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EDITORIAL

MAIN SECTION

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EDITORIAL

Mapping Beyond the Monodisciplinary Approach: Exploring the Potential of Mapping in Comparative Research Methods.

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Humanity is facing a wide range of transitions—from the climate crisis and energy transition to migration and digitalization—unfolding at multiple scales. These transformations impact urban, rural, and even uninhabited landscapes, often in cumulative or reinforcing ways. Industrial regions, cross-border territories, capital cities, and river-port areas exemplify the spatial intersections where global pressures are materializing. The scale and urgency of these challenges demand innovative, interdisciplinary approaches that account for the social, environmental, political, and economic dimensions of space.

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Geo-spatial mapping has long been a valuable resource across diverse disciplines—such as planning, geography, and the digital humanities—offering both visual and analytical insights that extend beyond traditional textual narratives. In this issue, geospatial mapping refers to the computer-based process of generating, visualizing, analyzing, and interacting with spatial data using digital tools. However, despite this wide applicability, mapping is often confined to single fields of study or specific case studies, constrained by national contexts, linguistic boundaries, or narrow temporal scales. To address the complexity of today's interconnected challenges, we need mapping methods that transcend geographic and temporal limitations and integrate multiple disciplinary perspectives—approaches that reflect the fluid, dynamic nature of territories rather than treating them as fixed or isolated spatial units.

This special issue, "*Mapping Beyond the Monodisciplinary Approach: Exploring the Potential of Mapping in Comparative Research Methods,*" aims to overcome these limitations by highlighting interdisciplinary and comparative methodologies that broaden the scope of digital mapping. Because maps are inherently visual and spatial, they are particularly well suited for comparative research, enabling scholars and practitioners to explore relationships, flows, and patterns across otherwise fragmented contexts. In doing so, they reveal contrasts and connections that support more comprehensive analysis.

A central theme of this issue is the role of scale in comparative analysis. The contributors demonstrate how digital mapping techniques can be applied innovatively across a range of fields, revealing that digital mapping is not merely a supplemental tool, but a foundational element in shaping interdisciplinary knowledge. These articles show how mapping at multiple scales can illuminate spatial dynamics while also emphasizing the need for methodological flexibility in grappling with complex realities.

The articles assembled here link mapping techniques to a wide array of spatial challenges—from historical urban morphology to infrastructure development. Grouped into thematic sections and spanning both historical and contemporary contexts, they illustrate how digital cartography informs interdisciplinary research, public debate, and policy. Ultimately, this collection positions mapping as an active, iterative process—one that fosters new inquiries and practical responses to global transformations.

1. Historical and Morphological Approaches

Applying Kevin Lynch's conceptual framework to historical cartographic material, the paper by Sahar Abdollahi, Martin de Jong, Jurian Edelenbos and Jan Fransen (2025) showcase a mapping-based approach that reveals long-term patterns of urban development in six cities in the Low Countries. Their study goes beyond description by systematically cate-

gorising morphological change and identifying recurring spatial dynamics. This method not only enriches our understanding of historical urban development, but also contributes to comparative research by examining several cities in parallel. Through the lens of geospatial mapping, the article demonstrates how spatial analysis of the past - using historical maps - can inform contemporary discussions on urban development and heritage conservation. It highlights the value of cartographic sources in revealing complex transformations and offers a compelling case for integrating mapping into broader urban studies.

While Abdollahi et al. use the map to explore the layered material history of the city, the following papers turn attention to lived experiences and the ethical considerations involved in visualizing movement and memory. They reveal that mapping is not just about spatial representation, but about capturing the layered socio-spatial experiences, memories, and power relations embedded in place. They highlight how mapping practices can trace, surface, and make sense of the personal stories, emotions, and everyday encounters that shape—and are shaped by—urban and territorial transformation.

2. Socio-spatial Experiences and Narratives

Vincent Baptist (2025) studies the case of Katendrecht, a former pleasure district in the port-city of Rotterdam, now undergoing rapid waterfront regeneration and gentrification. He investigates how long-term residents, who witnessed Katendrecht's changes since the 1970s, experience walking through today's redeveloped neighborhoods. Methodologically, the paper combines walking interviews and time geography, producing space-time maps that trace both the spatial routes and temporal pauses or 'stillstands' during these resident-led walks. Due to its random paths and non-rigid interview structures, this approach captures the authentic, spontaneous recollections and place-based reflections of this neighborhood. Mapping these interviews reveal patterns that go beyond individual memories, uncovering shared reactions to specific urban features, appreciation for renovated historic facades, critique of the scale and design of new developments and the ambivalence towards the district's transformation. The outcome is a layered interpretation of how time and space intersect in the lived experience of locals in this 'new' Katendrecht undergoing such significant spatial and socio-cultural changes.

In their paper, Elena Dorato and Richard Lee Peragine (2025) critically study the mobility of agricultural works in Ferrara located in northeastern Italy, within the Po Valley (Pianura Padana), near the Adriatic Sea. This area is historically shaped by large land-reclamation projects that transformed marshlands into fertile agricultural lands, making it one of Italy's major agro-industrial production zones. Ferrara's agricultural sector relies heavily on migrant, seasonal, and day labourers, many of whom are

exploited through the illegal system of caporalato — gangmasters who control recruitment, transport, and payment. Aim of their research is to map the commuting and mobility patterns of those migrant day-labourers exploited under the illegal caporalato system, using surveys, interviews, fieldwork, and GIS analysis. However, the authors argue that mapping alone cannot address the deeper political-economic roots of exploitation embedded in such capitalist agricultural production. The study reveals critical gaps and barriers, such as opaque labor and mobility arrangements, resistance from both workers and employers, and the difficulty of gathering reliable, non-coerced data. Therefore, the authors call for 'critical mapping', an approach that recognises mapping not solely as a technical tool, but as a space for political and ethical reflection. Instead of seeking to 'fix' mobility through technocratic solutions, the authors advocate for a combined mapping with deep structural critique, on-ground investigation and a high level of awareness to limitations and unintended consequences that might accompany attempts to visualise and intervene in exploitative labour regimes

Juan Sanz Oliver, Gregory Bracken and Víctor Muñoz Sanz (2025) study on the role of mapping in regenerative modernist housing estates, focusing on t'Hool in Eindhoven, Netherlands and Montbau in Barcelona, Spain. The research uses critical cartography to assess how these mid-century neighbourhoods, once celebrated for their experimental designs and social ambitions, perform today against the ideals of the 'Open Society'. While the two cases study areas share many similarities, they differ in crucial ways. 't Hool, built in the late 1960s in Eindhoven, emerged from a bottom-up cooperative process, with strong resident participation, diverse housing typologies, and spatial strategies designed to support flexibility and community identity. Montbau, by contrast, was a top-down public housing project from 1950s–70s Barcelona, shaped by CIAM modernist ideals but constrained by political, economic, and topographical challenges, leading to a more rigid structure despite its early innovations. By combining archival research, site visits, spatial analysis and Bakema's 64 Open Society principles, the authors show that while these sites offer rich lessons in human-centered urbanism, their renewal faces deeper challenges. They argue that mapping cannot be reduced to a technical exercise of documenting or redesigning space, but rather must be understood as a political and ethical exercise that reflects on power relations, historical legacies and the risk of oversimplifying complex urban realities. Instead of seeking one-size -fits-all design fixes, the study calls for a critical, reflexive approach that blends mapping with historical sensitive, sociological insights and transdisciplinary collaboration, in order to offer both site-specific lessons and broader principles for more inclusive and sustainable urban regeneration.

3. Analytical Mapping for Specific Typologies

Although the paper by Das, Rahman et al. (2025) does not reveal a macro-level comparative analysis, it clearly demonstrates the value of analytical mapping for specific typologies. Focusing on the micro-climatological performance of campus street types, the authors use GIS-based techniques - such as Inverse Distance Weighted (IDW) interpolation and Ordinary Least Squares (OLS) regression - to visualise and analyse spatial data. Their approach combines quantitative datasets with spatial analysis to reveal localised patterns and correlations that might otherwise go unnoticed. In doing so, the study demonstrates how digital mapping methods can address small-scale spatial challenges with broader implications. The analytical model developed provides a transferable framework for assessing the climatological performance of other urban typologies, extending the relevance of the study beyond the immediate site. This paper demonstrates how typology-focused mapping approaches can support sustainability research and inform spatial planning, even in cases where the study itself is not explicitly comparative or macro-scale.

Merten Nefs' paper (2025) also shows how mapping can be used for in-depth spatial analysis and to challenge dominant narratives, especially when applied to specific spatial typologies. His research focuses on the logistics landscape of the Netherlands, using a counter-mapping approach that combines multiple datasets, including OpenStreetMap (OSM), company data (LISA), business park inventories (IBIS) and the Key Register of Addresses and Buildings (BAG). The result is an open-access dataset and interactive dashboard that visualises the extent and character of logistics space across the country. Using GIS-based techniques and typological analysis, the research reveals spatial patterns that are often invisible to conventional planning. By challenging both the data and its gaps, Nef's work highlights the analytical potential of mapping, while also pointing to the limitations and needs of transdisciplinary research. In doing so, she contributes to a broader understanding of how analytical mapping can inform the governance of complex and often overlooked spatial systems.

4. Geospatial Frameworks and Digital Tools for Planning

The Bauhaus of the Seas Sails geospatial platform is a digital tool designed to support sustainable development in coastal and port-city territories. Michael Rodrigues, Lukas Höller and Alankrita Sarkar (2025) present a work developed under the New European Bauhaus initiative, this open-access platform integrates spatial data, sustainability metrics, aesthetics, and narratives to foster cross-disciplinary dialogue and informed decision-making. Two research cases underscore its versatility: one explores health and wellbeing in the transnational Rhine watershed, using a multi-

scalar approach grounded in Max-Neef's Human Scale Development model; the other investigates cross-border planning in the Flemish-Dutch Scheldt Delta, focusing on integrative urbanism and stakeholder collaboration. The platform's grid-based system enhances spatial analysis by improving data processing and resolution flexibility. Through these functions, it offers a valuable foundation for participatory planning, knowledge sharing, and transnational cooperation. As a flagship of the New European Bauhaus vision, the platform bridges science, policy, and local communities, positioning itself as an essential instrument for addressing complex socio-ecological challenges in Europe's coastal regions. It exemplifies how digital innovation can align environmental, social, and spatial goals toward a more resilient and inclusive future.

The following section explores how mapping also operates as a participatory and educational tool. These contributions show that maps are not only for analysis and planning, but also for empowering communities, shaping learning, and fostering inclusive dialogue. Together, they illustrate how geospatial tools can link high-level policy with everyday experience.

5. Participatory Mapping and Pedagogical Tools

The 'Mani in Mappa!' (Hands on Map!) initiative, part of the EU-funded I-CHANGE project, demonstrates how citizen science and participatory mapping can drive sustainable urban mobility planning. Carlone et al. (2025) present an activity conducted in Bologna, Italy. The activity engaged students, local stakeholders, and citizens in a serious game that simulated real-world mobility challenges using fictional personas. By mapping daily routes and transport choices on both paper and digital maps, participants identified barriers to sustainable transport, such as gender inequities, caregiving responsibilities, and inadequate infrastructure for vulnerable groups. The project revealed how mapping, when used as a collaborative and experiential tool, fosters critical reflection and knowledge co-production. Participants' interaction with the maps deepened their understanding of urban complexity, empowering them to suggest inclusive mobility solutions. While digital maps offered precision, paper maps enhanced collective spatial reasoning and dialogue. Interviews confirmed the tool's educational and transformative potential, though challenges remain in engaging underrepresented groups and ensuring data accuracy. Overall, "Mani in Mappa!" illustrates how integrating maps into citizen science can democratize urban planning, build environmental awareness, and amplify marginalized voices.

Ingrid Mulder, Michael Rodrigues, María Reyes, Ariele Empirio and Alankrita Sarkar (2025) contribution explores value mapping as a transformative pedagogical tool for addressing complex urban and landscape challenges through a values-based approach. Centered on a Master-level course titled "Design & the City," the study demonstrates how students

use cities as learning ecosystems to explore sustainability issues through design. By creating value maps, students visually articulated the diverse and sometimes conflicting values of stakeholders, fostering critical thinking, collaboration, and inclusive design practices. These visual tools help students and practitioners navigate the "green dilemmas" of urban development by grounding interventions in shared values. The methodology emphasizes contextual specificity, participatory engagement, and long-term sustainability goals.

Practise

Kersten Nabielek (2025) introduces the Spatial Outlook 2023 by the PBL Netherlands Environmental Assessment Agency, presenting four imaginative scenarios for how the Netherlands could look in 2050, addressing the nation's pressing spatial and environmental challenges. These scenarios serve not as blueprints, but as tools for fostering informed, inclusive debate on future spatial planning. Developed through a multidisciplinary process combining GIS-based land use modeling and design research, the maps visualize key themes such as energy, housing, climate adaptation, and nature. They functioned as "conversation pieces" during development, "communication tools" in public outreach, and "boundary objects" in participatory workshops, bridging diverse stakeholders. Balancing visual clarity with technical accuracy, the maps make complex spatial issues tangible for policymakers and the public alike. The approach underscores mapping's vital role in navigating uncertainty and envisioning sustainable, climate-neutral futures.

Miscellanea

The contribution by Jasmin Suroor Abdulghafoor and Ismaeel Emad Hani (2025) with the title "Computer-Aided Decision-Making for the Highest Sustainable Reuse of Historic Buildings " uses data-driven a assessment method for the sustainable reuse of historic buildings, with a focus on the Al-Barood Khana building in Mosul. The research introduces a software system — MAROHB — that uses multi-criteria decision-making algorithms to assess the highest and most sustainable reuse options for heritage structures. By combining architectural and urban requirements, the program calculates compatibility scores across potential functions, helping decision-makers identify reuse strategies that prolong a building's life while respecting its cultural and historical significance. Rather than treating adaptive reuse as a purely technical or economic exercise, the authors argue that sustainable reuse must balance architectural integrity, cultural value, social needs, and environmental concerns. Their work shows that digital tools, when carefully designed, can enhance—not replace—expert judgment, stakeholder participation, and ethical stewardship. By testing

MAROHB on the case of Al-Barood Khana, the study demonstrates how computational approaches can support informed, context-sensitive decisions that safeguard historic buildings for future generations.

Across thematic sections, this special issue underscores that mapping is not a neutral exercise but a powerful tool for revealing hidden inequities, supporting informed decision-making, and fostering cross-sector collaboration. Whether tracing historical urban layouts, protecting the identities of vulnerable populations, or planning for climate resilience by 2050, the contributors use maps as both instruments of insight and platforms for critique. We invite readers to view these contributions as interconnected case studies demonstrating how spatial tools cannot only represent our world, but help shape more just and sustainable futures.

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Abdollahi, Sahar "Patterns in Morphological Evolution: Comparing Changes in Six Medieval City-Centres in the Low Countries (1720–2020)" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024).

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Carlone, Teresa and Selene Tondini "Mapping Sustainable Futures: cartographic maps' role in citizen science for participatory research in sustainable urban mobility" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024).

Rahman, Iftekhar and Subrata Das "An Analytical Study on Campus Street Types Considering Sustainable Landscape Microclimate" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024).

Dorato, Elena, and Richard Lee Peragine "Critical Notes on Mapping the Mobility of Agricultural Workers in the Province of Ferrara: The (Ethical) Importance of Opacity" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024).

Mulder, Ingrid; Rodrigues, Michael; Reyes, María; Empirio, Ariele and Sarkar, Alankrita. "Value Mapping as a Pedagogical Tool to Understand Complex Urban and Landscape Challenges" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024)

Nefs, Merten. "Counter-Mapping Spatial Footprint and Economic Activity of the Logistics Complex in the Netherlands" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024)

Nabielek, Kersten. "Mapping Scenarios for the Netherlands in 2050" *European Journal of Creative Practices in Cities and Landscapes* 7, no. 1 (2024).

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Suroor Abdulghafoor, Jasim and Emad Hani Ismaeel. "Computer-Aided Decision-Making for the Highest Sustainable Reuse of Historic Buildings" European Journal of Creative Practices in Cities and Landscapes 7, no. 1 (2024).

Lukas Höller holds a B.Eng. in Landscape Architecture from Weihenstephan-Triesdorf University of Applied Sciences and finished his M.Sc. in Architecture, Urbanism and Building Sciences, and Track Urbanism at Delft University of Technology with Cum Laude in 2020. He is currently doing his PhD researching inland port-city territories and territorial wellbeing along the Rhine at the Delft University of Technology Urbanism Department, Section of Spatial Planning & Strategy. He is also part of the Leiden-Delft-Erasmus PortCityFutures research group and is involved in several research and planning activities.

Yvonne van Mil is a researcher at the Department of Architecture at Delft University of Technology. After graduating in Delft in 2009, she worked for 10 years as an independent researcher, collaborating with various heritage and academic institutions. She specialises in spatial history and geospatial mapping, with a particular interest in the history of (regional) strategic planning. She worked on the publication of the *Atlas of the Dutch Urban Landscape* (2014), the first overview of urbanisation in the Netherlands from a long-term perspective. She is co-author of several books, including *Port City Atlas. Mapping European Port City Territories* (2023), *Driven by Steel. From Hoogovens to Tata Steel 1918-2018* (2018), *Atlas van het Westland* (2016) and contributed chapters to the *Atlas van de Schie* (2016). The focus of her research is on mapping-based research methods for the comparative analysis of complex urban and rural landscapes in transition.

Michael Rodrigues is a Geographer dedicated to innovating spatial data visualization and enhancing communication to reach broader audiences. Currently a Postdoctoral Researcher at the Chair History of Architecture and Urban Planning within TU Delft's Faculty of Architecture and the Built Environment, his research focuses on rendering spatial data more accessible and comprehensible. His aim is to facilitate learning about the surrounding world and empower stakeholders to make informed decisions.

MAIN SECTION

Patterns in Morphological Evolution: Comparing Changes in Six Medieval City-Centres in the Low Countries (1720-2020)

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ABSTRACT

To the perceptive observer, similarities in the urban structures and architecture of medieval city centres in the Netherlands, Belgium, and a strip of North-Western France will stand out. Indeed, they have been part of the Low Countries for a long time until separation led them to be governed by different institutional regimes for the past few centuries. This paper offers a novel qualitative method to examine the evolution of urban form through time, based on Kevin Lynch's urban form elements. It systematically compares the changes in the morphology of the historical centres over the past three centuries with the help of digitised maps. Changes in Lynch's morphological elements (nodes, edges, landmarks, and paths) are analysed to understand the characteristics of the urban evolution in six cities. In this contribution, we have studied three large cities (Amsterdam, Antwerp, and Lille) and three mid-sized ones (Leiden, Leuven, and Arras), all of which have well-preserved city centres. Our findings are based on a unique way of using well-developed historical cartography for mapping the morphological evolution over time and allow for further in-depth investigation of which trends and events cause these changes.

KEYWORDS

Urban Morphology Evolution, Kevin Lynch, Medieval Cities, Low Countries, Historical Comparative Analysis

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Mapping Morphological Evolution in Medieval Cities in the Low Contries

Cities are dynamic entities that show which morphological evolution over time can be examined. Some expand, some decline, yet others remain reasonably constant over time. More specifically, city centres in urban communities dating from medieval times show relative continuity, allowing us to study alterations due to military conquest, industrial or technological revolution, or demographic growth to be examined much more closely and precisely. Historical maps can help us shed light on the long-term evolution of city developments and their physical shape. They allow us to spot continuity and change in morphological elements over time and, if combined with the systematic application of a suitable conceptual framework, to analyse these changes and make sense of them.[1]

Medieval cities in Europe have their original footprint in a particular era and, unless destroyed in the course of time, continue to share specific characteristics and patterns related to that origin with each other. Comparing the texture of their urban cores with each other, as well as the transformation they go through across the centuries, tells us a lot about what morphological evolution took place. In this contribution, we apply this idea to continuity and change in cities of which the current city centres emerged in the Low Countries of the later Middle Ages, usually at the intersection of important waterways and trade routes. In those days, what is now known as the current Netherlands and Belgium, but also that strip of North-Western France, which comprises the departments of Nord and Pas-de-Calais, constituted a loosely united historical unity with a common style of architecture, shared urban patterns, and similar lifestyles.

Many important morphological changes in medieval city centres relate to the demolition of urban construction in response to or accommodating military, technological, economic, or demographic incentives. While some of that heritage has been entirely preserved or has at least had a lasting impact on the morphological patterns of these cities, other elements may have vanished from view. For instance, the star-shaped citadel in Lille, built as the city's fortification, has been preserved and is still used as a French military base today. But in Antwerp, the citadel and an enceinte around the city were completely dismantled in 1859. Defensive walls protected cities from military conquest in the past and thus acted as fixation lines but were, in some cases, more recently experienced as constraints to economic and demographic expansion and removed.[2,3] Leuven preserved some of its walls, while Arras completely dismantled them. We

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1 Elvin K. Wyly, "Continuity and Change in the Restless Urban Landscape," *Economic Geography* 75, no. 4 (1999), 309-338.

2 J. Le Goff, "Costruzione e distruzione delle torri della città murata," in *La città e le mura,* De Seta G. e Le Goff J. (eds), (Roma-Bari, Laterza 1989), 1-10.

3 Guido Zucconi, *La Città Dell'Ottocento* (GLF editori Laterza, 2005).

used the six maps four times to show the morphological basis with their key elements in each of the cities. Subsequently, we indicated which of these elements had been removed or added to the map roughly 100, 200, and 300 years later. This allowed us to systematically analyse long-term morphological changes in medieval cities, shedding light on the factors that shape urban development. Identifying continuity and change is vital for urban historians, planners, and geographers, particularly to understand how cities adapt to external pressures and allow policymakers and planners to make informed decisions about preserving historical urban cores while managing socio-economic development. Previous studies about urban form have mostly focused on geographical and typological approaches, and the evolution of urban morphology based on Kevin Lynch's elements in urban form has rarely been studied using historical maps. Nor does existing academic work on the topic simultaneously consider the morphological evolution of medieval cities crossing long time scales while comparing several ancient cities in the Low Countries.[4,5,6,7] That makes our contribution, despite its exploratory nature, new to the field. To our knowledge, this is the first study in which a combined diachronic and synchronic approach rooted in Lynch's framework is applied to investigate changes in ancient urban forms using historical cartographies. This unique intersection of urban morphology and evolutionary theory provides new perspectives on the adaptive dynamics of medieval cities, allowing for a more profound understanding of how urban morphology evolved across the centuries under the influence of the external environment.

In the rest of this article, the following steps will be taken. Section 2 introduces the currently dominant strands in morphological theory and clarifies why we chose Lynch's main thoughts in 'The Image of the City' as the backbone of our analytical framework. The third section clarifies the methods we used to collect and analyse our findings. We subsequently present our collection of 24 cartographic maps along with a systematic overview of their changing morphological elements in section 4. Finally, section 5 offers a broader discussion of the findings and looks at future implications of this study.

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4 Pierre Gauthier and Jason Gilliland, "Mapping Urban Morphology: A Classification Scheme for Interpreting Contributions to the Study of Urban Form," *Urban Morphology* 10, no. 1 (2006), 41.

5 Karl Kropf, *The Handbook of Urban Morphology* (John Wiley & Sons, 2018).

6 Anne Vernez Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," *Urban Morphology* 1, no. 1 (1997), 3-10.

7 Vítor Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities* (Cham: Springer, 2016).

Urban Morphology

Morphology, as a discipline, studies the physical shapes and structures of organisms to reveal the mechanisms driving their evolution and the development of their constituent parts.[8] The analogy between organisms and urban morphology is rooted in the idea that cities, like living organisms, grow, adapt, and evolve in response to internal dynamics and external conditions.[9] Similarly, urban morphology investigates the various elements of urban form, such as streets, plots, and buildings, and their interconnections. It is rooted in urban ecology and seeks to understand the processes that shape cities and their adaptation over time.[10] In yet other words, urban morphology encompasses the study of urban form, actors, and their processes of emergence, evolution, and transformation.[11] According to the latter definition, urban 'morphology' is much broader than 'form' alone since it involves the social context around that physical shape, including actors and institutions leading to their emergence and transformation. However, in this article, we will merely focus on the process of change in the urban form elements as such and disregard their socio-institutional context even though it offers many clues as to mechanisms explaining the underlying dynamics for transformation. We will come to this point in the final section.

Cities are, in morphological terms, extremely complex systems, knowledge of which is pursued by a wide variety of academic disciplines. Massive efforts have been made to define this organised spatial structure to understand the basics of urban evolution.[12,13,14,15,16,17] Urban morphology is a growing cross-disciplinary field of research, attracting worldwide interest among scholars in architecture, geography, and planning. More recently, it has also attracted attention from sociologists, economists, and experts in cultural heritage conservation and restoration. It provides knowledge about urban form, its constituting elements, and the processes leading to their evolution over time by facilitating rigorous cross-city comparisons of different cities to identify the similarities and differences in their evolutionary patterns. The outcomes of such analyses are also an

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8 Stephen Jay Gould, "D'Arcy Thompson and the Science of Form," *New Literary History* 2, no. 2 (1971), 229-258.

9 Patrick Geddes, *Cities in Evolution: An Introduction to the Town Planning Movement and to the Study of Civics* (London: Williams, 1915).

10 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

11 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

12 Michael Batty, "Complexity and Emergency in City Systems: Implications for Urban Planning," *Malaysian Journal of Environmental Management* 10, no. 1 (2009), 15-32.

13 *Gauthier and Gilliland, "Mapping Urban Morphology," 41.*

14 Kropf, *The Handbook of Urban Morphology*.

15 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

16 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

17 Amos Rapoport, *Human Aspects of Urban Form: Towards a Man—Environment Approach to Urban Form and Design* (Elsevier 2016).

essential tool for heritage protection and historical conservation since they reveal which urban elements have been preserved or eliminated and how this has happened.[18]

Morphologists can be classified in their knowledge contribution to the field by the kind of data, the methodology they apply, the tools they use, the interpretative concepts they adopt, and their specific interpretation of urban form. Moudon has categorised the field of urban morphology as initially consisting of three main schools: a British, an Italian, and a French one, based on the different kinds of data they generally utilise to analyse places and the patterns they identify and use in their comparisons. [19,20,21,22,23]

In the twentieth century, two mainstream schools were developed parallel, led by M. R. G. Conzen (1907-2000) and Gianfranco Caniggia Muratori (1933-1987), with concerns in diverse disciplines, namely geography and architecture.[24] In the British School, the main aim of urban morphology is to describe and explain. Their approach is primarily historical and geographical and focuses on town planning. Its main analytical ingredients are the plot, block, street, building types, and land use.[25,26] On the other hand, the Italian school hails from an architecture-oriented approach. It developed the fundamental concepts of type and fabric, as well as the idea of the organism, by highlighting the spatial arrangement of the form as a synthetic unit of material, structure, and compositional plan. Its prescriptive and design-driven approach has been labelled 'typo-morphological'.[27] Like the Italian school, the French school emerged in opposition to the modernist movement in promoting historicity and the traditional inheritance of cities. As a sort of intermediary between the British and Italian schools, it expanded the morphological perspective by blending design with geography, incorporating insights from literature and the social sciences. What all three schools have in common, however, is that they all consider the plots and the buildings located on them as the main units for analysis for studying urban patterns. Form, resolution, and time constitute the three fundamental components in any urban morphological research on any

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18 Kropf, *The Handbook of Urban Morphology*.

19 *Batty, "Complexity and Emergency in City Systems: Implications for Urban Planning," 15-32.*

20 *Gauthier and Gilliland, "Mapping Urban Morphology: A Classification Scheme for Interpreting Contributions to the Study of Urban Form," 41.*

21 Kropf, *The Handbook of Urban Morphology*.

22 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

23 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

24 *Yina Sima and Dian Zhang, "Comparative Precedents on the Study of Urban Morphology" (2009).*

25 Michael Robert Gunter Conzen, *Thinking about Urban Form: Papers on Urban Morphology, 1932-1998* (Peter Lang 2004).

26 Michael Robert Gunter Conzen, "Alnwick, Northumberland: A Study in Town-Plan Analysis," *Transactions and Papers (Institute of British Geographers)*, no. 27 (1960), iii-122.

27 Gelareh Sadeghi and Baofeng Li, "Urban Morphology: Comparative Study of Different Schools of Thought," *Current Urban Studies* 7, no. 4 (2019), 562-572.

type of city, whether conducted by geographers, architects, or urban planners.[28] Due to growing international exchange in academia, the distinction between various 'schools', and in fact, even the very use of that term, has now largely disappeared.

In recent years, more quantitative strands in morphological research have been introduced and gained influence, leading to the emergence of morphometrics as a subfield within morphology. Bill Hillier's Space Syntax is a new and innovative system of theories and techniques for mathematically analysing spatial configurations. The tendency of space syntax for studying urban morphology is a diverse concern and is sometimes integrated with GIS. Through digital maps, Hillier attempts to measure and even quantify the relationship between social power and spatial form.[29] The approach introduced by Michael Batty is based on generating cities from the bottom-up and complexity theory that presents new kinds of computational models, such as cellular automata (CA), agent-based models, and fractal geometry. [30]

These latest quantitative approaches in urban morphology require very detailed digital and manipulable maps and extensive open data for processing. Since our analogue sources on city historical city centres date from past centuries, we were not able to apply these recent methods. Instead, we have chosen to adopt the classical terminology of Kevin Lynch (1960), whose work exemplifies a more psychological perspective of urban form as residents and visitors experience it as lay people. What sets Kevin Lynch's image of the city approach aside from the above schools is his attempt to fill the gaps in objective city forms by using mental maps that reflect 'general impressions' rather than 'detailed facts', which lend themselves well to interpreting the headlines of historical evolution based on a more limited sets of maps/data. Lynch's cognitive approach provided a framework to reflect on the complex synergy between the 'urbs' (built environment) and the 'civitas' (people and activities changing over time).[31] For Lynch, the physical environment was an embodiment of time, providing an opportunity to sense continuity with past periods, the present, and the future. Conservation of that environment was a prerequisite conditional to protecting that continuity. Lynch mentions three aspects of urban morphology: spatial relations in physical form, relations between humans and the built environment, and historical relations that make up the formation and transformation processes. Lynch's work has offered environmental psychologists not just a topic of interest but also a feasible methodology to study the topic area through his five-part assessment of city form using mental maps. His perceptual approach to defining urban

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28 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

29 *Tasos Varoudis et al., "Space Syntax Angular Betweenness Centrality Revisited" (2013).*

30 Luca D'Acci, "On Urban Morphology and Mathematics," *The Mathematics of Urban Morphology* (2019), 1-18.

31 Kropf, *The Handbook of Urban Morphology*.

form discerns paths, landmarks, edges, nodes, and districts as central elements of urban form that represent what the city's form means to the people who live there. They can be defined as follows:

- *Paths* are routes that people use to move throughout the city, including sidewalks, alleys, streets, roads, boulevards, railroads, and waterways.
- *Edges* are boundary areas between two distinct phases, spaces, or districts: linear breaks in continuity, including fortification walls, canals, shores, ports, and rails.
- *Nodes* are strategic focus points where various paths cross, which serve for orientation purposes but also as gathering points or attention points, including marketplaces, squares, public spaces, and junctions.
- *Landmarks* are external physical objects that can be used as reference points, including monuments, churches, castles, belfries, and city halls.
- *Districts* are areas characterised by common characteristics. Since the districts selected in this study are all historical city centres of medieval cities, they will not be treated as a variable below. Instead, they are the complete spatial unity in which the other four are analysed.

We consider the four Lynchian concepts of paths, edges, nodes, and landmarks as the most appropriate urban form elements for studying century-long morphological evolution to be contextualised to any culture since they are most straightforward to highlight and best to remember for users of urban space. They help us comprehend what changes materialise and where. In the section below, the operationalisation of these concepts for our study will be developed based on Lynch's approach.

Methodology

In longitudinal studies, changes in variables are examined during the passage of time. While a substantial body of literature has focused on urban morphology, work on the evolution of urban morphology over long periods of time is relatively thinly spread and experience with modern methods and techniques to measure it is rare.[32,33,34] Among the large variety of possible approaches to dealing with morphological change, we have selected historical maps to depict overall processes of change. We have collected maps of the urban cores of six cities from the former Low Countries through the centuries. They all have relatively well-preserved city centres, which can be conveniently analysed in terms of alterations

32 *Conzen, "Alnwick, Northumberland: A Study in Town-Plan Analysis," iii-122.*

33 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

34 Peter J. Larkham, "The Study of Urban Form in Great Britain," *Urban Morphology* 10, no. 2 (2006), 117.

in their morphological elements. We have done this for two cities in each of the three involved countries, one large and one mid-sized in each country: Amsterdam (large) and Leiden (mid-sized) in the modern-day Netherlands, Antwerp (large) and Leuven (mid-sized) in current Belgium and Lille (large) and Arras (medium-sized) in the part of France that used to have close ties with (or was part of) the former counties Flanders and Hainaut. We collected detailed, originally analogue, but recently digitised cartographic maps of the city centres of all six cities at four key moments in time (1720, 1820, 1920, and 2020). These periods were selected to capture significant socio-economic and technological shifts that influenced urban morphology: the pre-industrial era (1720), the early industrial period (1820), the height of industrialisation and urban expansion (1920), and the contemporary era of post-industrial urban transformation (2020). Using these maps, we created inventories of morphological changes across three critical intervals (1720–1820, 1820–1920, and 1920–2020) and conducted detailed analyses to identify patterns and drivers of urban form adjustments. This study is a comparative historical study that is longitudinal (diachronic) and (synchronic) at once. It is longitudinal in the sense that it follows the evolution of medieval cities over time employing historical maps, and it is synchronic and comparative in that this same evolution is examined for six different medieval cities. Historical maps are excellent resources for various research applications, especially for the explicit investigation of morphological change over time and are generally regarded as valuable for showing the past and the present situation in a spatial format. The exponential growth of available map scans, stored and maintained in digital archives and on the Internet, that could be easily accessible and downloadable enables researchers to analyse and process data in various scientific studies disciplines. Although their adequacy has sometimes been criticised for being insufficiently valid or reliable, this problem seems to apply to a much lesser extent to historical maps topographically representing smaller local areas.[35] While the reliability issue depends on not only scale but also the measuring techniques used in surveying and the purpose for which the map was produced, Elwin Koster introduced the Virtual Cities project, which visualises the errors that are generated in the process of geo-referencing. Using the RMS error viewer shows the level of accuracy of the map and identifies how much a chosen point will deviate from its real coordinates.[36] On the other hand, because of the low quality of the ancient maps, it is not possible to generate reliable knowledge on the size and shape of ancient blocks and streets and the advanced digital processes of that information. Considering these limitations, historical maps are likely to be the best possible source when it comes to displaying the correct features in the correct locations at the

35 A. Kent, "No Title," *The Value of Historical Maps: Art, Accuracy and Society* (1998).

36 E. Koster, "Urban Morphology and Computers 10 Years on E. Koster," *Urban Morphology* 13, no. 1 (2009), 74-76.

correct time. Therefore, in this study, historical maps have been selected for the longitudinal comparative study of medieval city centres in the Low Countries. The urban cores of the six cities originated in the late Middle Ages and were located in economically and culturally loosely coupled Low Countries. The selection of historical city centres was based on three indicators: (1) having a medieval structure, (2) the current population size of the entire city, and (3) having cities represented from all three different countries which the historical Low Countries now straddle. This resulted in our choice for Amsterdam, Antwerp, and Lille as cities with current populations (500,000 - 1,000,000) and well-preserved medieval city centres in the Netherlands, Belgium, and France, respectively and Leiden, Leuven, and Arras (50,000-100,000) as cities with medium-sized populations in those same countries. Alternatives for the large ones would have been Rotterdam and Brussels, but the historical cores of both have been subject to enormous damage or renovation over time, making them unsuitable for our purposes. Among the medium-sized ones, there would have been many alternatives in the Netherlands and Belgium and only one in France (Dunkirk), but we have simply selected one well-known and suitable example in each of the three countries. A systematic comparison of maps representing the topography of these six city centres in different centuries enables us to visualise the changes in their 'Lynchian' morphological elements in relative detail. Additionally, the secondary data, in the form of contemporary and historical maps, has been derived from bibliographical studies, formal data, photographs, and documentary records on websites. The three websites used for old maps in this study include collections of scanned maps modelled by cartographers a century ago:

www.oldmapsonline.org: Old Maps Online is a portal that allows easy access to historical maps in libraries worldwide.

https://www.davidrumsey.com: online map archives and libraries such as the David Rumsey Map Collection contain more than 150,000 maps ranging in date from around 1550 to the present. The site is free and open to the public.

https://commons.wikimedia.org: Wikimedia Commons is a media file repository that makes available public domain and freely licensed educational media content (images, sound, and video clips) to everyone. It comes from various archaeological museums and sites around the world.

https://earth.google.com/web/search: the current maps of the cities have been downloaded from Google Earth with the advanced feature of providing images and street views.

We use online historical maps because scanned map processing is the most efficient and effective method to extract historical information by overlaying and toggling back and forth between different maps. The advantage of using online maps is having free access to high-resolution maps that can be easily downloaded and used digitally. Moreover, the

applications of Photoshop and PowerPoint have been employed to analyse and process maps.

Topographic maps of all six city centres (Amsterdam, Antwerp, Lille, Leiden, Leuven, and Arras) depicted in four different years (1720, 1820, 1920, and 2020), resulting in 24 maps assisted us in making a diachronic and synchronic comparison of the six cities in four different centuries possible. Using the specific symbol (see legends below the maps) and yellow colour, we inserted and highlighted the morphological elements (node, edge, landmark, and path) into the historical maps of the year 1720. We followed the same procedure for all subsequent maps (1820, 1920, and 2020). However, there we gave the elements a green colour if they were new and made a first appearance on the map, a yellow colour if they had been preserved or consolidated from before, and a red colour if they had disappeared from the map (in comparison with the map of the previous century. After analysing the maps with the green, yellow, and red elements depicted on them, we made overview tables listing each city for each timeframe (1720-1820, 182-1920 and 1920-2020) and how many alterations of each type of Lynchian element had taken place. We were able to discern various specific subtypes (for the interval 1720-1820, for instance, landmarks could be subdivided into castles, churches, libraries, houses, warehouses, hospitals, banks, and hotels). Still, since these were somewhat variable and tended to change over time, we included them in our overview tables for completeness but did not process them for further analysis. The result of this exercise was a numerical indication of the changes that had occurred in each city per morphological type in each timeframe.

Studying the history of medieval cities revealed that these cities developed around marketplaces on which monuments such as cathedrals and city halls emerged where people convene for their socio-cultural and economic activities. Specific time-bound spatial elements, such as fortification walls, trading halls, narrow zigzag street patterns, abbeys, and castles, define what medieval cities represent in morphological terms. The major streets radiated from a central square to the gates with secondary arteries. [37]Although most medieval cities had the same essential urban structure, they underwent divergent processes of transformation in their spatial texture as they evolved through the centuries. All six case studies selected in our analysis followed complex evolutionary paths due to diverse military, political, industrial, economic, and demographic factors, which profoundly influenced their urban development. However, the broader societal developments and trends do not explain the morphological transformations in each timeframe as such (there are multiple intermediary institutional and other variables between those macro-developments and the morphological micro-adjustments), but they provide

37 Leonardo Benevolo and Carl Ipsen, *The European City*Blackwell Oxford, 1993).

general indications of how large-scale transformations and on-the-ground urban restructuring may hang together.

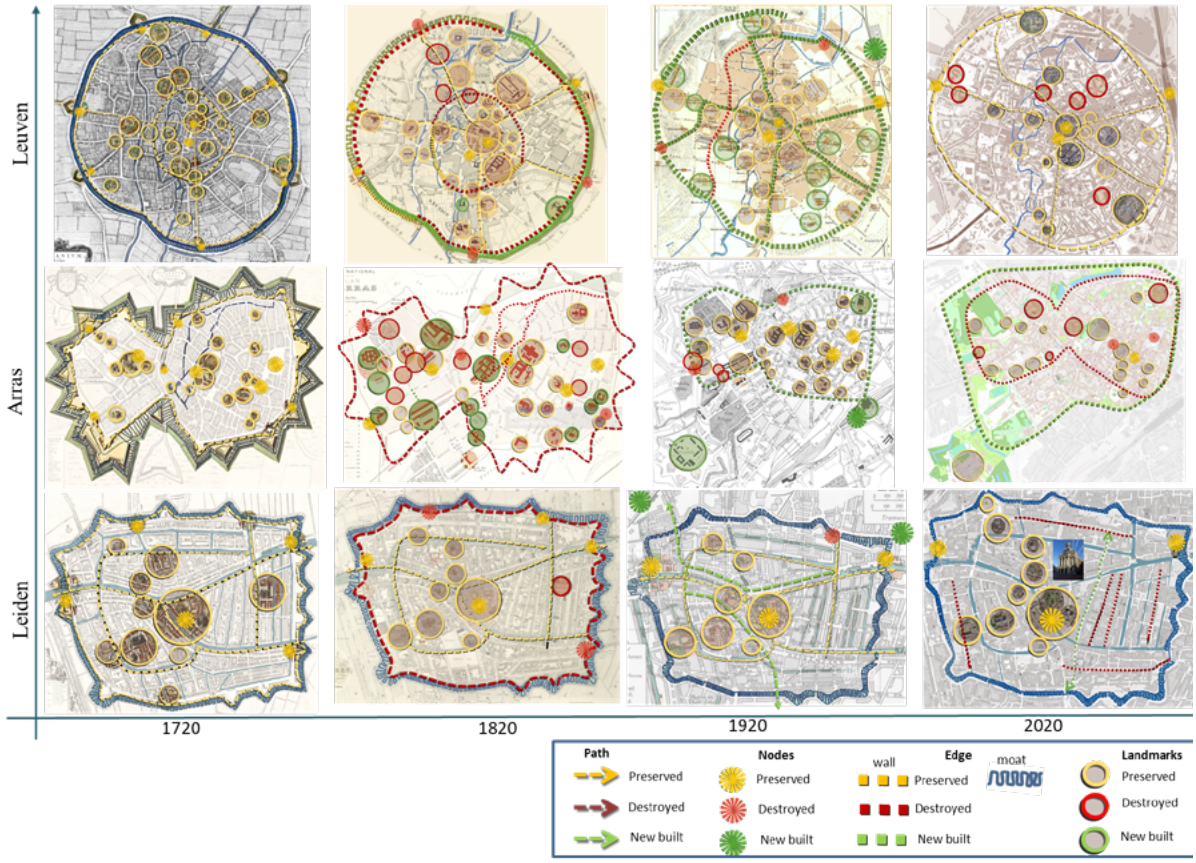
Findings

This study focuses on medieval city centres in local communities dating back to the late Middle Ages in the territories representing the Netherlands in those days. The maps presented in this section contain all 24 maps (six cities at four different moments in time), which serve as basic empirical evidence and then proceed to describe the main findings that can be gleaned from them: Which Lynchian morphological elements (paths, nodes, edges, and landmarks) changed in the historical inner city district of Amsterdam, Antwerp, Lille, Leiden, Leuven, and Arras and when did these changes occur? Map 1 presents the maps of all three large cities (Amsterdam, Antwerp, and Lille) for the years 1720, 1820, 1920, and 2020, and Map 2 does the same for the three medium-sized cities of Leuven, Arras, and Leiden.

The maps in the first column show the starting positions of all three cities in 1720. What stands out in these maps is the impressive fortification walls, especially in Antwerp and Lille, the high number of landmarks in Amsterdam and Antwerp, as well as the location of water on the Southern shore of Amsterdam and Antwerp and the prevalence of the local canals in Amsterdam that already present in those days. Moving towards the right, the maps show that many new elements, particularly landmarks and nodes, appear in green. At the same time, several 'old' monuments appear in red, implying they have been removed from the urban tissue. This pattern is more distinct in Antwerp and Lille than in Amsterdam, showing lower dynamic change levels in Amsterdam. This trend continues into the maps of 1920 in all three cities, with the major difference in fortifications having been torn down (displayed in red). However, overall, Amsterdam and Lille have better-preserved cityscapes than in Antwerp. The final result of this balance between continuity and change is shown in the maps for the year 2020: the essential morphological structure is still the same in all three cities as it was in 1720, complemented by a relatively rich collection of original buildings and urban spaces. Although there were few changes in the street network, the width of streets has often changed, and some canals have disappeared. On the other hand, the fortifications have been replaced with more functional edges (transition to new surrounding districts), and a substantial part of the landmarks and nodes have changed over time.

