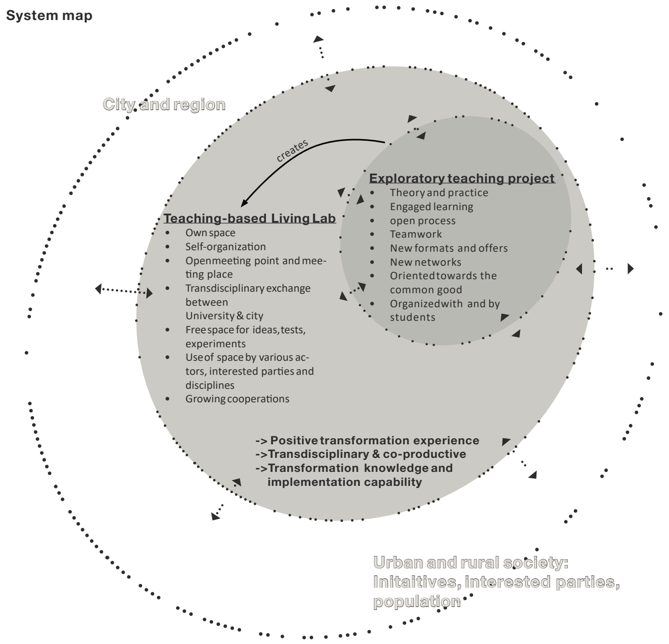
7 Poster Exhibition

From Exploratory Teaching Projects to Urban Living Labs

Bottom-up Research Spaces for a New Public-Civic Collaboration

Karlsruher Institut für Technologie

System map



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Excerpts from in:takt: in:takt on the Breite Weg, senior academy, silent disco, summer party with food rescuers (© in:takt team, 2021-25)

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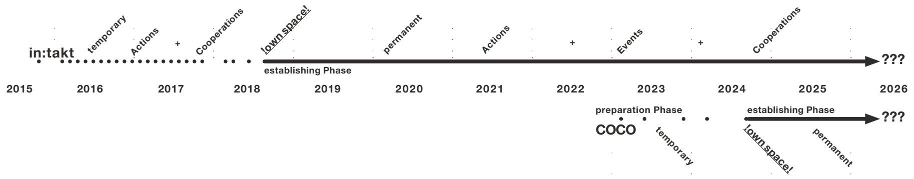
Excerpts from COCO winter semester 2024-25: Repair Café, opening of the "Open Passage", research workshop "Mobile in old age",
(© Moritz Franke, Ralf Schuster, Melina Ehrenteit, 2024-25)

Timeline



Hendrik Weiner
Brandenburgische Technische Universität Cottbus-Senftenberg

Keywords
Urban Living Lab, Transdisciplinarity, Co-Design, Co-Production, Third Mission, Co-Education

Abstract
Exploratory teaching projects, expanded to include „engaged learning" (Chmelka et al. 2023) and „live projects" (Harriss et al. 2014), bring the academic sphere into the urban space. They work exploratively, facing open problems, multiple actors, shifting contexts, and sudden change. To this end, they use the participatory design and action research approach (cf. Telier et al. 2011, Chevalier et al. 2013). This turns them into teaching and research projects and offers the opportunity to establish interdisciplinary and transdisciplinary working methods and co-design processes. In open living labs, they create a new urban practice on the cross-cutting issues of urban development, sustainability and democracy. Based on the preliminary work and developments of the city lab "COCO_CommonigCottbus" in Cottbus and "in:takt – Free space for all" in Magdeburg, the framework conditions, processes, opportunities for urban society and challenges for those involved will be presented and discussed.

Living Lab in progress
These living labs were initiated from teaching and are still being developed. They provide low-threshold, non-commercial access for encounters and create a new type of space for engagement, local project work, and mutual knowledge exchange. Its open, networked project structure creates opportunities for transdisciplinary collaboration and co-design processes. Students meet city residents here, and specific activities and formats are developed and tested. Collaborations are developed here, and people work together spontaneously. These interactions create a training space for dealing with diversity, openness, and change, as well as a space for collaborative research on current, open issues. Through teamwork, responsibility is distributed across many shoulders, and students are the protagonists. Thanks to their strong roots in the city and open mindset, these labs address the interdisciplinary themes of urban development, city-making, sustainability, resilience, democracy, and the common good, surpassing disciplinary approaches. The projects ultimately aim to establish a culture of collaborative cooperation and co-creation, forming a basis for the co-production of the city. Designed as open infrastructure, they aim to have a broad impact on urban society.
To achieve this, teaching-based living labs require stable support structures and strengthened resources for organization, networking, and project work. Initially started out of the university, they have not yet received financial support from the local authority or the space owners. Currently, the diverse aspects and tasks, ranging from operation and coordination to content-related work and strategic development, can only be addressed in a rudimentary and selective manner.

Conclusion
To strengthen and further develop the approach of a bottom-up teaching and research space, stronger cooperation is necessary between the university, civil society initiatives, and the public sector. Through a strategic public-civic partnership, an innovative, open, and community-oriented infrastructure could be created. This infrastructure would serve as an urban living lab for co-education, cooperation, community,and dealing with complex social issues and development processes.

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MOBILITY AND URBAN SPACE

KIT 200 JAHRE

How to Work with the Index for Inclusion in Real-World-Laboratories

A Guide to Promoting and Reviewing Inclusive Values in Real-World Laboratories

technische universität dortmund
sbp
UmBau Labor
BAU KULT UR NORDRHEIN WESTFALEN

RESEARCH QUESTIONS

1. how can the IfIRL be applied to remodelling processes?
2. how inclusive is the UmBauLabor designed? What barriers exist?
3.What impact do inclusive structures have on transformation processes?

THEORETICAL FRAME

SDGs: „Leave No One Behind" → Meaningful Participation in all Projects → Reallabor quality criteria + Code of Ethics → How to Operationalise? → Index for Inclusion from the educational sciences. → Validation through customisation, application, evaluation & impact research

CASE STUDY. UmBauLabor Gelsenkirchen

PROJECT KEY DATA
Duration: 2023-2026
Location: Gelsenkirchen-Uckendorf
Building: Residential/commercial building (1902)
Responsible organisation: Baukultur NRW

fig1: Photo: Sebastian Becker

GOALS AND FOCUS AREAS

1) Circular Economy and Resource Efficiency: Materials and building life cycles are analyzed for their reusability and circularity.Deconstruction and reconstruction processes are documented and evaluated to promote sustainable construction practices.
2) Participation and Inclusion: Citizens, local stakeholders, and experts are actively involved in planning and implementation.The goal is to ensure meaningful participation, where all participants are recognized as equal contributors.
3) Learning and Rethinking Processes: The project serves as a platform for knowledge exchange and co-creation. It aims to raise awareness of the need for a construction transition integrating ecological, economic, and social dimensions.