Map 2 repeats the same exercise for the historical cores of medium-sized cities Leiden, Leuven, and Arras. The maps indicate that traditional landmark architecture and cultural heritages incurred severe damage, especially in Arras and (to a lesser extent) Leuven. On the other hand, as shown in green, a remarkably high number of development projects inside the historical city centres

MAP 1 Morphological changes in Antwerp, Lille and Amsterdam



MAP 2 Morphological changes in Leuven, Arras and Leiden

		1720 - 1820						1820 - 1920						1920 - 2020					
Antwerp	Path	-Canals -Streets -Railroads	5 0 0	5	-Canals -Streets -Railroads	0 0 2	2	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 2	2	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 2	2
	Edge	-Coastline -Fortification -Moats	0 2 0	2	-Coastline -Fortification - Moats	0 2 0	2	-Coastline -Fortification -Moats	0 0 1	1	-Boulevard -Fortification -Moats	1 0 0	1	-Coastline -Fortification -Moats	0 1 1	2	-Boulevard -Fortification -Moats	1 0 0	1
	Node	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	1 2 0	3	-Squares -Marketplace -Entrance gates	1 1 2	4	-Stations -Port -Entrance gates	2 0 0	2	-Station -Marketplace -Entrance gates	1 0 2	3	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	1 5 0 5	11	-Service(hospital bank-hotel -Churches -Militaries -Warehouse- houses	6 4 7 5	20	-Castles -Churches -Militaries - Services(post- hotel-state)	1 7 5 5	18	-House -Churches -Militaries -Services(hospital bank- museum)	0 4 4 4	12	-Castles -Churches -Militaries -Services(post- hotel-state)	0 3 4 0	7	-House -Churches -Militaries -Service(hospital- bank- museum)	0 1 0 0	1
Amsterdam	Path	-Canals -Streets -Railroads	1 0 0	1	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	12 0 0	12	-Canals -Streets -Railroads	0 0 1	1	-Canals -Streets -Railroads	5 0 0	5	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 0 0	0	-Coastline -Fortification -Moats	0 0 0	0	-Coastline -Fortification -Moats	0 1 0	1	-Boulevard -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0
	Node	-Squares -Marketplace -Entrance gates	0 1 2	3	-Stations -Port -Entrance gates	1 0 0	1	-Squares -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	2 0 0	2	-Station -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Hotel -Warehouses- houses	0 3 1 2	5	-Churches -Militaries -Service(institute palace-hotel) -Warehouse- houses	7 3 6 2	18	-Castles -Churches -Militaries - Services(post- hotel-state)	1 1 0 0	2	-House -Churches -Militaries -Services(hospital bank- museum)	0 0 0 0	0	-Castles -Churches -Militaries -Services(post- hotel-state)	0 3 0 0	3	-House -Churches -Militaries -Beurs	0 0 0 1	1
Lille	Path	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	4 0 0	4	-Canals -Streets -Railroads	0 4 1	5	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Coastline -Fortification -Moats	0 2 0	2	-Boulevard -Fortification -Moats	1 0 0	1	-Coastline -Fortification - Moats	0 0 1	1	-Boulevard -Fortification -Moats	1 0 0	1
	Node	-Squares -Marketplace -Entrance gates	0 0 1	1	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	1 0 0	1	-Station -Marketplace -Entrance gates	0 1 1	2	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	0 2 0 0	2	-Churches -Militaries -Warehouse- houses -Service(hospital bank-hotel	0 2 7 0	9	-Castles -Churches -Militaries - Services(post- hotel-state)	0 1 1 0	2	-House -Churches -Militaries -Train station -Services(hospital bank- museum)	0 2 2 1 0	5	-Castles -Churches -Militaries -Services (theater)	0 2 5 1	8	-Grand palace -Churches -Militaries -Service (theater)	1 2 1 1	5

TABLE 1 Morphological changes (1720-1820, 1820-1920, 1920-2020) in three large medieval cities in the Low Countries.

can also be observed in Arras and Leuven. In Leiden, higher levels of stability and continuity can be observed in terms of demolition and new construction: nearly all urban elements are yellow on all its maps. In Arras and Leuven, the city walls have been totally removed and leave limited trace on the urban form (in Leuven, city walls were preserved in some places, but moats and rivers were filled and transformed into motorways). The historic inner city of Leiden is still surrounded by its ancient moats (but without the walls).

To further systematise the general impression obtained based on the maps above, we have generated two tables displaying the amount of change in each city. These tables detail the type of morphological elements, the timeframe, and the extent of both "red" destructions and "green" new constructions. The "yellow" preserved areas are excluded from the tables, as they represent unchanged elements. Table 1 shows this count for three large cities in three periods of time.

What stands out from Tables 1 and 2 is that during the 18th century, few changes occurred (and consequently, continuity was high) in Leiden and Lille. The

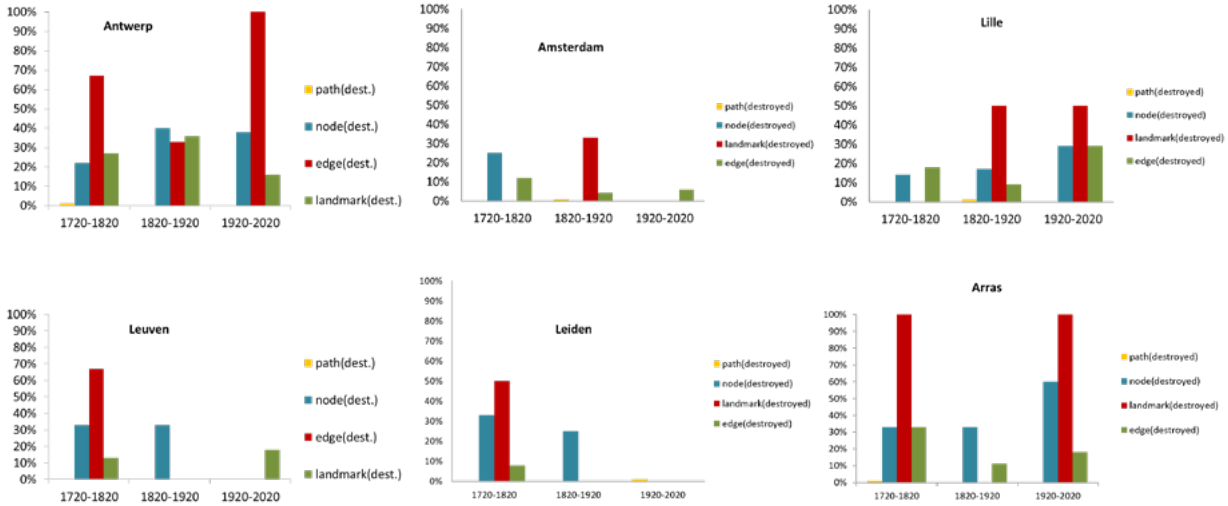
		1720 - 1820						1820 - 1920						1920 - 2020					
Leuven	Path	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	1 0 0	1	-Canals -Streets -Railroads	0 0 1	1	-Canals -Streets -Railroads	1 0 0	1	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 2 0	2	-Lineal Park -Fortification -Moats	1 0 0	1	-Coastline -Fortification -Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0
	Node	-Squares -Marketplace -Entrance gates	0 0 3	3	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	1 0 0	1	-Station -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Collages -Houses	1 0 0 2	3	-Service(hospital bank-hotel -Churches -Militaries -Warehouse- houses	0 1 1 0	2	-Castles -Churches -Militaries - Services(post- hotel-state)	0 0 0 0	0	-House -Churches -Militaries -Services(hospital -Institution	0 2 0 1 6	9	-Castles -Churches -Militaries -Library -Palace	0 1 3 1 1	6	-House -Churches -Militaries -Service(hospital- bank- museum)	0 0 0 0	0
Leiden	Path	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 2	2	-Canals -Streets -Railroads	6 0 0	6	-Canals -Streets -Railroads	0 1 0	1
	Edge	-Coastline -Fortification -Moats	0 1 0	1	-Coastline -Fortification - Moats	0 0 0	0	-Coastline -Fortification -Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0
	Node	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 1	1	-Stations -Port -Entrance gates	2 0 0	2	-Station -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	0 1 0 0	1	-Service(hospital bank-hotel -Churches -Militaries -Warehouse- houses	0 0 0 0	0	-Castles -Churches -Militaries - Services(post- hotel-state)	0 0 0 0	0	-House -Churches -Militaries -Services(hospital bank- museum)	0 0 0 0	0	-Castles -Churches -Militaries -Services(post- hotel-state)	0 0 0 0	0	-House -Churches -Militaries -Service(hospital- bank- museum)	0 0 0 0	0
Arras	Path	-Canals -Streets -Railroads	3 0 0	3	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 1 1	2	-Coastline -Fortification - Moats	0 0 0	0	-Coastline -Fortification -Moats	0 0 0	0	-Boulevard -Fortification -Moats	1 0 0	1	-Boulevard -Fortification - Moats	1 0 0	1	-Boulevard -Fortification -Moats	1 0 0	1
	Node	-Squares -Marketplace -Entrance gates	0 0 3	3	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	1 0 0	1	-Station -Marketplace -Entrance gates	0 3 0	3	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	0 7 0 0	7	-Churches -Militaries -unknown -Service(hospital	2 4 6 1	13	-Castles -Churches -Militaries - Services(post- hotel-state)	0 3 0 0	3	-Institution -Churches -Militaries -Train station -Services(hospital bank- museum)	1 0 1 1 0	3	-Castles -Churches -Militaries -Services (Hospital)	0 3 1 1	5	-Grand palace -Churches -Militaries -Service (hospital)	0 0 0 0	0

TABLE 2 Morphological changes (1720 -1820, 1820-1920, 1920-2020) in three medium-sized medieval cities in the Low Countries.

numbers indicate that in Antwerp and Arras, urban expansion occurred at a rapid pace and consequently affected the historic inner city with a higher rate of irreversible damage to fortification walls, canals, and historical monuments. At the same time, Amsterdam and Leuven occupied a middle position. Landmarks made the most considerable contribution to the number of changes among the removals and the new appearances. Moreover, the edges, including fortification walls, have been destroyed in almost all cities except Amsterdam and Lille.

The tables also show the morphological changes in the period from 1820 to 1920. The dominant picture seems to be very much the same, with few changes in Leiden and many in Antwerp; however, within this period of time, the number of morphological adjustments dwindled significantly in Arras, while their amount actually increased in Lille (but still remained significantly below that of Amsterdam and especially Antwerp). Again, landmarks were the main contributors to morphological transformation.

Table 2 then shows the changes in urban form elements in medium-sized ancient cities over time. As we can see, in the 20th century, there was more



GRAHP 1 Comparison of Kevin Lynch's urban form elements across three time periods (1720–1820, 1820–1920, 1920–2020) in six medieval cities of the Low Countries.

stability, and the number of changes declined significantly. Nonetheless, the figures for the disappearance of landmarks still express that a respectable number of historical monuments were sacrificed in all cities except Leiden. On the other hand, Leiden and Amsterdam lost several paths, a loss not experienced elsewhere.

The graphs above illustrate the morphological changes in six cities, providing insights into which elements underwent significant transformations and which remained relatively unchanged within the analysed timeframes.

Century-wise, we can conclude that the 18th century had the most dynamic changes in the removal and appearance of morphological elements in medieval city centres, followed by the 19th century. The 20th century, on the other hand, has shown far more clemency to the preservation of ancient Lynchian urban elements in the cities. Among the cities, we have established that Antwerp has been most subject to urban transformation, while Leiden turns out to be best preserved. Arras was particularly hard-hit in the 18th century, while the 20th century has been soft on it. For Lille, the exact opposite is true. Amsterdam (vis-à-vis Antwerp and Lille) and Leuven (vis-à-vis Leiden and Arras) occupy middle positions considering their relative size. Regarding the elements, landmarks underwent rather frequent alterations and thus seemed the most vulnerable element to destruction and replacement. This is potentially not surprising, given the fact that they are point constructions, the removal of which is most conveniently realised without damaging the entire urban tissue. The same does not apply to paths and nodes, which are more defining for the entire morphological structure of city centres: they also underwent a change in all cities but to a far lesser extent.

Moreover, although most paths remained at their original locations, we were unable to determine, based on Kevin Lynch's typology of elements

on maps, whether their pavements or breadth had changed over time. Lastly, the number of edge changes, but especially the nature of their transformation, was the most dramatic: the elimination of fortifications, city wall structures, and potentially the moats around them had enormous consequences for how the boundaries of the (historical) districts are perceived. Only Leiden escaped far-reaching change here, but even here, only the moat, not the fortifications, were preserved. More generally, in all cities, the most impressive (visible) destruction of historical heritage has occurred at the edges, such as with military infrastructure and fortification walls that appeared useless and obsolete.

Discussion

City centres located in municipalities with a long history play an important role as cultural hubs for the entire municipality or region in which they are located and reflect much of its local or regional identity. They have a distinct urban shape (through nodes, paths, and edges), which residents and visitors easily recognise as the main structure of a central district. They contain major monuments and buildings of architectural and historical significance (landmarks) and attract a variety of activities and services. However precious they may be, city centres are not impervious to the tooth of time. Periods of revolution and response to modern industrial society affected the future development of the cities and changed the face of many European medieval cities.[38] We have shown through maps the massive transformations they have gone through in response to complex challenges created by the macro-environment in which they operate. Although these challenges can be of a military, economic, technological, demographic, cultural or other nature, and this nature can vary per era, continuity and change are inherent features of urban morphological evolution through the centuries.

In some cases, such as in Amsterdam in 1872, impressive fortification works with high historical value were dismantled. However, conscious efforts were made to restore its character by digging the canals in line with the original shape for water management and defence purposes, and the monumental features of the city centre were largely preserved. Time did not favour all cities equally: Arras and Leuven were damaged considerably during the 18th century. For instance, Arras's fortification walls and historical monuments were almost entirely destroyed, primarily due to war and industrialisation. German troops burned its university library to the ground during World War II. In the 19th century Antwerp, the fortification walls, and the castle, as well as various landmarks, were demolished, including churches, authentic ancient houses, and military buildings, while several new buildings, an impressive and expansive port infrastructure,

38 Tonkao Panin, "The Politics of Style: Vienna and the Ringstrasse," *NAJUA: Architecture, Design and Built Environment* 30 (2016), C-03.

and a railway station were erected during these years. In Lille, on the other hand, although the city walls were torn down and the moats and rivers were filled, the castle still exists, and it is currently a major tourist attraction in the city. Not all six cities we have examined have gone through the same macro-societal trends and events. Some have been more war-stricken than others, and some have expanded more due to economic production development and population increases than others; however, each step of the way, they have had to make trade-offs between continuity and change. Some have favoured dramatic transformation and have chosen to dismantle the old and build the new, while others have been more cautious. It turns out that although one might have expected larger cities to be tilting more toward change than medium-sized ones, given the higher pressures they were subject to, this is only true to a limited extent. Antwerp has indeed been drastically redeveloped, but Lille is much less so. Leiden has shown remarkable continuity, but Arras, albeit still beautiful and impressive, has not. Amsterdam and Leuven occupy a middle ground here.

This study is a combination of collecting historical maps and analysing changes in Lynchian morphological elements that have helped us systematise what has changed in the period 1720-2020 in six cities of the ancient Netherlands, now located in three different countries. Although it is not high-tech, our combined diachronic and synchronic analysis of morphological transformation over time is certainly an innovative way to study and represent urban spatial characteristics and systematically portray the changes in historical city centres to identify points of continuity and change. Thus, the method applied in this research is fully replicable and reproducible for other cities and areas since it only requires the presence of historical maps and Kevin Lynch's concepts and relies on a comparison of cross-temporary and cross-spatial mutations.

Previous studies in urban form have focused on a much shorter timescale, generally covering only the last few decades, and rarely addressed the situation dating from before World War II. Nor does existing academic work on the topic simultaneously consider morphological evolution crossing long time scales while comparing various locations. That makes our study, despite its exploratory nature, a new contribution to the field. [39,40,41,42] Thus, this research offers a novel qualitative method to examine the evolution of urban form through time using mapping city images based on Kevin Lynch's urban form elements. It also contributes to the area of historical map analysis by offering a systematic morphological approach

39 *Gauthier and Gilliland, "Mapping Urban Morphology: A Classification Scheme for Interpreting Contributions to the Study of Urban Form," 41.*

40 Kropf, *The Handbook of Urban Morphology*.

41 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

42 Vítor Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities* (Cham: Springer, 2016).

that can be applied to older maps dating from before the digital era and yet allows them to be fruitfully used to analyse continuity and change through time. That said, there are obviously also limitations to the study conducted above. Although the outcome is that across the board, there were numerically comparatively few changes in the paths, nodes, and edges of city centres, this provides limited insight into how their dimensions (length, breadth, and width) have evolved or whether their functions have shifted significantly over time. The lack of data on functional transformations in urban elements from the Middle Ages makes it difficult to determine whether deliberate functional changes have occurred in sites that appear preserved. Arras, for instance, has no less than two gigantic central squares in its urban core, but one serves mainly as a parking lot while the other serves as an occasional marketplace and otherwise as a tourist attraction. Lynch's analytical method does not allow for viewing such functional subtleties but merely focuses on whether a node or landmark as such has emerged, remained or disappeared. Additionally, the analysis also lacks a comprehensive exploration of the cause-and-effect relationships underlying the observed transformations. While we have identified the mutations that occurred during three historical timeframes (1720–1820, 1820–1920, and 1920–2020) using green, yellow and red markers to denote paths, nodes, landmarks, and edges across the six central districts, we have not fully examined which macro-societal changes drove these micro-morphological alterations. Based on national and local histories, we can hypothesise the influence of factors such as military technological advancements, industrial expansion, and demographic growth. However, establishing concrete connections would require more detailed meso-level analyses to trace how macro-level developments translate into specific urban transformations. For example, the transformation of edges, such as fortification walls, in medieval cities like Amsterdam, Leiden, Antwerp, Leuven, Lille, and Arras is closely linked to the evolution of military technology and strategies. These changes reflect shifting priorities in urban defence, the obsolescence of medieval fortifications, and the gradual integration of former defensive boundaries into the urban fabric. This process illustrates the dynamic interplay between military innovations, technological progress, and urban expansion, emphasising how evolving societal needs shape urban morphology.

To deepen this understanding, future research should focus on unravelling the complex relationships between macro-level forces—such as socio-economic changes, technological advancements, and political dynamics—and micro-level urban transformations. Such studies could also explore practical applications for contemporary urban planning and heritage conservation, ensuring that historical insights inform sustainable urban development.

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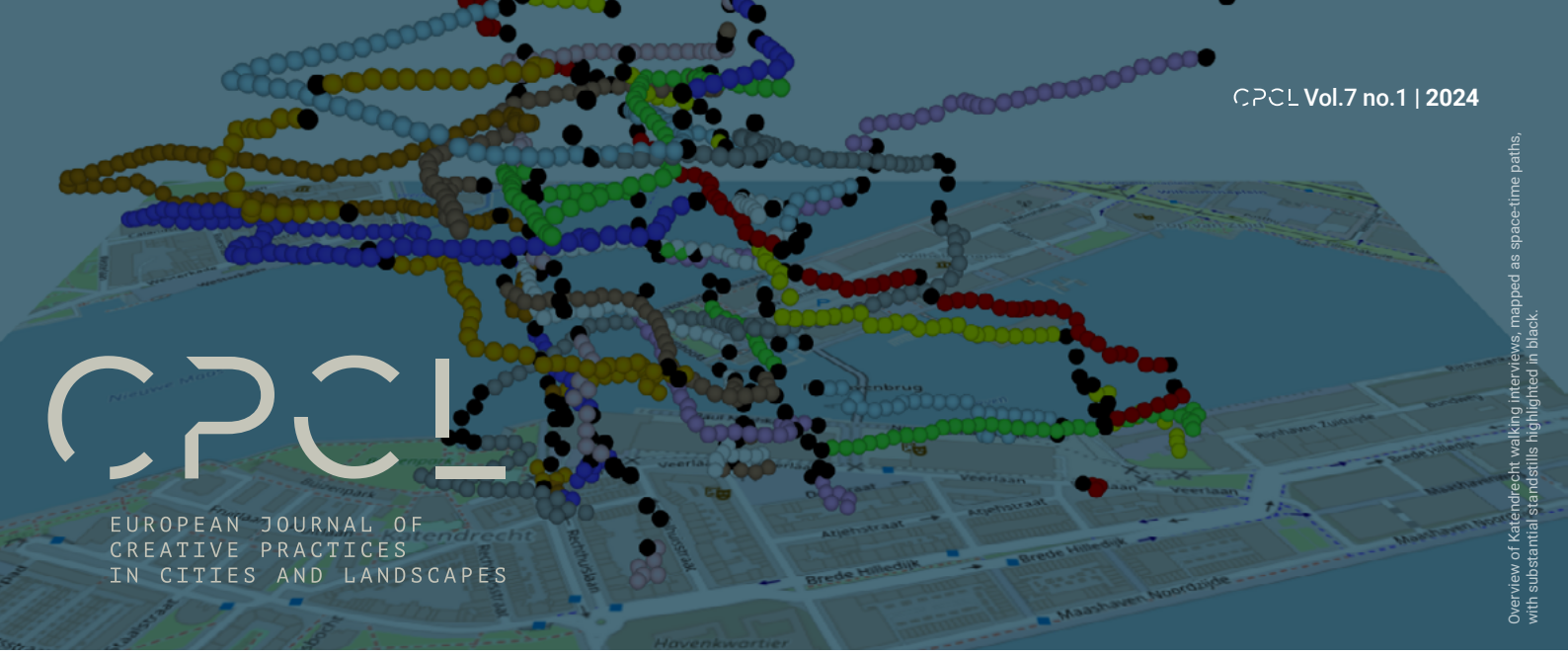

Overview of Katendrecht walking interviews, mapped as space-time paths, with substantial standstills highlighted in black.

MAIN SECTION

Mapping Walking Interviews in a Gentrifying Port City Neighborhood through Space-Time Paths

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ABSTRACT
Contemporary redevelopment and gentrification of urban waterfront areas has stimulated research on local residents' recollections regarding changes in their direct living environment. The peninsula of Katendrecht in Rotterdam, the Netherlands' main port city, constitutes a peculiar case in this respect, as its legacy of notorious maritime pleasure quarter has been overtaken by the neighborhood's recent urban renewal and waterfront regeneration processes. This article investigates how residents who have witnessed Katendrecht's decline as pleasure district experience walking through the redeveloped neighborhood nowadays. This case study demonstrates the potential for interdisciplinary synergy between different scholarly fields, through a specific mapping approach that links together the methodologies of walking interviews and time geography. By focusing on spatio-temporal 'standstills' in mapping the walking interviews' non-predetermined routes, overarching interview patterns are uncovered and participants' matching observations are identified, revealing a range of responses to a waterfront area's characteristics caught up in processes of gentrification.

KEYWORDS
gentrification; mapping; port city; time geography; walking interviews

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Introduction

To talk about port cities nowadays means to talk about waterfront regeneration. In the context of classic longitudinal planning perspectives on port city developments, as for instance put forward by Brian Hoyle, waterfront regeneration is perceived as one of the latest phases in reconsidering the relations between port and city entities: a logical outcome of the seaward expansion of many modern ports and the simultaneous abandonment of harbor areas located near city centers.[1] In this respect, "[t]he disuse of port areas and waterfronts, often dramatized in Europe, can be considered a normal process that will, at best, lead to rapid reutilization," Dirk Schubert remarks.[2] However, to talk about contemporary waterfront regeneration also means to talk about gentrification. As Alice Mah states: "(...) critics of waterfront development (...) argue that dominant development models are embedded in an uneven geography of capitalist development and result in the gentrification and cultural homogenization of urban landscapes."[3]

The global diffusion of waterfront redevelopment schemes throughout approximately the last half century has resulted in striking similarities when it comes to spatial and architectural transformations of waterfront zones. Urban waterfront renewal processes have also brought socio-cultural frictions to the fore, which often already lay dormant within specific local and historical contexts.[4] A seemingly purely infrastructural reshaping of waterfronts can thus be further connected to fundamental changes in their socio-cultural fabric. In this article, 'gentrification' is therefore not merely understood in terms of a neighborhood's changing housing stock and related municipal policies, but also in terms of its potentially wide-ranging socio-cultural ramifications and local residents' varying views thereon.[5] As Hoyle further highlights, "[r]evitalization [of waterfronts] sometimes pays a great deal of attention to commercial opportunities but not much to the social needs of resident communities,"[6] whereas "[t]he relative success of such developments will depend [among others on]

1 Brian Hoyle, "Global and Local Change on the Port-City Waterfront," *Geographical Review* 90, no. 3 (2000): 402-3, https://doi.org/10.1111/j.1931-0846.2000.tb00344.x.

2 Dirk Schubert, "Ports and Urban Waterfronts," in *The Routledge Handbook of Planning History*, ed. Carola Hein (New York and Abingdon: Routledge, 2018), 342, https://doi.org/10.4324/9781315718996-29.

3 Alice Mah, *Port Cities and Global Legacies: Urban Identity, Waterfront Work, and Radicalism* (Basingstoke and New York: Palgrave Macmillan, 2014), 57, https://doi.org/10.1057/9781137283146.

4 See for instance Astrid Wonneberger, "The End of "Community"? Concepts of Locality and Community Before and After the Spatial Turn in Anthropology: A Case Study of the Dublin Docklands," *Localities* 1 (2011): 125-58; Philip Boland, John Bronte, and Jenny Muir, "On the Waterfront: Neoliberal Urbanism and the Politics of Public Benefit," *Cities* 61 (2017): 117-27, https://doi.org/10.1016/j.cities.2016.08.012; and Heleni Porfyriou and Marichela Sepe, eds., *Waterfronts Revisited: European Ports in a Historic and Global Perspective* (New York and Abingdon: Routledge, 2017).

5 This is in line with Ruth Glass' initial coining of the term 'gentrification' in the 1960s. See Rowland Atkinson and Gary Bridge, "Introduction," in *Gentrification in a Global Context: The New Urban Colonialism*, eds. Rowland Atkinson and Gary Bridge (London and New York: Routledge, 2005), 3-4.

6 Hoyle, "Global and Local Change on the Port-City Waterfront," 403.

(...) integration of communities and localities involved. All of this demands (...), above all, a geographer's sense of place."[7]

In light of the above, the southern peninsula of Katendrecht in Rotterdam, the Netherlands' main port city, constitutes a peculiar research case. Katendrecht's twentieth-century history of notorious maritime pleasure quarter has been overtaken by the neighborhood's contemporary revitalization. The discrepancy between Katendrecht's past as a deviant district and its current situation as one the port city's most coveted areas has become a recurring point in critical discussions about the gentrification processes unfolding along Rotterdam's waterfronts.[8] It therefore proves relevant to ask how residents who have witnessed Katendrecht's life phase as disreputable pleasure zone regard the neighborhood's contemporary transformations, even more so because it were local inhabitants themselves who initially called for giving the district a more livable residential appeal during the post-war period.

This article centers on the mapping of interviews conducted in today's redeveloped Katendrecht, with residents who have witnessed Katendrecht's decline as maritime pleasure district in the 1970s. This rather specific case study approach is adopted to demonstrate the larger potential for interdisciplinary synergy between different scholarly fields, particularly oral history and urban geography. In this article's case study, the methodologies of walking interviews[9] and time geography[10] are connected to each other in a specific mapping approach that holds potential to be developed further for other research contexts and spatial scales. The adopted mapping approach lays bare the analytical potential of the dimension of time, often neglected in geospatial research. Compared to 'space', 'time' has also only recently been taken into account in critical investigations of gentrification.[11]

After first introducing Katendrecht's modern history and the adopted research methods, the case study is operationalized by considering individual walking interviews of one hour each with twelve local residents that were conducted in the neighborhood. The interview routes were not

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7 ibid., 415.

8 Eelkje Christine Bosch, "GentrifiKatendrecht," *Vers Beton*, July 2, 2020, https://www.versbeton.nl/2020/07/gentrifikatendrecht/; Tessa Hofland, "Katendrecht wordt hipper en hipper (en daardoor onbetaalbaar voor de oorspronkelijke bewoners)," *AD*, July 31, 2023, https://www.ad.nl/rotterdam/katendrecht-wordt-hipper-en-hipper-en-daardoor-onbetaalbaar-voor-de-oorspronkelijke-bewoners~a4215dd9/.

9 Also called 'go-along'. See Margarethe Kusenbach, "Street Phenomenology: The Go-Along as Ethnographic Research Tool," *Ethnography* 4, no. 3 (2003): 455-85, https://doi.org/10.1177/146613810343007; and James Evans and Phil Jones, "The Walking Interview: Methodology, Mobility and Place," *Applied Geography* 31, no. 2 (2011): 849-58, https://doi.org/10.1016/j.apgeog.2010.09.005.

10 See Torsten Hägerstrand, "What about People in Regional Science?" *Papers of the Regional Science Association* 24 (1970): 7-21, https://doi.org/10.1007/BF01936872; and Shih-Lung Shaw, "Time Geography: Its Past, Present and Future," *Journal of Transport Geography* 23 (2012): 1-4, https://doi.org/10.1016/j.jtrangeo.2012.04.007.

11 See Suleiman Osman, "What Time is Gentrification?" *City & Community* 15, no. 3 (2016): 215-9, https://doi.org/10.1111/cico.12186.

predetermined, and participants were instead given the autonomy to spontaneously decide the trajectories themselves. The generated data of the interview routes combine spatial and temporal dimensions, which have been mapped as space-time paths, inspired by the framework of time geography. By focusing on spatio-temporal 'standstills' in mapping the routes, overarching interview patterns are uncovered and participants' matching observations are identified, revealing a range of responses to characteristics of this waterfront area caught up in processes of gentrification.

Katendrecht: From Stigmatized to Gentrified Port Neighborhood

In present-day Rotterdam, Katendrecht is often still observed and understood through the lens of particular maritime urban legacies stemming from its long-standing stigmatized position in the port city.[12] In the post-war period, the neighborhood became synonymous with the designation of 'red-light district' after it had taken over the majority of prostitution activities in the port city, following the destruction of related Rotterdam neighborhoods throughout the first half of the twentieth century.[13] During this earlier time period, Katendrecht's role as Chinatown district already took the upper hand in characterizing its deviating profile. From the 1910s onwards, Chinese migrants arrived in Rotterdam, initially to be employed as strikebreakers in the port. They were stationed in Katendrecht, where their numbers quickly added up to a few thousands by the 1930s. Katendrecht therefore became known as "the largest Chinese colony in the Netherlands."[14]

The isolated position of Katendrecht in Rotterdam can be pinpointed to a more fundamental level still, related to the layout of the port itself. The modern peninsular shape of Katendrecht emerged through the creation of two new port basins in the early twentieth century, the Rijnhaven and Maashaven, respectively north and south of its territory (Fig. 1). Katendrecht's population was therefore entirely surrounded by the industrial port complex: railway tracks and warehouses encircled the peninsula's core residential area, which comprised only a handful of streets (Fig. 1).

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12 Karel Davids, "De 'rosse' Kaap: Over het stigma van een Rotterdamse buurt, 1900-1985," in *Onderscheid en minderheid: Sociaal-historische opstellen over discriminatie en vooroordeel*, eds. Herman Diederiks and Chris Quispel (Hilversum: Uitgeverij Verloren, 1987), 150-73; Han Meyer, *Operatie Katendrecht: 'Demokratisering' van het sociaal beheer van de grote stad* (Nijmegen: SUN, 1983), 55-7.

13 Vincent Baptist and Paul van de Laar, "Pleasure Reconsidered and Relocated: Modern Urban Visions in the Wake of Rotterdam's Discontinued Amusement Areas," in *Hustle and Bustle: The Vibrant Cultures of Port Cities*, eds. Carola Hein, Robert Bartłomiejski and Maciej Kowalewski (Leiden: Brill, 2025), 108-12.

14 Paul van de Laar and Arie van der Schoor, "Rotterdam's Superdiversity from a Historical Perspective (1600-1980)," in *Coming to Terms with Superdiversity: The Case of Rotterdam*, eds. Peter Scholten, Maurice Crul and Paul van de Laar (Cham: Springer, 2019), 47, https://doi.org/10.1007/978-3-319-96041-8_2.

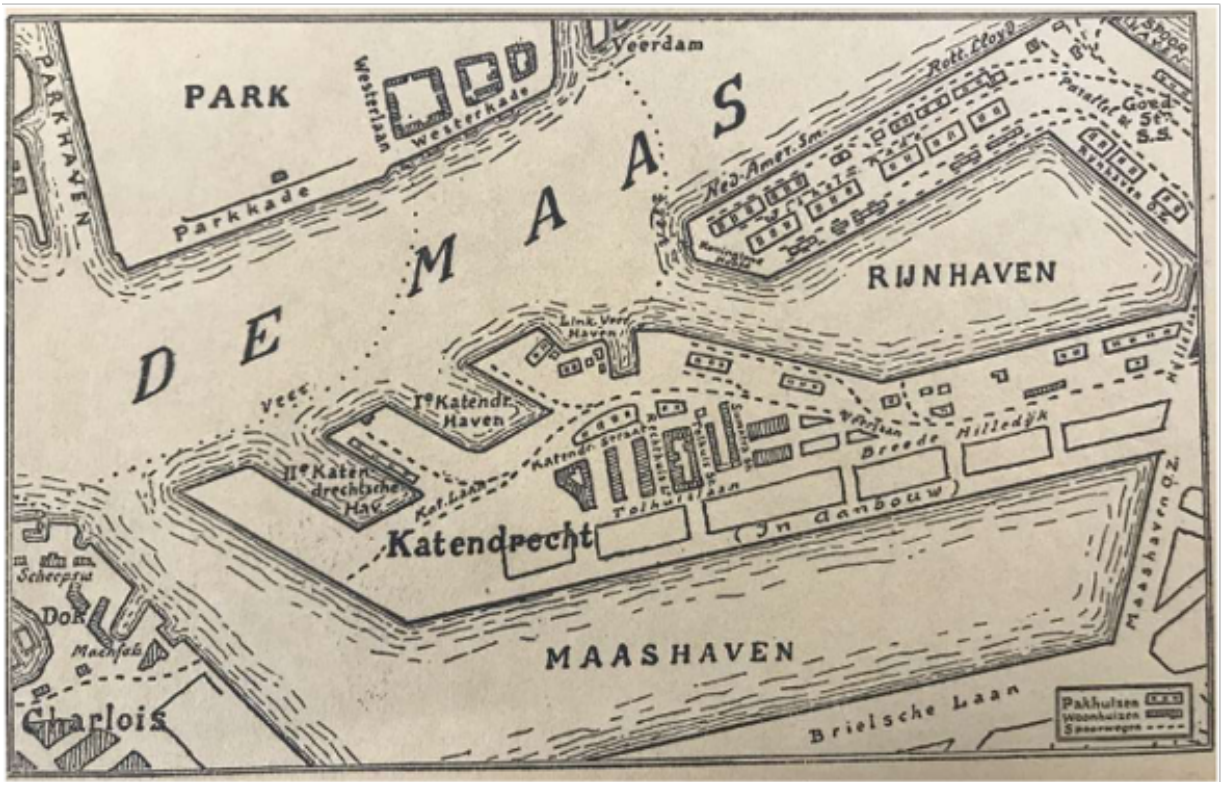

FIG. 1 Historical map of Katendrecht, with dark hatchings in the middle indicating the neighborhood's original central residential area (Source: De Jongh et al., 1904)

In contrast, a recent neighborhood map hanging at Katendrecht's main entrance shows how the local landscape is now dominated by numerous high-rises along the waterfronts (Fig. 2).[15] These new buildings' housing capacity easily surpasses the couple of thousands of inhabitants that historically populated the district. The type of gentrification that Katendrecht has become subjected to seems in line with the phenomenon's most advanced stages, characterized by corporate real estate schemes and municipal policy facilitation.[16] Rather than direct physical displacement of its original inhabitants, Katendrecht's recent redevelopment particularly manifests itself in a recomposition of the district's population, accompanied by the establishment of new, trendy enterprises for culture and commerce.[17]

Before these transformations, another shift in character was first fought out in Katendrecht. The neighborhood's transition from red-light zone to a more normalized residential area was initially sparked by growing local

15 For a more detailed analysis of changes in Katendrecht's built environment, see Vincent Baptist and Yvonne van Mil, "Open Waterfronts or Closed Water Forts? New Ways of Mapping Redeveloped Waterfronts' Accessibility," in *The Port Cluster Landscape*, ed. Beatrice Moretti (Berlin: JOVIS, forthcoming).

16 Manuel B. Aalbers, "Introduction to the Forum: From Third to Fifth-Wave Gentrification," *Tijdschrift voor Economische en Sociale Geografie* 110, no. 1 (2019): 2-6, https://doi.org/10.1111/tesg.12332.

17 Cf. Jan Rath, *Hippe ondernemingen, culturele consumptie en nieuwe stedelijkheid: Effecten van commerciële gentrificering* (Rotterdam: Erasmus School of Social and Behavioural Sciences, 2022), 7-21.

FIG. 2 Contemporary poster of Katendrecht, highlighting high-rise projects key to recent neighborhood transformations (Source: Stichting Historisch Katendrecht, "Transitie")

unease over the increasingly criminalizing and commercialized role of the district's sex industry in the 1970s.[18] Nevertheless, the nuisance of prostitution activities was not the sole reason for Katendrecht's deteriorating situation. During the 1970s, different policy-related reports were commissioned to better understand neighborhood issues regarding livability and social well-being. These reports singled out the poor, neglected housing conditions of the district, causing people to consider moving out of the area and Katendrecht's population to decrease faster than that of the port city as a whole at the time.[19] In later years, this resulted in a focus on improving Katendrecht's residential facilities, especially at the expense of the neighborhood's previously dominant, notorious pleasure offerings, which were substantially reduced by the 1980s.[20] The local insistence on these urban renewal processes during the post-war period provides motivation to investigate how Katendrecht's current transformations are viewed by residents who populated the neighborhood during its final phase as infamous maritime district.

18 Davids, "De 'rosse' Kaap," 164-9.

19 K. Kapitany, *Rapport onderzoek Katendrecht: Een onderzoek onder wijkbewoners* (Rotterdam: Raad voor het Maatschappelijk Welzijn, 1973), 36-7, Rotterdam City Archives, https://hdl.handle.net/21.12133/BC3FDC9990BD49CFBB6696A13FAB1429; Projektgroep Katendrecht, *Beleidsplan Katendrecht* (Rotterdam: Projektgroep Katendrecht, 1977), 40-1, Rotterdam City Archives, https://hdl.handle.net/21.12133/FA082FB495B74FE58799A93D9A823CFB.

20 Davids, "De 'rosse' Kaap," 169.

Walking Interviews: Multidimensional Mapping Potential

Contemporary redevelopment and gentrification of urban waterfront areas has stimulated research on local residents' recollections regarding changes in their direct living environment. Interviews are often used in such studies to collect resident perspectives and opinions on neighborhood changes.[21] Some scholars have taken this a step further by conducting walking interviews, as "walking and talking can intimately capture people's feelings about place, and act as a powerful way of communicating about (urban) memories."[22] Methodologically, walking interviews necessarily comprise a simultaneity of actions, from walking along with interviewees to listening to (and often asking for further clarifications of) their descriptions and recollections of the traversed environment, as well as perceiving this very environment on the basis of participants' on-the-spot contextualizations.[23] Adopting this methodology comes with making certain trade-offs regarding the course of the interviews and the depth of obtained information, among others. This further relates to the degree of autonomy granted to interviewees in determining the walking route, but also to the particular types of data (and their level of structuredness) one wants to single out from the walks, and by which means these are further investigated.[24]

In some of the previously referenced studies, maps are used to mark significant sites of memory and routes of local culture, as foregrounded by interview participants. In this way, maps serve rather descriptive purposes,[25] while leaving their more intricate spatial-analytical potential largely untapped. Other studies build on the layering potential of maps to incorporate different types of, participant-specific, data, which often requires

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21 See for instance Philip Kasinitz and David Hillyard, "The Old-Timers' Tale: The Politics of Nostalgia on the Waterfront," *Journal of Contemporary Ethnography* 24, no. 2 (1995): 139-64, https://doi.org/10.1177/089124195024002001; Wonneberger, "The End of "Community"?"; Laura Balderstone, Graeme J. Milne, and Rachel Mulhearn, "Memory and Place on the Liverpool Waterfront in the Mid-Twentieth Century," *Urban History* 41, no. 3 (2014): 478-96, https://doi.org/10.1017/S0963926813000734; and Brian Doucet and Daphne Koenders, "'At Least It's Not a Ghetto Anymore': Experiencing Gentrification and 'False Choice Urbanism' in Rotterdam's Afrikaanderwijk," *Urban Studies* 55, no. 16 (2018): 3631-49, https://doi.org/10.1177/0042098018761853.

22 David Adams and Peter Larkham, "Walking with the Ghosts of the Past: Unearthing the Value of Residents' Urban Nostalgias," *Urban Studies* 53, no. 10 (2016): 2007, https://doi.org/10.1177/0042098015588683.

23 Jean-Paul Thibaud, "La méthode des parcours commentés," in *L'espace urbain en méthodes*, eds. Michèle Grosjean and Jean-Paul Thibaud (Marseille: Editions Parenthèses, 2001), 81. See also Kusenbach, "Street Phenomenology," further framing the method's potential from an ethnographic research perspective; and Maggie O'Neill and Brian Roberts, *Walking Methods: Research on the Move* (Abingdon and New York: Routledge, 2020), for a more comprehensive overview of this research methodology.

24 Maciej Kowalewski and Robert Bartłomiejski, "Is It Research or Just Walking? Framing Walking Research Methods as "Non-Scientific"," *Geoforum* 114 (2020): 60-1, https://doi.org/10.1016/j.geoforum.2020.06.002; Evans and Jones, "The Walking Interview," 849-58.

25 Balderstone, Milne, and Mulhearn, "Memory and Place on the Liverpool Waterfront," 480-4; Adams and Larkham, "Walking with the Ghosts of the Past," 2007.

more structured and survey-like research approaches,[26] and may potentially impede the spontaneous nature central to walking interviews.[27] In addition, previous map-based studies seem to forego another dimension inherent to the act of walking, namely 'time'. As walks rarely progress uninterruptedly, taking into account the accompanying temporal dimension can add additional insights to a certain spatial trajectory.

Here, it proves fruitful to highlight the classic methodological framework of time geography, originally developed by Torsten Hägerstrand in the 1960s-70s, which has taken both spatial and temporal dimensions into account in investigating people's quotidian transportations and interactions.[28] Hägerstrand formulated his central objective, to "understand better what it means for a location to have not only space coordinates but also time coordinates,"[29] particularly with an eye on transportation planning contexts. His proposed methodology for instance proved suitable for research on daily commuting, even up until today when such studies have also started to focus more on individual experiences of space, thereby actually bridging some ground with walking interview methods.[30] While Hägerstrand's time geography framework came with an extensive scientific notation system, its core methodological elements have been taken up and adapted across different disciplines.[31] For the Katendrecht walking interviews, the construction of space-time paths has been adopted to map and investigate the different individual walks after they were conducted.