PROCESS

The participation process in the UmBauLabor connects stakeholders, formats, and building phases. It highlights the iterative nature of collaboration, from material analysis and deconstruction to co-creation and community engagement, ensuring inclusive and transparent decision-making. The work with the Index aligns with this process, providing a framework to evaluate and adapt throughout.

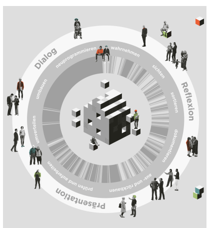


fig 2: Project graphic 'UmBauLabor'. Design: DESERVE

fig 3: Photo: Sebastian Becker

current PARTIZIPATIVE FORMATS
- Summer School (Sept. 2025)
- Student Research Projects
- Thursday openings
- Feedback cafés with neighbours
- Collaborative Material Workshops
- Exhibitions and Guided Tours
- „Im Diskurs" Professional Exchange
- Expert Gremium

THE INDEX FOR INCLUSION. Based on a set of inclusive values

The underlying values of the Index focus on inclusivity, equality, and participation, aiming to create environments where everyone feels valued and involved. These values guide the development of cultures, structures, and practices that reduce barriers, foster collaboration, and ensure that diverse perspectives contribute to meaningful and sustainable outcomes.

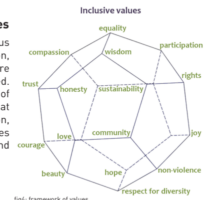
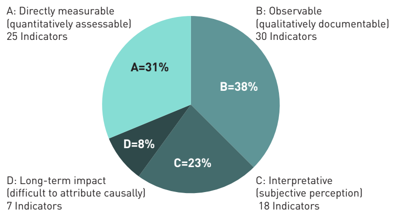


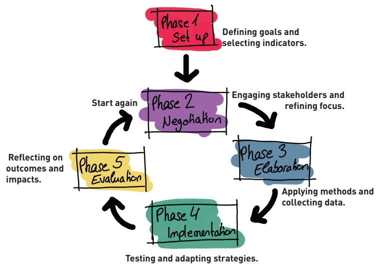
fig4: framework of values

METHOD MIX. 80 Indicators for a Comprehensive Triangulation Approach



A: DIRECTLY MEASURABLE: Quantitative data that can be systematically and objectively measured.
Methods: Document analysis: Reviewing reports, protocols, and written records.
Count variables: Measuring frequencies, participant numbers, or resource usage.
Approach: Data collection follows clear criteria.Can be complemented by active observation for validation.
B: OBSERVABLE: Qualitative data from observed processes and interactions
Methods: Participant observation: Actively observing activities and interactions.
Video analysis: Recording and analyzing processes to capture details.
Approach: Action Research; Observations are regularly reflected upon to minimize bias. Observations follow a structured guide for comparability.
C: NTERPRETATIVE: Subjective data shaped by participants' perspectives and experiences.
Methods:Interviews, Focus groups to understand collective opinions and dynamics.
Photovoice: Participants take photos and explain their significance.
Approach: Data collection is structured to cover relevant topics. Participants are actively involved in data collection. Results are reflected upon with participants.
D: LONG-TERM IMPACT: Data capturing long-term changes and impacts.
Methods: Follow-up: Tracking participants or projects to document long-term developments. Network analysis: Analyzing relationships and interactions to understand systemic changes.
Approach: Results are contextualized within the original goals. Analysis is conducted collaboratively with participants. Data collection is structured for comparability.

PROCESS INTEGRATION:



PHASE 1 . set up Defining goals and selecting indicators.

In the Setup Phase, the focus is on creating a strong foundation for inclusive collaboration. The three selected indicators A.1.5 (diversity of society), A.1.6 (diversity of identities and expertises), and A.2.3 (reflection of power relations) are a valid entry point in the work with the Index. They help participants explore the representation of diversity, the inclusion of various perspectives, and the dynamics of power within the RwL. This step sets the stage for identifying additional criteria and aligning the process with shared values.

PICK & CHOOSE WORKSHOP

1) Wheel of Power, based on Karen Crenshaw's work on intersectionality and power dynamics, is a tool to explore the first three indicators: A.1.5 (diversity of society), A.1.6 (diversity of identities and expertises), and A.2.3 (reflection of power relations). It visualizes power imbalances, highlights gaps in representation, and connects these insights to the indicators. The purpose is to reflect the own role in the process and identify barriers to inclusion, foster shared understanding, and co-develop strategies for equitable participation. It can be also used for mapping key actors on the Wheel to figure out their influence or power.

How to Use the Wheel in the workshop:
1)Mapping: Participants map theirselves based on their identity.
2)Reflection: Discuss imbalances, gaps, and their impact on collaboration.
3) Review the 80 indicators, focus on some indicators and deepen your understanding of their relevance for you and your project team
4)Connection: Link findings of part 1) to the indicators to address barriers and plan actions.
NOTE: Completing and reflecting on the wheel is not about comparison or competition but about self-reflection. Privileges are often blind spots and require thoughtful consideration of one's own position.

THE WHEEL OF POWER AND PRIVILEGE

The wheel's dimensions include descriptors and labels that may be considered too sensitive to discuss openly in certain settings. However, failing to be open about such labels amounts to ignoring real dimensions of inequality that exist in our society.

Scan the QR code in the center to anonymously fill out the Wheel yourself! Results will be shared at the end.

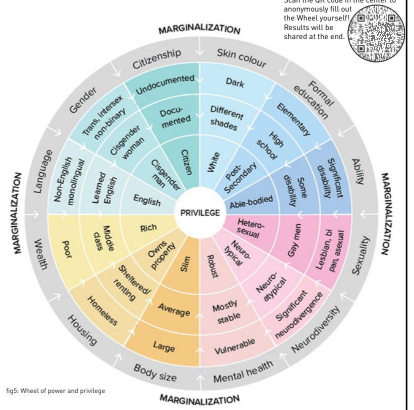


fig5: Wheel of power and privilege

WHICH INDICATORS WOULD YOU CHOOSE?

A.2.7 – Inclusion is regarded as an opportunity to develop the potential of all members
B.1.3 – The RwL organizes participation formats in a way that reflects diversity
C.1.8 – The RwL contributes to the empowerment of all participants

Scan the QR code to explore the Index for Inclusion in Real-World Laboratories (IfIR), including German version, and leave your feedback on the interactive Miro board!