Space-Time Paths: Interview Setup and Mapping Outcomes

Twelve individual walking interviews of approximately one hour were carried out in Katendrecht during the summer season, when the weather did not impose any issues on the walks themselves. The twelve respondents who participated had initially reacted to an interview call that was advertized across local media, history and community platforms in

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26 See for example Julie Bergeron, Sylvain Paquette, and Philippe Poullaouec-Gonidec, "Uncovering Landscape Values and Micro-Geographies of Meanings with the Go-Along Method," *Landscape and Urban Planning* 122 (2014): 108-21, https://doi.org/10.1016/j.landurbplan.2013.11.009; and Angeliki Gazi, Charalampos Rizopoulos, and Yiannis Christidis, "Localizing Emotions: Soundscape Representations through Smartphone Use," *Psychology: The Journal of the Hellenic Psychological Society* 23, no. 2 (2018): 69-85, https://doi.org/10.12681/psy_hps.22791.

27 Bergeron, Paquette, and Poullaouec-Gonidec, "Uncovering Landscape Values and Micro-Geographies of Meanings," 119.

28 Hägerstrand, "What about People in Regional Science?" 7-21.

29 ibid., 9-10.

30 See for example Julia McQuoid and Martin Dijst, "Bringing Emotions to Time Geography: The Case of Mobilities of Poverty," *Journal of Transport Geography* 23 (2012): 26-34, https://doi.org/10.1016/j.jtrangeo.2012.03.019; and Heike Marquart, Uwe Schlink, and S. M. Shiva Nagendra, "Complementing Mobile Measurements with Walking Interviews: A Case Study on Personal Exposure of Commuters in Chennai, India," *International Journal of Urban Sciences* 26, no. 1 (2022): 148-61, https://doi.org/10.1080/12265934.2020.1871060.

31 Shaw, "Time Geography," 1-2.

Rotterdam. The respondents were selected for the interviews on the basis of the fact that they had lived in Katendrecht in the 1970s, when local protests against the sex industry and in favor of urban renewal intensified. Respondents were given instructions before the walks and signed an informed consent form guaranteeing their voluntary and anonymous participation. The total group of interviewees consisted of eight male and four female participants, with ages ranging from 60 to 86. Further information on respondents' social background was not recorded, to keep participation thresholds low while acknowledging the local sensitivity that still surrounds Katendrecht.

As became evident during the interviews, the twelve participants made up a rather homogeneous group. The majority of participants were born in Katendrecht and had moved out of the district during the 1970s. Most participants would still frequently visit Katendrecht nowadays. The majority of participants also shared the fact that they had attended schools outside of Katendrecht. While the interview call was openly distributed, it arguably remained prone to effects of (self-)selection and response biases: people who look back on their time in Katendrecht more positively, for instance because they were able to receive education outside of the neighborhood that potentially benefited their personal development later on, may have been more inclined to revisit the district for an interview. The group of respondents may thus have produced a positive bias in evaluating Katendrecht's current state. While the obtained interview outcomes may therefore not simply be generalized, different personal views on Katendrecht's past and present were elicited through the walks. These could be detected afterwards by mapping the interview routes and uncovering their spatio-temporal overlaps.

"In time-space the individual describes a *path*," Hägerstrand remarked.[32] As mentioned before, participants were given the opportunity to freely determine their interview paths themselves, starting from their past or current family address, while a sound recorder and GPS tracker were used to capture the interview data. Questions posed during the interviews were also not predetermined, but primarily revolved around asking participants further clarifications on particular viewpoints they expressed about the neighborhood, in such ways as to retain the flow of a natural, open conversation. Temporal interruptions during the walks were explicitly accepted and acknowledged, not only to provide a comfortable atmosphere for participants and install a sense of 'shared authority' in carrying out the interviews,[33] but also for the comparative mapping purposes.

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32 Hägerstrand, "What about People in Regional Science?" 10 (emphasis in original).

33 Bergeron, Paquette, and Poullaouec-Gonidec, "Uncovering Landscape Values and Micro-Geographies of Meanings," 119-20. For more info on 'shared authority' in the context of oral history research, see Alistair Thomson, "Sharing Authority: Oral History and the Collaborative Process," *The Oral History Review* 30, no. 1 (2003): 23-6, https://doi.org/10.1525/ohr.2003.30.1.23, building on Michael Frisch, *A Shared Authority: Essays on the Craft and Meaning of Oral and Public History* (Albany: State University of New York Press, 1990).

FIG. 3 Overview of Katendrecht walking interviews, mapped as space-time paths, with ephemeral standstills highlighted in black.

To further grasp the temporal dimension of the walks, it proves necessary to distinguish between ephemeral and more substantial 'standstills', as this also further informs the interpretation of participants' perspectives on the neighborhood, as discussed later. Some pauses during the walks simply occurred because of the crossing of streets, the general pace of some of the walks, or because it was easier for participants to briefly halt when explaining something. Other temporal interruptions carried more meaning and were often lengthier, when it involved a particular place or observation in the neighborhood that a participant wanted to explain in more detail.[34] In considering how the walking interviews not only unfolded in space but also through time, the resulting paths "can easily be shown graphically if we agree to collapse three-dimensional space into a two-dimensional plain (...) and use perpendicular direction to represent time."[35] These directives were followed in mapping the walking interviews: **Figures 3-5** show the visual representation of all Katendrecht walking interviews as space-time paths, mapped in QGIS, whereby the time passing during the interviews is represented through the upward movement of paths along a perpendicular z-axis. Through this particular mapping approach, standstills thus manifest themselves as vertical interruptions in the space-time paths.

Mapped as space-time paths, the collection of walking interviews reveals different overlaps in terms of routes that were taken and types of standstills that occurred along the way. While Hägerstrand stated that "a living body subject, [is] endowed with memories, feelings, knowledge,

34 In general, ephemeral standstills lasted no longer than a couple of minutes, while substantial standstills could last much longer.

35 Hägerstrand, "What about People in Regional Science?" 10.

FIG. 4 Overview of Katendrecht walking interviews, mapped as space-time paths, with substantial standstills highlighted in black.

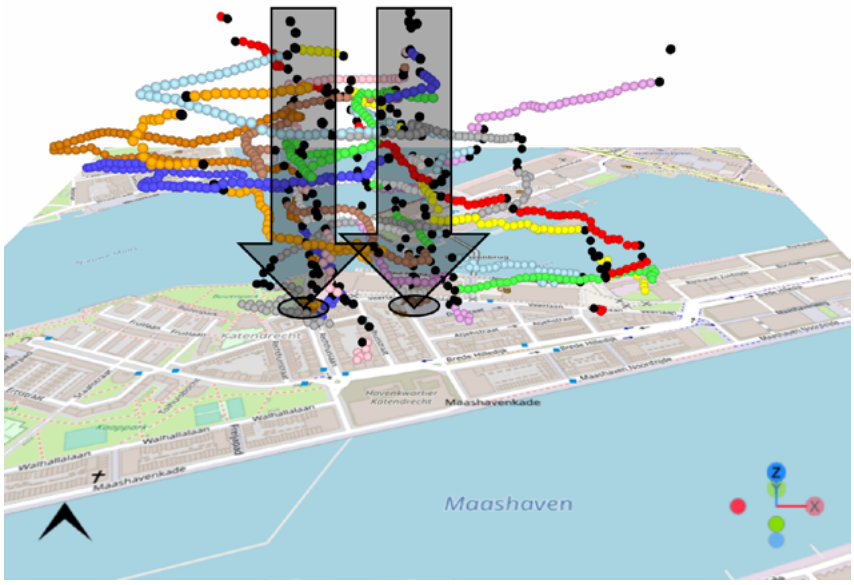

FIG. 5 Overview of Katendrecht walking interviews, mapped as space-time paths, with substantial standstills highlighted in black and arrows capturing clusters of standstills around Rijnhaven park entrance (left arrow) and Deliplein square (right arrow).

imagination and goals (...) decisive for the direction of [its] paths,"[36] an aggregation of this kind of information can move beyond individual perspectives and uncover broader patterns. The remainder of this article analyzes the space-time paths in this vein, i.e. by identifying main trends that the walking interviews' mapping makes visible, and subsequently linking this to commonalities expressed by participants during the interviews about certain spots and features in redeveloped Katendrecht. The following analysis therefore only limitly quotes interview excerpts, which were

36 Torsten Hägerstrand, "Diorama, Path and Project," *Tijdschrift voor Economische en Sociale Geografie* 73, no. 6 (1982): 324, https://doi.org/10.1111/j.1467-9663.1982.tb01647.x.

automatically transcribed after the walks,[37] and instead builds its arguments on key spatio-temporal insights.

First of all, different patterns can immediately be observed in the interview walks' ephemeral and substantial standstills across Katendrecht (Fig. 3-4). Ephemeral standstills are spatially scattered across the neighborhood: they do not immediately link to central spots in the area, although a large share occurred during interview passages through Katendrecht's core historical streets. At present, Katendrecht's central streets only house few retail shops. During the interview walks, various interviewees considered this a prominent lack (Respondent 1 (R1), R2, R5, R11, R12), especially when drawing comparisons to the many local retail businesses that marked Katendrecht's street sceneries in the past. Many of the ephemeral standstills during the walks arose when interviewees took a short break to reminisce over which local business used to be housed in a certain building. Often going hand in hand with such recollections were positive observations about recognizable historical facades that were recently renovated.[38] These ephemeral standstills thus produced interruptions during the walks in which participants balanced off and regarded typical signs of contemporary gentrification processes (the disappearance of local enterprises and the upgrading of historical buildings) in opposing ways.

Moving to the overview of substantial standstills, the space-time paths provide a less scattered impression (Fig. 4). Along the mapped time dimension, two perpendicular clusters of standstills can even be discerned, pointing to two nearby places in Katendrecht. The first one of these is Katendrecht's Deliplein square (Fig. 5, right arrow). Functioning as epicenter of the district's notorious pleasures until the 1970s, this square in the middle of Katendrecht now concentrates many of the neighborhood's new establishments, both commercial (bars and restaurants) and cultural (theater and museum venues). The interview mapping suggests that the Deliplein's role as cornerstone of Katendrecht's current socio-cultural revitalization cannot be overstated: the aggregation of mapped interview paths indicates that almost all interviewees made a prolonged stop near the Deliplein. In doing so, they often described the square's change of character since the 1970s. Also eagerly sought out by many interviewees was a park by the Rijnhaven waterside (Fig. 5, left arrow). This small open park repeatedly facilitated reflective standstills among participants. One respondent (R7) for instance recalled youthful swimming adventures

37 For an accompanying study that does use interview excerpts as main source of analysis, specifically to investigate issues concerning authenticity during the walks through Katendrecht, see Susan Hogervorst and Vincent Baptist, "Urban Redevelopment and the Role Played by Former Inhabitants in the Authentification of Katendrecht, Rotterdam," in *Urban Authenticity and Heritage after 1945: Creating and Contesting Identities and Images in European Cities*, eds. Achim Saupe, Christoph Bernhardt and Daniel Hadwiger (Abingdon and New York: Routledge, forthcoming). At the time of writing, a selection of the Katendrecht interview material was also being prepared for archiving in the Rotterdam City Archives collections.

38 See Hogervorst and Baptist, "Urban Redevelopment and the Role Played by Former Inhabitants," for further arguments linked to 'urban authenticity'.

by the park's quays, while also remarking how dangerous Katendrecht's past industrial landscape used to be for children left unattended. In that respect and with an eye on the future, R7 felt strongly about the area's recent clean-ups, despite nostalgic sentiments that arguably also keep playing a role:

> Nothing is forever… Things become different at some point, and that is not bad at all. Those older generations who live or used to live here, they always have a longing for the past, but also a longing for a better future.[39]

Lastly, the opposing connections between the Rijnhaven and Maashaven docks can be highlighted. As the northern Rijnhaven side partially maintains an open view through the aforementioned park, appreciated by former residents, the southern Maashaven waterfront has instead systematically been filled up with new housing blocks, replacing old industrial storage facilities. This transformation started a few decades ago, and is emblematic of contemporary waterfront redevelopment processes in other port cities too. Many interviewees (R2, R3, R4, R7, R12) stood still at some point during their walks to comment at length on the Maashaven buildings' physical properties and spatial layout, although they always did so while keeping a substantial distance from the newly built constructions. This attitude during the interviews seemed to tie in with shared critical comments about various of the Maashaven's housing projects, which participants often considered disproportionate and aesthetically unpleasing in appearance. One respondent (R1) for instance lamented the buildings' rather asocial grouping and orientation blocking the water:

> Those harbor sheds weren't as high as those houses. And when it was evening, you could see the lights on the other side [of the water, in the past]. (…) Now people come home in the evening, and they have the kitchen downstairs next to the outside door, but the living room is at the back. And when the children then go to bed, all the lights go out. So when you arrive [in this street at the Maashaven side], it's all black, all dark…[40]

The fact that none of the interviewees felt inclined to cross the street along the Maashaven to approach its new buildings can be discerned from the mapped walking routes. Keeping their original three-dimensional structure in mind, none of the space-time paths end up closely to the Maashaven side, leaving it an empty area on the overview. Aided by this mapping approach, geospatial 'gaps' can thus also be identified and further investigated.[41]

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39 Vincent Baptist, *Interview with R7* (2022).

40 Vincent Baptist, *Interview with R1* (2022).

41 Cf. Carola Hein and Yvonne van Mil, "Mapping as Gap-Finder: Geddes, Tyrwhitt, and the Comparative Spatial Analysis of Port City Regions," *Urban Planning* 5, no. 2 (2020): 152-66, https://doi.org/10.17645/up.v5i2.2803. See also Bergeron, Paquette, and Poullaouec-Gonidec, "Uncovering Landscape Values and Micro-Geographies of Meanings," 120.

Conclusion

In a recent report of the PortCityFutures research group, a visit to Katendrecht's Deliplein turns into the question of who is most responsible for gentrification processes occurring along Rotterdam's waterfronts: is it the architects and planners who envision the neighborhood's new facilities, or rather the politicians and policymakers instructing them, or even other parties altogether?[42] This is telling for the discussions that often arise about gentrification. This article's case study has followed a different approach by conducting participatory research with old Katendrecht residents themselves, through walking interviews with non-predetermined routes. This methodological setup does come with limitations and biases, and ultimately "can never be completely spontaneous, as it always involves a minimum degree of deliberate co-construction on the part of the researcher and the participant."[43]

Nevertheless, the conducted interviews have generated a range of opinions on local neighborhood changes, from rejection of new building projects by the waterfront to appreciation of old building facades' renovations, and more ambivalent reflections between nostalgic local sceneries and future-oriented neighborhood improvements. The adopted mapping approach, combining interview walks' spatial and temporal data dimensions, has allowed to identify patterns that go beyond individual testimonies. It reveals a new topography of Katendrecht as gentrifying port city district, where the meaning and significance of certain local spaces connect to the duration and frequency of people's standstills during the walks. The underexplored dimension of time in both geospatial analysis and gentrification research is directly activated through this methodological approach, but its potential for further implementation also reaches beyond the specific context of gentrification or port cities. In the case of Katendrecht, at least, the mapping of interview routes for overarching interpretations of underlying patterns better illuminates the paths taken by this maritime urban district, navigating its way out of past controversies and into new ones defining the contemporary port city.

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42 Sabine Luning, Carola Hein, and Paul van de Laar, "PortCityFutures in Rotterdam: Conversations on the Waterfront," *Leiden Anthropology Blog*, February 9, 2021, https://www.leidenanthropologyblog.nl/articles/portcityfutures-in-rotterdam-conversations-on-the-waterfront.

43 Bergeron, Paquette, and Poullaouec-Gonidec, "Uncovering Landscape Values and Micro-Geographies of Meanings," 120.

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The reclaimed agricultural territory of the province of Ferrara, between the city (top left) and the Adriatic Sea.

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MAIN SECTION

Critical Notes on Mapping the Mobility of Agricultural Workers in the Province of Ferrara: the (Ethical) Importance of Opacity.[1]

The paper was conceived and structured jointly by the two Authors, who co-wrote the "Introduction" and the final section ("Critical Mapping: The (Ethical Importance of Opacity"). Elena Dorato wrote paragraphs 1 ("Agri-Food Production, Exploitation and Rural Mobilities in Ferrara's Province") and 2 ("The Project: Mapping the Home-Work Mobility of Agricultural Workers"), while Richard Lee Peragine wrote paragraph 3 "The Contradictions of Visualizing Agricultural Work Relations"

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ABSTRACT
This article presents an on-going research project developed by the Department of Architecture of the University of Ferrara and AMI Ferrara regarding home-work mobility patterns in local agro-industrial production. By combining quantitative and qualitative research tools (i.e. literature review, surveys, interviews, GIS-mapping), this research originally aimed to research habits, needs, and propensity to change of agricultural workers in the area in relation to home-work mobility. The investigation therefore necessarily has to confront "caporalato". Bearing in mind existing power relations and the inherent opacity of dynamics in agricultural work, we highlight the difficulties encountered by the mapping campaign, as well as the dangers of its instrumentalization when addressing such work relations. By emphasizing the tendency of agricultural day-labourers to defy localization, we aim at departing from this lack (or absence) of information to suggest the relevance of a critical approach to mapping in contemporary racial capitalism. The paper finally proposes substantial theoretical frameworks, extensive field research and investigative campaigns on-the-ground in contrast to the strictly vertical, top-down and technocratic approach of traditional mapping, in order to answer to mobility habits and needs of agricultural workers.

KEYWORDS
critical mapping; survey; caporalato; rural mobility; agro-industrial production

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Introduction

This paper sets out to discuss mapping agro-industrial workers' mobility patterns in the north-eastern Italian province of Ferrara. Mobility in agricultural labour is, in fact, the object of an on-going research at the Department of Architecture of the Ferrara University together with AMI Ferrara, the local Agency for public transport and mobility-related facilities, aimed at providing alternative forms of transport to those arranged through "*caporalato*": a practice whereby the recruitment and payment of day-laborers - in this case in agriculture - is subcontracted to a gangmaster, or, in Italian, a *caporale*.

However rightful in its aspirations, charting the mobility of agricultural workers raises ethical questions concerning the operativity of the practice of mapping itself and highlights the fact that, in capitalist modes of production, alternative forms of transport alone arguably will not be able to overcome *caporalato*. On the contrary, this would require a multi-level, comprehensive political and economic adjustment. In this sense, we will posit an alternative form of mapping which departs from such a critical stance, and calls for substantial theoretical frameworks, extensive field work and investigative campaigns on-the-ground that counter the predominantly vertical, top-down and technocratic approach of traditional mapping.

Mobility is central to the organization of *caporalato* since workers are usually forced to pay for car-rides to and from work. This payment however stands for the multifarious ways in which such mobility arrangements entrench workers' exploitation in agricultural production, that is: a) by allowing *caporalato* to violently appropriate significant parts of workers' wages in exchange for transport (and other essential services), thereby indebting workers and reducing actual retributions, as well as contractual bargaining power; b) by pushing migrant day-labourers into relations of dependency *vis-à-vis* the mobility of *caporalato*, all the more so since this mediation intersects the spatial segregation produced by peripheral accommodations, one that cuts off migrant workers from essential services or support and also splinters political organization; c) by organising, often through physical and psychological coercion, a cheap and pressured labour force, in order to preserve labour productivity for producers and answer the demanding requests of large-scale retail distribution. More accurately, then, mobilities play a key role in (re)producing *caporalato* itself, as well as workers' exploitation in agro-industrial production.[2]

The project we will describe comprises qualitative research regarding the current situation of agricultural production in the country, lengthy institutional negotiation, interviews and questionnaires, field surveys and the

2 Osservatorio Placido Rizzotto - FLAI-CGIL, VI Rapporto Agromafie e Caporalato (Roma: Futura Editrice, 2022).

design of potential new mobility services (through changes to existing lines of public transport, the implementation of new, tailored services, or the activation of private contractors). One of its main prerequisites is being able to *map* the specificities of home-work rural mobility across Ferrara's vast landscape of agricultural production. However, mapping, in the initial phase of this project - that which, for the most part, will be described in this contribution - has strayed from a properly cartographic dimension and rather comprised a set of actions which together constitute the preconditions of cartographic work itself, namely, examining inherently opaque information, as well as navigating private and institutional power relations at work in the process of gathering data. In other words, the aim is to highlight how the constitutive opacity of agricultural work, and the ethico-political implications arising from this condition, mean that such a project of mapping is not without its limits and contradictions. We thus intend opacity, not as a synonym for illegality, but, quite literally, as a quality proper to that which is difficult to understand or locate, and, thus, to map.[3]

Yet, the wager of what follows will be that these difficulties do not, or should not, constitute an impossibility that can be circumvented via a refinement of technological means, or through the insistent proposal of new questionnaires, but are actually a further reason to address them by suggesting alternatives to current forms of mobility and, in broader terms, production. In this sense, a critical reflection on mapping in relation to this research cannot but expose the point at which mapping comes up against a form of unpredictability that cannot be overcome by traditional mapping itself, but requires strengthening alliances with more qualitative, on-the-ground approaches.

We will firstly contextualize our research project within agricultural production in Italy, highlighting the structural issue of, as well as the State's current disposition and action plan toward workers' exploitation and *caporalato*. Secondly, we will present our ongoing research project concerning mobility in the Eastern section of Ferrara's province and, thus, detail the process, results and limitations of such a work, specifically with regard to mapping. Finally, we will try to argue that the unsurmountable gaps in and resistance to the process of mapping in this project might be understood as information in themselves, yet a sensitive one which must be critically addressed.

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3 In this sense, we will not engage with the ontological argument regarding opacity that is famously associated with French-Martiniquan poet and philosopher Édouard Glissant; see, in particular, Poetics of Relation (Ann Arbor: University of Michigan Press, 1997). This however does not mean we do not acknowledge the fertility of the notion of opacity, and of other concepts developed by Glissant, to the fields of geography - Heidi Bojsen, Géographies Esthétiques de L'imaginaire Postcolonial (Paris: Editions l'Harmattan, 2011) - urban studies - Abdoumaliq Simone, Improvised Lives. Rhythms of Endurance in an Urban South (Cambridge: Polity, 2018) - or urbanism - Garth Myers Rethinking Urbanism. Lessons from Postcolonialism and the Global South (Bristol: Bristol University Press, 2020). On opacity as a lens to study the intersections between urbanisms and agricultural work in Southern Italy, see Camilla Rondot, Abitare l'Opacità (Siracusa: LetteraVentidue, 2022).

Agri-Food Production, Exploitation and Rural Mobilities in Ferrara's Province

The mediatic attention given to violent and tragic episodes during work, in particular to Satnam Singh's gruesome death in the Agro-Pontino on June 19, have so far made 2024 a year of political fermentation around the issues of *caporalato* and workers' exploitation in the agri-food industrial complex. Grisly injuries and deaths in connection to agriculture have made the exploitation of predominantly migrant day-laborers surface intermittently in the media at least since the 1980s.[4] Once again, recent episodes have brought under the spotlight the insistence of a "submerged" feature in Italian agricultural production that, with variations, has actually characterized Italy since its post-unitary period,[5-6] if not earlier.[7] Within the scope of the Next Generation EU-funded National Recovery and Resilience Plan (PNRR), one of the stated goals of current political initiatives by the Italian state in this context has been that of overcoming exploitation in agricultural work, along with migrant ghettos and encampments that revolve around agri-food production and maintain relationships with criminal networks. So far, this strategy has amounted to little change. On the other hand, the rhetorical power and spectacularization implicit to its narrative fail to recognize exploitation as a structural, deep-rooted characteristic of agricultural work in capitalist modes of production.

This aspect of agro-industrial production in Italy speaks volumes about the (dis)continuities in the project of national unification, as well as its contemporary ramifications: from land reclamation and rural mobilities[8] at the hands of foreign investors or the Piedmontese government in the late nineteenth century, through Fascist and post-WWII mass emigration, urbanization and developmental policies, to the current intersections between the carceral geographies of migration to the European Union, global commodity chains and racialized labour. In this sense, Satnam Singh's death must be considered as part of a long history of violence and struggles associated with agricultural production in Italy.

In fact, as geographer Timothy Raeymakers makes clear in his recent book "The Natural Border", the bordering regime which permits the exploitation of agri-food workers today in the peninsula is an ingrained character of the Mediterranean agrarian mode of production, insofar as it prolongs the

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4 Enrico Pugliese, L'Italia tra Migrazioni Internazionali e Migrazioni Interne (Bologna: il Mulino, 2002).

5 Irene Peano, "Spatiotemporal Stratifications: Engaging Containment and Resistance in Italian Agrifood Districts," Public Culture 34, no.3 (2022): 385-392; Pino Arlacchi, La Mafia Imprenditrice. Dalla Calabria al centro dell'inferno (Milan: Il Saggiatore, 2007).

6 Pino Arlacchi, La Mafia Imprenditrice. Dalla Calabria al centro dell'inferno (Milan: Il Saggiatore, 2007).

7 Timothy Raeymakers, The Natural Border (Ithaca and London: Cornell University Press, 2024).

8 Micheal Bell and Giorgio Osti, "Mobilities and Ruralities: An Introduction," Sociologia Ruralis 50, no. 3 (2010): 199-204.

geographies of racial and economic differentiation produced by the slave trade in the Mediterranean which contributed to the shift from a feudal society to an incipient form of capitalism. Raeymakers calls this historical process of racial division "natural racialization", to account for the ways in which multiple racisms naturalize certain groups into permanent forms of non-belonging within liberal capitalist societies. In this context, EU-funded state politics, such as that of "overcoming" rural labour encampments in Italy, are ambiguous *vis-à-vis* the contemporary agri-food industrial complex, and serve a two-fold (and two-way) purpose: through a selective process of inclusion/exclusion,[9] the State discharges elementary social reproduction onto the workers themselves but seizes on it by sustaining illegal forms of intermediation and employment in agricultural production. In other words, while condemned, *caporalato* and worker's exploitation are functional to the State's capitalist accumulation. We might then actually refer to a form of "*caporalato* capitalism," or:

> "a mode of production and exploitation that thrives on the historical relation between labour, capital and public authority in the domain of industrialized agriculture, and which continues to reproduce migrant labour as an adversely incorporated force that produces wealth."[10]

Compared to a slightly higher rate (40%) in the South, similar forms of labour exploitation are also significantly present in Central and Northern regions of Italy, where irregular work constitutes 20 to 30% of total.[11] Rather than a matter of "rotten apples," these phenomena permeate agricultural production at its core, thereby problematizing the racist and urban-centric view that *caporalato* and workers' exploitation are exclusively rural and backward dynamics connected to the mafia (*viz*., Southern), or accidental events.

Although the area has not been the object of research in relation to agricultural exploitation, one of such territories in the North of Italy indicated in FLAI-CGIL's Report is the province of Ferrara, that is, the focus of our research project. Such a research deficit is all the more noticeable given that the largest land-reclamation projects in the peninsula fall under the provinces of Ferrara and Rovigo. Today this part of the Po Valley (*Pianura Padana*) is in fact home to some of the largest agricultural production facilities in Italy. However, the Eastern section of Ferrara's province is also one of the very few non-mountainous areas in Italy among the many "Aree Interne"(*internal areas*) defined by the Strategia Nazionale Aree Interne (2012-2020).[12] It is, in fact, characterized by low population density, low

9 Sandro Mezzadra and Brett Neilson, Border as Method. Or the Multiplication of Labor (London and Durham: Duke University Press, 2013).

10 Domenico Perrotta and Timothy Raeymaekers, "Caporalato Capitalism. Labour Brokerage and Agrarian Change in a Mediterranean Society," The Journal of Peasant Studies 50, no. 5 (2022): 3.

11 Osservatorio Placido Rizzotto-FLAI CGIL, VI Rapporto Agromafie e Caporalato, 25-26.

12 For further information, please see: https://www.camera.it/temiap/documentazione/temi/pdf/1375588.pdf?_1702652730824

birth rates and an aging population, high rates of land abandonment and an overall deficiency of public services, including mobility, which contribute to a generalized lack which affects not only seasonal migrant workers, but the local population as a whole.[13] *Caporalato*, in particular, is reinforced by the specificities of this territory: such a spatial segregation, the lack of mobility services and infrastructure, in fact, allow *caporali* to hold a monopoly on mid- and long-distance home-work mobility and thus, as highlighted above, also on other aspects of the everyday life of workers.

FIG. 1 The reclaimed agricultural territory of the province of Ferrara, between the city (top left) and the Adriatic Sea.

Territorial deprivation, exploitation and rural mobilities in the province of Ferrara have been documented since the end of the post-unitary period. Land reclamation and the late (and relatively contained) industrialization brought about a substantial transformation of social relations and modes of production which, until then, were for the most part predicated on cattle agreements (a kind of customary salaried relationship) and large masses of farm-laborers. As described by the social historian Michele Nani, land newly colonized as a result of vast engineering projects created large concentrations of land ownership, as well as a mobile rural proletariat that merged into the previous trajectories of labour mobility.[14] *Caporali*, initially political or religious mediators acting between landowners and the many agricultural workers (*boari, braccianti, garzoni*, depending on their skills, mobility and status), were crucial in this context. The need for non-local workers was then a result of the transformations of agricultural enterprises, both in terms of size and structure. Faced with large class struggles and strikes at the turn

13 Elisa Vitale Brovarone, Giancarlo Cotella and Luca Staricco, Rural Accessibility in European Regions (London: Routledge, 2022).

14 Michele Nani, "Uno sguardo rurale. Le migrazioni interne italiane viste dalle campagne ferraresi dell'Ottocento," Meridiana 75 (2012): 27-57.

of the 19th century, the *caporale* took on a conflictual role.[15]

The mediation by *caporali* is then not the result of an accidental convergence between the relatively small-size of farms (especially in the South), high numbers of non-European migrants and criminal activity - although the intensification or presence of each of these aspects is strictly connected to it - but a structural feature of agricultural production which today takes on new forms and relations, also within the organization of large and successful companies.[16] The agri-food industry ultimately makes racialized bodies pay the brunt of its low profits in the context of global supply chains.

While its intensity may not be comparable to other regions of Italy such as Foggia's Capitanata,[17] the Piana di Gioia Tauro[18] or the Piana del Sele,[19] *caporalato* and workers' exploitation in the province of Ferrara, especially in the area of Portomaggiore, have activated local institutions and led to punitive actions against gangmasters and illegal labour recruitment since 2018, as well as a large investigation into subcontracting and exploitation in 2017, following a fatal road accident.[20] In June 2024, going home after their shift at a local plant nursery, two Pakistani men died and five more were injured when an Opel Zafira crashed into a canal close to Portomaggiore, just a couple of days before Satnam Singh's death.[21]

Fatal episodes in the Eastern province of Ferrara thus paint a stark picture of the exploitation of day-labourers. The *Rete Lavoro Agricolo di Qualità*(Quality Agricultural Work Network)[22] has been recently created precisely to mobilize a set of actions, among which are interventions in terms of mobility, that is, the object of our specific research project.

Yet, as put by Mezzadra and Neilson: "[t)he control of labour mobility is also one of the key sites where the expanding frontiers of capital continue to intertwine with political and legal borders".[23] Labour exploitation

15 Michele Nani, "Fattori, caporali e capisquadra. Note su mediatori e «mercato» del lavoro agricolo nel Ferrarese dell'Ottocento," Mélanges de l'École française de Rome - Italie et Méditerranée modernes et contemporaines 129, no.1 (2017).

16 On larger companies producing Made in Italy products, see the detailed acount of prosecco production in Osservatorio Placido Rizzotto-FLAI CGIL, VI Rapporto Agromafie e Caporalato, 211-225.

17 Alessandro Leogrande, Uomini e caporali. Viaggio tra i nuovi schiavi nelle campagne del Sud (Milan: Mondadori, 2008).

18 Irene Peano, "Within and Against Racial Segregation: Notes from Italy's Encampment Archipelago," Lateral: Journal of the Cultural Studies Association 10, no. 2 (2021).

19 Gennaro Avallone, Sfruttamento e Resistenze (Verona: Ombre Corte, 2017).

20 Altro Diritto-FLAI CGIL. 2024. Inchieste in corso di analisi al 2023. Available at: https://www.adir.unifi.it/laboratorio/tabella.htm (last accessed 25th September 2024).

21 The fact that one of the major police operations against workers' exploitation and illicit mediation in the province of Ferrara in 2023 was called "Zafira" already points to the central role played by mobility in the organization of caporalato.

22 The "Rete Lavoro Agricolo di Qualità" is a protocol which should coordinate a common effort among institutions and private companies to prevent illegal work and caporalato in agricultural production so as to support agricultural productivity and Made in Italy products. Ferrara's was established in 2023.

23 Mezzadra and Neilson, Border as Method, 93.

in Italian agro-industrial production, in fact, pivots around mobility, as part of today's "mobility regime"[24] of migration. First, at a large international scale, by fuelling the mechanism of inclusion/exclusion at the border(s) of the EU: long-distance mobilities in which spaces, devices and logistics involved in cross-border movement and reception become the site of exploitation, all the while incorporating cheap labour force; second, at a more localized scale, by replenishing the labour needs of territorial production and dumping the costs of essential services, such as transport, and labour reproduction onto migrant workers;[25] but also, third and last, at the national scale, by establishing forms of internal "hyper-mobility"[26] aimed at disciplining migrant populations and distributing them across the geographic cores of Italian agricultural production. In this sense, mobility is a multi-scalar lens to index the structural exploitation of migrant populations in relation to agricultural production.

Any project that attempts to tackle *caporalato* and labour exploitation through mobility must therefore reckon with the fact mobility does not coincide with the mere transport of people, but is an essential component of the exploitation that is constitutive of capitalist modes of production.

The Project: Mapping the Home-Work Mobility of Agricultural Workers

Bearing in mind the limits and contradictions of the agri-food industry in contemporary capitalism outlined above, this paper will try to engage with one among the spectrum of "solutions" that have been suggested - especially, at the level of institutional policies - to counter the injustices related to agricultural production. We can subdivide these actions into two kinds: a) legal, potentially including changes to residence and citizenship permits, labour policies and healthcare services, but so far limited to actions of a punitive nature, and b) infrastructural, that is, supposedly ameliorative or preventive. The latter kind, which this article will *critically* engage with, advocates for both suitable accommodation and adequate forms of transport to bypass workers' exploitation, as well as the unlawful intermediation of *caporali*.

In this section, we will elucidate the possibility and upsides of such a project of bypassing forms of illicit mobility, while remaining wary of its possible instrumentalization and shortcomings. This critical stance toward the effectiveness of infrastructural actions is not to argue that such interventions might not improve contingent conditions for workers in the everyday,

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24 Mimi Sheller, Mobility Justice. The Politics of Movement in an Age of Extremes (Verso Books: London and New York, 2018).

25 Elena Tarsi, "Quando la mobilità è il parametro dello sfruttamento. Migrazione e agricoltura," Contesti. Città Territori Progetti, 136-151 (2019).

26 Martina Tazzioli, "Governing migrant mobility through mobility: Containment and dispersal at the internal frontiers of Europe," Environment and Planning C: Politics and Space 38, no.1: 3-19 (2020).

but to call for a careful consideration of their capacity to bring real change to the very extractive structure of agricultural work within contemporary racial capitalism.

In the context of current political auspices, and in coordination with AMI, in February 2024 we set out to negotiate and design a local service of transport that could initially facilitate home-work mobility for agricultural labourers working in the Easternmost sections of the Ferrara province, and then, in a second moment, potentially counter the current lack of access to and presence of mobility services which characterizes the predominantly-rural and deprived population of the area. In order to do so, it was necessary to: i) identify and involve private agri-food companies in the region that might be interested in co-funding, or even just formally joining, this project; ii) map the habits, needs and inclination towards change in the mobility patterns of workers (starting from an origin/destination matrix), while answering the requests of such companies; iii) negotiate with AMI possible strategies for implementation and funding to submit to local, regional and, to a lesser extent, national administrations.

The preventive action highlighted above - housing and transport - evidently requires some form of mapping, but faces from its start considerable obstacles: where do the high-number of migrant, seasonal and, potentially, illegal(ized) workers live and work? What are their means of transport? What are their timetables and needs? How can institutions - granted political conditions push them into doing so - respond to this submerged, illegal(ized) or illicit dimension of agri-food production, and, thus, how can mapping produce relevant information, since most of the potential data in itself escapes mapping's definitional hold? One might in fact conclude that while their intention is supposedly that of providing adequate homes and forms of transportation, State institutions have little information regarding existing arrangements in terms of work, inhabitation and mobility, in light of the inherently elusive, mobile and abject forms these have in agri-food production. Moreover, while mapping's shortcomings are thus mostly to do with workers' very conditions of accommodation and mobility, its effectiveness is also obstructed by often-conflictual power relations or, indeed, *power as a relation*.

To clarify these aspects, we will briefly consider an example from our mapping campaign, bearing in mind cartography plays a secondary role in this exposition. Based on the Italian regulatory framework regarding the mapping and monitoring of home-work mobility by employees of companies, organizations and institutions,[27] we devised, in collaboration with AMI, two different questionnaires. The first was submitted to HR managers and aimed at collecting quantitative information regarding

27 "Home-Work Commute Plans" - PSCL(Interministerial Decree No. 179, May 12, 2021, art. 3, paragraph 5. Available online: https://www.gazzettaufficiale.it/eli/id/2021/05/26/21A03111/sg is a law aimed primarily at the reduction of the environmental impact caused by private car use in regular home-to-work commutes.

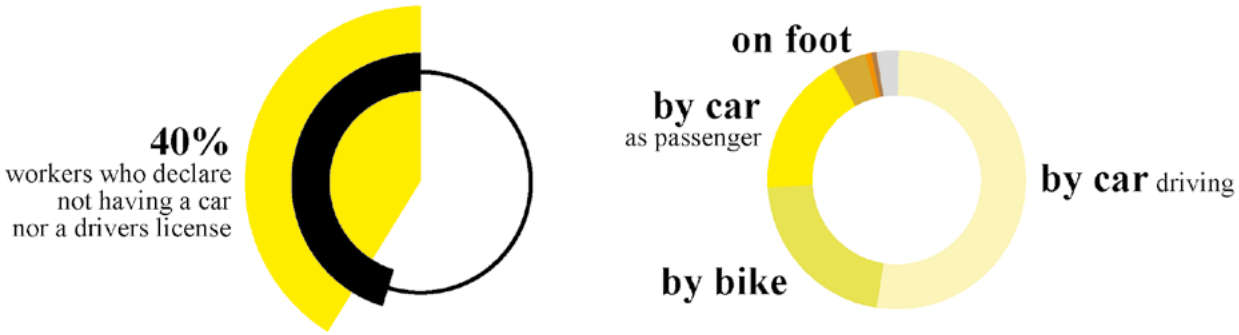

FIG. 2 Some data from the questionnaire submitted to a pool of 547 agricultural workers. Graphic elaboration by the Authors, 2024.

the internal organization, the kind services offered - particularly in support of employee mobility - and the arrangement of work shifts and production cycles in agricultural businesses, while the second was directed at workers. The latter was distributed directly by such companies in Italian, English, and Urdu, with the possibility to either fill it in online, using the businesses' intranet platforms, or through printed forms handed out at the end of work shifts.

This already proved to be more challenging than expected, either because the distribution was not immediate and effective, or due to resistance and refusal by workers to fill in the form itself. The first difficulty stems from the fact of having to negotiate with economic operators the content, anonymity and mode of distribution of the survey - for instance, while anonymous, one of the main companies involved in the project asked workers to sign their survey; or because the questionnaire had to be printed out, possibly due to workers' lack of access to the online form via smartphones. The second difficulty too stems from power relations within the working environment and concerns the extent to which workers ignored, resisted or refused to fill in the survey, at least the first time the survey was issued. The reasons are multiple and cannot be easily categorized, nor do we know, of course, how frequently workers to some extent declined to participate, but we can nevertheless suggest a convergence of several likely factors: our faults in the distribution and content of the questionnaires; high-incidence of asymmetrical contractual relations within the working environment, which, above all, pose a threat to workers with irregular(ized) jobs and juridical status; significant language barriers; inability to read and/or write.

We might further discuss these aspects by briefly focusing on some of the data we were able to collect for one specific agri-food business. The semi-structured questionnaire consisted of 19 questions (15 of which were multiple choice and 4 open-ended), divided into four sections: general information such as home address, gender, age; work shifts; mobility habits regarding home-work mobility; mobility needs and propensity for change. Our survey was answered by 546 workers - a large number, considering the company employs about 600 people. In terms of mobility,

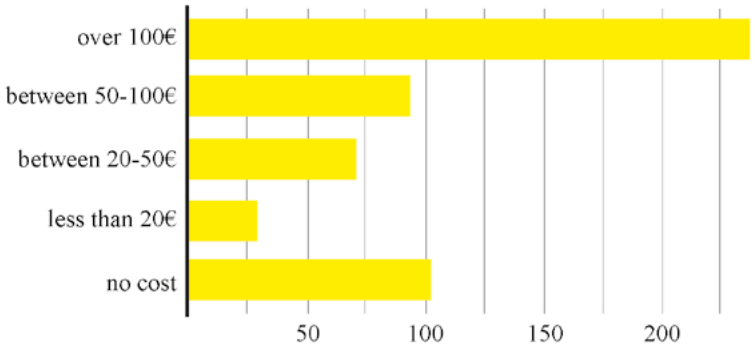

FIG. 3 Answers to question 14: "On average, how much do you spend on transport to and from work per month?". Graphic elaboration by the Authors, 2024.

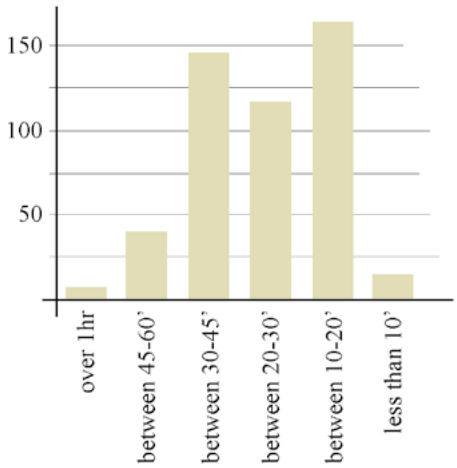

FIG. 4 Answers to question 13: "On average, how long does it take you to get to work?". Graphic elaboration by the Authors, 2024.

323 declared that they owned a car and 221 did not; 288 in fact drive to work, 96 are passengers in someone else's car, and a considerable share of the remaining (117) cycle to work.

Based on our results, 234 of the total 546 employees that answered the survey spend more than 100 euros a month to go to work: a significant amount considered the modest salaries of agricultural workers.[28] We might add to this that 98 people take between 30 and 45 minutes to get to work, 86 between 20 and 30, and 125 between 10 and 20.

Finally, the transfer of this data onto GIS-software shows that Portomaggiore, Ostellato and San Giovanni di Ostellato are the main centers of origin for movements to and from work(Fig. 5) although the actual-route map(Fig. 6) reveals just how far workers actually come in every day - Monselice to the North and Bologna to the South, meaning, a labour pool with a radius of approximately 90 kilometres, spanning across several provinces and two regions.

28 Osservatorio Placido Rizzotto-FLAI CGIL, VI Rapporto Agromafie e Caporalato, 17-29.

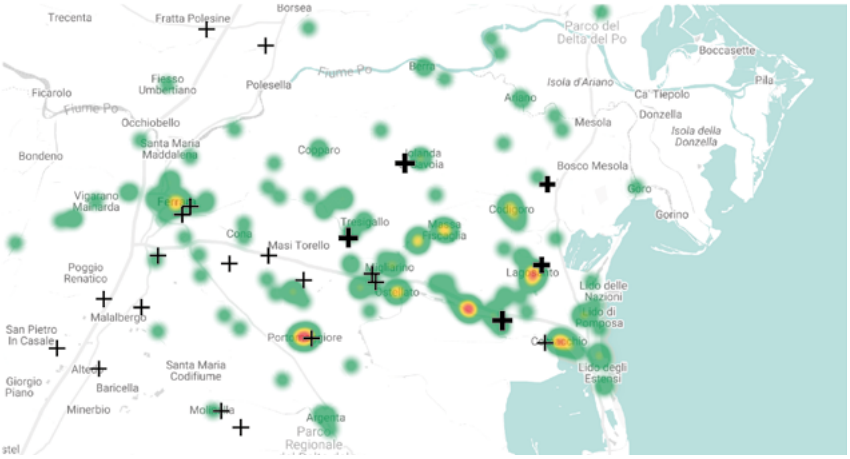

FIG. 5 Heat map showing the origins of workers' daily mobility (i.e. declared place of residence) and the location of the main agri-food companies in the area, as mapped by the Osservatorio Placido Rizzotto. Graphic elaboration by the Authors, based on web-GIS visualization from questionnaire responses.