A Participatory Approach to Operationalizing Inclusive Values

The Index for Inclusion in Real-World Laboratories (IfIR) reflects key principles that are also central to the Ethics Code for Sustainability Living Labs (2024, unpublished) and builds on the inclusive didactics of Booth and Ainscow (2016). These principles emphasize reflexivity, equity, and empowerment in participatory processes, which are essential for fostering meaningful participation. The IfIR provides a structured framework to operationalize inclusive values through measurable indicators, enabling researchers and practitioners to evaluate and promote inclusivity in diverse contexts. This approach resonates with findings by Schäpke et al. (2018), who highlight the importance of reflexivity and co-creation in real-world laboratories to achieve transformative societal impact.

The IfIR aligns with recent findings by Epp et al. (2025), who emphasize the need for scaling inclusivity in living labs to achieve broader societal impact. By addressing „scaling out" (engaging diverse stakeholders), „scaling deep" (embedding inclusive values), and „scaling up" (influencing policy), the IfIR is meant to bridge the gap between ethical principles and actionable strategies.

Practical Relevance:
The IfIRL not only provides a systematic approach to evaluating inclusivity but also supports the selection of tailored methods for different contexts. For example, in the UmBauLabor, direct measurability is being used to assess demographic diversity, while interpretability captures the subjective experiences of participants. This comprehensive framework is currently being applied in the UmBauLabor project in Gelsenkirchen, focusing on circular economy and sustainable building practices. The project is in the process of engaging diverse stakeholders to demonstrate how inclusive participation fosters innovative solutions and strengthens community ownership. This flexibility ensures that the Index can be adapted to the unique needs of various RwLs, making it a valuable tool for fostering equitable and impactful societal transformation.

References
Booth, T., & Ainscow, M. (2016). Index for Inclusion: A Guide to School Development Led by Inclusive Values. Index for Inclusion Network Limited.
Baukultur Nordrhein-Westfalen e. V. (2023). UmBauLabor: Circular economy and resource efficiency in construction. https://baukultur.nrw [accessed 18.07.2025]
Epp, J., Demir, M. H., Liste, L., Nilsen, B. T., Sahakian, M., Zhan, M., Walter, C., & Biresselioglu, M. E. (2025). Scaling the impact of the energy transition through inclusivity and diversity across living labs. Sustainability: Science, Practice and Policy, 21(1), 2527474. https://doi.org/10.1080/15487733.2025.2527474
Hillerbrand, R., Parodi, O., Dusseldorp, M., & Does, E. (2024). Ethical guidelines for real-world laboratories: A framework for responsible research and practice. Sustainability Science, 19(1), 12–25.
Dusseldorp, M., Hillerbrand, R., Parodi, O., & Does, E. (2025] Ethikkodex für Reallabore der Nachhaltigkeit- finaler Entwurf. https://www.reallabor-netzwerk.de/downloads/ethikkodex_reallabore-der-nachhaltigkeit.pdf [accessed 18.07.2025]
Rocha Menocal, A. (2020). Why does inclusion matter? Assessing the links between inclusive processes and inclusive outcomes. OECD Development Co-operation Working Papers, 71.
Schäpke, N., Stelzer, F., Caniglia, G., Bergmann, M., Wanner, M., Singer-Brodowski, M., et al. (2018). Jointly experimenting for transformation? Shaping real-world laboratories by comparing them. Sustainability Science, 13(1), 187–204.
UNSDG. (2019). Human rights-based approach to sustainable development: Leave no one behind. Retrieved from https://unsdg.un.org
fig.1-3: UmBauLabor. Source: Baukultur Nordrhein-Westfalen e.V., 2023, https://baukultur.nrw/fokus/umbaulabor/ (accessed 18.07.2025).
fig 4: Framework of Values. Source: Booth, T., & Ainscow, M. (2016). Index for Inclusion: A guide to school development led by inclusive values (4th ed., p. 11). Index for Inclusion Network.
fig.5: Wheel of Power and Privilege. Source: Alberta Teachers' Association. (n.d.). Dimensions of power and privilege. https://teachers.ab.ca/news/dimensions-power-and-privilege [accessed 05.07.2025]

The content is based on the author's own scientific work and was translated and summarized with the assistance of an AI-powered model (GPT technology), then critically reviewed and revised.

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Bridging nature and data for transformative futures

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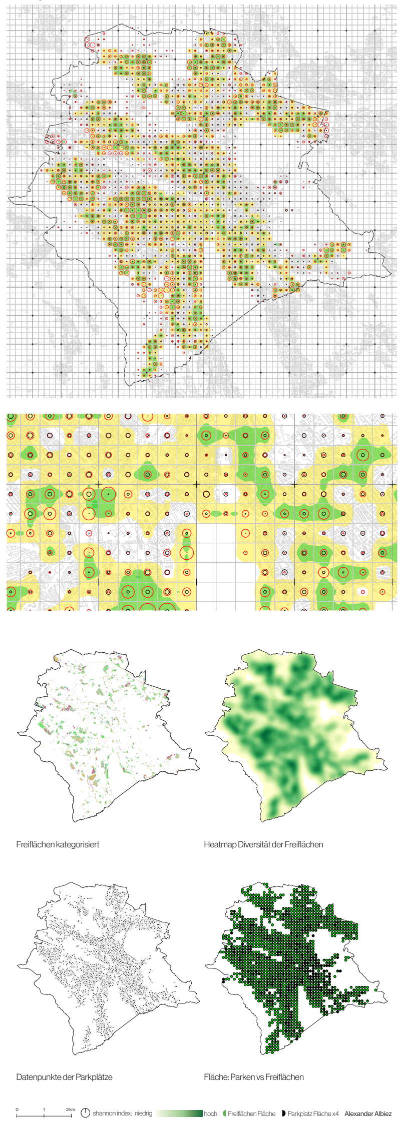
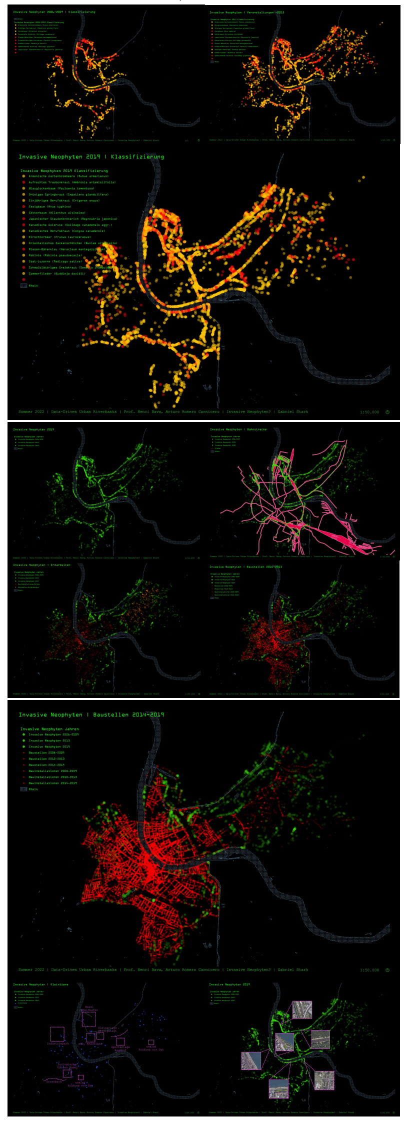
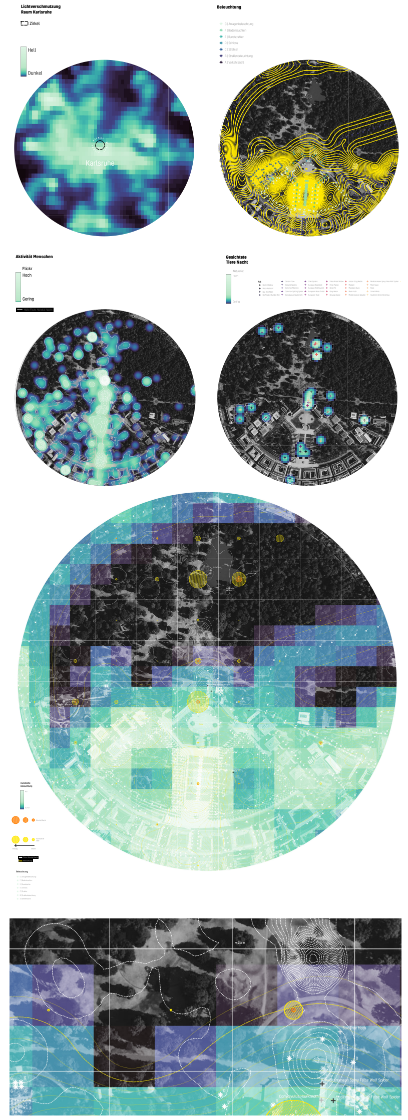
Diversity of the urban commons in Zürich. Alex Albiez, Arturo Romero Carnicero



Invasiven oder Einwanderer? Gabriel Stark, Arturo Romero Carnicero



Ecosystems of night and light pollution. Sebastan Dremel, Elena Heilig, Arturo Romero Carnicero



Urban transformation today demands more than improved infrastructure or smarter cities. It calls for radically new ways of imagining the relationship between urban environments and ecological systems. This presentation emerges from a broader research initiative investigating how speculative narratives, grounded in computational mapping and urban nature data, can serve as transformative tools in the design process—particularly in middle-sized European cities of approximately 100,000 to 500,000 inhabitants.

These cities often offer fertile ground for ecological innovation, yet they are underrepresented in planning research. The work we present today explores how Geographic Information Systems (GIS) and open geospatial datasets can move beyond their conventional role of technical analysis to become generative engines for speculative urban design.

This approach is based on the concept of "naturecultures"—the idea that nature, technology, and society are entangled in dynamic, co-constructed relationships. The methodology explored here fosters this entanglement through a hybrid of data-driven design, posthuman ecological theory, and speculative thinking. By integrating digital tools and ecological imagination, we aim not to predict urban futures, but to provoke, interrogate, and shape them. Within this framework, we present three case studies developed in the GIS-based design laboratory at KIT's Department of Architecture. Each uses data to construct speculative futures challenging normative urban paradigms, inviting multi-species perspectives.

Diversity of the Commons. This study rethinks the concept of urban commons through biodiversity indices such as the Shannon Index. By mapping species diversity across public spaces in Zürich, students visualized the ecological value of these shared spaces—revealing invisible layers of biodiversity embedded in daily urban life.

The speculative proposal imagines multispecies commons councils where human and non-human needs are negotiated. Design interventions include bee habitats, amphibian corridors, and soil restoration micro-sites. Here, commons are not only social assets, but ecological governance platforms where interspecies relationships are materially supported.

Invasiven oder Einwanderer? This project challenges the framing of non-native species as inherently harmful. Using long-term neophyte distribution data in Basel, students mapped the presence and movement of invasive plants and animals alongside human urbanization trends.

The speculative scenario reframes these species as ecological migrants—potential contributors to urban resilience under changing climatic conditions. Rather than eradicating them, the design proposes spaces of cohabitation and functional integration, where these species support degraded soils, biodiversity corridors, or urban food webs.

Ecosystems of Night and Light Pollution. This case study explores how artificial light affects nocturnal species and ecosystems in urban settings. By combining satellite data on light emissions with biodiversity observations, students identified critical overlaps between high light zones and ecological corridors in Karlsruhe's Zirkel district.

The resulting speculative scenario proposes a network of "urban night corridors"—deliberately darkened routes designed to preserve ecological functions of the night. These corridors allow for bat migration, insect pollination, and bird rest stops, while offering humans renewed encounters with the night sky. Rather than treating light as a neutral default, this project repositions darkness as an ecological infrastructure.

Conclusion. These three cases reflect a larger ambition: to transform how designers see, interpret, and act with data. In reframing GIS not as a neutral analytic tool, but as a speculative medium, we can open up plural, ecologically literate futures. This work does not propose a fixed method, but a new posture of practice—one where designers become mediators between data, ecology, and imagination, crafting narratives that push us beyond the probable and into the possible.

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URBAN.KIT Urban Transformation - Connecting Urban Sustainability Labs

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KIT 200 JAHRE

Strategies to Scale Real-World Labs for Regional Transformation

transformR

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Federal Ministry of Research, Technology and Space

Co-design process with regional actors

Kick-off Meeting
October 2023
- Gathering of interested actors
- Development of Real-World Lab Ideas

Elaboration Phase I
Development of ideas in thematic groups:
- How can the ideas be put into practice?
- Which stakeholders still need to be involved?

Consolidation Meeting
December 2023
- Presentation of elaborated ideas
- Collegial consultation
- Outline and planning of further work

Elaboration Phase II
- How will the project be successful?
- How can success be measured?
- When must which step be taken?

Concretization Meeting
January 2024
- Presentation of elaborated ideas
- Collegial consultation
- Detailed planning of Real-World Lab implementation

Real-World Labs in the Transform-R project

Cycling Street
Developing an intermunicipal cycling street as a new planning and governance approach.

Neighbourhoods of mobility transition
Redistribution of street space with involvement of residents and businesses to strengthen livability and socially equitable urban neighborhoods.

Photovoltaics and electromobility
Supporting municipalities in implementing PV projects in conjunction with mobility infrastructure, focussing on parking lots.

Sustainable mobility to tourist destinations
Travel to and from tourist destinations in the region is heavily dependent on cars. Aim is to explore ways of making leisure trips more sustainable through alternatives to the private car.

Commuting differently
Changing commuter mobility through a commuting experiment and developing a permanently available regional service for municipalities and districts.