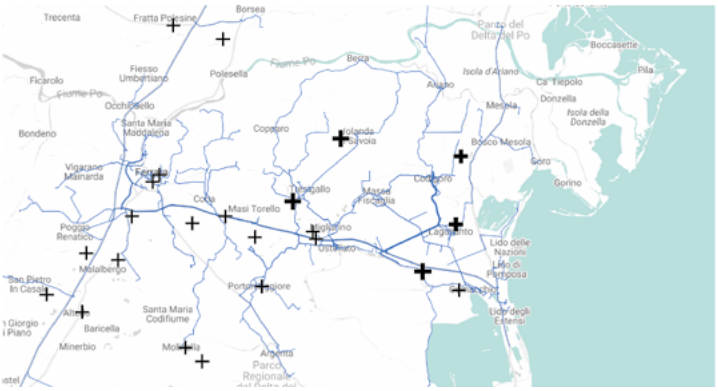

FIG. 6 Route map of daily mobility and the location of the main agri-food companies in the area, as mapped by the Osservatorio Placido Rizzotto. Graphic elaboration by the Authors, based on web-GIS visualization from questionnaire responses.

Taken out of context, part of this data is a fair reflection of the Italian mobility landscape,[29] since more than 52% of the population sample drives into work, spending quite some time of their day (between 60 and 90 minutes) at the wheel. What is surprising, however, is the fact that 21% of the company's workers cycle to work. Unexpected not only in terms of numbers, but also because roads in the area do not have cycling lanes: cycling, in fact, takes place, in most cases, along freeways, next to fast traffic - a dangerous aspect pointed out by many workers in the survey. This high incidence of cycling is due to the fact that most of the workers who cycle live in San Giovanni di Ostellato, a small municipality at about 5 kilometres from the company, most likely in the same residential unit, as confirmed by interviews: several answers to the survey in fact described the same point of origin, if not the same address. Cycling then is not due to an "ethical" or virtuous choice, of course - although it might arguably be more pleasant or convenient than other means of transport for some

29 ISFORT, 20° Rapporto sulla mobilità degli italiani. Il passato, il presente, il futuro. Report, 27 November, 2023. Available at: https://www.isfort.it/wp-content/uploads/2023/12/RapportoMobilita2023_Def.pdf (last accessed 25th September 2024).

- but to social and spatial arrangements produced by the need of cheap, unskilled labour in agricultural work. The risk of analyzing data in purely quantitative terms overlooks the specificities of agricultural production, along with its social and geographical characteristics.

Within the pool of 546 questionnaires that were answered, we can focus on 151 surveys that were printed and filled in by hand by workers in order to further problematize our results and pose relevant questions regarding the efficacy and implications of mapping in such a context. These answers in fact allow us to gather information regarding the habits and needs of mobility of predominantly non-Western European day-laborers in the region, in particular, Pakistani men. In fact, 56 people out of the 151 cycle to work, that is, almost half the total share of those who answered the survey for the whole company; 42 travel as passengers in private cars - again, almost half of all answers; 41 drive into work, that is, a mere 12% of the total who own a car (323), although the sample population (151) is over a fourth of the total (546).

Considering these 151 surveys filled in by hand, we can highlight several issues that cannot be taken at face value, that is, as a mere number to be spatialized on a map: the large-number of bike riders is not a form of "independence" or "green" mobility;[30] among the driving 12% of the 151 who answered the survey by hand some are likely to be the drivers of fellow workers (for instance, drivers of the infamous fleet of Opel Zafira); the fact of being forced to sign the survey (at times, with name and surname) arguably means its answers are given under some form of duress; some of the data is apparently incoherent, or rather, poses further questions regarding the organization of mobility, for example: some workers apparently drive but do not have a driving license, or do not have a car but drive; finally, many of these 151 answers did not give or gave only partial answers to questions regarding satisfaction with their current mobility: some attest to great frustration, but others express a disarming satisfaction with working conditions - in this sense, many described the fact of not being satisfied, but, surprisingly, also not being willing to change, under any circumstance, their current arrangement in terms of mobility. Finally, the overall opacity of work, accommodation and mobility arrangements, as well as the ambiguity of working through indicators of satisfaction exposes a constitutively aleatory behaviour that does not reflect the objective structures which dictate the conditions of agricultural work.

With this brief description of results, we do not mean to downplay what we find are the project's rightful aspirations, but to argue that it is evidently difficult to trace a clear profile of the potential users of alternative means of transport which could bypass *caporalato* and thus reach, in this

30 This number is even more surprising considering how workers who bike to work are systematically subjected to physical violence in other parts of Italy. See: Tarsi, "Quando la mobilità è il parametro dello sfruttamento", 136.

specific research, an adequate level of information that can be turned into comprehensive mapping. The habits and needs of mobility are not easily understood, in fact, if not in the context of the hardship and evasive nature of work in agricultural production: there is a constitutive opacity which obstructs the research that complements and leads to cartographic representation, which therefore cannot be grasped through canonical, straightforward forms of mapping. Habits, needs and satisfaction of workers are hard to map when work, and mobility, are reduced to exploitation. This opacity, we might say, corresponds to the "submerged" characteristic of labour relations; to the extractive and exploitative dimension which is at the core of agricultural work in capitalist modes of production.

However, the claim of this contribution is that this lack of information, indifference, or resistance and refusal to answer might precisely be one of the results of mapping, more so given the object of research. This gap in information actually reveals the exploitative dimension, as well as plasticity of agricultural work and production. Our goal would thus be to address such an absence - what is supposedly an impossibility to complete mapping, if not at the risk of exerting further duress over that which or those who are being mapped - and turn it into a possibility to discuss and *critically* map an otherwise unmappable topic. Working around this gap not with the goal of filling it in, but in order to suggest the (ethical) importance of accepting negative results while mapping the arrangements of agricultural work. In this sense, mapping could become a form of critique - something we will try to outline in the next section by further borrowing on some aspects of our project and on relevant literature on critical mapping.

The Contradictions of Visualizing Agricultural Work Relations

British landscape architect James Corner has famously insisted on the emancipatory potential of mapping against its strictly coercive, governmental use. In his words: "[…) on the contrary, mapping is perhaps the most formative and creative act of any design process, firstly disclosing and then staging the conditions for the emergence of new realities".[31] Yet, looking at mapping in practice, in the context of our project, how far can it take us in terms of liberation? Indeed, mapping can be an "[...) extremely shrewd and tactical enterprise, a practice of relational reasoning that intelligently unfolds new realities out of existing constraints, quantities, facts and conditions",[32] but it is highly relevant that we first insist on analyzing such an existing context, beyond its apparent quantitative givenness.

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31 James Corner, "The Agency of Mapping: Speculation, Critique and Invention," in Mappings, ed. Denis E. Cosgrove (London: Reaktion Books, 1999), 91.

32 ibid., 100.

By definition, as architect and planner Laura Kurgan succinctly puts it, "Maps locate".[33] In other words, maps are never neutral and never *just* a map, but, from their very beginning, are caught up in a web of governmental and military technologies and apparatuses: a product and production of power. Mapping is not simply a form of representation but the definition of objective outcomes: "Maps construct space - physical, propositional, discursive, political, archival, and memorial spaces.".[34] Taking into account today's ubiquitous, vertical and three-dimensional processes of accurate and totalizing visualization, representation and localization, maps tend to gloss over, or even disguise, the contradictions, unevenness and violence of social relations.[35]

In this regard, we might bring up a recent example of mapping in the context of institutional action *vis-à-vis* agricultural work relations in Ferrara's province. Portomaggiore's local council recently initiated a campaign to detect, via software and on-the-ground "technical" assessments, the presence of overcrowded accommodation in town.[36] This online platform allows the local administration and its police force to locate the main "hubs" in which seasonal workers, mostly from Pakistan, find temporary accommodation. The preventive measures regarding housing solutions, in this action, blur with the strictly punitive nature of policing, troubling and breaking though the division between private and public spheres. Such a form of mapping, one which arguably leads to detection, eviction and possibly detention, is to be understood within the underlying presuppositions of institutional political action and its intersections with the PNRR. In the fight against *caporalato*, there is a high risk - and evidence - that maps legitimize the encroachment by disciplinary and biopolitical mechanisms into the lives of racialized labour populations, thereby making such a form of control an end in itself rather than a mere externality of current political measures; all the more so given the current global political conjuncture between EU migration management, war and extreme climatic events. The initiative in Portomaggiore further stresses the need to recognize agricultural production beyond purely economic metrics, as it enters into a highly conflictual and politicized domain. Far from coinciding with the technical service of cartography, mapping becomes a contested multi-faceted and multi-media tool adjusted to economic output and policing measures.

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33 Laura Kurgan, Close Up at a Distance. Mapping, Technology, and Politics (New York: Zone Books, 2013), 16.

34 ibid., 14.

35 Alberto Toscano and Jeff Kinkle, Cartographies of the absolute (Winchester and Washington: Zero Books, 2008).

36 "Alloggi sovraffollati, c'è la mappa. Un software trova il caporalato", Il Resto del Carlino, September 9th, 2024. Available online: https://www.ilrestodelcarlino.it/ferrara/cronaca/alloggi-sovraffollati-ce-la-mappa-un-software-trova-il-caporalato-dd9a40a7?live (last accessed 25th September 2024).

Following Marxian critique, we maintain this is because mapping agricultural work entails, *de facto*, an attempt to *visualize* social relations, that is, to represent capital. When it comes to mobility, indeed mapping becomes a tool for processes of accumulation and valorization to continue as they are: "be it through the form of the city or the movement of commodities and workers' bodies,(mapping mobility) is fundamental to managing circulation," where circulation indicates the immaterial circulation process of capital, as much as the movement of "stuff," including people.[37]

Borrowing on Alberto Toscano and Jeff Kinkle's work on "cognitive mapping" as an aesthetic-political endeavour to visualize and situate class relations at the global scale - or, as the authors put it, the "absolute," that is, an infinite totality which defies representation and lacks a locatable centre, in other words, capital - one dare say that our project is asked to map, beyond the medium of maps alone, that which resists mapping.[38] Of course, Toscano and Kinkle's theoretical work gestures toward critical aspects and artistic practices that present few points of contact with our specific project - although the notion itself of "cognitive mapping" derives from a reappraisal of urbanist Kevin Lynch's famous work - yet its framework allows us to point to the fact that our mapping can be conceived as a possible attempt to visualize class, race and gender relations within a global capitalist economy, from the purview of the space of mobility. This critical insight finally allows us to broach a set of questions that have consequences for the practice of mapping, all the more so when confronted with the manifold relations between production, consumption and distribution in agricultural work. From this critical stance, in fact, we may ask (but not answer exhaustively): what are the objective effects of mapping agricultural work? What ethical concerns do these effects bring up and how to mediate the necessities of change with those of control?

To this end, we can return to the specificities of our project. Within the limitations of current political conditions, the mapping campaign produced two ways to implement an answer to the hardship of agricultural work in terms of transport. These two "solutions" were not intended to be distinct, but, in our view at least, part of a gradual process; a two-phase or two-fold plan toward improving "mobility justice," that is "an overarching concept for thinking about how power and inequality inform the governance and control of movement, shaping the patterns of unequal mobility and immobility in the circulation of people, resources, and information."[39]

Mapping the habits and needs of workers, as well as employers, in terms of mobility suggests systemic intervention on existing public transport routes. Yet, such a form of transport is left no room for manoeuvre due to

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37 Deborah Cowen, The Deadly Life of Logistics. Mapping violence in global trade (Minneapolis: Minnesota University Press, 2014), 100-102; 191.

38 Toscano and Kinkle, Cartographies.

39 Mimi Sheller, Mobility Justice. The Politics of Movement in an Age of Extremes, 38.

underfunding and current overstretching of its lines and drivers; it therefore cannot be reorganized. The project then can only propose either a privately funded line of transportation or an official car-pooling service via workers' access to a telematic application. In the first case, a private company would provide either a double or a single ride to and from work at specific times of day, depending according to work shifts. Due to its schedule (partial incompatibility of shift work with other activities), limited capacity of buses (compared to the high number of workers) and route (scattered territorial distribution of the population), the transport would neither benefit nor be accessible to local residents, nor to most workers throughout the rest of the day. The second option, car-pooling, on the other hand, would be cheaper, more flexible and, importantly for institutions, immediately at hand, providing a quick answer to the current political and mediatic attention given to *caporalato* and workers' exploitation in agriculture.

It is quite evident that both "solutions" will not change the structure of agricultural work; nor can they be considered adequate proposals in terms of mobility justice. In the first case, public transport may allow a reduced number of workers to circumvent *caporali*, but the service will not have an impact on exploitation, since no accessible form of transportation is provided for anything else *other than* work; in the second case, a legal form of carpooling is likely to merely reproduce the injustices of *caporalato* via its institutionalized form, also due to the fact that the organization or attendance of such an operation would be difficult to actually monitor. In other words, it is not enough to provide alternative forms of transport for workers if the goal is exiting the exploitative system of *caporalato*.

Critical Mapping: The (Ethical) Importance of Opacity

Thus, our attempt to locate and actively contribute to the ameliorative, preventive actions put in place by State institutions comes, above all, with ethical concerns, as well as methodological and operative challenges put forward in the previous section. In this sense, our proposal for an alternative form of transport to bypass *caporalato* leaves in place, if not actually legalizes, exploitation. Although we do not know the actual spatial arrangement and social structures of day-labourers in the region, in fact, it is safe to say that we are trying to locate people who intentionally wish to avoid localization. And mapping is one of the main operations to implement such a project: one which leads workers to and from work, grounding its organization around the imperative of production, without providing transportation in other times of day, or for other users, such as the already-isolated residents of the Eastern sections of Ferrara's province.

The contradictions we have outlined regarding the possibilities of mapping in the context of the current political effort to contrast *caporalato* and

workers' exploitation in agricultural production, however, should not be seen as an invitation to withdraw from mapping. On the contrary, it wishes to call for a practice that accompanies mapping with careful analyses of the economic logics and social arrangements which subtend and derive from production itself. The recognition of exploitation as a structural and unsurmountable characteristic of agricultural work in capitalist modes of production, as well as of the reproduction of migrant, racialized cheap labour within contemporary mechanisms of differential inclusion/exclusion is not an ancillary aspect but the precondition for a form of mapping that does not further entrench inequalities - distancing us even more from an improvement in terms of mobility justice - and is not reduced to a purely technical operation. This opens up to an ethical concern always already at stake in mapping as a form of critique. In the words of critical GIS scholar, Matthew W. Wilson:

> "Abstaining seems radical, but it is a reaction to the ways in which even participatory mapping has enabled exploitation, as maps and local spatial knowledge become utilized in ways that exceed or even negate any simple emancipatory agenda. This should not be surprising as mapping is fundamentally capturing. But this should not cause us *not* to map. Instead we should recognize the stakes and the need for being strategic in our mapping work.(…) Studying, doing, and abstaining from mapping is to understand our technopositionality within these geometries. As mapmakers and allies in mapmaking, we can never be outside these configurations."[40]

The fact relations are caught up in the logics of accumulation and power does not mean we can simply withdraw from them but opens up to a space of critique as part of the practice of mapping, or *critical mapping*. We might therefore ask, neither solving such a contradiction nor seeking to evade it, whether we can accept the questionnaire's answers, in light of the fact that a number of them - arguably those given by the share of people whose habits and needs were, originally, the object of our research - were given under duress, and are, subsequently, incomplete and incoherent; or ask to what extent our project, undergirded by a purely technocratic approach, can actually be considered to be ameliorative. Is our project reduced to the technical service of cartography? Is it free from a consideration on ethics because of its socially-oriented intentions?

We can here only provide partial answers. Yet, tweaking Corner's call for emancipatory mapping and bearing in mind the incompleteness of our mapping campaign, we might argue that mapping mobility, which is in this context mapping capital: "is not a question of accuracy or resemblance, in which aesthetic form would be a mere instrument for knowledge, but constitutes a kind of force-field in which our conceptions of both

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40 Matthew W. Wilson, New Lines. Critical GIS and the Trouble of the Map (Minneapolis and London: University of Minnesota Press, 2017), 40-41.

modes of production and aesthetic regimes are put to the test."[41] It is in this sense, that mapping becomes critical, insofar as it tries to expose the limits and contradictions of mapping within capitalist modes of production and the current political conjuncture, not as a form of passivity or retreat from the practice of mapping, but as a way to question the operativity of such a practice itself. In the case of our specific project, we thus need substantial theoretical frameworks, extensive field work and investigative campaigns on-the-ground that parallel the vertical, top-down and technocratic approach of traditional mapping, in order to answer to the habits and needs of mobility of agricultural workers.

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41 Toscano and Kinkle, Cartographies, 23

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MAIN SECTION

The Open Society in the Twenty-First Century: Comparative Critical Cartographies for Assessing and Designing in ‘t Hool, the Netherlands and Montbau, Spain

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ABSTRACT

Today’s urbanization pressures present complex challenges in sustainable and socio-ecological transitions. Historical planning tools and theories, such as the Open Society concept, offer alternative approaches to regeneration and inclusivity. Critical mapping is a growing method in urban regeneration. However, we observed that this tool has not been sufficiently explored in a comparative fashion. In this paper, we examine the Open Society concept by comparing and contrasting ’t Hool, Eindhoven and Montbau, Barcelona to assess the concept’s continuing relevance for the regeneration of Modernist housing in the twenty-first century. We construct a comparative critical cartography using mixed-methods (mostly qualitative) to highlight interspatial relations on both neighborhoods. This method is a tool that aids us to highlight power-knowledge relations and detect spatial patterns from different fields, to extract site-specific lessons that inform urban regeneration. This research bridges the gap between theory, design and practice providing tools and comparative approaches to promote more transdisciplinary and more holistic approach to space and place. Addressing the complexity of space with a creative and systematic approach should address the relativism of site-specific knowledge and turn it into more generalizable lessons for urban regeneration.

KEYWORDS

open society; comparative critical cartography; creative practices; ‘t Hool (the Netherlands); Montbau (Spain)

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Introduction

The global pressures of urbanization have thrown up complex challenges as we work towards common goals of sustainability. These include climate change and energy transition, housing, migration and social inequality, digitization, etc. These complex and dynamic tasks require the necessity of addressing those research and design challenges with a more multidisciplinary approach, transdisciplinary methods, tools and instruments[1].

The basic need for housing is a cyclical and chronic demand in our cities and informs the concept of the Open City introduced by Richard Sennett in *Building and Dwelling* (2019), which was, in turn, influenced by Jaap Bakema's Open Society, which he introduced in 1959 at the Congrès International d'Architecture Moderne (CIAM) XI in Otterlo, the Netherlands. This concept (further developed by Bakema with Team 10) attempted to create urban conditions for society to prosper[2]. These good intentions did not always successfully translate into practice, however. When Modernist housing estates were built their shortcomings were amplified by multiple and accumulative crises (social, environmental, economic, etc.). Some estates have been demolished. We would argue that under a sustainable development framework this approach should not be the first option. Moreover, Modernism's planning legacy and its experiments should not be forgotten (both successes and failures); we should be trying to regenerate, refurbish, and protect to enrich this historical dimension of our cities.

The socio-ecological transition in these regeneration projects and processes is complex and requires novel approaches that can foster a multidisciplinary approach in researching and designing those spaces. The employment of critical cartographies in urban regeneration processes is a growing field. Yet, we have observed that the potential for comparative research of it has not been explored enough. We hypothesize that critical cartography, used in a comparative fashion, can provide insights beyond traditional methods. Thus, we formulate the following question: to what extent can a comparative approach employing critical cartographies can gain novel insights and generate useful lessons (both site-specific and general) about urban renovations in the twenty-first century?

In this paper, we reappraise the concept of the Open Society by comparing and contrasting 't Hool, Eindhoven and Montbau, Barcelona to assess the concept's continuing relevance for the regeneration of Modernist legacy in the twenty-first century. We construct our comparative critical cartography through mixed-methods (mostly qualitative) to highlight the power-knowledge and interspatial relations of both neighborhoods. We aim to bridge the gap between research and design, and allow for a broader and deeper

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1 Hein & van Mil, 'Towards a Comparative Spatial Analysis for Port City Regions Based on Historical Geo-spatial Mapping', 2; 7.

2 Van den Heuvel, *Jaap Bakema and the Open Society,* 18-19.

understanding of these case studies while also providing tools and comparative approaches that embrace a more cross-cultural exchange of knowledge promoting a transdisciplinary and more holistic approach to space and place. Addressing the complexity of space with a creative and systematic comparative approach should address the relativism of site-specific knowledge and turn it into more generalizable knowledge and transferable principles.

This article begins with a theoretical framework for creative practices and then outlines our comparative critical cartography. The methodology section explains how we proceeded with our on-site inquiries, this is followed by a brief introduction to the two case studies, and a synthesis of our History cartography, with its results. Finally, we draw conclusions on the continued relevance of the Open Society concept today.

Comparative Critical Cartography: A Tool for Creative and Reflexive Professionals

Many scholars from education and practice have called for a novel epistemology for creative and reflexive urban practices (Sennett, Corner, Hein, among others). They call for creative, committed, and reflexive professionals[3] who are striving for high-quality explorations. Those professionals require tools to address the gaps in knowledge of the complexity and multiplicity that enriches our cities[4]. Some see the necessity of addressing those complex research and design challenges with a more transdisciplinary approach, methods, and instruments[5].

We detected little literature on the comparative aspect of critical cartographies on urban regeneration processes. More creative practices and comparative approaches are needed to bring fresh perspectives, methods and tools, and knowledge from different disciplines to address the fluid character of territories and their wicked problems[6]. We are convinced that critical cartography is a powerful tool for exploring and investigating space and for constructing new narratives and imaginaries to enrich places.

Grounded in a solid theoretical framework, critical cartography can be operationalized for different approaches in professional practice[7]. The concept is based on Critical Theory, which promotes analytic tools and methods to free us from power-knowledge relations and structures with the aim of fostering creativity and emancipation through independent thought (critique) and

3 Schön, *The Reflective Practitioner,* 287-290.

4 De Solà-Morales, *A Matter of Things*, 26.

5 Hein & van Mil. 'Towards a Comparative Spatial Analysis for Port City Regions Based on Historical Geo-spatial Mapping'..

6 Nijhuis & de Vries, 'Design as Research in Landscape Architecture', 91.

7 Sanz, Bracken & Muñoz, 'Critical cartographies for assessing and designing with planning legacies', 13.

meaningful experience[8].

Critical cartography emerged in the late 1980s in opposition to hegemonic definitions of mapping as progressive and emancipating (i.e., value-free) transcriptions of the environment[9]. Since the epistemological break made by Brian Harley (1989), the legitimacy and assumptions of professional cartographic enterprises have been subject to debate by relevant scholars such as Harley, Pickles, Wood and Crampton among others. The conception of maps displaying natural and unchangeable spatial orders used to be a kind of geographical common sense[10] but intensive attacks on the fundamentals of cartographic history, theory, and practice have shown an awareness of both the 'history of critique within the profession of cartography, and such a longer history of critique of critical thinking in mapmaking as a whole'[11]. This critique of the cartographic profession revealed more creative and emancipatory approaches to map-making, as did the emergence of new geospatial technologies, such as Google Earth and OpenStreetMaps. Specifically, some (GIS) platforms saw a potential for 'democratizing' map-making[12]. These two factors have unprecedented value and relevance to map-making and are instrumental in any conversation about exploring and designing space and allows engagement with other disciplines to enrich collaborative conversations when addressing common urban challenges, such as sustainability.

These scholars uncovered the potential for maps to be tools for analysis and critiques of power-knowledge relations and discourse. They highlight the importance of the spatial visualization of complex phenomena to reveal obvious and/or hidden interrelations. Most importantly, they show how maps can be utilized creatively to approach the complexity of space in cities, and landscapes. This creative approach to map-making is relevant for any spatial discipline, such as planning, geography, architecture, landscape, anthropology, sociology, ecology, economy, etc.

What interests us is the strong relationship between knowledge formation in relation to space and how it is stabilized trough power-knowledge relations that can be situated geographically. This allows the concept of critical cartography to be used as a medium contributing to novel perspectives of knowledge in a more inclusive and genealogical way. This genealogical approach to knowledge resonates with James Corner's examination of the agency of mapping and the understanding of map-making as a cultural project[13]. He sheds light on the creative practices of mapping and the potential it holds for enriching experience and diversifying worlds. Mapping can be a very powerful tool for understanding historical transformations of territory and revealing the

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8 Crampton, 'An Introduction to Critical Cartography', 14.

9 Wood, *Rethinking the Power of Maps*, 120.

10 Gramsci, *Selections from the Prison Notebooks,* 9.

11 Wood, *Rethinking the Power of Maps*, 120.

12 Bryan, 'Maps and Power', 1.

13 Corner, 'The Agency of Mapping', 89.

intrinsic logic of spatial orders and patterns, which in turn allows for the communication of findings and enables discussions on future development[14].

Critical cartography is an analytical tool that can liberate researchers from existing power-structures and enable them to approach the complexity of space in a creative way[15]. This enables us to address several items relating to space, including the objectification of space from a Eurocentric approach[16]. It also allows us to address space holistically through a multidisciplinary approach and allows for other ways of knowing the characteristics of other cultures (e.g., Asian, indigenous, etc.), ultimately contributing to a more holistic approach to space. The combination of qualitative and quantitative techniques for addressing the complex and dynamic nature of the environment and its wicked problems[17] allows us to be more objective or intersubjective[18]. It can also be a more open-ended instrument allowing for 'reflective conversation with the situation'[19] among diverse actors involved in decision-making and the design of new landscapes.

Our approach to critical cartography departs from Corner's call for more creative mapping processes: 'mapping is perhaps the most formative and creative act of any design process, first revealing and then staging the conditions for the emergence of new realities'[20]. This follows Gilles Deleuze and Félix Guattari's appeal for more open-ended forms of creativity: 'the map it is entirely oriented towards an experimentation in contact with the real(…) it has to do with performance'[21], in which mapping alternates processes of accumulation, de-territorialization, and re-territorialization and allows us to assess built projects from different topics and perspectives. Thus, mapping displays an ambivalent function, it is analytical and projective at the same time[22]. This ambivalent function allows us to utilize the map as a tool for reflection on the research-by-design approach[23] and the practices that form urban proposals. In other words, we consider mapping as an instrument operating between the reality of a territory and its new imaginings; hence it is partly objective and partly subjective[24]. Moreover, this 'in-between' condition allows us to visualize and communicate findings using diverse visual means and languages in addition to the map (pictures, zoomed-in plans, sections, axonometric, pattern language, visual sequences, atmospheres, etc.). This diversity allows us to design for the complex and dynamic nature

14 Hein & van Mil, 'Towards a Comparative', 4.

15 Crampton, 'An Introduction to Critical Cartography', 14.

16 Sanz, Bracken & Muñoz, 'Critical cartographies', 13.

17 Nijhuis & de Vries, 'Design as Research', 91.

18 Zonneveld, 'Visual storytelling: Assessing the power of maps in planning', 220.

19 Schön, *The Reflective Practitioner,* 95.

20 Corner, 'The Agency of Mapping', 89.

21 Deleuze & Guattari, *A Thousand Plateaus,* 12.

22 Zonneveld, 'Visual storytelling', 219.

23 Nijhuis & de Vries, 'Design as Research', 93.

24 Corner 2011; Zonneveld 2022; Sanz, Bracken & Muñoz 2023.

of cities and landscapes. The combination of diverse research techniques and approaches allows us shed light on interspatial relations and flows in a holistic manner.

Our approach to mapping combines the analytical and the critical. Site visits allow us to approach places sensibly, allowing us to see beyond linear discursive approaches and explore more freely. This process work both ways: the critical approach to case studies sheds light on patterns that are not perceived on site. The combination of critique and a close experience of the place finds articulation through complementary media working with the map to describe relations in different scales, disciplines, and times. This understanding of mapping allows us to use it systematically as an analytical and projective instrument. We creatively approach our assessment of the Open Society and its 64 principles by empirically unfolding the diversity of dimensions and perspectives to add depth to our understanding of these different urban renewal projects.

Methodology

In our view, comparative critical cartography can provide a novel systematic processes and approach (e.g., deterritorialization/reterritorialization) for addressing space holistically (through themes, time, and scales). This allows us gain new knowledge, and understand its genealogical formation by engaging in transdisciplinary research and design.

Our approach is a combination of mixed media (hand and digital drawings) to spatialize and contrast the results of our research into some of the principles of the Open Society in our two case studies, 't Hool in Eindhoven and Montbau in Barcelona. These critical cartographies are used for evaluating but also have potential use in subsequent design strategies and performance assessment[25]. Due to space constrains, we will only display the comparisons of the History cartography[26].

Using qualitative and quantitative mapping techniques, including GIS and Corner's layering strategy[27], we explore and depict different aspects and dimensions of the Open society in our case studies. We mostly use qualitative methods and techniques[28] to highlight knowledge-power relations. These allow us to critically map the complex spatial patterns across disciplines and specific cases with time (e.g., palimpsest analysis (Corboz 1983)) to explore the context sensitivity of the projects for an Open Society. Moreover, we identified hidden blockages (failed causal interrelations across and within topics) that we call 'urgencies' while also

25 Sanz, Bracken & Muñoz, 'Critical cartographies', 3.

26 See Appendix I an overview of all five cartographies in Sanz, Bracken & Muñoz 2023.

27 Corner, 'The Agency of Mapping', 235.

28 In specific cases we use quantitative methods (Space Syntax, spatial and form analysis, catchment areas, etc.).

seeking potentials for spatial, procedural, and programmatic patterns that can unlock those blockages. In this way, we attempt to bridge the methodological gap by providing a visual means for understanding these places and their environments.

The assessment framework for evaluating the case studies combines Bakema's 64 principles[29] with fieldwork [30] (see Appendix I) leading to a new formulation of these principles that enables us to evaluate Bakema's ideas while also providing inspiration and guidance for design strategies[31]. The framework examines the case studies holistically. Diverse topics, fields, and perspectives enrich our understanding of the complexity of urban matters and allow for more multi-disciplinarity in addressing 'wicked or ill-defined issues', i.e., complex urban phenomena that create challenges to future sustainability. We also compare the case studies to highlight similarities and difference so derive lessons and point to general principles that could suit other places.

The case studies of 't Hool in Eindhoven (designed by van den Broek and Bakema) and Montbau in Barcelona (by López-Iñigo, Giráldez & Subías) have the following criteria: they are roughly the same size (c.30 hectares), located in Western Europe, built between the 1950s and 1970s, involve diverse public and private actors, share a willingness to experiment and innovate to foster urban life (e.g., programmatic mix and tenure, diversity in urban typologies, urban configuration that create identity for the communities, innovative typologies and construction systems, etc.), they share common platforms and networks of knowledge[32].

We have to say that being built (being able to measure empirically), the existing conscious/unconscious transfer knowledge and their historic relevance are decisive factors in the selection of these two cases.

Case studies: 't Hool, Eindhoven and Montbau, Barcelona'T Hool

The neighborhood of 't Hool is in the Woensel district of Eindhoven, the Netherlands. Designed by van den Broek and Bakema, Jan Stokla and Gerard Laus, it was completed between 1968 and 197233 (see Figure 1). 'T Hool covers approximately 33 hectares and is home to approximately

29 See in van de Heuvel, *Jaap Bakema,* 280.

30 Sanz, Bracken & Muñoz, 'Critical cartographies', 5.

31 As mentioned in Sanz, Bracken & Muñoz 2023, these principles should be revised using a subaltern framework and a literature review to address their aims for diversity and inclusion in the twenty-first century.

32 While there was a certain degree of knowledge transfer between 't Hool and Montbau, there was no conscious application of the Open Society as a concept in the latter; it landed indirectly due to replication of spatial arrangements.

33 "Achtergrond" SGV 't Hool Foundation, last accessed February 6, 2025, https://www.woonwijkhethool.nl/achtergrond/.

1,000 dwellings[34]. This project allows us to empirically measure several Open Society's principles. It is protected as a national monument[35]. It displays experimentation and innovation in spatial and procedural terms (as seen in Team 10 conversations on growth and change, open forms, grids, user participation, scale association, etc.). This gives a special value to this housing estate because it manifests avant-garde ideas about human-centered in architecture and urban planning in the 1960s[36]. 'T Hool embraces diverse lifestyles and inclusivity through its design process and outcomes. This was achieved by the fact that the proposal was driven by strong residential participation – the architects acted as agents between the diverse stakeholders (cooperatives, housing associations, municipality). The proposal allowed for diverse forms of living with nine house types, and variations that made 12 different types based on residents' requirements[37], combining high-, medium-, and low-rise architecture with urban planning in different configurations, as well as two different types of tenure/ownership[38]. It also strove for a coherent relationship between dwellings and their immediate environment[39] (see Figure 2). New ideas about mobility allowed for a smooth transition between inside and out in each cluster). Centrifugal principles also allowed for more compositional variety, with each cluster addressing transitions in scale across the urban environment. This merging of spatial qualities and principles achieved a smooth transition from private to public[40]. Experimental prototypes called 'growing houses' addressed potential future needs of households[41]. Finally, the relation between urban and architectural scales is masterfully articulated to address qualities of privacy, permeability, safety, etc. These features reflect some of the principles of Bakema's Open Society, especially his search for physical, emotional (social), and spiritual conditions[42] and the fostering of diversity and inclusivity so that individuals and communities can flourish.

Montbau

Montbau is located in the Horta-Ginardó district of Barcelona, Spain, in the foothills of the Collserola mountains (Fig. 1). The project site is 31

34 "De ontstaansgeschiedenis van 't Hool in Eindhoven" SGV 't Hool Foundation, last accessed February 6, 2025, https://www.woonwijkhethool.nl/achtergrond/geschiedenis/.

35 Rijksdienst (RCE), "t Hool Eindhoven', 3-4.

36 Risselada, "t Hool Housing Estate, Eindhoven, 1962-72', 170.

37 "De ontstaansgeschiedenis van 't Hool" SGV 't Hool Foundation, last accessed February 6, 2025, https://www.woonwijkhethool.nl/achtergrond/geschiedenis/.

38 Van den Heuvel, *Jaap Bakema,* 172-173.

39 Risselada,"t Hool', 170.

40 Rijksdienst (RCE), "t Hool Eindhoven', 3-4.

41 Risselada, "t Hool', 170.

42 Van den Heuvel, *Jaap Bakema,* 123.

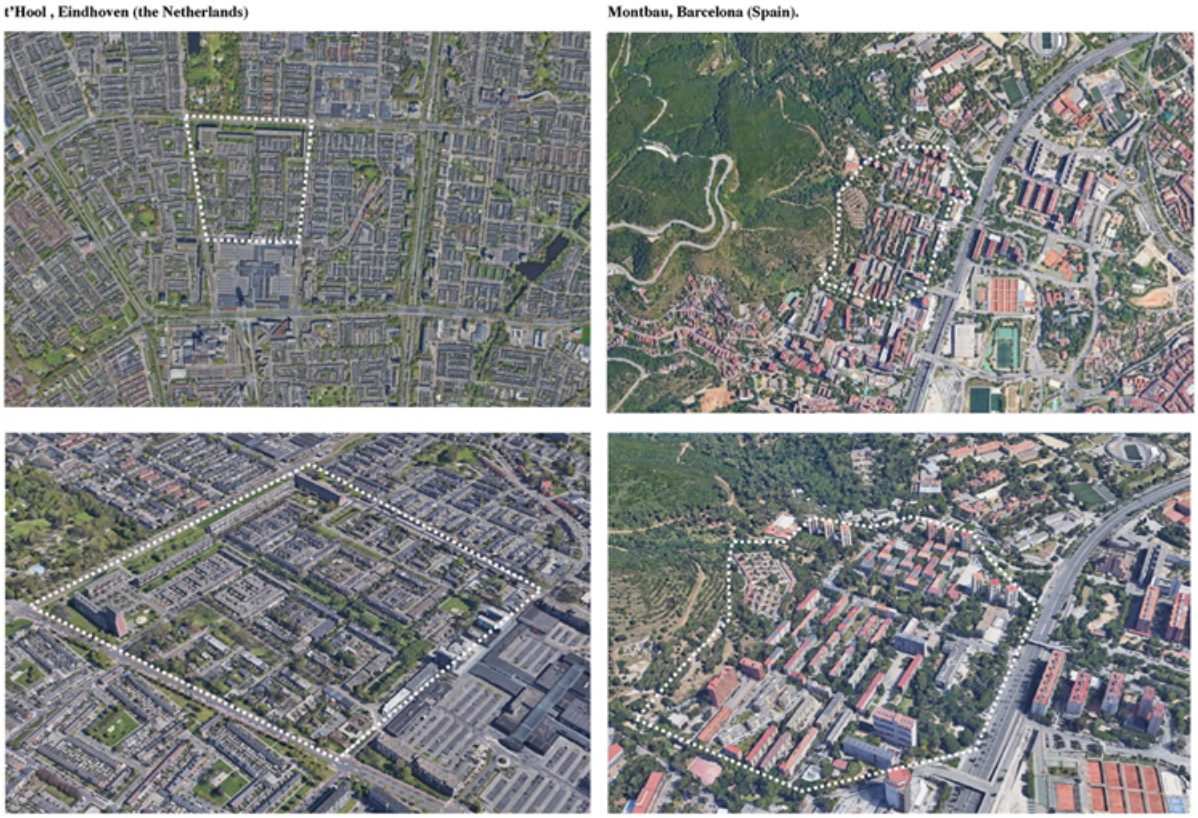

FIG. 1 Bird's eye view of 't Hool and Montbau's top plan and close up. Source: Google Earth.

hectares with 1,890 dwellings[43]. The original proposal by LIGS (López-Iñigo, Giráldez & Subías) was approved in 1957. The project was built between the 1950s and the 1970s but suffered from a number of modifications (densification, altered plans) in later phases. It is protected as a national monument[44] and shows an experimental character (with the application of CIAM principles and Dutch experiments by Opbow and De 8). Its willingness to innovate was inspired by international ideas, like the 'Siedlungen' model[45]. This was all the more remarkable for taking place during the closing phase of Franco's dictatorship. This experimentation aimed at bringing complexity and social diversity. This human-centered approach was central to the proposal. However, due to shortcomings (a too rigid application of CIAM's principles and economic issues, among other things) some of its good intentions failed[46]. Some sociological and anthropological aspects could have performed better (concepts highlighted by Jane Jacobs and James C. Scott, which we will look at in the next section). What did work, however, was the rich experimentation and diversity of housing types, with variations in volume heights and configurations. The central square is a strong urban element; it allows users to visually recognize the space as a center. The relation between the urban

43 DOCOMOMO, 'Redacción de la documentación de 256 elementos del catálogo inicial de edificios del plan nacional del patrimonio del siglo xx', 252-254.

44 Ibid., 252-254.

45 Ferrer, *Polígonos de viviendas en la comarca de Barcelona*, 13.

46 Bohigas, 'El Polígono de Montbau' 22-34.

and architectural scales is well articulated, with good permeability and access oriented towards the square, which helps people feel safe. The articulation of other squares within the complex creates a visually connected landscape. It also experimented with the first prefabricated housing blocks in Spain[47].

Comparative Critical Cartography: History

Both 't Hool and Montbau are protected monuments. This helps our critical cartography to measure and contrast them as well as link them to Bakema's Open Society principles[48]. In our research, we approach the deconstruction and reconstruction of space in a systematic and comprehensive manner. This process enables us to explore the Open Society concept in both case studies. Due to space constraints here, will be only focus on the comparisons of the historical cartography.

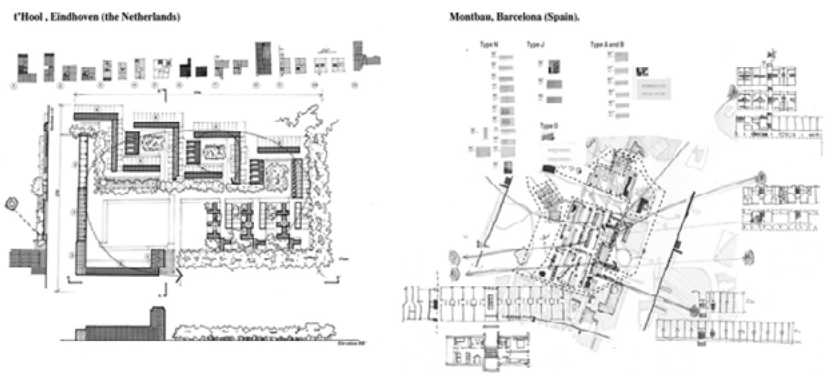

FIG. 2 High diversity of housing typologies and variations and centrifugal configuration of the urban centers within both case studies. Source: Made by authors (based on plans from HNI and COAC archive).

As previously mentioned, we construct each critical cartography by employing diverse methods[49] and techniques (e.g., literature review, site visits, spatial analysis), which provides us with a framework for incorporating diverse knowledge and dimensions. This helps us to visualize, analyze, assess, and contrast the case studies and also Jaap Bakema's 64 principles for an Open Society.[50] This systematic approach to deconstructing and reconstructing space allowed us to detect complex spatial interrelations among topics, times, and the urban and architectural scales (Fig. 3). With a further comparative analysis of the results from both cases we extracted insights on specific urgencies in addition to the sites' intrinsic and extrinsic potentials (Fig. 4). Reading forms as a pattern language acted as a common spatial language to allow for knowledge and

47 DOCOMOMO, 'Redacción', 252-254.

48 Van den Heuvel, *Jaap Bakema,* 280.

49 Mostly qualitative but with some quantitative in specific cases.

50 For a description of the deconstruction process carried out in 't Hool see Sanz, Bracken & Muñoz 'Critical Cartographies' 4; 8-10.

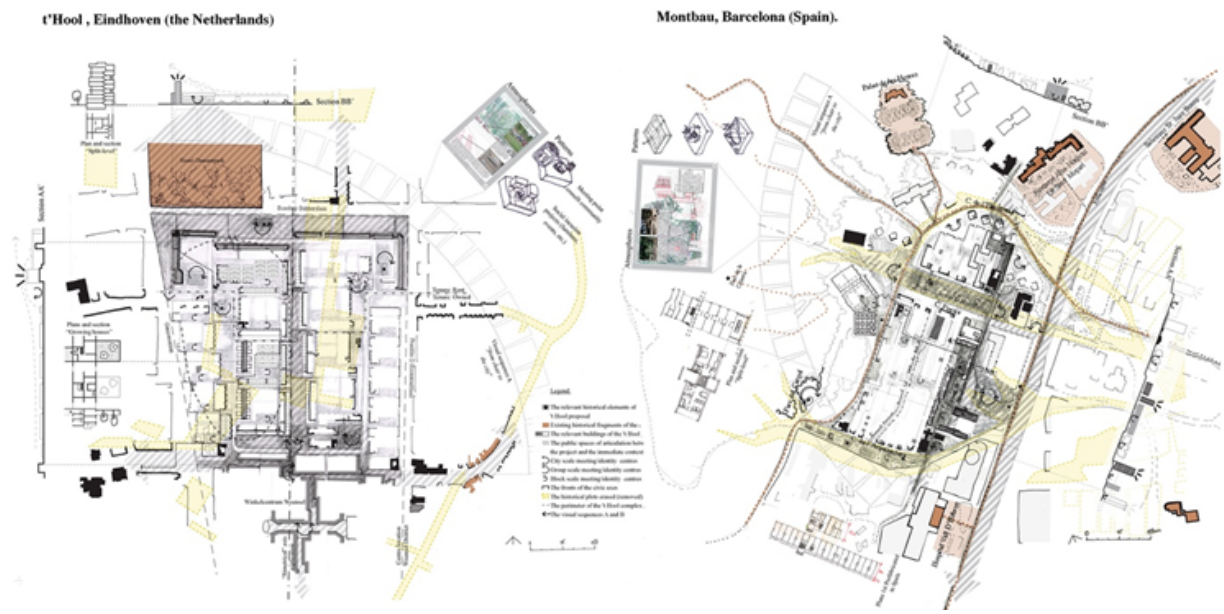

FIG. 3 Historical cartographies of ´t Hool and Montbau in a comparative fashion. Source: Made by authors.

lessons that were site specific but where we could also find similarities and differences allowing us to draw potentially transferable knowledge and lessons.