Transfer strategies to scale Real-World Labs

Regional steering circles
Regional steering circles bring together the various actors collaborating on the respective real-world lab to develop and manage project activities in a participatory process, facilitating knowledge transfer.

Empowering an actor for continuation and multiplication
Aims at establishing an actor on the regional level, who continues and scales the activities undertaken during the real-world lab, e.g. organizing commuting experiments, support for planning of parking lot solar panels.

Involving and convincing political actors
Involving political actors at local and/or regional level and presenting the measures, their objectives and relevance helps local actors to gain political support for the implementation of the measures.

Fostering practice dialogue
Entails the communication and dissemination efforts of the real-world lab topics into practice through informing on the progress of the labs in governance bodies on a regional level, written materials (e.g. brochures) and stakeholder workshops on a national level.

Capacity building for practitioners
Centered on the provision of competencies and expertise to relevant practitioners within the region and beyond. Informative events and workshops are held, especially on measures that are not yet widespread and about which there is little practical knowledge, enabling implementation.

Developing measures from a user´s perspective
Aim is to translate the results of the real-world labs into mobility transition measures. The measures are developed based on the user's perspective in a wider circle of existing real-word lab partners, but also other relevant actors and practitioners. In this way, measures meet the needs of the users and create acceptance.

Fostering public dialogue
Includes all forms of public dialogue on the topic of the real-world lab reaching from conventional public relations, social media activities to public events and other forms of science communication. This is important to inform the public about the projects and raise awareness for the respective issues.

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KIT 200 JAHRE

Test Area Autonomous Driving Baden-Württemberg - Real World Laboratory for Connected and Automated Driving

Albert Schotschneider[1], Tobias Fleck[1], Melih Yazgan[1], Rupert Polley[1], Julian Burger[1], Kevin Simon[2], Sven Ochs[1], Stefan Orf[1], Maximilian Zipfl[1], Marc René Zofka[1], Michael Frey[2], J. Marius Zöllner[1,2]
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[2] Karlsruhe Institute of Technology (KIT)

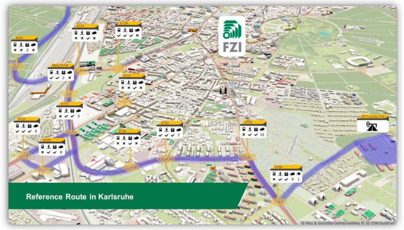
Abstract and Motivation

The Test Area Autonomous Driving Baden-Württemberg (TAF-BW) provides a real-world environment for the development and validation of new mobility concepts, especially autonomous and connected driving. TAF-BW is located in Karlsruhe and Heilbronn and covers a wide range of **public roads**, including motorways, urban roads with mixed traffic, residential areas with parking lots, and private traffic areas. Smart, interconnected road segments and traffic intersections that are equipped with **environment perception sensors and/or Vehicle-2-X (V2X) communication systems**, combined with a stationary control center and a mobile control center enable large-scale tests of next-generation mobility systems. Moreover, the TAF-BW acts as a **collaborative hub** that unites research institutions, manufacturers, and policymakers to catalyze the development of robust and interoperable systems.

TESTFELD AUTONOMES FAHREN BADEN-WÜRTTEMBERG

Test Areas – Karlsruhe Ostring

The Ostring is a four-lane street in Karlsruhe that connects the northern and southern parts of the city's eastern quarter. It **intersects with several major commuter roads and serves as the primary route** around eastern Karlsruhe, often experiencing heavy congestion. The testing area encompasses intelligent, connected, and contiguous intersections along and near the Ostring. The Ostring intersections are **characterized by heavy traffic and complex interactions between cars, trucks, pedestrians, trams, and cyclists.** Traffic signals and lane configurations are communicated through V2X, while integrated perception algorithms detect, track, and broadcast objects.

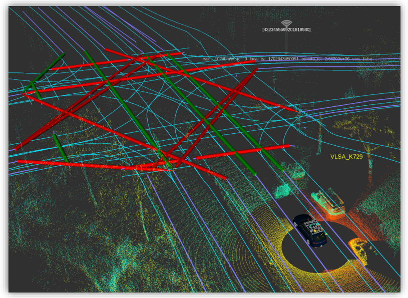


Test Areas – KIT Campus East

The KIT Campus East is a restricted area isolated from public traffic. Its road-like layout makes it **ideal for testing autonomous vehicles**, with simplified test drive requirements. As a restricted zone, it requires less complex data security declarations compared to public spaces. The campus features a central open area and a test intersection **equipped with traffic lights, V2X communication units, and LIDAR sensors.** This setup enables precise detection and tracking of vehicles and pedestrians during test scenarios. The traffic light phases can be directly controlled through an interface box.

Infrastructure – On-Site Perception

Reference camera sensors all over the test area **provide object list data including position, orientation, size, type and velocity estimates** of each object in the test area that passes the field of views of the perception system. Due to the high mounting positions on roadside steel poles, the stationary sensors of the test area provide a **nearly top-down view of the traffic scene** and the object data is less prone to occlusion for ground vehicles.



Infrastructure – V2X Communication

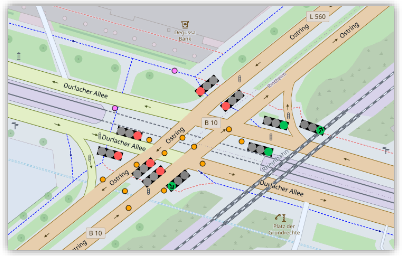
Most intersections in the TAF-BW are equipped with modern V2X hardware. Through V2X, **information exchange between vehicles and the intelligent infrastructure is possible**. Following the European Telecommunications Standards Institute (ETSI) standard, the V2X devices use the WLAN IEEE 802.11p/ITS-G5 standard and broadcast standardized V2X messages:

Cooperative Awareness Messages (CAM) enable Roadside Units (RSU) and vehicles to broadcast their presence, current speed, heading, and vehicle dimensions. Additional information, such as vehicle class can also be transmitted via CAMs.

Collective Perception Messages (CPM) enable vehicles and the infrastructure to share their perceived objects.

Map Data (MAPEM) provides a topological definition of all lanes in an intersection or road segment. These lanes are linked and classified to offer an accurate understanding of the road layout.

Signal Phase and Timing messages (SPATEM) allow the infrastructure to communicate traffic light phases and timing for specific lanes and maneuvers. This enables autonomous vehicles to navigate safely even without direct traffic light perception.