Here, we show one cluster of principles that relate to the experimental nature of the case studies (Appendix 1 shows full comparisons and observations for the History cartography). This has been done systematically for each cartography, where we observe some interrelation of spatial and procedural patterns coming from different disciplines (see Table 1). In the History cartography, we cluster principles under four topics for presenting and comparing results: 1) experimental character fostering urban life – sociological approach, 2) context sensitivity and dealing intelligently with site conditions, 3) housing crisis, political agenda and social movement, 4) growth in human beings – between survival and transcendence. We focus on the experimental characteristics (see Table 1)[51].

In the experimental and innovative character of the proposal, we select Principles 33, 40, and 62 from the History category and detect crossovers from other topics, such as socio-economics and form-scale (density) (which relate to Principles 1, 2, 7, 34, and 44). These principles interrelate because of the innovative approach of the case studies' urban and architectural design, e.g., with sociological studies and human-centered proposals, engagement of future residents in design decision-making, innovative typologies, and construction methods. To explore those principles in the case studies we deployed different approaches to sources, such as Andreas Faludi's method of 'performance in spatial planning'[52], as well as other literature reviews, archival processing, and the examination

51 For more information and other compared results, see Sanz, Bracken & Muñoz, 'Critical cartographies', 793.

52 Faludi, 'The Performance of Spatial Planning', 299-318.

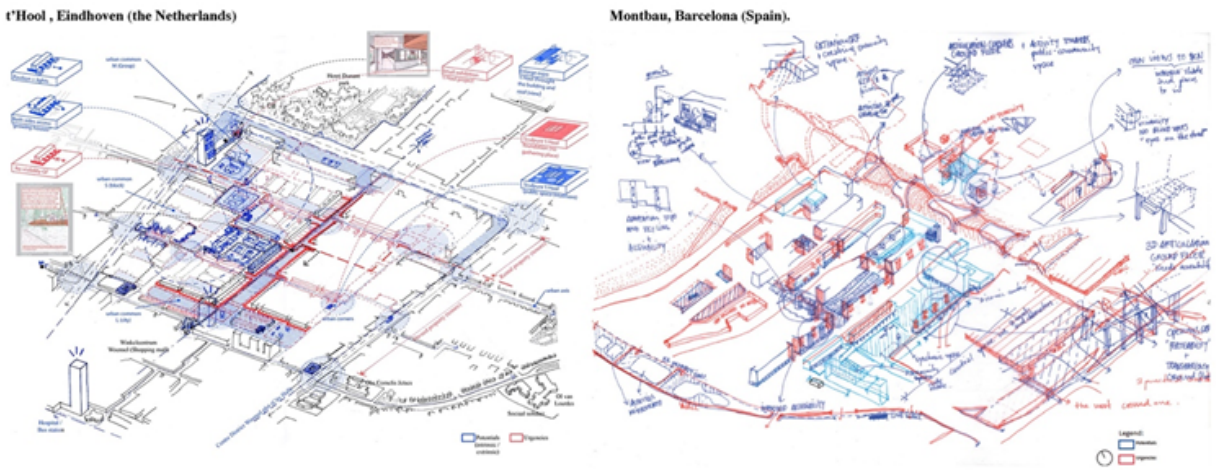

FIG. 4 Urgencies and Potentials from historical cartographies of ´t Hool and Montbau in a comparative fashion. Source: Made by authors

of morphological urban elements (Esteban 2009).

While deconstructing the accumulation of operations to reconstruct this cartographic angle, we provide a description of all layers relating to the History cartography (see Table 1).

The results obtained from the comparisons of the History cartography of 't Hool and Montbau allow us to empirically assess the Open Society in both. In the interests of clarity, the exposition and discussion on our results uses the above-mentioned categories but focusses on the most relevant innovative characteristics relating to human-centered design. We further subdivide the experimental and innovative characteristics into urban planning and architecture.

Firstly, we see the introduction of sociological and anthropological dimensions to urban planning and design. Both case studies attempt to address the urban project through human-centered approaches (Principles 1, 7, 33, 34, 62) to find common ground for fostering a diverse and inclusive Open Society. This search for diversity and inclusion is addressed by providing different conditions within the proposal (spatial, programmatic, ownership and tenure, and procedural). Some similarities highlight the sociological dimension that were incorporated into the urban proposal. We noted, however, that the methodological and operational steps were diametrically different: in 't Hool the process was more bottom-up; it was initiated by a social movement (from the Philips engineers who formed a cooperative[53]). In Montbau, the process was more top-down, initiated by a public institution initiative, *Patronato de Vivienda* (PMV), under a program of private incentives[54] which tried to create conditions for urban diversity. In both cases, however, diverse stakeholders wanted to provide high quality urban space. We can see that 't Hool performed better

53 "De ontstaansgeschiedenis van 't Hool" SGV 't Hool Foundation, last accessed February 6, 2025, https://www.woonwijkhethool.nl/achtergrond/geschiedenis/.

54 Ferrer, *Polígonos,* 10-11.

Theme: Experimental character and innovative approaches		
Similarities	**Differences**	**Comparison**
Users were part of the process: in 't Hool, participating during the entire decision-making process; in Montbau, during the construction phase.	The proposal processes were different: 't Hool bottom-up; Montbau was top-down.	Experimentation in typological diversity shows correlation with topographic complexity, with minimal or no topography (Possibility of very diverse combination due to easy construction that is related to economic viability); In places with accentuated topography, the possibility of typological combination is more limited due to the high spatial and technical complexity that results in a higher cost making it more affordable. The use of prefabricated construction systems facilitates subsequent modification, allowing flexibility of uses and distributions. This prefabricated construction system reduces the time and cost of the work. The configuration of centers through centrifugal forms allows the creation of identity centers of social interrelation or encounter that, depending on the position in the central plaza, creates conditions for different activities (e.g. open areas, sculptures, meeting places, unscheduled and ambiguous spaces, recreational and sports activities, etc.; intimate areas (not totally closed, living spaces, with trees, relaxation, etc.). ´t Hool seems to follow a fractal formation creates gradients and articulations between the different scales (type, block, group, place) and articulating the parts and whole. It has proven to be more effective to incorporate the sociological study at the beginning of the design and then transpose it to the place, adjusting it to its limitations. Always keeping the user in mind throughout the design process, (if possible, interacting with them). The different approaches in the urban development process (top-down / bottom-up) are approaches that show benefits in both cases and their combination shows very effective and efficient process opportunities, included from the beginning to the end. The attitude and motivation in participation, design and agreements is a key element to give vision to interested parties and foster common commitment to address today's challenge "sustainable growth" and socio-ecological transition. Promotion of good practices and selection of socially and environmentally committed teams. Promotion of urban experiments and innovative models in City making and Construction. The feeling of belonging to the place and community favors bottom-up community projects that solve local and global challenges on a small scale. We observe that this is the result of the programmatic mix of options for different typologies and ways of living, mix of tenure and property, diversity in housing sizes and variations, and diverse meeting spaces (interior and exterior of buildings) that vary. in its social function (public, collective, etc.)
Willingness to incorporate the sociological dimension in the urban development process.	In 't Hool, Bakema dealt directly with user-clients and adapted the scheme to their needs and the demands of the Municipality; in Montbau the Public Administration was the client and the LIGS architecture team relied on studies (interviews, programmatic schemes, etc.) (Bohigas, 1965) to determine the type of user to whom the action is directed.	
Experimental centrifugal composition of urban form configuring centers as well as spatial repertoire on how to deal spatially on the transitions between public and private using thresholds among other strategies (topfic: form, scale (density), matter)	In 't Hool the centrifugal composition of the urban form that adjusts such with displacement in plan seeking diagonal views to create connections and feeling of expansion, is a geometric pattern that seems that follows a fractal formation.	
Pioneering types and construction methods. (e.g. growing-houses, workshop-houses, prefabrication, split-level, etc.	In 't Hool is evident resulting from the avant-garde implementations with growing houses, split-level and prefabrication that allow for adaptation latter by the user.	
There was enthusiasm and a desire for experimentation and innovation, with a commitment from professionals to society and in promoting high quality of urban space.	In 't Hool was through application of the spatial repertoire accumulated (during the CIAM experiments) as well as the direct implementation of the discussions on growth and change in the avant-garde (Team 10) and against the CIAM model of Mass Housing development. In Montbau was through the application of "sociological parameters such as: diverse percentage of socio-economical profiles, introduction of cooperatives (economic model) to develop the proposal, and trips to Europe for learning the latest trends and solutions". Started applying the CIAM (Mass housing development principles) and it evolve along with the discourse and architectural trends and knowledge acquired in the global discussions within the network Modern Architecture and CIAM.	

FIG. 1 Comparison results of ´t Hool and Montbau and lessons. Source: Made by authors based on literature review, spatial analysis, empirical observations from site visits.

than Montbau according to Jane Jacobs' reading of urban life and its bottom-up approach[55]. James C. Scott warns against the imposition of schemes through legislative and programmatic apparatuses that result in social engineering[56]. Professional experts have specific knowledge and tools for operating in such a complex design process. However, they need to be aware of power-knowledge relations when mapping to incorporate more angles and voices for common understanding and agreement.

Secondly, we see experiments and innovations in construction methods, innovative dwelling typologies and configuration of urban ensembles, and spaces fostering urban life and a sense of community (as well as programmatic and ownership schemes to increase complexity and diversity). We observed that in both cases there was a large reservoir of housing types responding to things like different residents' needs, engagement in the process, types of tenure and ownership, and with different self-organizing entities such as cooperatives. This resulted in a certain degree of success in creating community identity. Also, innovative dwelling typologies, such as the 'growing houses'[57] and pioneering prefabricated construction systems used in combination with craftmanship and local materials and construction techniques led to what is perhaps the biggest achievement, which is the configuration of the central open spaces which are easy to identify through their centrifugal composition which is used to articulate space.

In this comparison, we speculate on some causal relationships. For example, one that seems clear to us is the richness of experimentation in the mix of housing types. 'T Hool shows better configurations and has more types and variations than Montbau, which seems to have several restricting factors, the most defining one would be that the topographic conditions of the hilly site which required complex and expensive solutions. These were not considered feasible at the time because these projects were meant to be affordable.

Discussion and Conclusions

We would like to reiterate here some of the aspects that make critical cartography such a useful way of conducting comparative research into specific sites to identify potential transferable knowledge. Insights gained from using historical tools for comparative analysis could serve to enrich at a global scale the collective cultural projects and processes of housing estate regeneration by embracing their historical legacies and providing the historical background and meaning to their spaces, we can better understand what goes into creating them.

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55 Jacobs, *The Death and Life of Great American Cities*, 422-423.

56 Scott, *Seeing Like a State*, 91-93.

57 Risselada, "t Hool', 170.

Using comparative critical cartography as a theory-practice tool can link generations of knowledge about space[58]. This tool also shows great capacity for communicating its findings effectively to inform design process. This holistic approach, with its objectivation and awareness of the intersubjectivity of space, provides a valuable tool for approaching knowledge in a genealogical way, which means it can be a good fit for cross-pollination between co-creative process, such as living labs, and urban laboratories. We are aware that there are limitations regarding these processes, especially when complexity or the number of stakeholders increases, which might require more effort from the designers. We recognize the crucial role of those creative, committed, and reflexive professionals to inspire and guide the spatial design towards inclusive, just, and sustainable development.

Our method also allows us to enrich knowledge within 'other' perspectives (e.g., subaltern) as well as contribute to trans-cultural knowledge exchange since maps are used as means of visual communication. In that regard, we need to warn about three limitations: 1) maps are constructed by power-knowledge dynamics between the map-maker and the map, 2) the increase in the necessity to generate systematic approaches to protocols and indicators for integrating diverse knowledge that incorporate values as well as data-driven processes, with advanced protocols and feedback loops operating in an iterative process, 3) there are material and user experiences (perceptions) to take into account and these are not always possible to communicate via a map.

Comparative critical cartography is proving to be a powerful tool for spatial exploration since it is objective and subjective at the same time, allowing for analysis and exploration simultaneously. This fits well with the reflective practices outlined by Donald A. Schön. To generate novel interspatial insights, relations need to be approached holistically, creatively and systematically. Comparative critical cartography allows us to detect interdependencies and serves as an effective method for contrasting case studies to identify urgencies as well as potentials (i.e., design strategies or principles in the form of patterns). This comparative analysis is somewhat brief, so it is only after a large number of inquiries into other case studies worldwide could we draw more decisive conclusions and make more definitive statements about these cases and this approach.

We observed that each place has its own idiosyncrasies in responding to its context (social, political, economic, environmental, etc.). From similarities observed in both case studies we identified potential causal relations between spatial elements, in the form of spatial patterns and spatial structures that connect across diverse fields and disciplines. After extensive study, the description and explanation of these casual relations can generate new knowledge. In other words, spatial design principles and

58 Sanz, Bracken & Muñoz, 'Critical cartographies', 13.

design process protocols can be transferred for more general use.

On the other hand, this method can be constructed using mixed methods to produce qualitative and quantitative results while noting similarities and differences in order to evaluate and draw initial conclusions while also generating site-specific and generalized (i.e., transferable) knowledge and, to a certain extent, draw conclusive lessons. The use of different techniques and sources has proved effective in describing and assessing the diverse aspects and dimensions of complementary spaces in relation to the assessment framework (i.e., Bakema's 64 Open Society principles). We had some limitations regarding performance, availability, and compatibility of some open-source data or because of the different climate conditions (these latter could be solved by using sensors to gather data; however, there could be limitations to this because of data and privacy protection). We agree with Carola Hein and Yvonne van Mill (2019) that the comparison of geo-spatial mapping of big data sets can potentially provide valuable insights in approaching space holistically and that go beyond traditional methods. This offers many possibilities but also some challenges, like those just mentioned.

Finally, we aim to contribute to our common pool of knowledge on methods and techniques that are available to modern housing estates for regeneration programs. In addition, we aim to shed light on knowledges and the lessons that can inform the stakeholders and decision-makers who are providing the strategies for addressing socio-ecological transitions in these case studies with potential design frameworks and principles in Modernist urban regeneration processes. Finally, to enrich the discussion and narrative on the cultural project of the Open Society and its legacy in twenty-first century.

Apendix I

	´t Hool , Eindhoven, the Netherlands.	Montbau, Barcelona, Spain.
1.- The relevant historical elements of the proposal.	Compiled from site visits, archival and cataloguing process. Data source from the platform pdok (set: pand) 2020.	Compiled from site visits, archival and cataloguing process. Data source from the platform ICGC (set: constructions) 2020.
2.- Existing historical fragments of the city.	Produced by examination of maps and palimpsest analysis (1930, 1970, and 2020). Data from the platform pdok and geofabriek (set: pand, openruimte, weg), official documents, and Historical Atlas of Eindhoven	Produced by examination of maps and palimpsest analysis (1940, 1970, and 2020). Data from the platform ICGC and geofabriek (set: construccions, transport, cobertes, relleu and hidrologia), official documents, and Carta Històrica de Barcelona (MUHBA)[1]
3.- The relevant buildings of the project.	This layer has been produced with a historical archival of literature reference (Forum text, CIAM congress text, HNI archive, etc.) and cataloguing during the site visits. The data source used was open data from the platform pdok (set: pand) 2020 and personal data produced from the site visits.	This layer has been produced with a historical archival of literature reference (Forum text, CIAM congress text, HNI archive, etc.) and cataloguing during the site visits. The data source used was open data from the platform platform ICGC and geofabriek (set: cobertes) 2020 and personal data produced from the site visits.
4.- The public spaces of articulation between the project and the immediate environment.	Produced using historical maps and a morphological analysis of the urban structure. Data from the platform pdok (set: pand, open ruimte) 2020.	Produced using historical maps and a morphological analysis of the urban structure. Data from the platform ICGC and geofabriek (set: cobertes, relleu and hidrologia), 2020.
5.- Group identity centres.	Produced via a morphological analysis of type/block/group units. Compiled using archival study of CIAM and Team 10 identity configurations in urban form thought-out the scales and observations during site visits. Data from the platform pdok (set: pand) 2020.	Produced via a morphological analysis of type/block/group units. Compiled using archival study of CIAM and Team 10 identity configurations in urban form thought-out the scales and observations during site visits. Data from the platform ICGC (set: cobertes) 2020.
6.- The centres of identity of the blocks.	Produced via a morphological analysis of type/block/group units. Compiled using archival study of CIAM and Team 10 identity configurations in urban form thought-out the scales and observations during site visits. Data from the platform pdok (set: pand) 2020.	Produced via a morphological analysis of type/block/group units. Compiled using archival study of CIAM and Team 10 identity configurations in urban form thought-out the scales and observations during site visits. Data from the platform ICGC (set: construccions, cobertes, relleu) 2020.
7.- The fronts of the civic axes.	Produced via morphological analysis of urban structure through a palimpsest analysis (using maps from 1930, 1970, and 2020) official documents, and Historical Atlas of Eindhoven. Data from the platform pdok (set: pand) 2020.	Produced via morphological analysis of urban structure through a palimpsest analysis (using maps from 1940, 1970, and 2020) official documents, and Historical Atlas of Eindhoven. Data from the platform pdok (set: pand) 2020.
8.- The historical plots eliminated.	Produced via a palimpsest analysis (using maps from 1930, 1970, and 2020) official documents, and Historical Atlas of Eindhoven. Data from the platform pdok (set: pand) 2020.	Produced via a palimpsest analysis 1940, 1970, and 2020). Data from the platform ICGC and geofabriek (set: construccions, cobertes, relleu), official documents, and Carta Històrica de Barcelona (MUHBA)[2]
9.- The perimeter of the ´t Hool complex (Place-group-block-type):	Compiled using information on municipal boundaries, land use from City Hall open data, and refined using a methodological analysis of the configuration of urban form (type/block/group/place). Data from the platform pdok 2020.	Compiled using information on municipal boundaries, land use from City Hall open data, and refined using a methodological analysis of the configuration of urban form (type/block/group/place). Data from the platform ICGC and geofabriek 2020.
10.- The visual sequences A and B, (From the chair to the city and viceversa).	Conducted using Gordon Cullens' cognitive approach to spatial patterns called serial vision and adapted to the detection of 'Atmospheric intensity' points that allows us to extract spatial patterns (to be address in following articles). Data source: photography from the authors during site visits.	Conducted using Gordon Cullens' cognitive approach to spatial patterns called serial vision and adapted to the detection of 'Atmospheric intensity' points that allows us to extract spatial patterns (to be address in following articles). Data source: photography from the authors during site visits.

TABLE 2 Layers and data set that construct Historical cartographies of ´t Hool and Montbau in a comparative approach. Source: Made by authors

1 https://www.barcelona.cat/museuhistoria/cartahistorica/index.html?lang=en#map=14/242185/5070759/2010//0/0/0/0

2 https://www.barcelona.cat/museuhistoria/cartahistorica/index.html?lang=en#map=14/242185/5070759/2010//0/0/0/0

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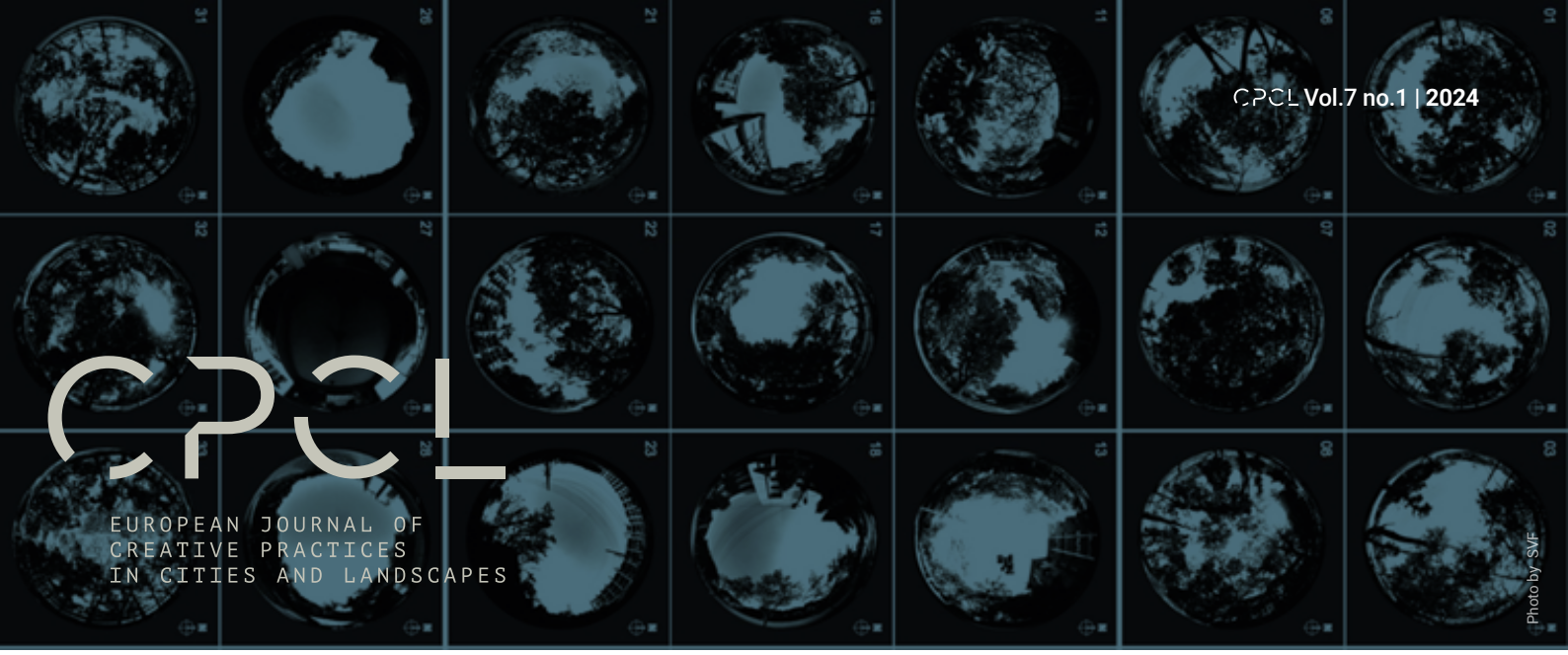

MAIN SECTION

An Analytical Study on Campus Street Types Considering Sustainable Landscape Microclimate

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ABSTRACT
This study investigates the influence of street space enclosure on microclimate within a university campus setting, classifying campus streets into open, semi-open, and street entry types. Microclimatic data was collected along a 2 km main spine and an additional 1.5 km street area. Enclosure was quantified using sky view factor analysis of photospheric data, and GIS analysis was employed to assess its impact on various microclimatic attributes. Results from inverse distance weighted (IDW) mapping reveal that open street types exhibit more favourable microclimatic conditions, whereas street entry types experience the least desirable conditions. Geostatistical analysis indicates a significant correlation between sky view factor and light intensity, while wind flow demonstrates a positive correlation, albeit without statistical significance. This research underscores the importance of street space design in shaping campus microclimates and offers insights for enhancing outdoor comfort within university environments.

KEYWORDS
microclimate, GIS, landscape, campus, street

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1. Introduction

The open areas within academic campuses, such as universities, play a substantial role in the day-to-day existence and behavior of the campus. Building a current university is very vital for regional competitiveness. 'It works in two ways: one is hardware, such as surroundings and infrastructure; the other is software, such as teaching, the capability for scientific research and influence'.[1] Rapid urban growth in developing countries throughout the last several decades has led to major transformations in land use and the extent of modern cities, resulting in many environmental problems in urban areas.[2] Urban areas, such as university campuses, are increasingly vulnerable to higher temperatures due to global warming and urbanization.[3-4] Many excellent campuses are defined through the electricity of their landscapes and open spaces and rely on these belongings as an ability to attract students. Microclimate considerations should be an integral part of the design of public outdoor spaces if they are to influence user behavior.[5]

Considering the necessary phase in a city, university campuses are each interrelated with and tremendously impartial to the urban microclimate. Campus areas, being a microcosm of urban areas, are vulnerable to the effects of rising temperatures as the world warms.[6] Considering functional variations, campuses have the shape of complicated built forms, and the plot ratio is usually low. Accordingly, these campuses have unique street patterns and open space configurations.[7] On a micro level, street geometries and the insertion of open spaces affect the elements of the microclimate, like sunlight, wind speed, humidity, and temperature.[8] Incorporating climate analysis into the design process needs to happen at an early stage before spaces are blocked off by uninformed decisions.[9]

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1 Lusheng Lin and Ya Dong, "A Study on the Campus Landscape Design of the National University of Singapore," *IOP Conference Series: Materials Science and Engineering* 301, no. 1 (January 2018): 12152.

2 Stella Tsoka, et al., "'Urban Warming and Cities' Microclimates: Investigation Methods and Mitigation Strategies—A Review." *Energies* 13, no. 6 (2020).

3 Tobi E. Morakinyo and Yu Fat Lam, "Simulation Study on the Impact of Tree-Configuration, Planting Pattern and Wind Condition on Street-Canyon's Micro-Climate and Thermal Comfort," *Building and Environment* 103 (2016): 262–75.

4 Huawei Li, et al., "Analysis of Cooling and Humidification Effects of Different Coverage Types in Small Green Spaces (SGS) in the Context of Urban Homogenization: A Case of HAU Campus Green Spaces in Summer in Zhengzhou, China," *Atmosphere* 11, no. 8 (2020).

5 Živa Ravnikar, Alfonso Bahillo, and Barbara Goličnik Marušić, "A Protocol for Microclimate-Related Street Assessment and the Potential of Detailed Environmental Data for Better Consideration of Microclimatology in Urban Planning," *Sustainability* 15, no. 10 (2023).

6 Elnaz Tajer and Beyza Sat, "Thermal Impact of Hard and Soft Surfaces in Landscape Design of a University Campus: A Case Study," Pre-print, 2024.

7 Hong Jin, Liang Qiao, and Peng Cui, "Study on the Effect of Streets' Space Forms on Campus Microclimate in the Severe Cold Region of China—Case Study of a University Campus in Daqing City," *International Journal of Environmental Research and Public Health* 17, no. 22 (2020).

8 Timothy R. Oke, "Street Design and Urban Canopy Layer Climate," *Energy and Buildings* 11, no. 1 (1988): 103–13.

9 Amany A. Ragheb, Ingy I. El-Darwish, and Sheif Ahmed, "Microclimate and Human Comfort Considerations in Planning a Historic Urban Quarter," *International Journal of Sustainable Built*

Cities are increasingly adapting urban planning to improve environmental quality for human comfort in response to climate change.[10]

Landscape architects need to be in a position to test their format solutions, which bear on the climatic performances. Without such perception of the urban microclimate and how landscape factors will affect it, designers can create urban landscapes that will perform poorly or even have a poor effect on the microclimate.[11] Unplanned future developments may additionally influence the Urban Heat Island (UHI) effect, although local weather exchange holistically, as the latest research, has included assessing the impact of layout interventions on temperatures and airflow in open areas.[12]

1.1 Significance of the Study

Landscape represents a skeleton for an outdoor environment of a campus. After commencement, the Shahjalal University of Science and Technology (SUST) campus is about 30 years of age and needs expansion in terms of departments and an increasing number of students. Yet the university needs more designed space, other infrastructural issues, and landscapes. So, it is necessary to rethink the expansion of the university in various sustainable ways possible. As space is scarce nowadays, it's time to think of vertical structures when considering the new development of the university. As per a recent university's strategy, tall structures are to be considered, where relevant research regarding campus landscape design is in dire need. Through proper research with a view to justifiable development, it is likely to have a sustainable model for the SUST campus for an appropriate educational and research environment. For a blissful and secure life for the instructing staff, students, and other employees, university campuses ought to be constructed on the groundwork of panorama planning and plan criteria, which also positively influences the great of the schooling gadget and scientific research.[13]

1.2 Objectives, Research Questions, and Expected Outcomes

This study investigates the microclimatic condition due to streets' space forms, focusing on sustainable landscape architecture design and planning of the SUST campus. Thus, the research considers open spaces due to street forms within the campus to investigate how landscape

Environment 5, no. 1 (2016): 156–67.

10 Ravnikar, Bahillo, and Goličnik Marušić, 'Protocol for Microclimate-Related Street Assessment."

11 Sanda Lenzholzer and Robert D. Brown, "Climate-Responsive Landscape Architecture Design Education," *Journal of Cleaner Production* 61 (2013): 89–99.

12 Schroth and Weihenstephan-Triesdorf, *Modelling Microclimates in the Smart City: A Campus Case Study on Natural Ventilation*.

13 Lin and Dong, "Campus Landscape Design," 12152.

architecture design interacts with the local microclimate. To categorize street forms into different types and study their respective microclimate features. Study the influence of Sky View Factor (SVF) on the surrounding microclimatic environment.

1.3 Literature Review

Microclimate can be considered as the situation of the photo voltaic and terrestrial radiation, wind, air temperature, humidity, and precipitation in a small outdoor area.[14] The elements influencing outside environmental remedies encompass the following: albedo, sky temperature, floor temperature, humidity, wind direction, air velocity, shortwave solar radiation, and lengthy wave radiation heat quantity.[15] The unique surface characteristics of that area significantly influence the microclimatic conditions in urban areas.[16-17]

Strong public activities can be seen in pleasant open city spaces that can contribute to the fantastic lifestyles contained by cities. However, there needs to be more records on alleviation prerequisites in indoor spaces, which will assist in the sketching and planning of such areas.[18] In such a context, micro-climatic prerequisites have become indispensable to open spaces' success. Light-colored pavements can help counteract the UHI effect by reflecting more sunlight and limiting surface temperatures. This can lead to lower urban temperatures and improved air quality in the city during the summer.[19-20-21-22] When designing outdoor public spaces, the macroscopic scale is significant as it reflects the scale at which the plan is implemented in the real space.[23]

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14 Robert D. Brown and Terry J. Gillespie, *Microclimatic Landscape Design: Creating Thermal Comfort and Energy Efficiency*, (New York: Wiley, 1995).

15 Ariya Aruninta, et al., "The Integration of Human Thermal Comfort in an Outdoor Campus Landscape in a Tropical Climate," *International Journal of GEOMATE* 14, no. 44 (2018): 26–32

16 Ilya M. D. Maclean, et al., "On the Measurement of Microclimate," *Methods in Ecology and Evolution* 12, no. 8 (2021): 1397–1410.

17 Natasha H. Gapski, et al., "Impact of Urban Surfaces' Solar Reflectance on Air Temperature and Radiation Flux," *Sustainable Cities and Society* 96 (2023): 104645.

18 Marialena Nikolopoulou and Spyros Lykoudis, "Thermal Comfort in Outdoor Urban Spaces: Analysis across Different European Countries," *Building and Environment* 41, no. 11 (2006): 1455–70.

19 Hayder Al-Gretawee, Scott Rayburg, and Melissa Neave, "THE COOLING EFFECT OF A MEDIUM SIZED PARK ON AN URBAN ENVIRONMENT," *GEOMATE Journal* 11, no. 26 (12 October 2017): 2541–46.

20 Hashem Akbari, Melvin Pomerantz, and Haider Taha, "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas," *Solar Energy* 70, no. 3 (2001): 295-310.

21 Haider Taha, Hillel Hammer, and Hashem Akbari, "Meteorological and Air Quality Impacts of Increased Urban Surface Albedo and Vegetative Cover in the Greater Toronto Area, Canada," *Lawrence Berkeley National Laboratory*, 2002.

22 Arthur H. Rosenfeld, et al., "Mitigation of Urban Heat Islands: Materials, Utility Programs, Updates," *Energy and Buildings* 22, no. 3 (1995): 255–65.

23 Ravnikar, Bahillo, and Goličnik Marušić, "Protocol for Microclimate-Related Street Assessment."

There is a sufficient grasp of the impact of local weather on cities. For instance, mutual shading in warm-arid climates protects the built forms from excessive heat, and spaced built forms in warm-humid climates allow better ventilation. Architectural features that do not adapt to the local climate will create problems.[24] Creating a comfortable microclimate can be achieved through various methods and degrees of preparation. For instance, green infrastructure typically creates a cooling effect and helps combat the UHI effect, while the design and height of buildings can impact wind speed.[25-26-27-28-29] Microclimatic configuration requires a conceptual grasp of how landscape elements can influence microclimatic elements like solar radiation and wind flow.[30] Plants can strongly affect microclimate. Trees and green areas can assist in cooling our cities and preserve energy. Trees can grant photo-voltaic defense to character homes during summertime, and evapotranspiration from trees can reduce heat. It also serves to mitigate the greenhouse effect, purify the air by filtering out pollutants, reduce noise pollution, prevent soil erosion, and have a calming effect on humans.

Landscape elements can guide the wind flow, reduce radiation, air temperature, and influence humidity. Amongst a variety of factors, the orientation of the street imposes a top-notch impact on the volume of photo voltaic radiation on the streets.[31] The air temperature of avenues depends upon the temperature of radiation, and the radiation is influenced by photo-voltaic sources. The massive place of the avenue receiving photo-voltaic radiation temperature and prolonged frequency of the temperature from radiation can be seen.[32] According to Chatzidimitriou,[33] streets having NE-SW orientation have higher temperatures during winter. Wind pace variants amongst streets can attain 2.7 m/s affected by the surrounding

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24 Marialena Nikolopoulou, Nick Baker, and Koen Steemers, "Thermal Comfort in Outdoor Urban Spaces: Understanding the Human Parameter," *Solar Energy* 70, no. 3 (2001): 227–35.

25 Farshid Aram, et al., "Urban Green Space Cooling Effect in Cities," *Heliyon* 5, no. 4 (2019): e01339.

26 Sukanya Ghosh, Deepak Kumar, and Rina Kumari, "Assessing Spatiotemporal Variations in Land Surface Temperature and SUHI Intensity with a Cloud Based Computational System over Five Major Cities of India," *Sustainable Cities and Society* 85 (2022): 104060.

27 Cláudia Reis and António Lopes, "Evaluating the Cooling Potential of Urban Green Spaces to Tackle Urban Climate Change in Lisbon," *Sustainability* 11, no. 9 (2019).

28 Tiantian Du, et al., "Effects of Architectural Space Layouts on Energy Performance: A Review," *Sustainability* 12, no. 5 (2020).

29 Ragheb, El-Darwish, and Ahmed, "Microclimate and Human Comfort," 156–67.

30 Brown and Gillespie, *Microclimatic Landscape Design*.

31 Nahid Mohajeri, et al., "A Solar-Based Sustainable Urban Design: The Effects of City-Scale Street-Canyon Geometry on Solar Access in Geneva, Switzerland," *Applied Energy* 240 (2019): 173–90.

32 Atsumasa Yoshida, Kazuhide Tominaga, and Shigeru Watatani, "Field Measurements on Energy Balance of an Urban Canyon in the Summer Season," *Energy and Buildings* 15, no. 3 (1990): 417–23.

33 Angeliki Chatzidimitriou and Simos Yannas, "Street Canyon Design and Improvement Potential for Urban Open Spaces; the Influence of Canyon Aspect Ratio and Orientation on Microclimate and Outdoor Comfort," *Sustainable Cities and Society* 33 (2017): 85–101.

elements. According to Sözens' study,[34] the average wind pace of streets having NS (North-South) orientation is around 3.7 m/s faster than that of the EW (East-West) streets and is around 1.1m/s faster than that of the streets having NE-SW orientation. The studies mentioned above propose that street orientations significantly affect street microclimate. However, the streets considered in this study are primarily continuous and complete. Yang W. et al (2018)[35] investigated how landscape design affects urban microclimate and thermal comfort in Singapore's high-rise residential areas by considering different design scenarios, including pavement, green, and blue features. He found combining shade trees with grass was the most efficient design strategy for staying cool. Concrete surfaces, air pollution, habitat depletion, heat islands, and increased energy consumption negatively impact urban microclimate.[36,37,38] Surface properties, including materials such as asphalt, concrete, vegetation, and buildings, play a key role in shaping the climate and thermodynamics specific to local environments within urban landscapes.[39-40]

The trees, with the aid of sun exposure effect and evaporation, will enhance the remedy around neighboring areas at tropical and sub-tropical cities.[41-42] The shading impact of bushes will decrease the Mean Radiant Temperature (MRT) of streets.[43] Morakinyo et al (2017)[44] studied the impact of timber on the microclimate of city street canyons in Hong Kong. As per the study, timber parameters (such as tree height, tree trunk height, and leaf-location index) impact thermal comfort during daylight and nighttime hours. It can be seen that low-density plantations of tall species are recommended for deep canyons; on the other hand, open areas and shallow canyons should pick the opposite. These studies on

34 İrem Sözen and Gül K. Oral, "Outdoor Thermal Comfort in Urban Canyon and Courtyard in Hot Arid Climate: A Parametric Study Based on the Vernacular Settlement of Mardin," Sustainable Cities and Society 48 (2019): 101398.

35 Wei Yang, Yaolin Lin, and Chun-Qing Li, "Effects of Landscape Design on Urban Microclimate and Thermal Comfort in Tropical Climate," *Advances in Meteorology* 2018, no. 1 (2018): 2809649.

36 Tianyu Xi, et al., "Study on the Outdoor Thermal Environment and Thermal Comfort around Campus Clusters in Subtropical Urban Areas," *Building and Environment* 52 (2012): 162–70.

37 Yafei Wang, et al., "Thermal Comfort in Urban Green Spaces: A Survey on a Dutch University Campus," *International Journal of Biometeorology* 61, no. 1 (2017): 87–101.

38 Li, et al., "Cooling and Humidification Effects."

39 Racine T. A. Prado and Fabiano L. Ferreira, "Measurement of Albedo and Analysis of Its Influence the Surface Temperature of Building Roof Materials," *Energy and Buildings* 37, no. 4 (2005): 295–300.

40 Salam R. O. Aletba, et al., "Thermal Performance of Cooling Strategies for Asphalt Pavement: A State-of-the-Art Review," *Journal of Traffic and Transportation Engineering (English Edition)* 8, no. 3 (2021): 356-373.

41 Diana E. Bowler, et al., "Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence," *Landscape and Urban Planning* 97, no. 3 (2010): 147–55.

42 Erik Gómez-Baggethun and David N. Barton, "Classifying and Valuing Ecosystem Services for Urban Planning," *Ecological Economics* 86 (2013): 235–45.

43 Chun L. Tan, Nyuk H. Wong, and Steve K. Jusuf, "Outdoor Mean Radiant Temperature Estimation in the Tropical Urban Environment," *Building and Environment* 64 (2013): 118–29.

44 Tobi E. Morakinyo, et al., "A Study on the Impact of Shadow-Cast and Tree Species on in-Canyon and Neighborhood's Thermal Comfort," *Building and Environment* 115 (2017): 1–17.

timber are generally at the center of attention on the shadow effect of bushes in summer. Plants are considered a very effective way to improve outdoor climate and are used to reduce environmental pollution, regulate the microclimate and purify the air. This is achieved by plants absorbing and redirecting solar radiation, minimizing longwave radiant heat, providing shade to reduce direct sunlight, and ultimately reducing water loss.[45] Trees have proven effective because they block shortwave radiation, reduce the exchange of longwave radiation, and generate evapotranspiration with less water use than turfgrass.[46] Researchers investigated the relationship between urban planning, urban microclimate, and outdoor comfort in four urban areas with different morphologies. They found that while dense tree coverage helps reduce heat stress, vegetation can have a negative impact on wind ventilation.[47]

The SVF suggests the functionality of city space in getting hold of solar radiation. The cost of SVF is considered by means of structure and greening.[48] Areas with lower SVF values usually have lower temperatures for the day, as they acquire a lesser quantity in terms of photo-voltaic radiation throughout sunlight hours.[49-50-51-52] SVF has a constrained effect on outdoor air temperature during the summer but has a big impact on global temperature.[53] At the same time, SVF also has a super effect on wind velocity.[54] The spatial forms of exceptional areas have one-of-a-kind influences on the microclimate.[55] Space varieties of campus affect its microclimate.[56] The types of buildings have a widespread impact on

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45 Huang, Chih-Hong, and Pin-Yi Lin, "The Influence of Evapotranspiration by Urban Greenery on Thermal Environment in Urban Microclimate," *International Review for Spatial Planning and Sustainable Development* 1, no. 4 (2013): 1–12.

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the duration of sunshine hours, common radiation temperature, and wind surroundings.[57] Considering the study of campus microclimate, we can sketch the out-of-door space varieties by considering out-of-door comfort and constructing warmness release.[58] Few studies have specifically addressed the effect of different surfaces on microclimate within the campus. Considering the diverse function of campuses, recognizing this delicate relationship is essential for sustainable campus planning.[59] As a necessary part of urban areas, campuses consist of a greater variation in space forms. Generally, university campuses have a lower plot ratio and a higher portion of open spaces. The students usually spend longer time in the outdoor areas. So, designing and planning the outdoor areas should get greater attention. Sustainability criteria should determine the design of open spaces on campus. The natural appearance and space quality of the outdoor facilities are the results of the proper allocation of requirements and implementation of sustainable design features in the university environment.[60]

2. Methodology

After reviewing the literature and observational study, relevant data were collected through scientific devices/instruments as applicable for microclimate data collection. The data were statistically analyzed and compared with a view to significant differences between landscape microclimates and the controls, i.e., street space forms. Such results are expected to demonstrate whether street space forms influence landscape microclimates in the studied climatic condition, which can further provide guidelines for sustainable landscape design considering the SUST campus. Considering the research tactic, the following steps were maintained (Fig. 1)

2.1 Experimental Design

The research surveys were designed to collect data from outdoor spaces during the hot-humid summer season. The surveys were performed for five (05) days in October at the SUST campus, Sylhet, Bangladesh, between 12-28th October during daytime (9 am-11 am) and afternoon (2 pm-4 pm), which is generally the peak hours of outdoor-space occupancy in the campus. The data aim to find the microclimate conditions in

(Cham: Springer International Publishing, 2017), 309-15

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FIG. 1 Research methodology

outdoor spaces. Sylhet is located at 24.8917˚N latitude and 91.8833˚E latitude in the northeastern region of Bangladesh and typically experiences a tropical monsoon climate. In summer, the average temperature can reach between 31.67˚C and 25.56˚C, while in winter, the average daily high temperature is below 25.56˚C and the coldest month has an average low of 13.33˚C a high of 24.44˚C.

The monitoring site is the SUST, located in Sylhet, Bangladesh. It covers an area of 320 acres. The campus landscape comprises open lands with walk-up buildings and a beautiful landscape of green and blue scapes. On the west and north sides of the campus, there are vacant lands with walk-up public buildings, while on the east side, the sector of Border Guard Bangladesh is situated, and on the south side, Sylhet Sunamgonj highway is located. Fig. (1) and (2) show campus forms and layout.

i.
Satellite view of campus

ii.
Drone view of campus

FIG. 2 Street, buildings, and green areas of the university campus.

2.2 Measurement Procedures

The campus has spacious outdoor areas with different types of streets: open, semi-open, and street-entry. Fig. 3 presents these street forms.

The observation points and route patterns are shown in Figure 4. Thirty-five observation points were selected, considering ground surface conditions and sky factors influenced by buildings and trees.