Control Center – Stationary Control Center

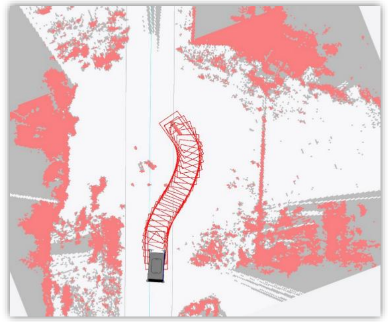
The TAF-BW control center at the FZI Research Center for Information Technology **monitors real-time data from the connected smart intersections** and vehicles. Intersection data, including CAMs, SPAT, and sensor diagnostics, is processed by the TAF-BW backend and is accessible via a web interface. Its modular design includes a data processing pipeline with sensor analysis and alert triggers. For smart vehicles (e.g. FZI Shuttles), the system **visualizes their diagnostics**. This comprehensive monitoring supports **remote issue identification and resolution**, paving the way for telesupervision and remote operation.

Control Center – Mobile Control Center

A mobile control center, based on a modified Mercedes-Benz Sprinter, complements the stationary control center. The vehicle serves two purposes: **recording environmental data during test drives and monitoring test vehicles from stationary positions**. The vehicle's sensor suite includes six LiDARs, two front cameras, and a roof-mounted pan-tilt unit compatible with a thermal camera. Positioning relies on high-precision GNSS with Dual-GPS and INS. The system includes WiFi/4G connectivity, with 5G pending. For data compliance, **camera footage is automatically anonymized**. The vehicle includes V2X communication capabilities and interfaces with traffic systems. Data processing occurs on a dual-GPU server, enabling both storage and machine learning applications. All interior equipment is rack-mounted for safety and accessibility.

Telesupervision and Remote Operation

Remote operation is possible from within the control center at the FZI, where vehicle data is transmitted via a 5G connection. In case of errors, ambiguous scenarios, or situations with low confidence, a **remote operator can support the vehicle by providing a waypoint** to ensure safe navigation. Over time, the control center can learn from such human interventions and **suggest waypoints automatically**, which would then only need to be approved by the remote operator.



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KIT 200 JAHRE

Towards an evaluation framework for action knowledge

Operationalizing footprint and handprint climate action within the climate action education project #climatechallenge

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Karlsruhe Transformation Center for Sustainability and Cultural Change (KAT)

Intro: The climate crisis calls for a socio-technical transformation marked by complexity and uncertainty. Participatory Technology Assessment (PTA) empowers change agents by providing action-oriented knowledge, reflecting its normative stance. This poster presents an evaluation framework for such knowledge, covering climate awareness, emotions, perceived action options, and individual and collective experiences. It is applied in the project *#climatechallenge*, which includes two action-oriented transformation experiments: the footprint and handprint challenges, where participants explore climate-friendly lifestyles and civic engagement.

Methods: The framework builds on previous educational practices with the climate action education workshop format *#climatechallenge* (Szaguhn et al. 2021), a handprint evaluation working group (also see: Heitfeld & Reif 2020), and experiences in ESD evaluation at KAT. An exploratory literature review (Gouch & Thomas 2012) identified relevant publications and scales through screening, sampling, analysis, and synthesis.

Results: framework consists of seven clusters structuring the questionnaires, for evaluating activities in *#climatechallenge* at different points of time.

Cluster	Description of the data collected	Survey point
(1) General information and socio-economic status	Allows the description of the sample	1
(2) Climate awareness	Quantitative data on climate and environmental awareness / consciousness	1, 2, 3
(3) Perceived options for action	Qualitative data, participants consider as possible actions in regard of climate friendly behavior (footprint and handprint related)	1, 2, 3
(4) Climate emotions	Quantitative data to assess climate related emotions (self-efficacy, climate anxiety, etc.)	1, 2,3
(5) General climate related behavior	Quantitative data to assess the everyday climate related behavior (footprint and handprint) of the participants in general, apart from the #climatechallenge	1, 2, 3
(6) Actual CO_2 emission savings and experiences within the footprint challenge	Qualitative data on the individual experiences of the participants; Quantitative data that can be used as a basis for estimating the CO_2 emissions saved	2
(7) Actual CO_2 emission savings and behavior in the handprint challenge	Qualitative data on the experiences the participants made in collective group work; Quantitative data that can be used as a basis for estimating the CO_2 emissions saved	3

Application into practice: The framework is implemented in a nationwide climate education project (2023–2025), see: www.climatechallenge.de. Data is collected at three time points in workshop series led by trained multipliers across four target groups, supporting project monitoring (see Fig. 1 and 2).

Fig. 1: Project partners and multipliers in different target groups of the #climatechallenge

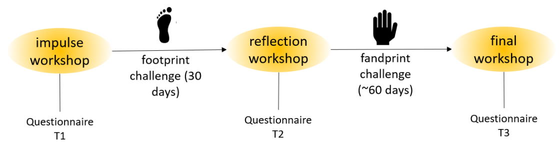
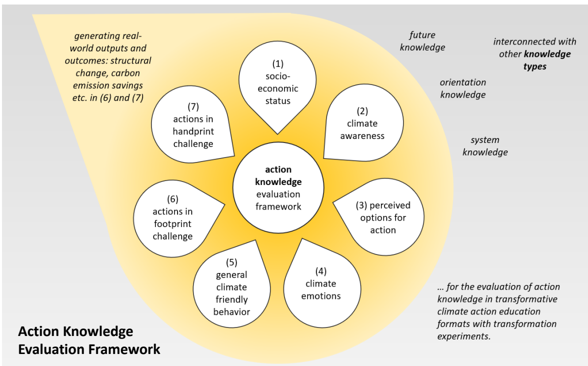


Fig. 2: Workshop series structure within a #climatechallenge

Discussion and Conclusion: The framework helps to operationalize climate action via footprint and handprint approaches. It thereby sheds a light on personal sustainability and also inner transformation processes, that provide orientation for future change agents within the socio-technical transformation, but without neglecting the need to evaluate real-world activities that drive structural change and a deep decarbonization.



Literature
Gouch, D., Oliver, S., & Thomas, J. (2012). An Introduction to Systematics Reviews. City Road, London: Sage Publications, 33(2), 216-221.
Heitfeld, M., & Reif, A. (2020). Transformation gestalten lernen: Mit Bildung und transformativem Engagement gesellschaftliche Strukturen verändern (S. 60) [Hintergrundpapier]. Germanwatch e.V. URL: www.germanwatch.org/de/19607
Parodi, O., Ober, S., Lang, D. J., & Albiez, M. (2024). Reallabor versus Realexperiment: Was macht den Unterschied? GAIA-Ecological Perspectives for Science and Society.
Szaguhn, M. (2025). Fußabdruck und Handabdruck: Soziale Praktiken für individuellen und kollektiven Klimaschutz als Beitrag zum SGD13. In: Leal Filho, W. (eds) SDG13 Climate Action: Prinzipien und Praxis vereinen. SDG - Forschung, Konzepte, Lösungsansätze zur Nachhaltigkeit. Springer Berlin, Heidelberg.
Szaguhn, M., Fricke, A., Wendeberg, E. (2025, in press). Towards an evaluation framework for action knowledge: Operationalizing footprint and handprint climate action within the participatory technology assessment project #climatechallenge. Karlsruhe: KIT Scientific Publishing.
Szaguhn, M., Sippel, M., & Wöhler, T. (2021). Mit #climatechallenge zu mehr CSR? Ein innovatives Lernformat für Verantwortungsübernahme in der großen Transformation. CSR und Hochschullehre: Transdisziplinäre und innovative Konzepte und Fallbeispiele, 237-251.
Trenks, H., Baumgärtner, V., Beecroft, R., Fricke, A., Meyer-Soylu, S. Selbstexperiment Nachhaltigkeit – eine Methode transformativer Bildung in: Defila, R., & Di Giulio, A. (Hrsg.) (2025). Transdisziplinär und transformativ forschen, Band 3. Eine Methodensammlung. Wiesbaden: Springer VS
WBGU (Hrsg.). (2011). Welt im Wandel: Gesellschaftsvertrag für eine Große Transformation; [Hauptgutachten] (2., Aufl). Wiss. Beirat der Bundesregierung Globale Umweltveränderungen (WBGU).

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Using Image-Based Social Media Content to Analyse Public Space Perception in Karlsruhe and Glasgow

Ali Khani, Karlsruhe Institute of Technology
Saman Yazdani, University of Strathclyde, Glasgow

Social Media data and Urban Design

Cities are undergoing rapid transformation, making it vital to understand how citizens perceive public spaces. Traditional tools such as surveys and ethnography are essential, but digital image-based data remain underexplored. Social media platforms like Flickr provide insight into user interactions, perceptions, and emotional connections to the urban environment. This research examines how visual data can foster more sustainable, inclusive, and care-full cities.

Research questions

How can data from social media be used to evaluate public spaces?
What kind of data could be useful for evaluation?
What kind of public places could be studied?
What are the possible approaches? Which one could be more fruitful?
On which level the data are useful?

Karlsruhe (Germany)
Kaiserstraße — historic pedestrian axis.

Glasgow (Scotland)
Buchanan Street — major cultural and shopping corridor.

Both are **pedestrianized streets**, connecting key attractions and drawing strong social media attention.
Study period: 2023, post-lockdown rise in online engagement

Photo Selection Process
Images sourced from public Flickr uploads (2023).
Excluded truth-indifferent content (cf. Frankfurt): images indifferent to meaning, created without concern for truth or civic identity.
Prioritized photos that contribute to understanding:
Architecture, Public squares, Festivals & events, Civic gatherings
Ensured thematic alignment across Karlsruhe and Glasgow:
Civic formality, Entertainment & festivity, Quiet domesticity, Public celebration
By filtering out empty imagery, the study focuses on photos that reflect citizens' real perceptions and cultural atmosphere.

Philosopher Harry Frankfurt describes a type of communication unconcerned with whether it is true or false — aimed only at producing an effect. This study avoids such **truth-indifferent imagery**, selecting photos that meaningfully represent civic life and urban identity.

Methodology
Mixed-Methods Approach
Qualitative visual analysis: Identified recurring themes (colors, cultural associations).
Example: blue & green → nature; grey → built environment.
Quantitative metrics: Posting frequency by season/day.
Measured success, engagement, and predictability of spaces.
Guided by a literature-based framework in urban and visual culture studies.
Limitation: single platform (Flickr) → partial view of public opinion

Image Title	Dominant Color 1	%	Color 2	%	Color 3	%	Visual Theme & Reading
K-July 30, 2023	Sky Blue	35%	Cream Facade	30%	Green Roof	20%	Clear Urban Identity, civic order, leisure
K-April 30, 2023	Golden Beige	40%	Grey Roof	25%	Lawn Green	20%	Historical Authority, legacy + formality
K-December 18, 2023	Neon Red	45%	Blue Lighting	35%	Black Shadow	15%	Urban Energy, night, festival, speed
K-September 30, 2023	Brick Rose	50%	Blue Sky	25%	Stone Grey	15%	Civic Structure, order, tradition

Image Title	Dominant Color 1	%	Color 2	%	Color 3	%	Color Theme
G-April 28, 2023	Gold/Orange Glow	35%	Sky Blue	25%	Deep Beige	20%	Night Carnival, Festive Urban
G-January 21, 2023	Stone Grey	40%	Grass Green	25%	Amber Lights	20%	Monumental Civic, Winter Tone
G-July 15, 2023	Skin Tones	30%	Flags & Blue Sky	25%	Pastel Walls	20%	Public Celebration, Civic Pride
G-September 5, 2023	Sandstone Brown	45%	Sky Blue	30%	Asphalt Grey	15%	Classical Urban, Clear Daylight

Contribution
Positions social media imagery as a tool in transformative urban research.
Highlights role of citizen-generated data in participatory planning.
Supports policymaking guided by collective care, cultural memory, and sustainability.
Bridges academia, policymakers, designers, and urban practitioners.

Next Steps
Expand dataset beyond **Flickr** to include platforms such as Instagram and TikTok for broader perspectives.
Conduct **comparative longitudinal analysis** to trace shifts in urban perception before, during, and after key events.
Integrate **ethnographic methods** (interviews, surveys) to complement image-based findings.
Aim to build a framework that supports **participatory urban planning** through citizen-generated visual data.

References (Selected)
Frankfurt, H. (2005). *On Bullshit.* Princeton University Press.
•Manovich, L. (2017). *Instagram and Contemporary Image.* Verso.
•Chun, B. (2020). *The Aesthetics of Global Protest: Algorithmic Authenticity.* Routledge.
•Rettberg, J. W. (2014). *Seeing Ourselves Through Technology: How We Use Selfies, Blogs and Wearable Devices to See and Shape Ourselves.* Palgrave Macmillan.
•McQuire, S. (2016). "The politics of public space in the media city." *Media, Culture & Society*, 38(4), 551–565.
•Graham, M., Zook, M., & Boulton, A. (2013). "Augmented reality in urban places: contested content and the duplicity of code." *Transactions of the Institute of British Geographers*, 38(3), 464–479.
•Highfield, T., & Leaver, T. (2016). "Instagrammatics and digital methods: Studying visual social media, from selfies and GIFs to memes and emoji." *Communication Research and Practice*, 2(1), 47–62.

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ENERGY AND DIGITALIZATION
MOBILITY AND URBAN SPACE

What makes Living Labs successful? A typology of barriers and success factors

Iljana Schubert, Paola Yanguas Parra, Anton Sentic, Evelyn Lobsiger-Kägi, Jasmin Oberkalmsteiner

Institute for Sustainable Development, ZHAW, Winterthur, Switzerland

INTRODUCTION

The consortium **SWEET SWICE** utilises LL to explore alternative ways of living and working in the context of the Swiss **energy transition** through co-creation, testing and validation with stakeholders.