SVF (%), temperature (˚C), relative humidity (%), day-light (lux), and wind speed (m/s) were measured. The air temperature and humidity were measured at four feet height from the ground using i) Temperature and

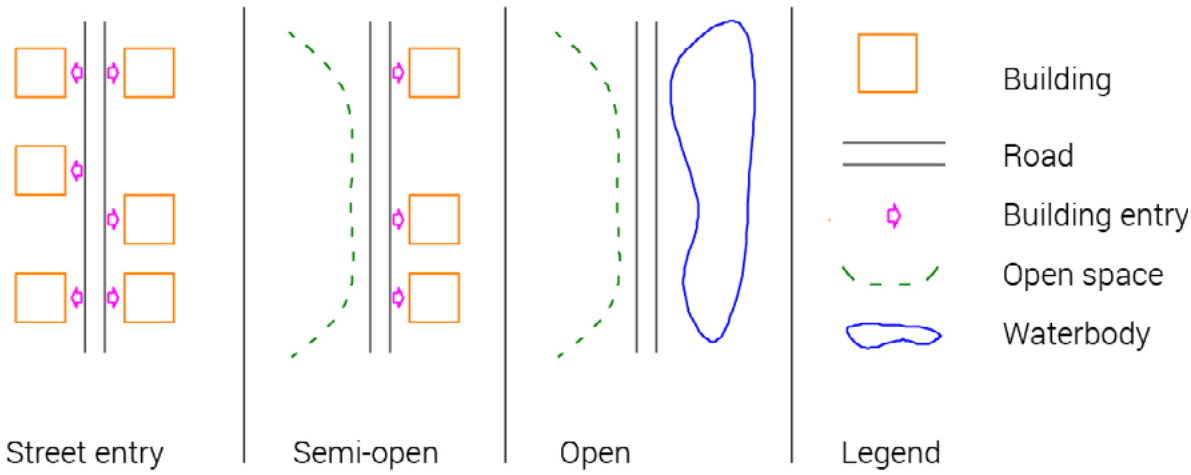


FIG. 3 Street types based on surrounding context

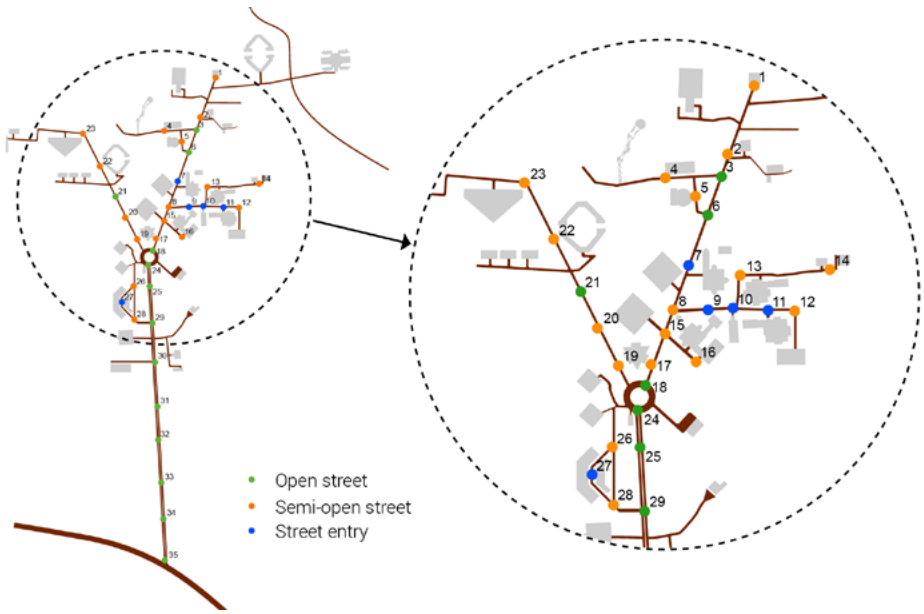


FIG. 4 Data collection points

Humidity meter, Brand: Smart Sensor, Model: AS847, Range (Temp.): -10˚C – 50˚C, (Humidity): 5% - 85% RH; ii) Light meter, Brand: Lutron, Model: LX-101A, Range: 0-50,000 Lux. The prevailing wind direction and air velocity were measured for five minutes at four feet height from the ground using iii) Digital Anemometer, Brand: Smart Sensor, Model: AR826, Range: 0-45 m/s(Fig.5(i),(ii),(iii))

Human perceptions of temperature are influenced by multiple climatic factors. It's not just about the air temperature, but also about various environmental elements like thermal radiation, convection, humidity, and heat conduction. In short, solar radiation is the primary source of heat, and a scorching ground surface adds to the intense heat we experience. Additionally, high humidity gives us that uncomfortable muggy feeling. When the wind flows, it gives relief from heat. Understanding all these factors helps us gain a better understanding of how we experience and react to temperature.

i.
Temperature and humidity meter

ii.
Light meter

iii.
Digital Anemometer

FIG. 5 Measuring Instruments

2.3 Sky View Factor (SVF)

'Cool PHP tool' was used to calculate the SVF. The extra portion outside the sphere (at the corners of the square) excluded using geometric calculation' (Fig.6),

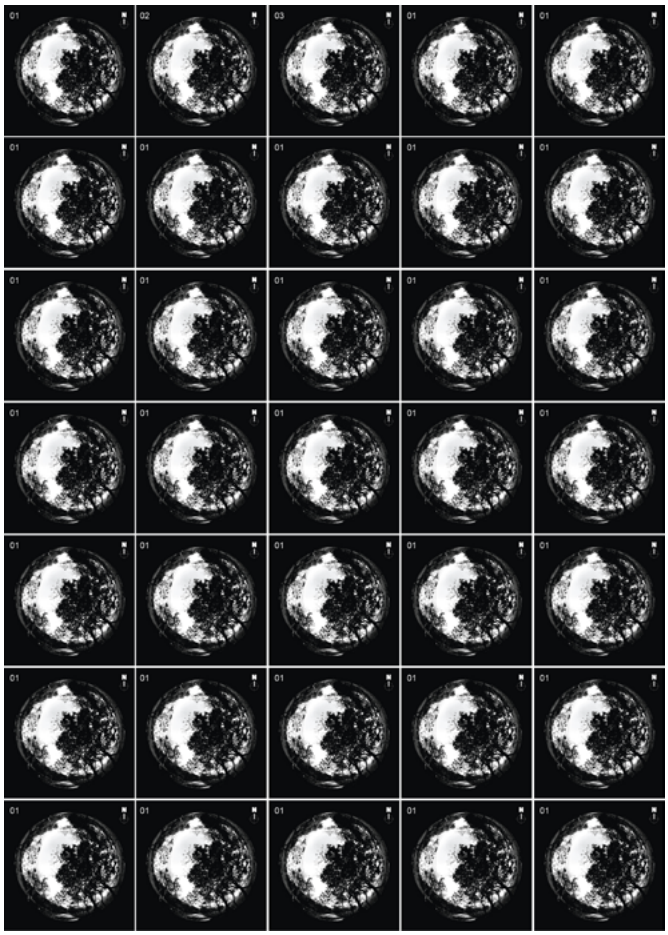
2.4 Normalization of Microclimatic Data

As there are data range variations considering different microclimate parameters, for comparative analysis among different parameters 'normalization of data' process was followed (Fig. 7) using the following equation:
Normalized data =((actual data-minimum)/(maximum-minimum))x100

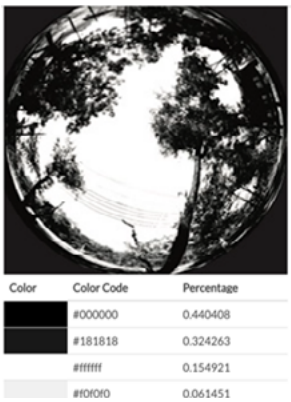
2.5 Analysis in GIS

The Inverse Distance Weighted (IDW) interpolation tool was used for visual analysis in GIS. The spatial distribution pattern of different microclimatic data and the identification of hot and cold spots were identified from the map. Visual analysis gave some idea of the correlation between different landscape elements and microclimate. For better understanding, a geo-statistical test was run in GIS.

'Ordinary Least Square (OLS)' spatial analysis in ArcMap was used for geo-statistical analysis in GIS. The influence of SVF on temperature, humidity, wind flow, and light were tested to identify statistically significant correlations and positive or negative impacts on the microclimate. In addition to statistical analysis, GIS supports finding any bias from the spatial distribution of the data. Moran's I test on the OLS residuals has been done to confirm that the data collection points and methods have been spatially unbiased.



i.
Image sphere to calculate SVF



Color	Color Code	Percentage
	#000000	0.440408
	#181818	0.324263
	#ffffff	0.154921
	#f0f0f0	0.061451

ii.
SVF image analysis

FIG. 6 SVF measurement process sample.

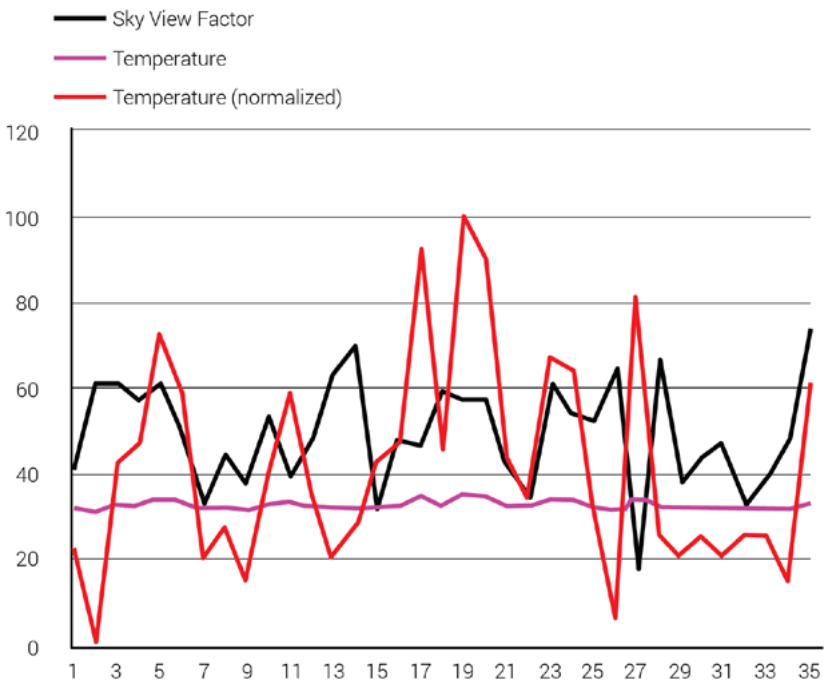
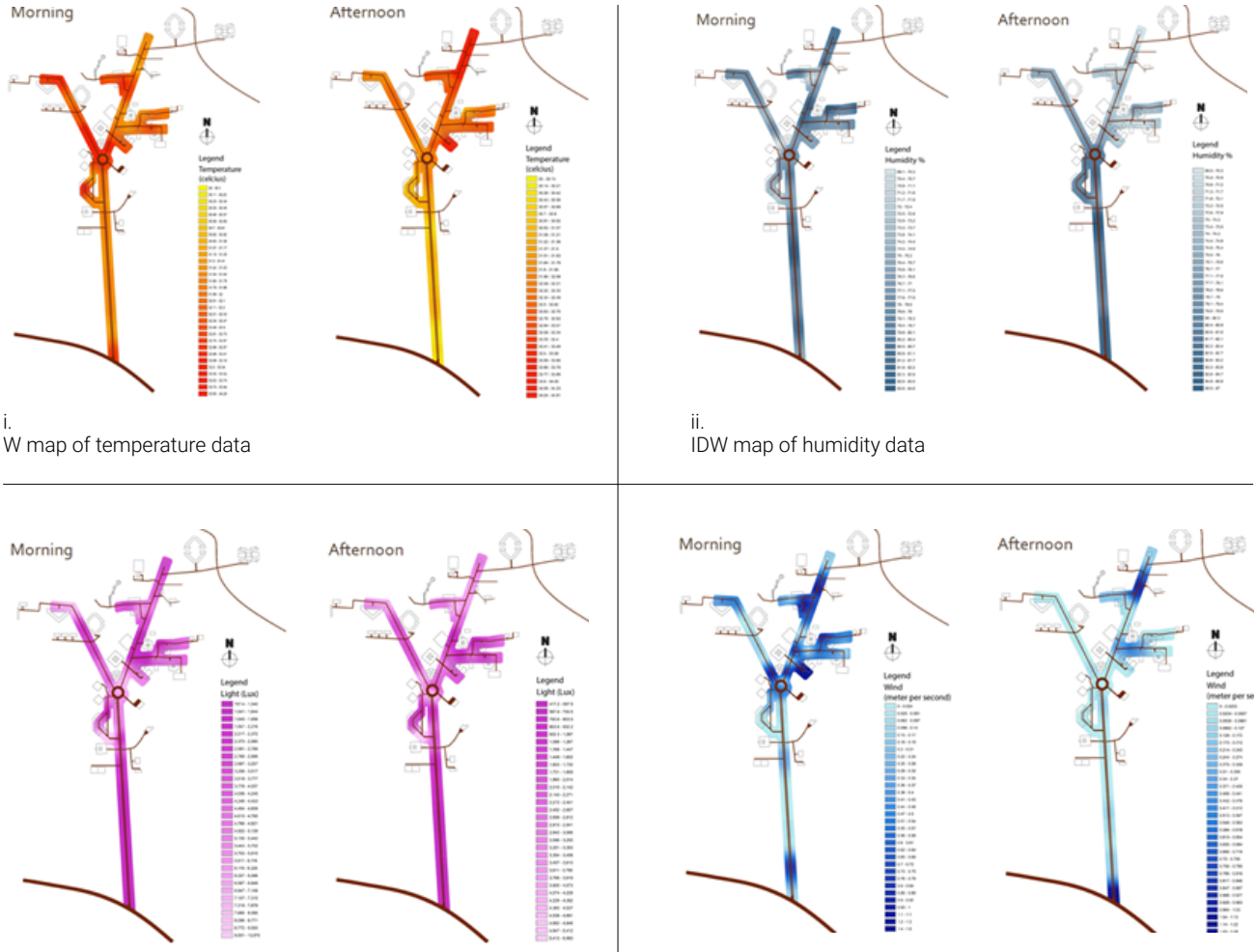


FIG. 7 Normalization of data for comparative analysis (sample graph)



i.
W map of temperature data

ii.
IDW map of humidity data

iii.
IDW map of light data

iV.
IDW map of wind flow data

FIG. 8 IDW maps of microclimatic data showing the variations around the streets of the campus.

3. Results and Discussion

As spatial features considering university campus streets are different, common block morphology parameter research on the relationship thermal environment is likely not to be fully applied considering the situation of campus streets. Microclimate data were collected from the data collection points in the morning and afternoon and compiled for visual and statistical analysis (Fig. 9).

3.1 Correlating SVF With Normalized Microclimatic Data

At the first stage of analysis, simple charts have been used to identify the pattern (Fig.-9 (i),(ii),(iii),(iv)). Temperature change in different data collection points shows a similar pattern with SVF. The intensity of temperature change is higher, but the pattern in the chart looks similar. Light also shows similar results in the chart. On the other hand, the humidity chart indicates an inverse relation with SVF. Though the data does not

Data Point	Sky View Factor %	Temperature °C (morning)	Temperature °C (afternoon)	Relative Humidity % (morning)	Relative Humidity % (afternoon)	Light Lux (morning)	Light Lux (afternoon)	Wind m/s (morning)	Wind m/s (afternoon)
1	40.6	31.5	34.4	81.2	69.6	3100	3050	0.1	0.1
2	60.4	30.7	34	82.5	76	4200	4040	1	1
3	60.4	32.2	34.2	72.3	70.9	5340	3950	0.9	0.6
4	56.8	32.4	32.8	81.1	73.3	3190	2510	0.2	0.1
5	60.4	33.3	32.2	67.6	70.5	7530	5180	0	1.1
6	49.6	32.8	33.2	77.9	74.9	2890	2510	0	0.6
7	31.6	31.4	32.7	83.2	71.9	1505	743	0	0
8	44.2	31.7	32.3	82.8	74	1315	2130	0.4	0.9
9	37	31.2	32.1	79.1	71.6	670	392	0.6	0
10	53.2	32.1	32.7	75.1	70.4	5440	3010	0.4	0.6
11	38.8	32.8	33	75.2	69.3	5100	1251	0	0.4
12	47.8	31.9	33	77.8	72.8	4430	2478	0	0.1
13	62.2	31.4	31.1	84.6	78.4	1810	750	0	0.9
14	69.4	31.7	31.6	82.9	77.2	5020	3400	0	0.5
15	31.6	32.2	32	77.4	77	5340	3500	0	0
16	47.8	32.4	34.7	75.4	71.3	5440	2020	0	1.6
17	46	34	32.9	76.4	76	8230	2590	0	0.9
18	58.6	32.3	31.7	79.4	83	7780	1600	0	0
19	56.8	34.3	31.5	69	78.9	4080	4560	0.1	1
20	56.8	33.9	32.2	78.1	76.9	4900	1916	0	0
21	42.4	32.3	32.1	73.7	76.4	3350	1917	0	0.1
22	37	31.9	32.5	77.5	76.6	2420	1887	0	0
23	60.4	33.1	31.8	78.5	75.3	8080	4280	0	0.5
24	53.2	33	31.9	75.7	82.1	5940	5450	0	0.6
25	51.4	31.8	32.3	81	83.6	6050	858	0.2	0
26	64	30.9	31	76.2	79.8	1030	876	0	0.3
27	17.2	33.6	30.9	73.7	79.5	4670	1339	0	0
28	65.8	31.6	31.1	71.7	81.4	14065	7030	0	0
29	37	31.4	31.3	75.8	75.6	1920	1721	0	0
30	42.4	31.6	30.5	80.2	87.1	2270	690	0	0.3
31	46	31.4	31.1	84.3	81.4	1423	1027	0	0
32	31.6	31.6	30.9	79.2	80.8	1427	420	0.1	0
33	38.8	31.6	31.2	77.6	79	1850	781	0	0
34	47.8	31.2	30.3	81.3	84.5	1911	459	0.1	0.8
35	73	32.9	30.4	75.6	84.6	1350	801	1.3	0.1

TABLE. 1 Collected microclimate data from data collection points (morning and afternoon)

show a consistent pattern in all points, in most cases, a higher SVF value decreases the humidity level at the data collection point. Change in wind flow does not have a significant relation with SVF. From this initial analysis using simple charts, we have identified temperature, humidity, and light as potential microclimatic factors that the SVF can affect. Wind flow does not show any potential correlation, but it should be kept as a variable in the statistical analysis for better understanding and more accurate results.

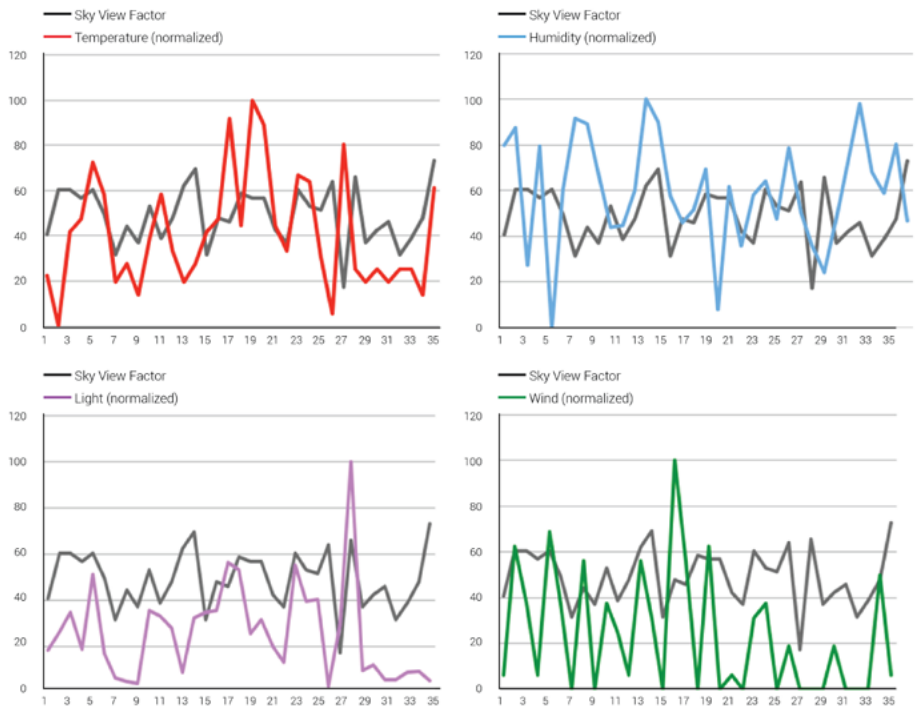


FIG. 9 Comparative chart between temperature, humidity, light, and wind with SVF.

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	69.90397	120.8403	0.578482	0.567255	116.699	0.599011	0.553662	--------
TEMP_M	-1.48912	2.793531	-0.53306	0.597918	3.043528	-0.48927	0.628205	1.56007
HUM_M	0.218759	0.630455	0.346986	0.731023	0.540993	0.404366	0.688811	1.629393
WIND_M	9.278809	4.826711	1.922387	0.064097	4.723601	1.964351	0.058812	1.052663
LIGHT_M	0.001596	0.000829	1.925426	0.063701	0.000779	2.047903	0.049411*	1.295485

TABLE. 2 Summary of OLS results

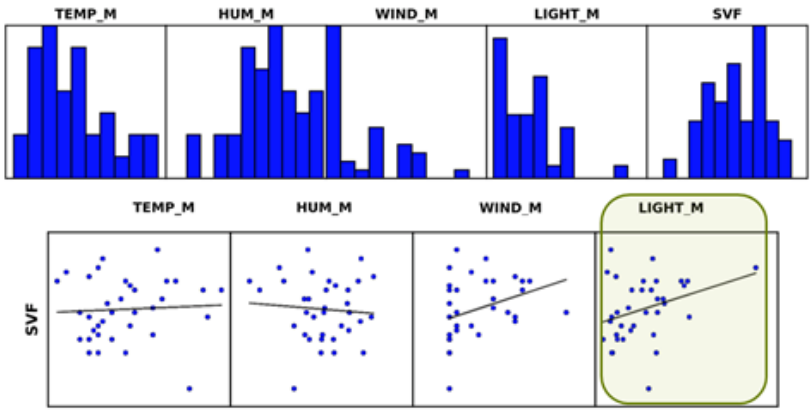


FIG. 10 Statistical relation of different microclimatic factors with SVF

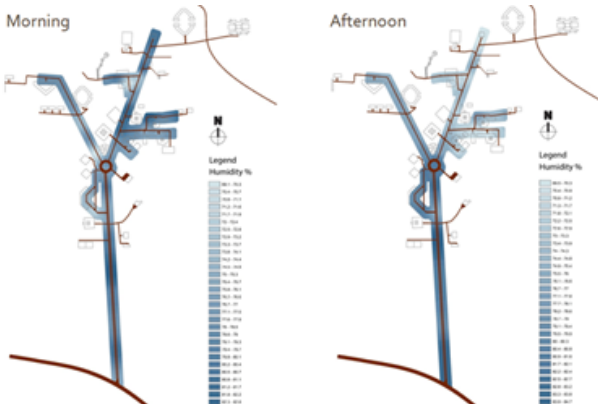


FIG. 11 IDW map of humidity level at street spaces in SUST campus

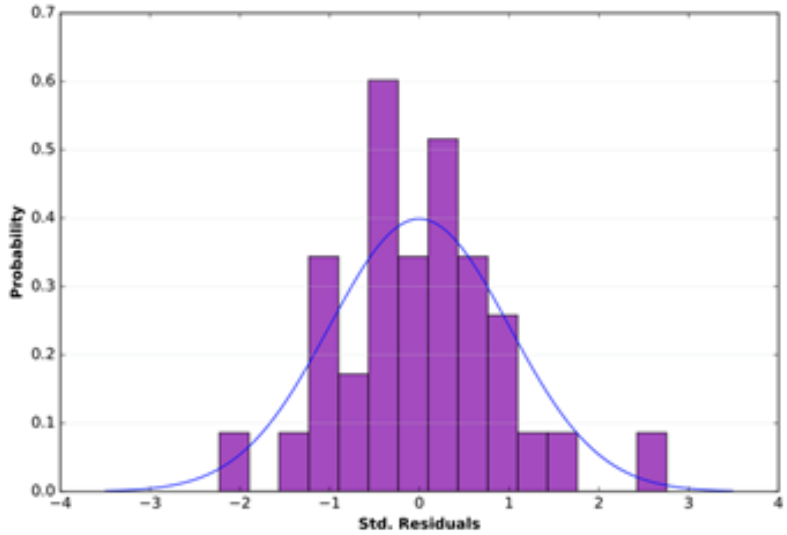


FIG. 12 Histogram generated from OLS test in GIS

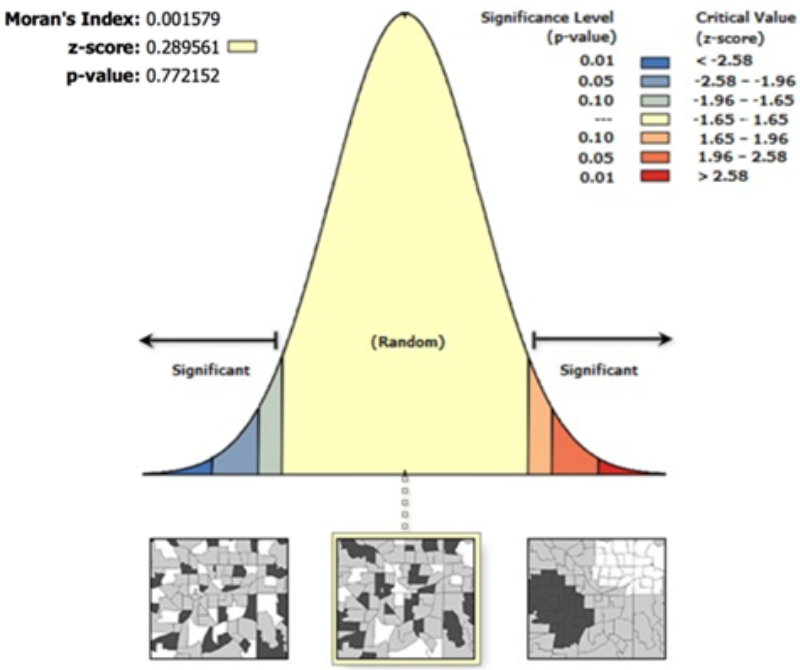


FIG. 13 Result from Moran's I test

3.2 OLS test and IDW map analysis in GIS

In the OLS test, the average of the microclimatic data in the morning and afternoon was selected as the dependent variable to test the geo-statistical correlation with SVF. Out of four variables: Temperature (TEMP_M), humidity (HUM_M), wind (WIND_M), and light (LIGHT_M), only light has a statistically significant correlation with SVF (Table. 2). Individual regression graphs (Fig. 10) of these factors show that temperature positively correlates with SVF, but the level of influence is relatively low. It reflects that though higher exposure to sunlight increases the temperature, the overall results have other influential solid factors. Humidity shows a slightly negative correlation with SVF. The visual analysis of the IDW map (Fig. 11) shows this factor is mainly influenced by proximity to water bodies. So, street space type does not highly influence humidity level. Wind and light have a higher level of influence from SVF (Fig. 10). Only light intensity level correlates statistically with SVF out of four climatic factors. The overall result from the OLS test shows a similar pattern with simple statistical analysis (Fig. 9). An important outcome of this geostatistical analysis is identifying a statistically significant correlation between SVF and microclimatic factors.

3.3 Testing the Residuals to Identify Spatial or Statistical Biasness of Climatic Data.

The histogram from the OLS test (Fig. 12) shows that the overall distribution of standard residuals fits with the model curve. So, the model performance for the OLS test is acceptable. At the next stage, standard residuals were tested with Moran's I spatial autocorrelation test in GIS. The result (Fig. 13) proves that the climatic data has no spatial biasness.

4. Recommendations

Increase plantation alongside the campus streets.

Keep natural corridors for better wind flow.

Introduce an integrated landscape plan to ensure better daylight and a comfortable microclimate.

Avoid street entry type and encourage semi-open street type in future extensions of the campus.

Introduce climatic simulation and environmental impact of upcoming building projects to examine the effect on microclimate before approving new building plans.

5. Conclusion

The study introduces an analytical model for evaluating the climatic performance of various street types within a campus environment. Despite

time constraints imposing some limitations on the study, the model's outcomes show promise. While the SVF provides a general perception of data collection point enclosure, integrating influential factors at the macro-scale is necessary for the next analysis phase. Campus planning should prioritize building structures and natural elements from the outset, as students spend considerable time outdoors. Consequently, designing the campus landscape to ensure a comfortable microclimate is crucial. Computer-based simulations can offer valuable feedback for future design proposals. However, analyzing existing landscape settings may be more effective in engaging users with varying levels of technical understanding. Therefore, replicating the proposed study model would benefit future research and design initiatives.

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Subrata Das is an associate professor in the Department of Architecture at Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. He teaches studio and lecture courses in urban design, environmental design, and computational analysis. His research focuses on urban analytics and environmental design, utilizing geographic information systems (GIS) to examine spatial form, performance, and policy implications. In professional practice as an architect and planner, he has contributed to public infrastructure, urban design, and regeneration projects, integrating evidence-based approaches to improve environmental quality and urban livability.

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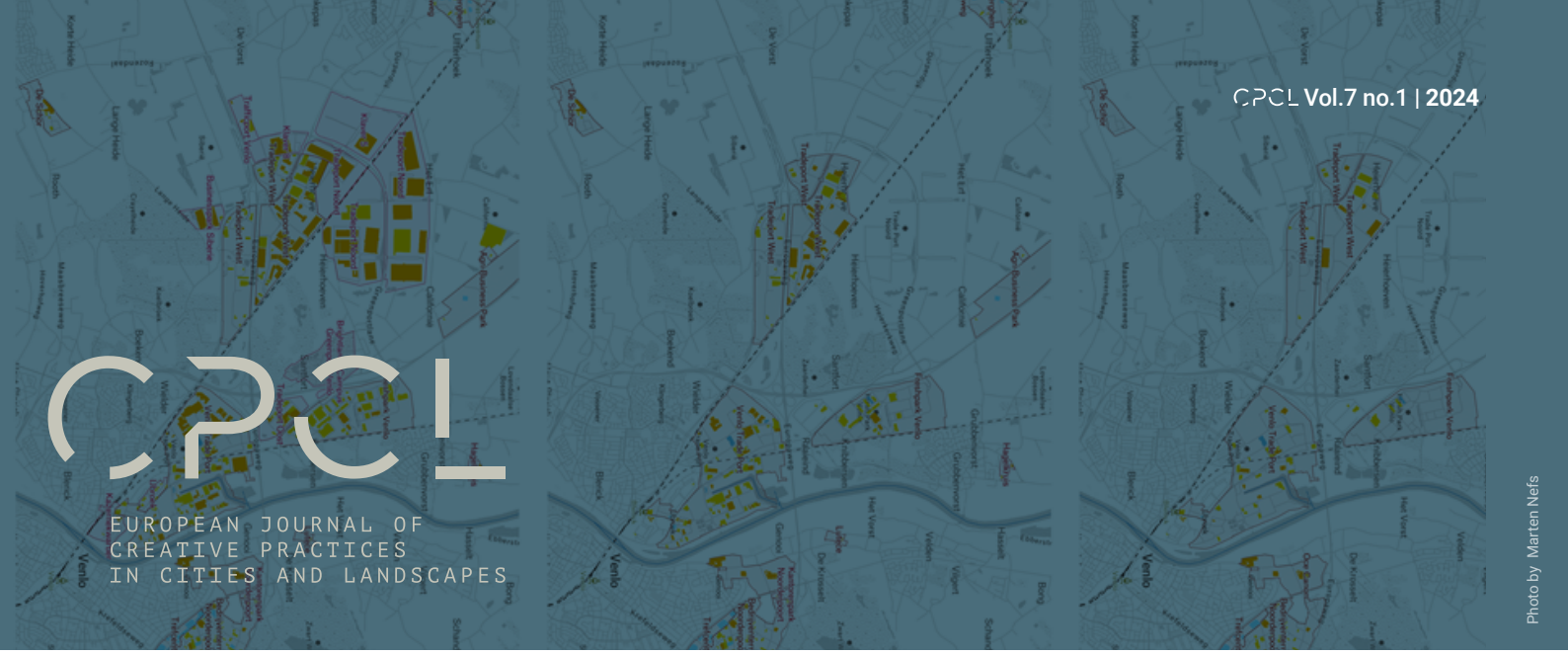

Photo by Marten Nefs

MAIN SECTION

Counter-Mapping Spatial Footprint and Economic Activity of the Logistics Complex in the Netherlands

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ABSTRACT

The growing footprint and the economic importance of the logistics complex has become an urgent planning topic on policy agendas in Europe, particularly in the Netherlands and its neighboring countries. The rise of the XXL warehouse is an important element in this discourse. The discourse typically features many different growth figures and maps on a highly aggregated level, whereas the source data are often not made available. Policymakers and researchers, however, need a more detailed comprehensive overview to make adequate decisions, analyze developments over time, and communicate with the broader public. This paper presents the counter-mapping process of compiling, validating, and sharing such a cartographic overview, including different types and size classes of distribution centers (DCs). It discusses several methodological and practical obstacles, as well as the use of an interactive map and a dashboard to inform a broader public, and the representation of the time dimension. Furthermore, it discusses insights of the open-access cartography of the logistics complex that challenge the common narratives outlined by the market and government, and it provides recommendations for the updating and improvement of the dataset and visualization.

KEYWORDS

Counter-mapping; logistics; distribution center; open-access; interactive map

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Introduction

The growing footprint and the economic importance of the logistics complex have become an urgent planning topic on policy agendas in Europe, particularly in the Netherlands and its neighboring countries. Increasingly, negative environmental effects of logistics, such as congestion, air-, noise- and light pollution, experienced by local communities, influence the planning discourse on the development of distribution centers—DCs.[1] Simultaneously, the societal benefits of such developments in an increasingly scarce space have become more doubtful, particularly the employment generated in and around DCs.[2] The rise of the XXL warehouse, larger than 40.000 sqm, is an important element in this discourse. The discourse typically features many different growth figures and maps on a highly aggregated level[3], whereas the source data are usually not made available.

Policymakers, however, need a more detailed comprehensive overview to make adequate decisions, communicate with the broader public, and create a level playing field for developers. For example, the trend of logistics sprawl and environmental effects of warehouses[4] cannot be discussed and mitigated when regarded through aggregated regional figures. Furthermore, local planning issues often relate to development of one or a few warehouses at a specific location. Such developments—and protests from the side of the community— cannot be well assessed and evaluated without placing them in a detailed historical and spatial context. Additionally, to set up effective criteria for logistics developers across regions, as to create a level playing field and avoid a waterbed effect that pushes developments to suboptimal locations, policymakers first need to have a structural and detailed view (not anecdotical) on the trends in distribution center projects. Such a detailed view includes the location, geometry, and landscape integration of DCs. Researchers therefore also need detailed data to provide such (open-access) insights into the issues above.

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1 Aljohani and Thompson, "Impacts of Logistics Sprawl on the Urban Environment and Logistics: Taxonomy and Review of Literature"; Yuan, "Environmental Justice in Warehousing Location: State of the Art."

2 Nefs, van Haaren, and van Oort, "The Limited Regional Employment Benefits of XXL-Logistics Centres in the Netherlands"; Tabak, "Boxes, Boom and Benefits? Identifying Effects of XXL Distribution Centres on Regional Economies in the Netherlands."

3 Bak, *Logistiek Vastgoed in Cijfers 2021(Logistics Real Estate in Figures 2021)*; Stec Group and Denc, *Logistiek: Naar Een Kernwaarde in Regionale Ontwikkeling(Logistics: Towards a Key Value in Regional Development)*.

4 Krzysztofik et al., "Beyond 'Logistics Sprawl' and 'Logistics Anti-Sprawl'. Case of the Katowice Region, Poland"; Dablanc, Ogilvie, and Goodchild, "Logistics Sprawl: Differential Warehousing Development Patterns
in Los Angeles, California, and Seattle, Washington"; Strale, "Logistics Sprawl in the Brussels Metropolitan Area: Toward a Socio-Geographic Typology"; Heitz, Dablanc, and Tavasszy, "Logistics Sprawl in Monocentric and Polycentric Metropolitan Areas: The Cases of Paris, France, and the Randstad, the Netherlands."

Thus, the scientific and societal debate on the spatial effects and planning of the logistics complex depends highly on the quality of the available information. Even after 40 years of Gateway to Europe policies in the Netherlands and several discussions on their effectiveness[5], there is still not a detailed open-access overview of the building stock of logistics. Certainly, there are consultancy firms and brokers who gather these data for their own use and occasionally publish selections and reports on an aggregated level. This is not enough, however, to sustain independent research on the topic and to enable governments to make policies from an equal information position as the market. The logistics land market, if it is to be a free and well-functioning market, requires transparency through equally available information for all actors on the demand and supply sides.[6] Simultaneously, unequal information positions and unfounded claims are instrumental in the occurrence of logistics sprawl and the existing bias in the policy narrative of logistics.[7] A more equal and transparent information position thus seems necessary to make just planning trade-offs.

This paper introduces an open-access dataset of the logistics complex of the Netherlands in 2021.[8] Considering the available sources at that moment as well as the academic standards, it may be considered the best possible dataset in that year: (i) documented and shared according to the FAIR principles—findable, accessible, interoperable and reusable; (ii) consistently gathered from sources that will be available in the foreseeable future; (iii) dating back to before 1980 when the phenomenon of distribution centers emerged; (iv) featuring high detail across the Dutch territory usable for publication and analysis; (v) featuring various functional and size categories, as well as other variables through which the data may be filtered for specific analyses.

The data are gathered from open sources (OpenStreetMap, building administration - BAG, business estate data - IBIS) and a closed source (LISA company microdata), the latter obtained with the help of Stichting LISA, Frank van Oort (Erasmus School of Economics) and Hans van Amsterdam (Netherlands Environmental Assessment Agency, PBL). The data are compiled by the author, validated in collaboration with Thomas Bonte and Carlijn Ligterink (Vrije Universiteit Amsterdam), Vera Loefs and

5 Nefs, Zonneveld, and Gerretsen, "The Dutch 'Gateway to Europe' Spatial Policy Narrative, 1980-2020: A Systematic Review"; Zande and Kreukels, "Rotterdam Network Mainport"; Kuipers et al., *Het Rotterdam Effect—De Impact van Mainport Rotterdam Op de Nederlandse Economie(The Impact of Mainport Rotterdam on the Dutch Economy)*; Van Duinen, "Mainport and Corridor: Exploring the Mobilizing Capacities of Dutch Spatial Concepts"; Van den Bergh, "Mainport Holland—Voor Onze Toekomst Bekeken Door 4 Vensters(Reviewed for Our Future Through 4 Lenses)."

6 Voss, "Transparency of Property Markets-the 1. National Level Market Report."

7 Nefs and Daamen, "Behind the Big Box: Understanding the Planning-Development Dialectic of Large Distribution Centres in Europe"; LeCavallier, *The Rule of Logistics—Walmart and the Architecture of Fulfillment*.

8 Nefs, "Dutch Distribution Centres 2021 Geodata."

Ana Luisa Moura (Deltametropolis Association). The data are available through a repository and they have been used for research, media articles, debates and education. Simplified versions of the data have been published on an interactive map and online infographics since 2019 to contribute to the public discourse. The data and visualization presented in this paper are focused on the planning discourse, whilst other (closed access) sources focus rather on the real estate perspective, based on other sources and sometimes featuring other types and size classes, as well as other time intervals.

The present dataset was compiled in the context of the PhD thesis Landscapes of Trade [9] to get an overview of the development of the logistics complex of the Netherlands since 1980. The thesis features various data visualizations demonstrating key parameters which appear in the discourse such as size, growth pattern, functionality, scale and employment of the logistics complex, on different scales. Other relevant aspects discussed include the relatively large spatial logistics footprint in The Netherlands compared to other countries, the spatial impacts, and the suitability of Dutch locations for certain types of logistics.

In the next section, the problem of logistics mapping is situated in the academic context of counter-mapping. In the third section, the available data sources on the logistics complex are introduced, along with their limitations. In the fourth section, the compilation method of the Dutch Distribution Center 2021 geodataset is presented and the challenges in this process are discussed. In section five the ways of publication and sharing of the data are discussed. Finally, insights of the open-access counter-mapping are discussed, and conclusions are drawn on the missing data and expansion of the dataset, as well as updating and continuity.

Counter Mapping of Powerful Systems Such as Logistics

The unequal information position regarding logistics introduced above is just one example of large powerful structures in society that lack transparency for sound democratic deliberation. There is a body of literature and practice in critical geography dealing with these issues. A concept within that field that is particularly relevant for this paper is counter-mapping. The concept was coined by Nancy Peluso regarding the indigenous mapping of forest territories, challenging the governmental figures in Indonesia. [10] Platform https://countermapping.com is inspired by Peluso's work and defines counter mapping as 'visual methods that explore & represent information, data and cultural practices.'

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9 Nefs, *Landscapes of Trade: Towards Sustainable Planning for the Logistics Complex in the Netherlands*.

10 Peluso, "Whose Woods Are These? Counter-Mapping Forest Territories in Kalimantan, Indonesia."

Bélanger[11] used the concept of counter-mapping in Ecologies of Power to understand the logistics and power structure of the US department of defense. The data-driven insights on the magnitude of the army's operations, for example in terms of fuel and costs, as well as mapping of the army's outposts in the Pacific and other regions of the world, has contributed to a more critical discussion on the ambitions and effects of US defense policy. Similarly, Hein[12] mapped the geography of the oil industry in the Netherlands, ranging from headquarters and refineries to petrol stations.

Also, in the field of geography of logistics efforts are made to increase insights into what is considered a rather closed sector.[13] For example, Coe & Hess[14] and Yuan[15] have mapped the employment and local impacts of large logistics centers in California, highlighting various inequalities and other issues. Various authors have written critical pieces on the logistics sector[16] , linking it to negative impacts of global trade, border effects, labor exploitation etc. Hesse presented a 'critical account of logistics operations and their relevance for the making (and unmaking) of territories.' An open-access highly detailed spatial overview of the growth pattern of logistics, however, is still lacking in many countries. The mapping described in the following sections aims to fill part of this gap in the Netherlands and provide insights that were not possible with the publicly available information before.

Compilation of Available Data on the Logistics Complex

The compilation and maintenance of a detailed dataset of distribution centers is challenging because of both the availability and the reliability of the data. The present compilation makes use of several sources (see flowchart in Figure 10.1):

1. *Open StreetMap* (OSM) is the most frequently updated open-access source of building geometry in high detail. Therefore, it is used as the basis for the building footprints at the starting point in the compilation. The categorization of the buildings in OSM (residential, industrial, etc.) however, is not reliable enough to use in the compilation.

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11 Bélanger & Arroyo (2016)

12 Hein (2018)

13 Frejlachová et al., *Steel Cities: The Architecture of Logistics in Central and Eastern Europe*.

14 Coe & Hess (2013)

15 Yuan (2018, 2019, 2021)

16 Khalili, *Sinews of War and Trade*; Cowen, *The Deadly Life of Logistics - Mapping Violence in Global Trade*; LeCavallier, *The Rule of Logistics—Walmart and the Architecture of Fulfillment*; Martin, "Desperate Mobilities: Logistics, Security and the Extra-Logistical Knowledge of 'Appropriation'"; Hesse, "Land for Logistics: Locational Dynamics, Real Estate Markets and Political Regulation of Regional Distribution"; Angélil and Siress, "Discounting Territory: Logistics as Capital Principle of Spatial Practices."

2. *Company microdata* of the Netherlands (2020 and 2017) can fill this functional gap. These proprietary data are not open-access and could be used for this research through an arrangement of the Erasmus University Rotterdam and PBL with Stichting LISA. The data provide a highly detailed overview of firm locations and their respective economic (sub)sector as well as employment numbers. Sometimes several (logistics) companies are registered in a single building. In such cases, the data is aggregated on the building level, summing up the employment of the companies and taking the function attribute of the largest company.
3. *Business estates* in the Netherlands are documented in the *Ibis* dataset. This open-access source is updated yearly with information supplied by the provinces. It includes existing and planned sites. As updates are performed on a yearly basis, there is some delay in for instance the number of hectares in the estate that are still available for development. It is a useful foundation for the compilation of the dataset, because it provides delineation and names of the business estates. Limiting the dataset to such estates was a key choice to keep it clean, since small firms (freelancers) located in residential areas are excluded in this way. It is possible that by doing this, small storage locations of city logistics are excluded as well. However, the research focuses on the logistics facilities located on business estates.
4. The *building administration* data of the Netherlands (BAG) is largely similar to OSM, but updated less frequently, at least until 2021. A great advantage of the newer versions of BAG is that they include construction years of the buildings. By joining this information to the data, it becomes possible to demonstrate the growth and growth pattern over longer periods of time. The small number of missing construction years was manually filled in using georeferenced historical maps.

Challenges in the Compilation Method

The step-by-step process of data compilation is shown in Figure 1, a flow chart describing the steps from the source data in the top to the resulting data in the bottom. First, the buildings are selected from the OSM data, when these are larger than 500 sqm and located on an Ibis business estate. Second, logistics companies are selected from the LISA data, following a list of SBI sector codes (Table. 1). This selection is done in three groups: (A) trade, import and export; (B) transport and logistics services; (C) XL retail centers. The documentation on the repository provides more detailed information on the dataset. [17]

17 Nefs, "Dutch Distribution Centres 2021 Geodata."

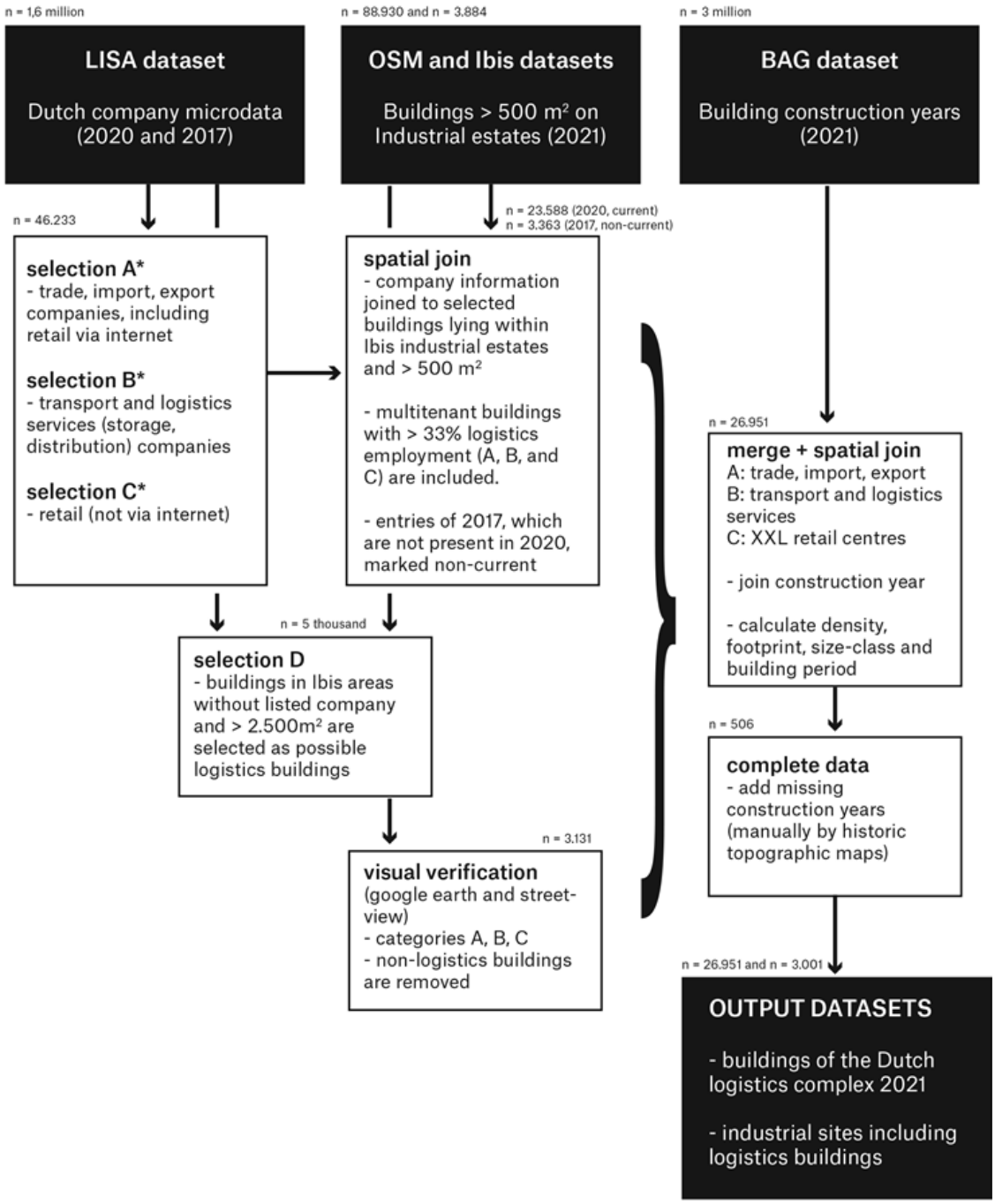

FIG. 1 Flow chart of data treatment.

An important step in the process is the inclusion of missing DCs that are not findable in the company microdata but are clearly visible in the field and on aerial pictures. Selecting the buildings from the first step that spatially match the logistics companies provides 80% of the resulting objects. The missing DCs, about 20% of the data including many recent XXL DCs, are selected by searching for buildings on business estates larger than 2.500 sqm—to maintain a workable number for manual verification—that do not have a LISA company entry. This selection is manually validated by using Google Earth and Streetview. Loading docks and Google company

SBI-2012 sector code (2-5 digits)	Description	Selection group (see flowchart) & Function in dataset
45.11.1	Import of new personal automobiles and light business automobiles	A: Trade, import, export
45.19.1	Import of new business automobiles	A: Trade, import, export
45.31	Wholesale and trading in automobile parts and accessories	A: Trade, import, export
45.40.1	Wholesale and trading in motorbikes and parts	A: Trade, import, export
46.2	Wholesale in agricultural products and livestock	A: Trade, import, export
46.3	Wholesale in food, drinks and tobacco	A: Trade, import, export
46.4	Wholesale in consumer goods (non-food)	A: Trade, import, export
46.5	Wholesale in ICT equipment	A: Trade, import, export
46.6	Wholesale in machines, equipment and accessories for industry and trade	A: Trade, import, export
46.7	Other specialized wholesale	C: XL retail center (ONLY IF located on business estate AND > 500 sqm)
46.9	Non-specialized wholesale	A: Trade, import, export
47	Retail	B: Transport and logistics services
47.91	Retail via postal order and internet	B: Transport and logistics services
49.20	Goods transport via rail	B: Transport and logistics services
49.41	Goods transport via road (excluding relocations)	B: Transport and logistics services
50.2	Maritime and coastal navigation (freight, tanker and towage)	B: Transport and logistics services
50.4	Inland navigation (freight, tanker and towage)	B: Transport and logistics services
51.2	Goods transport via air	B: Transport and logistics services
52	Storage and services for transportation	B: Transport and logistics services
53	Post and couriers	B: Transport and logistics services

TABLE. 1 List of SBI sector codes included in the broad definition of logistics in the dataset (see selection groups A and B in flowchart), as well as XL retail centers (selection C).

location information clearly indicate logistics in many cases. Often piles of construction materials or scrap, as well as Google company information, indicate that a building is used for other purposes, such as a construction or recycling company. Possible explanations for the lacking data are very recent constructions that have not been processed yet in the annual update, and the practice of leasing DCs from a third party or registering a DC at another company location.

The geodataset includes 26.951 logistics buildings in the Netherlands, built before November 2021, as well as the business estates they are in, and the outline of the East-Southeast (ESE) freight corridor of the Netherlands—the busiest logistics area of the country. The definition of the logistics sector elaborated and used in this research includes trade, import, export, wholesale, transportation, and warehousing activities, as well as e-commerce. Definitions of what a DC is are quite broad in the literature, usually including any building in which goods are (temporarily)

FIG. 2 Lacking logistics establishment data. Left: Tesla Motors Tilburg. Right: agrobusiness in Barendrecht. Source: Google Earth.

stored for commercial purposes in value- and supply chains.[18] Many real estate surveys focus on so-called XXL warehouses for logistics service providers, larger than 40 or 50 thousand square meters in ground floor space, for the purpose of market analysis.

This research, however, aims to assess the growth of the entire logistics complex, including medium and small storage buildings. To avoid irrelevant buildings such as small, dedicated office buildings and electrical installations, only logistics buildings larger than 500 sqm were considered in the data collection. Additionally, 4.533 large buildings of large retail centers on industrial sites were included, where consumers 'pick their own orders', such as construction materials stores; as well as 782 buildings including logistics co-activity, for example a hospital with a logistics company for medical materials. Manufacturing and recycling facilities, which often include logistics activities, are not included unless a separate logistics company is registered in the building. Depending on the focus of the analysis, a study may filter the data on, for example, XL (> 20.000 sqm) and XXL DCs (>40.000 sqm), used by traders and logistics service providers.

The dataset still underestimates the logistics spatial footprint, since often agricultural or manufacturing companies own logistics-style buildings and perform logistical tasks, without being registered as such (see examples in Figure 2). The actual use or vacancy of DCs at a certain moment, in terms of volume and market orientation of the goods, would be relevant to know but at present cannot be derived structurally from public nor proprietary data. This makes urgent public discussions on the scarcity of DC space more difficult, and the question which part of the logistics complex is needed to supply the Netherlands difficult to answer.

18 Keshavarz-Ghorabaee, "Assessment of Distribution Center Locations Using a Multi-Expert Subjective–Objective Decision-Making Approach."

FIG. 3 Lacking employment data of DCs (in grey).

Employment mapping of DCs

Employment has been a central argument in the policies facilitating logistics developments. Construction of transport infrastructure and DCs have often been promoted by claiming the creation of jobs. However, while this was a valid reason during periods of high unemployment, this has gradually become a moot point. The building boom of DCs since 2014 in combination with a tight labor market have led to permanent shortage of personnel, whilst attempts are being made to improve the productivity of the existing workforce through automation. Between 2015 and 2018 a Dutch employment agency observed increases in logistics job offers in six logistics regions of between 300 and 400%.[19]

In total, 896.912 people were employed in the sector in 2017 following the broad definition of logistics **(Table. 1)** used and calculated from the LISA microdata, or 11% of total Dutch jobs in that year. 70% of these jobs were performed inside a logistics building in a business estate as mapped above—the rest is arguably registered in office buildings of logistics companies and residential units of small entrepreneurs. Of total workers in the sector, 73% are men. Parttime workers, here defined as less than 12 hours per week, amount to 8% of men and 18% of women in 2017. Although

19 ManpowerGroup, "Transport En Opslag: Toenemende Schaarste Op Arbeidsmarkt(Transport and Storage: Increasing Scarcity on the Labour Market)."

exact mapping of employment data of individual companies is not permitted, a range of employment density could be published (see green shades in Figure 3). The detailed pattern of DC employment and its changes over time have also been published as a series of heatmaps with a 100x100m resolution.[20]

Employment numbers on logistics, although quite usable on the higher levels of scale (municipal or higher), have several blind spots on the level of individual buildings. As discussed above and shown in Figure 3, several recent XXL warehouses are not (yet) part of the LISA microdata. For analyses in the aforementioned PhD research, these had to be either excluded or provided with average employment numbers per function and size class. Another blind spot pertains to the highly fluctuating and unclear numbers of migrant labor, a considerable part of the labor force in logistics. The microdata should include workers from Dutch employment agencies, but it is unclear to what extent migrant labor is covered. The number of migrant workers in the Netherlands is estimated around 735 thousand in 2023, while research shows that the number of migrant workers can grow until 1.2 million in 2030. Especially in the ESE corridor, a large share of migrants works in DCs.[21] A third blind spot concerns the activities performed in DCs, the quality rather than the quantity of work. Often, besides logistical handling of goods, assembly and service tasks take place, which are not distinguished in the microdata, since the whole company falls under a single subsector (SBI).

Despite the image of logistics as a global growth sector, employment numbers develop quite differently across regions and areas. In the Netherlands as a whole, the logistics sector has grown slower than the total economy, in terms of employment. In some regions, especially in the ESE corridor, logistics employment has boomed and is becoming a heavy pilar of the regional economy. Also, on the local level there is much variation.

Despite the continuing growth in direct employment in logistics in the ESE corridor, this growth is characterized by a declining space quote: each newly built square meter of warehouse generates on average 25-30% less jobs than two decades ago[22]. This effect is strongest in logistics hotspot regions.

Digital Publication of Data and Maps

The dataset was published in different ways. There is an open-access repository on the 4TU Research Data portal, containing the data in various formats, accompanied by documentation and metadata. On this repository, versions can be controlled and updated, whilst the number of users is

20 Nefs, van Haaren, and van Oort, "The Limited Regional Employment Benefits of XXL-Logistics Centres in the Netherlands."

21 Roemer, *Jaarrapportage Arbeidsmigranten 2022*.

22 Nefs et al., 2023

FIG. 4 Online dashboard. See https://mertennefs.shinyapps.io/distributioncentres_geodata_app/

documented. At the time of writing the data repository shows about 2000 downloads and 4000 views.

As not all potential users of the data, such as policy makers and planners, have data-analytical and visualization capabilities, a data dashboard has also been provided. Figure 4 shows one of the pages in this online dashboard application, featuring filters in the left sidebar (used here to exclude one type and the smaller and medium sized buildings). The charts update real-time according to the filters. Other pages visualize data regarding the employment in logistics buildings, as well as the regional differences (building footprint, footprint per capita, specialization rates etc.). The final page contains a brief explanation and links to the repository and online map.

An accompanying online map viewer, showing the rampant expansion of the logistics complex since 1980, had more than 5000 unique views since 2019. Figure 5 shows the web interface, including a slider tool for the timeline and preset buttons to zoom into particularly relevant locations. The scope of the data and viewer is the territory of the Netherlands. In the map a white area is highlighted: the ESE corridor, the main case study area in the forementioned PhD research,[23] The zoomed-out view features business estates colored by construction year and expected road congestion in the ESE corridor. The zoomed-in view features individual buildings colored by three dimensions chosen in a toggle menu: (i) types of

23 Nefs, *Landscapes of Trade: Towards Sustainable Planning for the Logistics Complex in the Netherlands*.

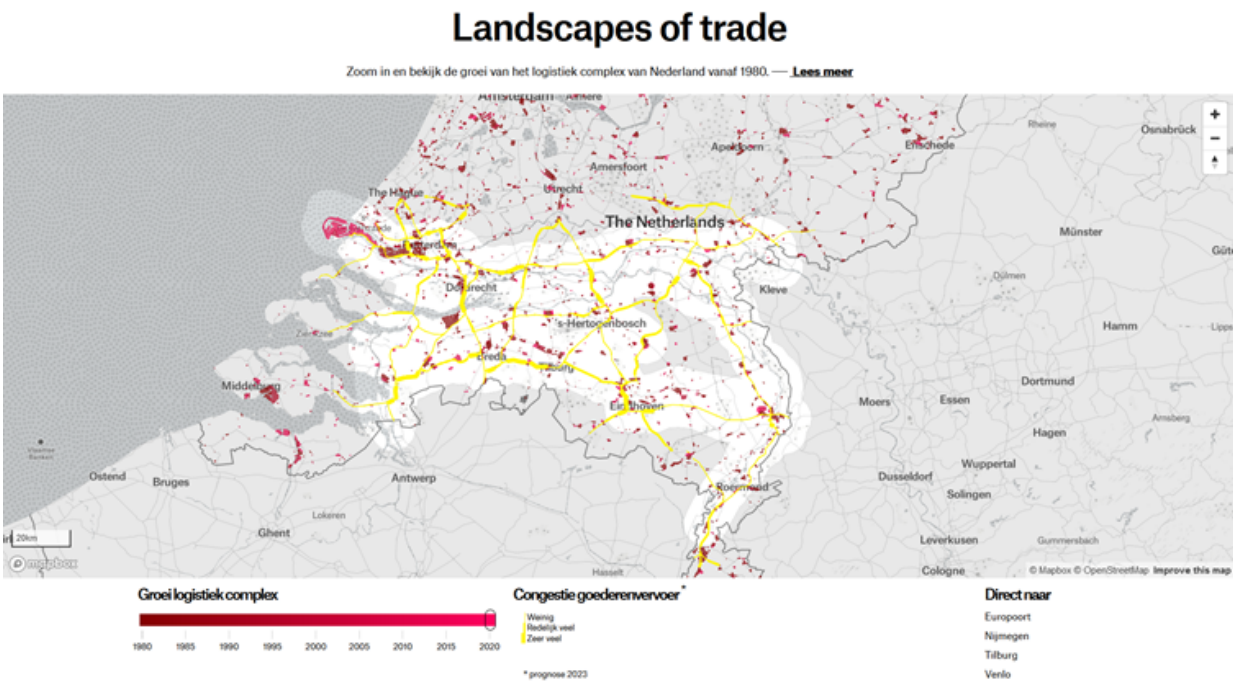

FIG. 5 Web interface of online interactive map. See https://mertennefs.eu landscapes-of-trade/

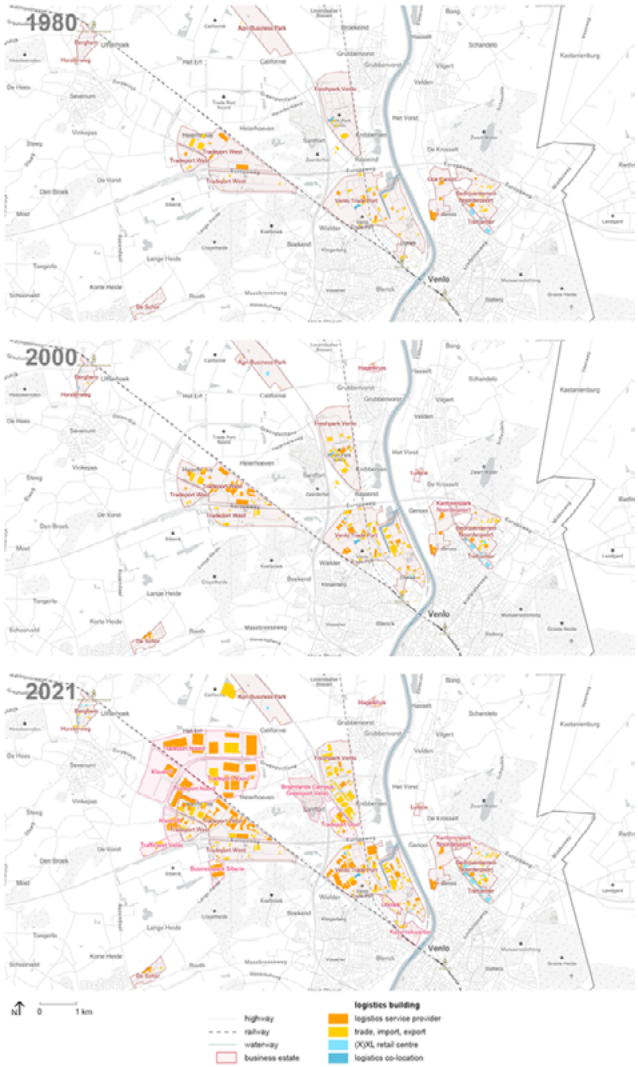

FIG. 6 Detailed panel map of Venlo 1980-2000-2021. See https://mertennefs.eu/landscapes-of-trade/

logistics activities (used in Figure 6), (ii) employment per square meter or (iii) size class of the buildings ranging from S to XXL. Figure 6 shows the zoomed-in view of the city of Venlo in 1980, 2000 and 2021.

Conclusion and Recommendations

Ongoing studies on the Dutch logistics complex and the recent discourse have pointed out that sustainable planning and development of the logistics complex requires open and equal information provision. Thus, it is crucial to introduce more centralized, independent, and open-access knowledge and information into the planning-development network. An informational level playing field would reveal good and bad practices; avoid undesirable 'quick flips'—opportunistic real estate transactions usually occurring in a situation of asymmetric information between private and public actors[24] ; demystify rhetoric fueled by 'not in my backyard' sentiments (NIMBY), lobbying, or other interests; and enable more conscious multi-level trade-offs.

The mapping of the logistics complex in the Netherlands, as described in this paper, has provided a more consistent (yet still partial) overview of this necessary information. The mapping, similar to counter-mapping by Bélanger e.a., has enabled insights that challenge the common views and narratives outlined by the market and governments, for example:

a) Despite the dynamic market cycles that dominate the news, the map and related infographics show a steady long-term growth of the logistics complex: a fourfold increase of the footprint since 1980. Stakeholders' claims over time that logistics growth has been coming to an end are thus not supported by the data.

b) The map shows that the logistics complex consists, besides the (X) XL warehouses that dominate the debate, for a larger part of small and medium size buildings, which are not being discussed. These smaller buildings, however, represent a larger share of the logistics workforce than the larger DCs.

c) Although much of the discussion focuses on logistics hotspots, the map shows that besides concentration there is also a strong pattern of dispersion or sprawl in less suitable areas.

d) The boom of logistics real estate has obviously generated jobs locally, but there are also locations where the logistics sector is moving away. Nationally, the sector lags compared to other sectors in the economy.

e) Contrary to many claims, regions facilitating development of XXL logistics parks have not attracted related manufacturing, R&D and

24 Nefs and Daamen, "Behind the Big Box: Understanding the Planning-Development Dialectic of Large Distribution Centres in Europe."

other desired activities close to those parks. These regions lost more tech-manufacturing and agro-food jobs than other regions.[25]

The full potential of the data is yet to be explored, in combination with other sources. Combining distribution center data with other data on, for example, production facilities, types of land use, urban density, infrastructure capacity and usage, different types of nuisance, biodiversity as well as environmental restrictions, may provide many insights that are useful in the policymaking process around logistics. Further studies are needed that follow such multifaceted and multidisciplinary approaches, to find spatial correlations and their underlying mechanisms.

In the described data, three relevant aspects of the growing logistics complex are still lacking. First, the territorial expansion of the logistics building footprint is only mapped within the Netherlands, while we know the artefact of the logistics complex stretches across national borders. At least Belgium and North-Rhine Westphalia should be added, from a Dutch perspective. There are several academic projects focusing on harmonization of data across borders (e.g. https://www.espon.eu/events/mapping-cross-border-interactions-along-borders-towards-novel-data-hub-eu-border-regions) and mapping cross-border phenomena such as water management (https://www.waternewseurope.com/the-netherlands-and-belgium-develop-cross-border-water-maps/). Closer cooperation between the Dutch Topsector Logistiek and their equivalent abroad could make this possible for logistics – such as VIL and VLAIO in Belgium. Second, the employment figures do not yet provide an overview of the proportion of labor with a fixed contract, flexible labor via agencies, and flexible labor from abroad (migrant labor). Reports suggest that in many distribution centers two thirds of the workforce consist of migrant labor, whilst they raise questions regarding housing and exploitation issues. Third, there is a lack of information on the exact activities and goods inside DCs. The current dataset of this paper is based upon a single company subsector per building, for example 'transport by road' or 'warehousing and logistics services.' In practice, however, manufacturing and service tasks in the supply chain increasingly take place in warehouses as well, known as value-added logistics (VAL). Another relevant dimension here is to what extent the goods stored and handled in the DC are oriented to the domestic or foreign market. [26] Including these three aspects, by gathering existing data and stimulating (or forcing) companies to provide (anonymized) data, would greatly improve insights for planners.

Nevertheless, given the detailed availability of information in the dataset discussed in this paper, relevant insights and information tools can already be provided for planning and development. It is up to local and

25 Nefs et al., 2023

26 Acocella, Cruijssen, and Fransoo, *Warehousification: Recommendations for the Future of Big Box Warehouses in the Netherlands*.

regional governments, as well as policy advisers, planners, designers, and developers, to apply the information and insights in practice and help update them by providing feedback and sharing practical experiences. A structural effort, however, is also needed to maintain the dataset and guarantee its relevance over time. At present, there is no arrangement for this. The author of the paper may attempt to update the data every couple of years, obtaining the necessary company microdata and performing the manual checks as described in the compilation method. Another possibility would be for national organizations, such as Dutch Statistics or the Environmental Assessment Agency (or even EU wide such as EUROSTAT), to assume the responsibility to fund, compile, validate and distribute the data open-access. Such organizations currently have limited means to enforce mandatory data submission by companies or governments, as is standing practice in e.g. the agricultural sector. New legislation would be required to make this possible. Collaboration in the updating and evaluation of the dataset may also improve the current sector definition, choice of size classes, aggregated function types and other functionalities. Such efforts would ensure that the Netherland, as a self-proclaimed logistics giant and 'gateway to Europe', maintains a transparent overview of its logistics complex.

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MAIN SECTION

Introducing the Bauhaus of the Seas Sails Geospatial Platform: A Spatially Enabled Mapping Framework for Analyzing Complex Territories

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ABSTRACT

This paper introduces an early version and ongoing development of a geospatial platform, developed for the Bauhaus of the Seas Sails, one of six lighthouse projects from the 'New European Bauhaus' (EU policy and funding initiative). This platform is a tool designed to analyze the coastal regions such as port-city territories, aimed at supporting sustainable development. The platform integrates open-access geospatial data with sustainability, aesthetics, inclusivity data, and narratives from land-sea interactions, enabling data-driven decision-making. Two ongoing research introduced in this paper, showcases the platform's usability and versatility: one investigates health disparities in Rhine Watershed cities, leveraging its multi-scalar and cross-border capabilities; the other explores transnational spatial planning in the Flemish-Dutch Delta, fostering stakeholder collaboration. Through testing and development of the platform using different research approaches, the aim is to create a dialogue between spatial experts, for positioning the geospatial platform as a valuable resource for promoting sustainable development in coastal regions, through enhanced data visualization, analysis, and knowledge sharing. Since the Bauhaus of the Seas Sails geospatial platform is still a work in progress, this paper introduces the platform with the focus on refining and optimizing its capabilities. The aim is to effectively integrate and visualize diverse geospatial data, ensuring and building upon the interplay with local values, and support multi-scalar, cross-border, and transnational spatial planning.

KEYWORDS

Geospatial mapping; geospatial platform; cross-border regions; mapping framework; port-city territories.

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1. Introduction

Coastal regions, by nature of their location, face significant environmental threats, including rising sea levels, extreme weather events, and erosion. Tools like web-mapping applications increase the accessibility and usability of information technology. As a counterpart to top-down planning processes, such an open-source GIS platform can enable bottom-up decision making and participation through awareness creation and information, education and increased literacy, local knowledge-creation and therefore create possibilities to gather contributions from all communities and participants whose voices and ideas would otherwise be excluded.

The New European Bauhaus, as a movement[1] to achieve the goals of the European Green Deal,[2] provides the right opportunity to engage and collect the knowledge from local communities and citizens. The (old) Bauhaus,[3] renowned for revolutionizing 20th-century design by bridging art, industry, and construction,[4] has inspired the European Union to envision a 21st-century counterpart.[5] The New European Bauhaus is committed to leading a movement aligned with the Green Deal, emphasizing sustainability and social inclusion.[6] Responding to this vision, the Bauhaus of the Seas Sails project[7] proposes a continental mobilization centered around the world's most fundamental natural resource: the sea. Initiated in response to the climate crisis, the Bauhaus of the Seas Sails project is an interdisciplinary, intergenerational, and interspecies movement addressing the complexity and scale of the problem. It posits that seas, oceans, and water bodies are the definitive global natural and shared space in the EU and the world. Established in 2022 with EU funding, the project consortium comprises 18 academic, cultural, and territorial partners across 7 pilots within 4 aquatic ecosystems. This project offers a valuable consortia and group of experts, to learn from the locally rooted activities, while exploring the EU's transition across various aquatic ecosystems.

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1 EU. "New European Bauhaus." Accessed October 16, 2024. https://new-european-bauhaus.europa.eu/index_en

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FIG. 1 The Bauhaus of the Seas Sails geospatial platform. Source: Bauhaus of the Seas Sails geospatial platform (https://bauhaus-seas.app)

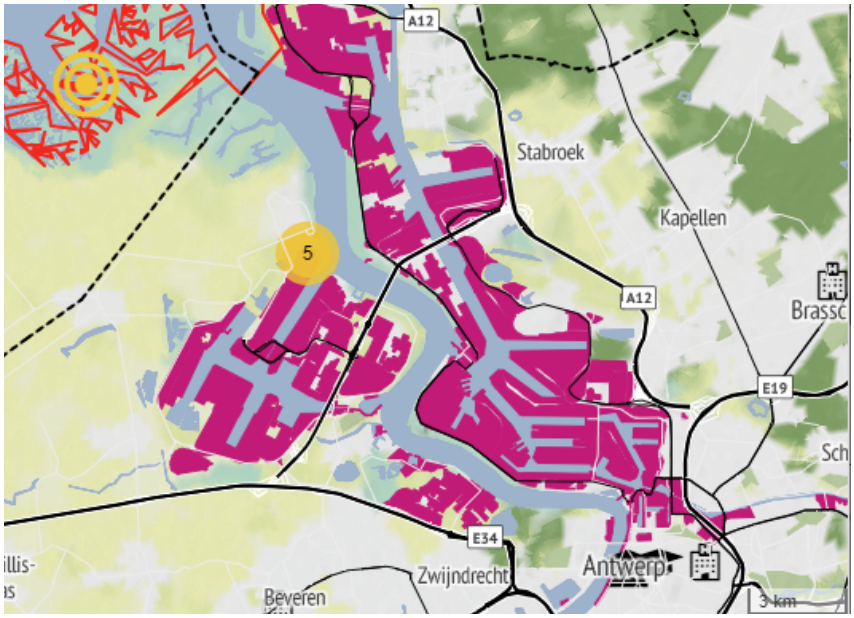

FIG. 2 A specific location zoomed at a local scale. Source: Bauhaus of the Seas Sails geospatial platform (https://bauhaus-seas.app)

With a focus on coastal regions and their relationship with the sea, the Bauhaus of the Seas Sails project aims to explore how we can engage with water bodies in a sensitive, conscious, and balanced manner. This encompasses climate regulation, preservation of ecosystems and biodiversity, and sustainable management of resources. Embracing the challenge of applying design to complex socio-ecological and more than anthropocentric issues, the project significantly impacts the UN's sustainable development goals and the EU's strategic priorities.

The Bauhaus of the Seas Sails geospatial platform[8] is a developing online

8 EU. "Bauhaus of the Seas Sails geospatial platform" Accessed October 16, 2024. https://bauhaus-seas.app

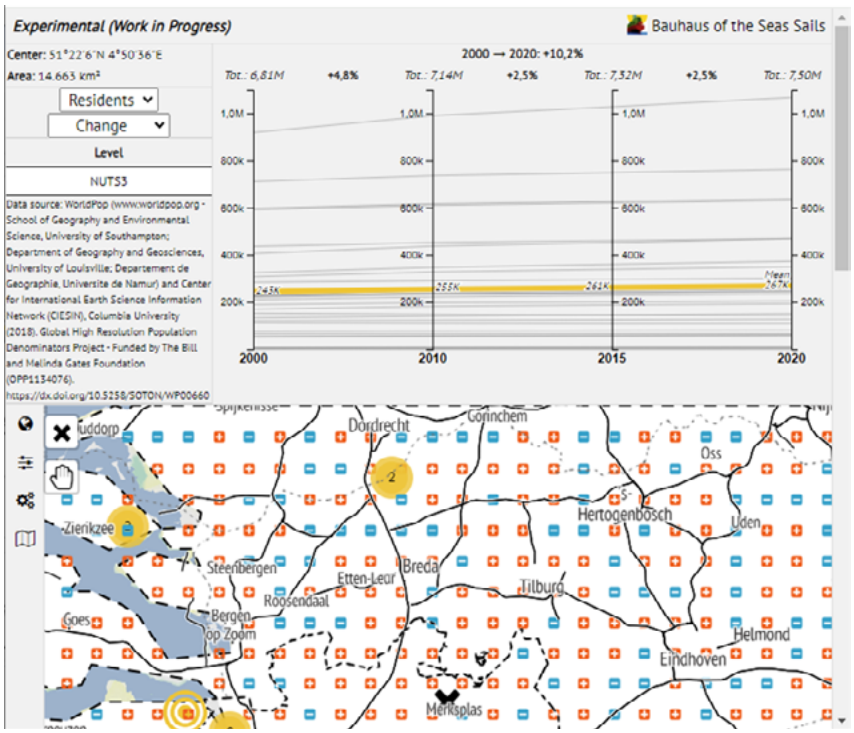

FIG. 3 Result of an analysis across the Delta region. Source: Bauhaus of the Seas Sails geospatial platform (https://bauhaus-seas.app)

system that combines open-access geospatial data, data on sustainability, aesthetics, and inclusiveness, as well as stories and narratives about the pilots participating in the project (Fig. 1).

This platform will enable efficient analysis, visualization, and sharing of open data and project-generated information within the project initiative and provide a foundation for living labs and the dissemination of findings by enabling the integration, visualization, and analysis of spatial data in real-time. Users of the platform will have the ability to engage with and gain insight from several layers of data based on the implementation of the drops (pilot actions). The first users are the consortium partners of the Bauhaus of the Sea Sails project who are testing the platform, while it is being developed. After the development of the platform, any individual can learn and engage with the platform. The platform already offers a variety of tools for creating captivating interactive map visualizations. With easy navigation and interaction options, users can explore and analyze inaccessible geospatial information in a user-friendly manner (Fig. 3).

The platform will serve to study the impact of the drops (pilot actions) and ripples (pilot demonstrators) in the diverse locations undergoing similar water-related transformations. Through its tools and functionality, the platform seeks to create a connection between science, technology, education, art, and culture, based on the ideals of the New European Bauhaus. The overarching goal of the platform is to: (1) engage users, (2) facilitate value-based discussions through interactive visualizations and (3) create a possibility for easier comparisons among the European coastal cities.

The geospatial platform is built on three core pillars. Firstly, the platform

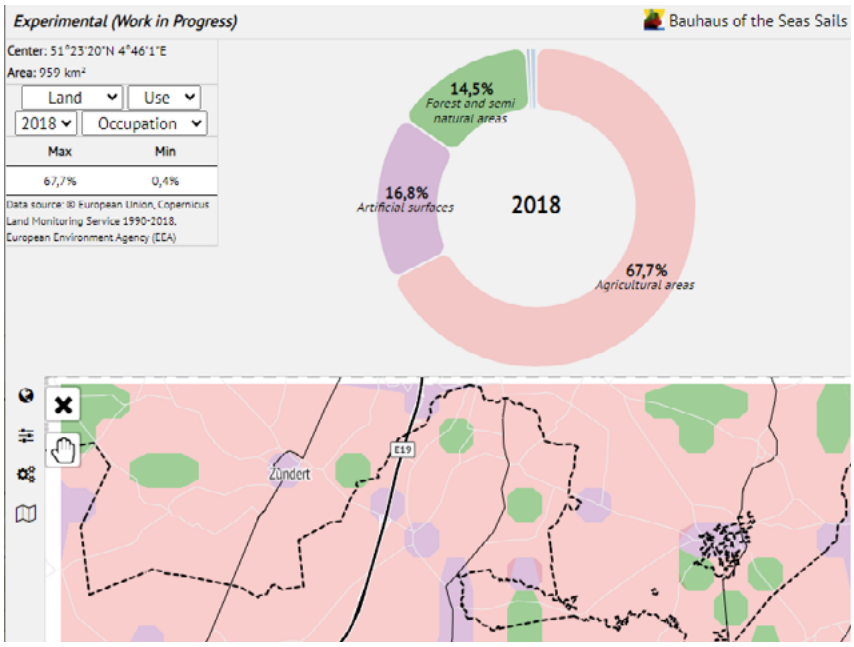

FIG. 4 A visualization of land use across the Delta region. Source: Bauhaus of the Seas Sails geospatial platform (https://bauhaus-seas.app)

allows users to create visually appealing and comprehensible maps, charts, graphs, and various additional graphical representations. These visualizations serve as the foundation for informed discussions and to contextualize the work done in the project across various locations. The visualization tools provided enable users to analyze patterns, relationships and trends within geospatial and statistical data (Fig. 4).

Secondly, the platform offers a comprehensive suite of analytical methods for performing complex spatial analysis. These powerful analytical tools enable users to gain valuable insights based on geographic patterns and relationships. Unlike proprietary software, geospatial platforms built with open-source software are free to use, significantly reducing costs. There are no recurring license fees, and the open-source nature allows for the flexibility to modify, extend, or customize the platform to suit specific needs. This adaptability ensures the Bauhaus of the Seas Sails platform can be tailored to various use cases without being constrained by predefined features. Lastly, through the narrative layer, the platform facilitates sharing of information generated within the Bauhaus of the Seas Sails project, serving as a repository and allowing consortium members to publicly share the effectiveness and impact of initiatives and their subsequent effects (Fig. 5).

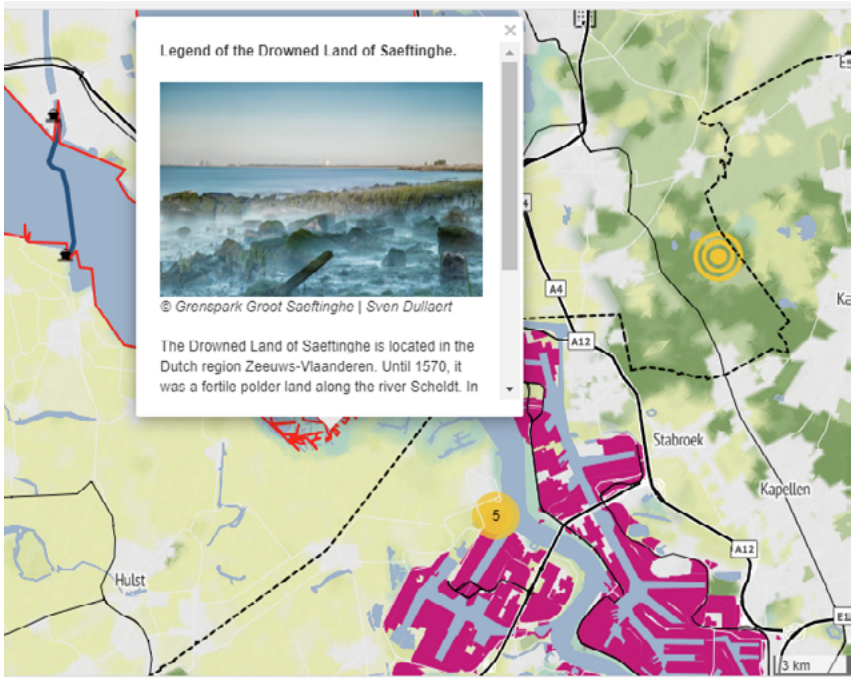

FIG. 5 Example of the narrative layer. Source: Bauhaus of the Seas Sails geospatial platform (https://bauhaus-seas.app)

The platform aims to establish a foundation for understanding and analyzing the crucial and intertwined socio-ecological challenges encountered in coastal regions. Examples of such complex and interrelated environments are port-city territories.[9] They are distinguished by their multifaceted nature, interconnectivity, and operation across various scales,[10] where the needs of natural environments overlap with human activities and influences, but also multiple stakes and interests interfere with each other and create wicked problems to be solved. Examples for this are the development and expansion of infrastructure to support the continuous global economic activities of ports, alongside catering to the needs of local urban functions within growing urban areas, that often result in conflicts[11] and imbalance which can lead to socio-spatial injustices,[12] economic exploitation and pollution,[13] spatial and environmental conflicts,[14] involvement in extractive industries,[15] and increasing global material and

9 Carola Hein (ed.) *Port Cities: Dynamic Landscapes and Global Networks*. (London: Routledge, 2011).

10 Dirk Schubert, Cor Wagenaar and Carola Hein. "The Hoist of the Yellow Flag": Vulnerable Port Cities and Public Health." *Journal of Planning History* 21, no. 1 (2022): 56-78.

11 Carola Hein. "The Port Cityscape: Spatial and institutional approaches to port city relationships." *PORTUSplus* 8, no. Special Issue (2019).

12 Francesca Savoldi. "Contested port cities: A global geography of community conflicts". *PortCityFutures.* (2021, February 17).

13 Olaf Merk. "The competitiveness of global port-cities: synthesis report." *OECD Regional Development Working Papers* (2013).

14 Salvador del Saz-Salazar, Leandro García-Menéndez and Olaf Merk. "The Port and its environment: methodological approach for economic appraisal." *OECD Regional Development Working Papers* (2013).

15 Carola Hein, (ed.) *Oil Spaces: Exploring the Global Petroleumscape.* (London: Routledge, 2021).

resource consumption.[16] A holistic lens and multiscale perspective facilitates a comprehensive understanding of the intricacies involved in the development and sustainability of complex territories.

2. Enabling a Data-Driven Mapping Framework for Complex Territories

The emergence and evolution of geospatial platforms have significantly transformed the field of geographic information systems (GIS), enabling a broad range of applications across various sectors. These platforms now go beyond traditional mapping and visualization, playing critical roles in areas such as disaster management, urban planning, and environmental monitoring.[17]

Geospatial platforms have advanced from the early days of GIS, which were primarily focused on static data representation, to sophisticated systems capable of real-time data processing and analysis. The incorporation of technologies such as cloud computing, mobile computing, and big data analytics has greatly expanded their capabilities, enabling more efficient data management and analysis.[18] In parallel, the architecture of these platforms has evolved to emphasize user interactivity and integration with emerging technologies.[19]

Furthermore, the introduction of Web GIS has revolutionized access to and utilization of geospatial information. Research by Chen et al. highlights the significance of Web GIS in facilitating the sharing and collaboration of geographic data among users.[20] The interactive nature of these platforms encourages user engagement and enhances the overall value of geospatial data.[21] Web GIS has also democratized access to geographic information, allowing users without formal GIS training to work with spatial data.[22] Through the visual representation of intricate spatial data, mapping improves accessibility and understanding, enabling users to make well-informed decisions that contribute to sustainable development.[23] The geospatial platform effortlessly incorporates spatial data

16 James Corbett et al. "International maritime shipping: the impact of globalisation on activity levels." Globalisation, *Transport and the Environment* (2010): 58.

17 Kriswibowo et al. "Exploring the role of geospatial technology in disaster management of batu city: qualitative analysis using rqda method". *Journal of Information Technology and Computer Science*, 6, no.1 (2021): 80-95.

18 Elwakil et al. "New architecture for mobile GIS cloud computing". *Ijarcce*, 4, no.10 (2015): 1-7.

19 Ananda et al. "Towards a new methodology for web GIS development". *International Journal of Software Engineering & Applications*, 7, no.4 (2016): 47-66.

20 Chen et al. "The research of urban fundamental geographical information system based on webgis". *Applied Mechanics and Materials*, (2012): 170-173.

21 Noviansyah et al. "Web GIS of tourism: voyage and forecast". *International Journal of Engineering Technology and Natural Sciences*, 5, no.1 (2023): 1-9.

22 Zhang "Expanding library GIS instruction to web mapping in the age of neogeography". *Journal of Map & Geography Libraries* 16, no.3, (2020): 264-282.

23 Georgios Kouziokas. "Geospatial based information system development in public

from diverse sources, encompassing environmental, demographic, and socio-economic datasets. This comprehensive perspective on port-city dynamics is indispensable for making informed decisions.[24]

The platform will offer a range of analytical maps that address diverse dimensions, such as air and water quality, energy consumption, and land-use patterns. This diverse thematic approach ensures that decision-makers can access pertinent information for specific planning and policy initiatives. The incorporation of interactive visualization techniques, such as heatmaps, overlays, and time-series animations, elevates the user experience and simplifies data exploration.[25] The interactive features enable users to delve into spatial relationships and patterns within the data, offering deeper insights.[26]

The geospatial platform not only requires real-time data processing but also emphasizes real-time visualization capabilities. Handling data streams in real-time introduces additional challenges such as data synchronization and enabling near-instantaneous processing.[27] For the geospatial platform to deliver efficient performance and rapid response times, it must effectively handle large datasets and support high-performance processing. This capability becomes crucial when dealing with real-time complex spatial analyses or accommodating multiple concurrent users.[28] The platform achieves this by employing a custom-built geospatial indexing approach that partitions geographical space into highly regular cells. In order to enhance data query operations, a geographical search engine was developed.