Drawing on LL and transition literature, we propose a framework allowing **systematic synthesis of factors influencing LL**, and a methodology to validate this framework with the existing literature and practitioners.

We aim to identify, cluster, and interpret key factors that influence LL success in transition contexts. By bridging the analytical depth of academic research with the practical needs of LL managers and stakeholders, **such an approach can help transform scattered insights into structured, practice-oriented guidance (management tool) for the LL community**.

ANALYTICAL FRAMEWORK

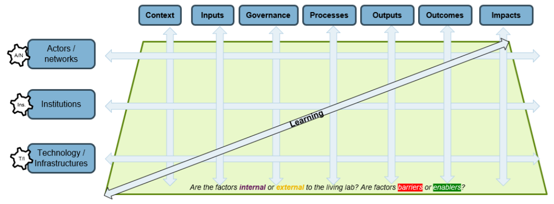


Figure 1: Conceptualisation of the main dimensions of the analytical framework.

METHODOLOGY

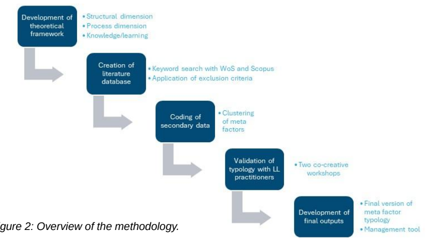


Figure 2: Overview of the methodology.

PRELIMINARY RESULTS
(77 out of 159 papers coded)

Enablers-meta factors & meta categories

1. Participant recruitment and retention
- Foster public commitment and ownership (citizens)
- Leverage existing relationships and networks for recruitment
- Provide financial compensation for participation, to reduce attrition

2. Stakeholder engagement and collaboration
- Provide a neutral, inviting meeting space
- Engage diverse range of stakeholders: citizens, companies, government, and academia (intrinsically/positively-inclined)
- Build trust, use trust-building activities for long-term partnerships
- Inclusive community culture through dialogue, shared goals (common language)
- Open, transparent, but also target- group oriented communication (i.e. different channels, digital tools to share information - gather ideas from stakeholders
- Practice expectation management, demonstrate tangible progress and 'quick wins'

3. Capacity building and training
- Integrate living lab activities into academic curricula and research projects
- Offer training and capacity building programs for stakeholders

4. Learning and knowledge
- Create a process of continuous, reflexive evaluation and knowledge-sharing, integrating multidisciplinary expertise
- Document failure and success to support learning and growth of the living lab

5. Entrepreneurship and innovation support
- Provide infrastructure and resources to support the growth of start-ups and innovative businesses
- Promote the living lab as a platform for showcasing and scaling innovative solutions
- Connect living lab participants with business incubators and accelerators

6. Contextual adaptation and policy integration
- Align living lab activities with regional policies and development plans, and include administration
- Leverage existing infrastructure, initiatives and resources within the local context
- Foster collaboration between living lab (participants) and policymakers

7. Governance
- Clear organizational structures, roles leadership/management, with transparent, adaptive, and aligned goals & decision-making
- Secure diverse, adaptive financial resources and develop viable business models for long-term sustainability and impact
- Long-term, stable physical, digital, and institutional infrastructure, embedded in real-life settings
- Establishment of relationships/trust takes time

Barriers - meta factors & meta categories

1. Biased participation and recruitment
- Biases in participant recruitment, apathy in communities
- Difficulties in measuring public value and real-life impacts of living labs

2. Low stakeholder engagement/ commitment
- Reluctance of participants to commit due to open-ended, not clearly defined goals, and lack of clarity on resources
- No LL/ transformation interest from people in power/key positions
- Challenges in establishing long-term partnerships, shared decision-making structures
- Challenges due to low trust, limited motivation, inconsistent involvement, and exclusion of diverse or underrepresented actors.
- Conflicting interests and fear of losing control or gaining limited influence
- Difficulty in addressing consultation fatigue
- Negative mindset of local stakeholders towards change

3. Differences and barriers in communication and understanding
- Differences in concepts, language, assumptions and methods, across disciplines and backgrounds
- Challenges in establishing common understanding and accepting uncertain assumptions, lack of flexibility/openess and low tolerance for failure
- Missing LL mindset and/or experience with transformation processes or LL-methods within (research) team

4. Expectation management and goal clarification
- Tension between learning goals of researchers and success expectations of practitioners
- Challenges in balancing control, co-creation, and scalability in living lab experiments

5. Evaluation and learning
- Limited baseline data, lack of structured evaluation, hindering learning and impact (measurement)
- Limited generalizability of findings

6. Exclusion and uneven power dynamics
- Persistent, unclear or unbalanced power relations (towards funding organisation) and strategic behavior leading to exclusion and disempowerment
- Limited power or room for experimentation

7. Institutional silos and fragmentation and boundary issues
- Departmental silos and different mandates within municipal organizations
- Tensions between local and global costs/benefits and conflicting priorities across administrative areas
- Disconnected experimentation spaces, isolated from other policy domains
- Lack of integration and embedding of living lab initiatives within existing institutional structures
- Jurisdictional ambiguity
- Difficult coordination between organisations
- Lack of clear roles and weak institutional coordination, or insufficient political support.

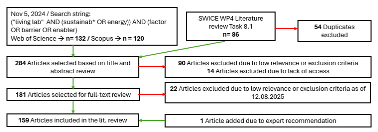
8. Inadequate technological and infrastructure support
- Unreliable digital tools, lack of user-friendly systems, or insufficient infrastructure & knowledge

9. Organizational and cultural barriers
- Risk aversion and resistance to change in governmental organizations
- Slow administrative processes, lack of innovative methods
- Perceived risks and lack of benefits in collaborating, especially for SMEs and users

CONCLUSION

- The preliminary results suggest that the **proposed framework is useful and comprehensive to classify all barriers and enablers** from the scientific literature review.
- **Bias in the LL literature towards: 1. actor and institutional factors & 2. governance and process-related factors and activities**, highlights important research gaps of often overlooked but important factors for the successful implementation of LL.
- **Little reflection or understanding of learning processes in the LL literature**, considering the importance of this dimension for experimentation and scaling-up of transformation processes within the wider society.

LITERATURE REVIEWED



LIMITATIONS

- Disclaimer for literature review exercises that deal with the LL literature and their interpretation/extrapolation: some factors (e.g. co-creation) are used with very different definitions and understandings in the LL literature.

FUTURE WORK

- Future validation and refinement are planned through ongoing collaboration within SWICE and other research consortia.
- Development of final typology of enablers and barriers meta-factors (for scientific publication).
- Development of a management tool for LL practitioners.

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