A hierarchical grid system serves as a fundamental tool in many web-based applications for indexing and retrieving spatial data based on geographic location.[29] A grid structure systematically organizes geospatial data into a hierarchy of nested cells, with each level representing a distinct level of detail or granularity.[30] This hierarchical organization enhances the

administration for sustainable development and planning in urban environment." *European Journal of Sustainable Development* 5, no. 4 (2016): 347-347.

24 Benedetta Ettorre et al. "Co-Planning Port–City 2030: The InterACT Approach as a Booster for Port–City Sustainable Development." *Sustainability* 15, no. 21 (2023): 15641.

25 Rufu Qin et al. "Web-based 3D visualization framework for time-varying and large-volume oceanic forecasting data using open-source technologies." *Environmental Modelling & Software* 135 (2021): 104908.

26 Jo Wood et al. "Interactive visual exploration of a large spatio-temporal dataset: Reflections on a geovisualization mashup." *IEEE transactions on visualization and computer graphics* 13, no. 6 (2007): 1176-1183.

27 Dominik Brunner et al. "Distributed geospatial data processing functionality to support collaborative and rapid emergency response." *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 2, no. 1 (2009): 33-46.

28 Michelle Hamilton et al.. "Web-based geospatial multiple criteria decision analysis using open software and standards." *International journal of geographical information science* 30, no. 8 (2016): 1667-1686.

29 Cogan Shimizu et al. "A Pattern for Features on a Hierarchical Spatial Grid." in *Proceedings of the 10th International Joint Conference on Knowledge Graphs*, 108-114. (2021).

30 Mingke Li and Emmanuel Stefanakis. "Geospatial operations of discrete global grid systems—a comparison with traditional GIS." *Journal of Geovisualization and Spatial Analysis* 4

efficiency of spatial queries across various scales, enabling seamless exploration from country regions to localized areas.[31] This data structure serves as a powerful mechanism for organizing and conducting efficient spatial queries on geospatial data. By partitioning geographic space into a hierarchical tessellation of highly regular cells, the method significantly accelerates spatial queries and effectively narrows down the search space.[32] The hierarchical structure enables queries to swiftly identify and retrieve relevant data that are within the desired spatial area without the need to examine every single data point on the database. This optimization substantially reduces computational costs and greatly enhances query performance. Using a regular grid aids in providing smooth gradients and making it easier to measure differences between cells. It is important to choose the right kind of cell shape for the grid system. To ensure ease of use, polygons like triangles, squares, or hexagons are typically preferred since they tile easily. Taking performance into account, the platform employs square cells.

The grid-based approach within the platform plays a crucial role in efficiently organizing and querying geospatial data. It offers numerous optimizations for spatial queries, enabling fast and accurate retrieval of data. Additionally, the method facilitates zooming and Level-of-Detail (LOD) capabilities, allowing users to visualize and analyze data at varying levels of detail.[33] The grid-based method also supports aggregation and summarization operations on-the-fly, providing valuable insights from geospatial data in a concise manner. One of the key advantages of hierarchical grid systems is their ability to facilitate aggregation and summarization operations.[34] The structured hierarchy allows for efficient summarization of data by aggregating information at higher levels of the structure. Moreover, the hierarchical grid system enhances data compression and storage efficiency, thereby optimizing resource utilization on the server-side. Overall, this method is an essential component within the geospatial platform, effectively addressing scalability and performance concerns. By leveraging the hierarchical grid system in the platform, users gain the ability to efficiently retrieve and analyze geospatial data across different scales. From broad overviews to detailed analyses, this structure allows users to explore and summarize geospatial data in an organized and scalable manner within the platform.

(2020): 1-21.

31 Fei Hu et al. "A hierarchical indexing strategy for optimizing Apache Spark with HDFS to efficiently query big geospatial raster data." *International Journal of Digital Earth* (2018).

32 Terence Smith et al. "Requirements and principles for the implementation and construction of large-scale geographic information systems." *International Journal of Geographical Information System* 1, no. 1 (1987): 13-31.

33 Aaron Gardony, Dalit D. Hendel and Tad T. Brunye. "Identifying optimal graphical level of detail to support orienting with 3D geo-visualizations." *Spatial Cognition & Computation* 22, no. 1-2 (2022): 135-160.

34 Wei Wang, Jiong Yang and Richard Muntz. "STING: A statistical information grid approach to spatial data mining." in *Vldb*, vol. 97, 186-195. (1997).

The platform's grid-based approach facilitates visualization and analysis of geospatial data by enabling users to zoom and take advantage of LOD capabilities.[35] Without requiring extensive manual input, the platform automatically selects the appropriate level within the data hierarchy for analysis predicated on user interactions. This way the geospatial platform provides users with a streamlined visualization experience. Its custom-built geographical search engine seamlessly retrieves and displays data with varying levels of detail, dynamically adjusting resolution to match the user's chosen zoom level or area of interest.

3. The Platform's Versatility: Two Contrasting Research Proposals

The Bauhaus of the Seas Sails geospatial platform enables the comprehensive analysis of spatial data through an integrated approach. It embraces three complementary mapping approaches: 1) multi-scalar, 2) multidisciplinary, and 3) cross-border. These approaches enable the platform to handle data at various spatial scales, incorporate data from different disciplines, and integrate data from across international borders, respectively. As a result, the platform provides a powerful tool for analyzing spatial data and gaining insights into complex phenomena and allowing for diverse approaches in different research studies. In this paper, we introduce two different ongoing research to critically utilize and analyze the geospatial platform and provide refined inputs for further development. These research can also be seen as possibilities to contribute to the content of the platform.

3.1. Health and Wellbeing Research in Port Cities

One of the projects currently engaging with the development, testing and data acquiring of the Bauhaus of the Seas Sails geospatial platform seeks to leverage its capabilities for analyzing health and well-being in port-city territories along the transnational watershed of the Rhine river. This research project identifies the need for a conceptual advancement of existing localized city-centric views on health and wellbeing approaches and for a more holistic need-based research and planning framework for analyzing health and wellbeing that is able to scale up and across larger interrelated regions or 'Territories of Wellbeing'.[36]

Watersheds, or river basins - as alternatives to coastal regions - in this case along the Rhine river, can be understood as natural planning regions,[37] delim-

35 Bo Huang, Bin Jiang and Hui Li. "An integration of GIS, virtual reality and the Internet for visualization, analysis and exploration of spatial data." *International Journal of Geographical Information Science* 15, no. 5 (2001): 439-456.

36 Lukas Höller. *From Healthy Cities to Territories of Wellbeing: Transforming second-tier port cities along the Rhine.* 2024(unpublished manuscript).

37 Jaqueline Tyrwhitt. "The Valley Section, Patrick Geddes' World Image." *Journal of the*

iting the territory of interest based on natural geographies that determine many of the anthropogenic and climate-related challenges on health and wellbeing unfolding on a territorial, cross-border scale. This links closely to the concept of bio-regionalism[38], which sees natural features as the underlying base for political, economic and cultural systems and thus accepts the principle that human societies and their habitats adapt to their surroundings and adhere to the inherent laws, capabilities, and constraints of the natural world. Such a territory can become a suitable environment to test the opportunities and limitations of an up- and cross-scales approach to health and wellbeing, particularly as a planning approach oriented to the sustainable, just and fair development of the region, because of three main reasons.

Firstly, port-city territories along the Rhine share complex natural and human-induced challenges through their common river geography. Secondly, those networks of non-primary cities entangled through for example port- and logistic-related flows of goods, people and innovation are an excellent example of polycentric and cooperative urban systems. Investigating them as an interconnected web of urban, non-urban and natural continuums, rather than isolated urban containers helps to avoid a first-city bias in sustainability research and strategy making. Thirdly, the high level of shared economic, spatial and administrative integration as well as cultural and historical proximity, the history of forward-looking cross-border and inter-metropolitan cooperation between ports, industries, medium-sized, non-primary cities, regional, national, and supranational governments, based on institutions with a long track record of collaboration, can help develop to exploit existing capacities and emerge new and common policies to create healthier environments for all.[39]

Yet, there is a need for operationalizing planning frameworks that can benchmark the current status of risks and challenges for health and wellbeing holistically, as well as identify existing and envision new capacities throughout the whole territorial scale in order to overcome them. The research focuses on Manfred Max-Neef's[40] Human Scale Development (HSD) model, which emphasizes a multidimensional understanding of time, space and needs satisfaction. The HSD model provides a conceptual framework and practical assessment tool that can guide the evaluation of health and wellbeing in large territories, such as the Rhine watershed since: 1) the systematic structure of nine universal human needs and sets of contingent satisfiers make the model fit for comparability and transferability; (2) the typological organization of satisfiers allows the definition of simultaneities, complementarities and trade-offs between needs; (3) the

Town Planning Institute 37, no. 3 (1951): 61–66.

38 Janis Birkeland and Cam Walker. "Bioregional Planning." in *Design for Sustainability*, 236-241. (London: Routledge, 2012).

39 Lukas Höller. *From Healthy Cities to Territories of Wellbeing.*

40 Max-Neef, M. A., Elizalde, A., & Martin Hopenhayn. *Human scale development: Conception, application and further reflections.* (New York: The Apex Press, 1991).

basis on existential categories of satisfiers and goods allow the investigation of spatial, institutional, personal and societal conditions of need satisfaction; and (4) the participatory and adaptive nature of the framework allows for community involvement during evaluation, planning and policy development.[41]

The geospatial platform can help to facilitate a mapping-approach that responds to the fuzziness of the multiple overlapping political, economic, cultural and ecological arenas. The port-city territories along the Rhine are not objective containers, but have to be defined as contingent, 'variable geometries',[42] and are the "product of interrelations".[43]

Firstly, such territories are continuously re-shaped through various functional, morphological and institutional dimensions, essential when looking at different urban and non-urban environments on different spatial and relational scales. Adopting a multi-scalar perspective is essential for the platform to adeptly navigate mentioned simultaneities, complementarities and trade-offs between needs and (dis)satisfaction across a large transnational watershed. Through the integration of data on diverse spatial levels, the platform can play a pivotal role in recognizing and addressing the underlying causes of health and wellbeing disparities within port-city territories. A geospatial platform allows for the implementation of dynamic and interactive graphics and maps and enables interaction by, e.g. selecting, filtering, overlaying, comparing and zooming.[44]

Secondly, indicators of health and wellbeing (dis)satisfaction can be implemented, viewed and compared at different levels of detail (LoDs). Issues like air and water pollution frequently extend beyond international boundaries, necessitating collaboration and coordinated efforts among stakeholders across diverse jurisdictions.[45] Yet harmonized datasets are not always available for such a territorial scale and national and regional datasets don't always perfectly match. The platform can assist in tackling cross-border challenges related to data availability, differences in data collecting methodologies, comparability and transferability by disaggregating datasets from different administrative units or other boundaries, but also from different data providers and sources by re-aggregating them onto a scalable grid. This helps to analyze the whole watershed as well as to compare smaller single or multiple localities within the territory, fitting the idea of seeing such complex territories as relational, but also fits the

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41 Manfred Gasper "Max-Neef's model of human needs understood as a practical toolkit for supporting societal transitions". *International Institute of Social Studies*. (2022).

42 Gordon Macleod and Martin Jones. "Territorial, scalar, networked, connected: In what sense a 'regional world'?." *Regional studies* 41, no. 9 (2007): 1177-1191.

43 Doreen Massey. *For Space*. (London: Sage 2005).

44 Rob Kitchin and Gavin McArdle. "Urban data and city dashboards: Six key issues." in *Data and the City*, 111-126. (London: Routledge, 2017).

45 Kyum Seung Kim et al. "Transboundary air pollution and cross-border cooperation: Insights from marine vessel emissions regulations in Hong Kong and Shenzhen." *Sustainable Cities and Society* 80 (2022): 103774.

idea of universal needs and contingent ways of satisfaction coming from Max-Neef's HSD model.

Thirdly, the variable geometry of such complex and relational territories is shaped by different theoretical lenses and practical aims, e.g. determined by certain frameworks, such as the HSD model. The nine universal human needs and the evaluation of need (dis)satisfaction includes insights from various professions such as geography, environmental science, and sociology. Adopting a multifaceted approach, the platform enables users to map individual health factors, analyze environmental determinants and spatial assets, evaluate socioeconomic and cultural factors, monitor health interventions, thus fitting the HSD approach of benchmarking various existential categories of health and wellbeing satisfiers, e.g. spatial, institutional, personal and societal conditions.

Lastly, empowering communities with access to health and wellbeing data and tools for analyzing their living environment allows them to actively participate in health planning and decision-making processes. This, in turn, promotes shared responsibility and community-driven solutions.[46] The platform can guide participatory sessions, such as Urban Labs, visualizing, filtering and combination data to create individual health and wellbeing stories in order to inform and explain the current state of health and wellbeing to a multitude of actors, to identify their current need (dis)satisfaction, raise awareness of development trajectories in cities, regions and countries and, in the long run, propose suitable strategies to altering those courses, guiding the formulation of effective policies that address the determinants of health and wellbeing in a just and participatory manner.[47]

3.2. Transnational Spatial Planning in the Flemish-Dutch Scheldt Delta

Comprehensive data collection on cross-border regionalism in Europe is a complex endeavor.[48] The Flemish-Dutch Scheldt Delta constitutes an intricate and interconnected system that operates across various scales, requiring transnational spatial planning approaches. Spanning across multiple countries, this unique transnational estuary[49] holds immense significance (geographical, economic, environmental, sociocultural) for the

46 Muhammad Shakil Ahmad and Noraini Bt Abu Talib. "Empowering local communities: decentralization, empowerment and community driven development." *Quality & Quantity* 49 (2015): 827-838.

47 Ursula Von Rueden et al. "Socioeconomic determinants of health related quality of life in childhood and adolescence: results from a European study." *Journal of Epidemiology & Community Health* 60, no. 2 (2006): 130-135.

48 Jiannis Kaucic and Christophe Sohn. "Mapping the cross-border cooperation 'galaxy': An exploration of scalar arrangements in Europe." *European Planning Studies* 30, no. 12 (2022): 2373-2393.

49 Geopark Schelde Delta. "Geopark Schelde Delta." Accessed October 16, 2024. https://www.scheldedelta.eu/en

regions it traverses. From its origins to its extensive network of tributaries, the Scheldt Estuary not only shapes the physical landscape but also serves as a crucial economic and ecological artery. Situated between the two largest ports of Europe,[50] Rotterdam and Antwerp-Bruges, this region presents a unique opportunity for transnational cooperation in the pursuit of sustainable development.

As a part of Bauhaus of the Sea Sail, this Delta region (Grenspark Groot Saeftinghe) is being researched upon as one of the six pilots. Going deeper into the territorial values and planning, a supporting research concentrating in this transnational territory is developing at TU Delft and Erasmus University - "Integrative urbanism at a time of climate change". This is an attempt to compile and evaluate the planning strategies and instruments in search of synergy between the challenges and impact from different stakeholders (citizens as society, port and governance), learning about the values from their historical relationships with the territory. The transnational delta faces a multitude of challenges, from climate change to economic development, demanding a multidisciplinary approach.[51] Climate change, particularly rising sea levels and extreme weather events, underscores the need for transnational cooperation.[52] However, the historical dynamics of cooperation as well as competition between the ports of Rotterdam and Antwerp, coupled with administrative borders, complicate the decision-making process for spatial design and planning. Despite the historical success of economic and infrastructural cooperation, the citizens are facing challenges for communicating their values to economic and government stakeholders. EGTC Linieland van Waas and Hulst, promotes cross-border cooperation by offering structural solutions for border bottlenecks and promote social and economic cohesion in the region.[53] This is being done at the local scale. However, there exists a gap in considering socio-cultural values and acknowledging local initiatives within the decision-making process at the national policymaking processes. This research builds upon the insights of previous studies that highlight the tension between economic-driven port development and the broader interpretation of success by cities, encompassing citizen well-being and livability.[54] These factors underline the need for a comprehensive co-design framework for strategic collaboration for facilitating their interactions and harnessing the collective knowledge for future transnational

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50 Eurostat. "Maritime freight and vessels statistics." Accessed October 16, 2024. https://ec.europa.eu/eurostat/statistics-explained/SEPDF/cache/6652.pdf

51 Joost Hintjens, Thierry Vanelslander, Martijn Van der Horst, and Bart Kuipers. "Towards a bio-based economy in ports: The case of the Flemish-Dutch delta." *International Journal of Transport Economics* 42, no. 2 (2015): 229-247.

52 Åsa Persson and Adis Dzebo. "Exploring global and transnational governance of climate change adaptation." *International Environmental Agreements: Politics, Law and Economics* 19 (2019): 357-367.

53 EGTS. "EGTS Linieland." Accessed October 16, 2024. https://www.egtslinieland.eu/

54 Carola Hein, Ingrid Mulder and Hilde Sennema. "A Call for Value Literacy in Port City Transitions." *European Journal of Creative Practices in Cities and Landscapes* 4, no. 2 (2021): 108-129.

planning. The limited sharing of knowledge and data exchange across national boundaries presents significant challenges to the development of collaborative solutions and the sharing of best practices. This issue is multifaceted, encompassing legal, organizational, and technical barriers to cross-border data exchange and interoperability.

In this research, the transnational Flemish-Dutch delta is being hypothesized on key theoretical perspectives to frame the study within the context of non-standard geographies, particularly learning from the theories of Port Cityscape[55] and Transnational Urbanism.[56] Another new ESPON project,[57] for border regions establishes the relevance, value, and urgency of working in cross-border regions at the time of climate change is "Territorial Governance of Non-standard Geographies". It aims to provide valuable policy advice on optimizing territorial governance mechanisms by integrating formal frameworks with soft spaces of governance. This suggests the necessity for cross-pollination of shared knowledge between spatial datasets and the societal values, to foster effective approaches to address transnational and cross-border regional issues.

In order to comprehend the intricacies spanning from local to transnational Delta scales, an analysis encompassing quantitative, qualitative, and spatial dimensions is being researched upon. The geospatial platform will be extensively used as a tool to bring the spatial and analytical implications of all the statistical data and their trends in conjunction with the stakeholder narratives and local values. The utilization of the platform within the Flemish-Dutch Delta region serves a crucial purpose for three main reasons. Firstly, it facilitates the collection of both local and national planning practices and instruments in cross-border regions, aiding in a comprehensive understanding of initiatives. Secondly, the platform enables the assessment of spatial data and stakeholders narratives related to planning and policy instruments, allowing for an in-depth analysis of land-sea interaction and transformations. Lastly, by testing the platform as a co-design tool to foster shared knowledge among users, it highlights gaps and enhances collaborative practices. This way, the research contributes to the platform's content, through the learnings and exchanges of the co-design processes, promoting shared knowledge among stakeholders and facilitating collaborative practices. By transcending national boundaries and pooling expertise from the Netherlands and Belgium, users can collaboratively tackle shared challenges. The geospatial platform stands out as a valuable tool for examining transnational planning in the Flemish-Dutch Delta.

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55 Carola Hein. *The Port Cityscape: Spatial and institutional approaches to port city relationships.*

56 Michael Smith. "Transnational urbanism revisited." *Journal of Ethnic and Migration Studies* 31, no. 2 (2005): 235-244.

57 ESPON. "Nostageo - Territorial Governance of Non-standard Geographies". Accessed October 16, 2024. https://www.espon.eu/espon-2030/thematic-actions-plans/governance-new-geographies/territorial-governance-non-standard

This research aims to contribute to the advancement and refinement of the platform, enhancing its goal of empowering users to visualize and geolocate their activities, analyze relationships among diverse stakeholders. Overall, the geospatial platform is expected to be functioning as a tool for policymakers, planners, and stakeholders, providing a thorough understanding of the complex social-ecological system in the Flemish-Dutch Delta. This knowledge sharing platform lays the groundwork for formulating effective policies, interventions, and strategies to confront the region's challenges. The findings of the research will establish the geospatial platform as a strong tool for data analysis in similar regions, supporting transnational cooperation, tackling shared challenges, and fostering sustainable development.

4. Discussion

The intricate dynamics in coastal regions, specifically among port-city territories, are at the forefront of urban development challenges. These territories are strategically positioned along coastlines and waterbodies, often co-developing within or close to urban environments and function as hubs of trade, embodying a delicate balance between global economic needs, environmental stability and societal values. The continuous evolution of these complex territories necessitates innovative solutions that not only address their vulnerabilities but also leverage their unique characteristics for sustainable development. The Bauhaus of the Seas Sails geospatial platform provides a versatile toolset for comprehensive analysis of these complex territories.

The foundational understanding of port-city territories as dynamic and vulnerable urban environments underscores the significance of sustainable development. The geospatial platform represents a pioneering initiative that amalgamates open-access geospatial data, spatial information on port-city territories, and narratives about the pilots involved in the project. This platform offers an integrated approach, embracing visualization, analytics, and narrative sharing as its core pillars. It fosters a connection between science, technology, education, art, and culture, aligning with the ideals of the New European Bauhaus.

One of the distinctive features of the platform is its ability to facilitate the study of drops (pilot actions) and ripples (pilot demonstrators) in diverse locations undergoing water-related transformations. By enabling efficient analysis, visualization, and sharing of open data, the platform creates a foundation for living labs and the dissemination of findings. The platform, grounded in the New European Bauhaus vision, aims to engage users and foster value-based discussions through interactive visualizations. Visualizations not only serve as the bedrock for informed discussions but also contextualize project work across various locations. The analytical suite empowers users to perform complex spatial analyses, gaining

valuable insights into geographic patterns and relationships. The narrative layer acts as a repository, allowing consortium members to share information about the effectiveness and impact of initiatives.

An essential aspect of the geospatial platform is its emphasis on mapping, driven by a multi-scalar, multidisciplinary, and cross-border approach. This methodology enables the platform to handle data at various spatial scales, incorporate insights from different disciplines, and integrate data across international borders. In turn, this approach provides a powerful tool for analyzing spatial data, offering diverse perspectives and methodologies for different research proposals.

Two contrasting research proposals within the platform highlight its versatility. The health and well-being research in port-city territories takes advantage of the platform's multi-scalar and multidisciplinary approach. Recognizing the multifaceted nature of health disparities, the platform integrates data from diverse spatial levels, and acknowledges the importance of cross-border collaboration. This research proposal showcases how the platform can be instrumental in addressing complex urban health challenges, promoting equity, and contributing to sustainable development.

On the other hand, transnational planning in the Flemish-Dutch Delta demonstrates the platform's capability to handle intricate systems and diverse stakeholder dynamics. The platform aids in visualizing stakeholder locations, analyzing relationships, and assessing impacts. By revealing concentrations and distribution patterns, the platform enhances communication and coordination, guiding the development of sustainable practices. This research proposal exemplifies the platform's role in facilitating transnational cooperation and addressing challenges such as climate change through comprehensive spatial analysis.

The geospatial platform's innovative grid-based approach to data organization and retrieval stands out as a key for mapping. This approach not only optimizes performance and scalability but also supports real-time visualization capabilities. The hierarchical grid system enhances spatial queries, enables efficient summarization of data, and ensures resource efficiency on the server-side. This methodology is fundamental to the platform's ability to provide users with a streamlined visualization experience, dynamically adjusting resolution based on user interactions.

5. Conclusion

The Bauhaus of the Seas Sails geospatial platform emerges as a valuable tool. This open-access platform offers a comprehensive solution for analyzing complex territories. It integrates geospatial data, spatial information on port-city territories, and narratives, fostering collaboration through visualization, analytics, and knowledge sharing.

Aligning with the New European Bauhaus ideals, the mentioned functionalities and capabilities of the geospatial platform can help to bridge the communication between disciplines - science, technology, education, art, and culture - and users - citizens, politics, academia and practice, from various backgrounds This fosters user engagement and value-based discussions. The platform's strength lies in its multi-scalar, multidisciplinary, and cross-border mapping capabilities. This allows researchers to analyze data across various scales, integrate diverse disciplines, and transcend international borders. This empowers users to conduct complex spatial analyzes, gaining valuable insights into geographical patterns and relationships. Additionally, a narrative layer facilitates knowledge sharing by allowing consortium members to share information about the effectiveness and impact of various initiatives.

The platform's versatility is demonstrably evident in the two showcased research proposals. One proposal focuses on health and well-being in port-city territories, while another tackles transnational planning in the Flemish-Dutch Delta. These diverse cases highlight the platform's adaptability in addressing complex urban challenges and fostering transnational cooperation. In essence, the geospatial platform is a transformative tool that not only addresses the challenges faced by port-city territories but also aligns with the vision of the New European Bauhaus, promoting sustainability, inclusivity, and innovation. As a dynamic and comprehensive platform, it lays the groundwork for informed decision-making, collaboration, and the pursuit of a resilient and sustainable future for complex territories.

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MAIN SECTION

Mapping Sustainable Futures: Cartographic Maps' Role in Citizen Science for Participatory Research in Sustainable Urban Mobility

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ABSTRACT
Nowadays, climate change shows irreversible consequences for the well-being of humanity, territories, and resources. The city of Bologna (Italy) is facing environmental, societal, and digital challenges that are currently featured in urban spaces worldwide: air pollution and intense urban mobility, due to anthropic activities and ever-increasing urbanization. To tackle these issues, the H2020 I-CHANGE project "Individual Change of HAbits Needed for Green European transition" aims to illustrate the possibility of collective behavioral change by engaging civil society in citizen science initiatives (Goudeseune et al., 2020; Vohland, 2021). Emphasizing climate change awareness and sustainable lifestyles, the research prioritizes openness, accessibility, and participatory knowledge production. Investigating cartographic maps' role in citizen science, the study explores behavioral shifts towards sustainability. This contribution proposes the "Mani in Mappa!" (Hands on maps) initiative as a potential citizen science activity that involves maps as a dynamic tool for scientific research, education, and participation. The scientific component involves applying the concept of citizen science, engaging people in the shared collection and processing of data on Bologna's mobility system. The educational dimension is expressed through serious games, transforming gaming into a tool for message transmission, information exchange, and training. Finally, participation is facilitated by using geographic information systems for public involvement. This multidimensional approach aims to enhance active citizen awareness in sustainable urban mobility and to promote behavioral change to sustainable mobility.

KEYWORDS
citizen science, mapping serious game, sustainable urban mobility, participatory geographical information system

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Introduction

In the contemporary world, climate change is influencing the well-being of humanity, the health of urban areas, and the accessibility to resources, with irreversible implications. Its effects impact complex socio-spatial systems marked by economic, social, and territorial inequalities resulting in diversified consequences on social groups. To achieve a just Socio-Ecological Transition, aiming to establish a new sustainable perspective for urban spaces, it is crucial to open the promote collaboration among all stakeholders identified in the Quintuple Helix of Innovation.[1] The concept of Just Transition, as understood in this paper, promotes social, economic, and environmental equity in the pursuit of a sustainable future. By sustainable future, we mean one that "meets the basic needs of the present without compromising the ability of future generations to meet their own needs".[2] This process must occur within an ethical framework of equity, which refers to the level of fairness in outcomes for different individuals or social groups.[3] The overarching goal is to ensure that the transition towards a more sustainable society does not leave anyone behind but instead reduces inequalities and provides equal opportunities for well-being and development. Civil society plays a pivotal role in sustainability projects, aimed at democratizing knowledge and research in the environmental field. To incorporate non-expert knowledge, research should pursue objectives of openness, accessibility, and participatory knowledge creation. Among the potential tools of collaborative research in the processes of participatory knowledge production, citizen science is one of the most frequently utilized.

Citizen science or collaborative science is a research method that involves people who are not trained in science:[4] research activities combine an openness of researchers to the public and local communities with

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1 Elias G. Carayannis, Thorsten D. Barth, and David FJ Campbell. "The Quintuple Helix innovation model: global warming as a challenge and driver for innovation." *Journal of innovation and entrepreneurship* 1 (2012): 1-12. https://doi.org/10.1186/2192-5372-1-2. The Quintuple Helix model builds upon the foundational frameworks of the Triple Helix and Quadruple Helix. The Triple Helix framework centers on the production and utilization of knowledge within the context of university-industry-government relations - *Leydesdorff, Loet and Meyer, Martin. (2003). Triple Helix of University-Industry-Government Relations. Scientometrics. 58. 191-203. 10.1023/A:1026276308287* - and the Quadruple Helix expands this model by incorporating a media-based and culture-based public dimension - *Carayannis, Elias and Campbell, David. (2009). 'Mode 3' and 'Quadruple Helix': Toward a 21st century fractal innovation ecosystem. International Journal of Technology Management - INT J TECHNOL MANAGE. 46. 10.1504/IJTM.2009.023374* - As a further elaboration of this model the natural environment is integrated in the framework, emphasizing how essential it is to incorporate this dimension into the construction of a comprehensive analytical framework that interlinks knowledge and innovation with environmental considerations. In this context, the perception and experience of the environment by the citizenry become crucial elements in the development of climate awareness and into the formulation of environmentally and urban sustainable solutions.

2 Gro H. Brundtland, *Our Common Future: Report of the World Commission on Environment and Development*. (Geneva, UN-Dokument A/42/427, 1987).

3 Deborah S. Rogers, "Socioeconomic Equity and Sustainability." In *Global Environmental Change*, 933–41, 2014. https://doi.org/10.1007/978-94-007-5784-4_62

4 Mordechai Muki Haklay, Daniel Dörler, Florian Heigl, Marina Manzoni, Susanne Hecker, and Katrin Vohland. "What is citizen science? The challenges of definition." *The science of citizen science* 13 (2021). https://doi.org/10.1007/978-3-030-58278-4_2

a process of shaping scientific citizenship that leads to wider accessibility of traditional scientific knowledge.[5] The European Citizen Science Association (ECSA) articulates the inclusivity of science toward non-exclusively technical domains as an experimental arena embracing alternative models of democracy and the production of public knowledge.[6] The basic idea is to build knowledge and expertise that is accessible and participatory, producing new data, information, and perspectives, creating domains of knowledge able to grasp the complexity of a multifaceted phenomenon such as climate change, environmental challenges, and future urban scenarios.

The research here presented used mapping methodologies in addition to the traditional data collection activities with low-cost sensors and participative scientific actions. Mapping, far beyond a mere spatial representation, has increasingly become a central and transformative process in disciplines focused on understanding and shaping territories. From the ancient period, maps have been used as directional tools for spatial orientation, and graphic instruments designed to represent places with particular attention to scales, objectives, symbols, and legends (e.g., Mercator projection).[7] Powell[8] observes that while maps have historically been conceived as directional tools, their function has evolved to include a variety of different forms in contemporary disciplines.

According to Corner,[9] the distinction between tracing and mapping lies in their intrinsic nature: tracing is limited to reproducing existing reality, propagating the redundancies of a pre-described world, while mapping is an act of discovery and revelation. Mapping does not merely represent what is visible and known but explores the hidden connections between what was and what is, uncovering previously invisible links and reformulating the existent. This process applies to topographical features and extends to the hidden forces that shape space, from natural processes to social relationships, making mapping an inherently creative and formative act in any design process. Mapping, therefore, is distinguished by its ability to represent existing complexities and actualize their potential. This process allows for the imagination and creation of new spatial and social

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5 Rick Bonney, Jennifer L. Shirk, Tina B. Phillips, Andrea Wiggins, Heidi L. Ballard, Abraham J. Miller-Rushing, and Julia K. Parrish. "Next steps for citizen science." *Science* 343, no. 6178 (2014): 1436-1437. https://doi.org/10.1126/science.1251554 ; Hauke Riesch, and Clive Potter. "Citizen science as seen by scientists: Methodological, epistemological and ethical dimensions." *Public understanding of science* 23, no. 1 (2014): 107-120. https://doi.org/10.1177/0963662513497324

6 Jaume Piera, Karen Adriana Soacha Godoy, Sonia Liñan, Carlos Rodero García, Xavier Salvador, and Ana Álvarez. "European Citizen Science Association (2022). Conference Proceedings." (2022).

7 The Mercator projection is a conformal cylindrical map projection of the Planet Earth presented by Flemish geographer and cartographer Gerardus Mercator in 1569.

8 Kimberly Powell, "Making Sense of Place: Mapping as a Multisensory Research Method," *Qualitative Inquiry* 16, no. 7 (June 16, 2010): 539–55, https://doi.org/10.1177/1077800410372600

9 James Corner. "The Agency of Mapping: Speculation, Critique and Invention." In *The Map Reader*, edited by Martin Dodge, Rob Kitchin, and Chris Perkins, 89-101. Wiley Books, 2011. https://doi.org/10.1002/9780470979587.ch12

configurations, transcending the rigidity and simplification of current reality. Corner emphasizes that the greatest power of mapping lies in its *exploratory inventiveness*, which renders mapping an active agent of cultural intervention. In this sense, mapping becomes a tool for representing the world and for transforming it, opening new possibilities for interpretation and intervention.

Further elaborations on this perspective, several studies describe mapping as an analytical practice that goes beyond the mere representation of data.[10] The process of mapping begins with the selection of a particular characteristic of interest, followed by the collection of data and its organization into a map. The goal is to create a visual construct that is more than the mere sum of its parts - a pattern that, when brought together, can add a new layer of understanding to the data itself. In this way, the map becomes a powerful tool for visualizing connections between data and for looking beyond, revealing hidden patterns and actual connections that would otherwise remain unseen. Moreover, the process of mapping inverts the traditional analytical power, which often separates theoretical knowledge from practical, situated experience.[11] Hall e Smith identify a "logic of inversion" in which movement itself—the act of moving through space—becomes an action of knowledge, a way of exploring and understanding the external world. In this sense, mapping is not merely an act of static representation but a dynamic process that integrates experience and knowledge, allowing for a deeper and more situated understanding of space. An important perspective considers the city and the urban fabric as representations of human complexity[12]. However, contemporary science often fails to capture this complexity, seeking to reduce phenomena to simplifications that ultimately lose their nature and explanatory power.[13] This inability to represent complexity has serious consequences for understanding and managing urban space, as it leads to the fragmentation of interactions that compose it, compromising the ability to think, create, and live the urban environment meaningfully.

Given these premises, the integration of mapping in citizen science has emerged as a promising avenue for enhancing public involvement and data collection.[14] In recent decades, the methodological function of maps has expanded, taking on new and more articulated forms that surpass

10 Tom Hall, and Robin J Smith. "Knowing the City: Maps, Mobility and Urban Outreach Work." *Qualitative Research* 14, no. 3 (January 24, 2013): 294–310. https://doi.org/10.1177/1468794112469623; Franco Moretti, *Atlas of the European Novel: 1800-1900*. (United Kingdom: Verso Books, 1999).

11 Hall and J Smith. "Knowing the City: Maps, Mobility and Urban Outreach Work."

12 Darko Radović. "Measuring the Non-measurable: On Mapping Subjectivities in Urban Research." *City Culture and Society* 7, no. 1 (February 9, 2016): 17–24. https://doi.org/10.1016/j.ccs.2015.10.003

13 Sandra D. Mitchell, *Unsimple truths: Science, complexity, and policy.* (Chicago: University of Chicago Press, 2009).

14 Andrea Wiggins, and Kevin Crowston. "From conservation to crowdsourcing: A typology of citizen science." In *44th Hawaii international conference on system sciences*, 1-10. IEEE, (2011). https://doi.org/10.1109/HICSS.2011.207

their traditional use as the sole means for orientation. In this context, mapping has become a powerful tool for describing physical space while also exploring the relational, conceptual, and cognitive dimensions of places.[15] Social maps, for instance, highlight the relational nature of phenomena, while conceptual and mental maps are used to graphically describe ideas or concepts, and cognitive maps organize and render legible the physical and social characteristics of how a place is perceived by an individual.[16] In this way, maps not only represent physical space but also explore its experiential and perceptual dimensions. Within the social sciences, maps are used as research tools, which are then accompanied by explanatory texts. The themes addressed vary according to the specific objectives of the research, but all maps share the ability to represent space in ways that go beyond cartography, capturing the living experience and the historical, geographical, and social context of a place.

In this context, integrating data and maps is emphasized with an approach that values the direct experience of space, identifying and describing the connections and complexities that only those who live in the urban fabric can recognize. This type of research does not replace but complements and enriches traditional cartographic approaches, which have become too intertwined with top-down power and a reductive and simplified view of the world.

These are the theoretical foundations upon which the citizen science activity "*Mani in Mappa*" (trad. "Hands on Map!" from now on MIM) was built, as part of the broader Horizon 2020 "I-CHANGE" project. After the mapping activity, in-depth interviews were conducted with participants, aiming to explore the relevance of using maps both as tools for data collection and representation and as a process of co-constructing shared knowledge, specifically regarding the mobility system in the Municipality of Bologna, Italy. The following sections will outline the research context, I-CHANGE, and its theoretical underpinnings, including living labs and citizen science, before briefly describing the urban mobility mapping activity in Bologna, "Mani in Mappa!" Finally, we will present participants' reflections on the role of maps and the conclusions drawn from the entire research experience.

15 Powell, "Making sense of place: Mapping as a multisensory research method."

16 Kevin Lynch. *The image of the city.* (Boston: MIT press, 1964).

The I-CHANGE Project

The H2020 I-CHANGE project "Individual Change of HAbits Needed for Green European Transition"[17] aims to illustrate the possibility of collective behavior change by engaging civil society in citizen science initiatives[18]. The project is structured around the recognition that developing and strengthening citizen science initiatives enhance awareness of climate change impacts in urban areas and encourage behavioral shifts toward more socially and environmentally sustainable lifestyles.

The Project is structured around a network of Living Labs (LL)[19] set up in six cities in Europe (Amsterdam, Barcelona, Bologna, Dublin, Genoa, Hasselt), two in extra-European countries, one in West Asia (Jerusalem) and one in West Africa (Ouagadougou). Firstly, implemented in urban areas,[20] LL used to be carried out for the design of information and communications technology (ICT) innovations[21] as "a user-centric research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real-life contexts."[22] In recent years, we witness a growing implementation of LL methodology in participatory and collaborative research[23] across the level of sustainability, environment and

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17 The I-CHANGE project is a 3.5-year H2020 funded project started in November 2021. The project is coordinated by CIMA Foundation and the University of Bologna serves as the scientific coordinator. The main objective is to enhance awareness regarding the issues associated with climate change by directly collecting environmental and socio-economic data using innovative and user-friendly tools. The competences involved span from climate and meteorological modeling to social and economic sciences, citizen engagement, stakeholder management, ethics and responsible research and innovation as well as communication of scientific findings through continuous storytelling and serious games. All the information is available at https://ichange-project.eu/.

18 Goudeseune, Lise, Hilde Eggermont, Quentin J. Groom, Xavier Le Roux, Carole Paleco, Helen Elizabeth Roy, and T.C.G.E. van Noordwijk. "Citizen Science Toolkit for Biodiversity Scientists". *Zenodo,* November 6, 2020. https://doi.org/10.5281/zenodo.3979343; Katrin Vohland, Anne Land-Zandstra, Luigi Ceccaroni, Rob Lemmens, Josep Perelló, Marisa Ponti, Roeland Samson, and Katherin Wagenknecht. *The science of citizen science.* (Springer Nature, 2021). https://doi.org/10.1007/978-3-030-58278-4

19 Mokter Hossain, Seppo Leminen, and Mika Westerlund. "A systematic review of living lab literature." *Journal of cleaner production* 213 (2019): 976-988. https://doi.org/10.1016/j.jclepro.2018.12.257; Hans Schaffers, and Petra Turkama. "Living labs for cross-border systemic innovation." *Technology Innovation Management Review* 2, no. 9 (2012). http://doi.org/10.22215/timreview/605

20 Diana Chronéer, Anna Ståhlbröst, and Abdolrasoul Habibipour, "Urban Living Labs: Towards an Integrated Understanding of Their Key Components," *Technology Innovation Management* Review 9, no. 3 (March 26, 2019): 50–62, https://doi.org/10.22215/timreview/1224

21 Veronika Zavratnik, Argene Superina, and Emilija Stojmenova Duh. "Living Labs for Rural Areas: Contextualization of Living Lab Frameworks, Concepts and Practices" *Sustainability* 11, no. 14 (2019): 3797. https://doi.org/10.3390/su11143797

22 Mats Eriksson, Veli-Pekka Niitamo, and Seija Kulkki. *State-of-the-art in utilizing Living Labs approach to user-centric ICT innovation-a European approach.* Lulea: Center for Distance-spanning Technology. Lulea University of Technology Sweden: Lulea. 2005. Online under: http://www.cdt.ltu.se/main.php/SOA_LivingLabs.pdf?fileitem=2402350

23 Soini, Katriina, Carl Cyrus Anderson, Annemarie Polderman, Carlone Teresa, Debele Sisay, Prashant Kumar, Matteo Mannocchi, et al. "Context Matters: Co-creating Nature-based Solutions in Rural Living Labs." *Land Use Policy* 133 (August 7, 2023): 106839. https://doi.org/10.1016/j.landusepol.2023.106839; Birgitta Bergvall Kareborn and Anna Stahlbrost, "Living Lab: An Open and Citizen-centric Approach for Innovation," *International Journal of Innovation and Regional Development* 1, no. 4 (January 1, 2009): 356, https://doi.org/10.1504/ijird.2009.022727

climate change related issues, for its ability to pilot actions and initiatives in "real life" contexts and involve stakeholders to co-create innovations and/or practical solutions to environmental or societal problems.[24] The local context of LL appears to be crucial as the main idea is to integrate aspects of the contextual sphere – cultural, environmental and economical,[25] to activate innovation processes in that system.

Each LL involved in I-CHANGE works on several aspects ranging from monitoring climate-related phenomena (air pollution, extreme events, energy consumption), to evaluating intervention as means to mitigate the effects of climate change and generate co-benefits for the environment at urban level (sustainable mobility/transportation, waste management). These activities are being conducted using citizen science methodologies, whereby relevant stakeholders are engaged in the collection of data pertaining to the phenomena under examination. This process is intended to facilitate the identification of potential social, policy, and economic solutions, as well as to promote individual and collective behavioral change.

The implementation of citizen science is a crucial element in the pursuit of a just Socio-Ecological Transition. It serves as an effective instrument for fostering environmental awareness, behavioral change, and social transformation within communities. The Just Transitions Framework[26] underscores the significance of citizen science as a means of facilitating equitable societal transitions towards sustainability. This framework highlights the practical aspects of stakeholder engagement that facilitate behavioral and social change. By incorporating the input of citizens at the level of scientific research, we can ensure that a range of perspectives and local knowledge are integrated into sustainability efforts, thereby enhancing the relevance and effectiveness of these initiatives. By employing citizen science within the Just Transitions Framework, we can collectively devise sustainable solutions that are equitable, inclusive, and anchored in the lived experiences of diverse community members, thereby propelling a Just Ecological Transition.[27]

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24 Margarida Rodrigues, and Mário Franco. "Importance of living labs in urban Entrepreneurship: A Portuguese case study." *Journal of Cleaner Production* 180 (2018): 780-789. https://doi.org/10.1016/j.jclepro.2018.01.150

25 Karin Feurstein, Alexander Hesmer, Karl A. Hribernik, K. D. Thoben, and J. Schumacher. "Living Labs: a new development strategy." *European Living Labs-a new approach for human centric regional innovation* (2008): 1-14.

26 Stephen Williams and John Robinson, "Measuring Sustainability: An Evaluation Framework for Sustainability Transition Experiments," *Environmental Science & Policy* 103 (November 6, 2019): 58–66, https://doi.org/10.1016/j.envsci.2019.10.012

27 David J. Abson, Joern Fischer, Julia Leventon, Jens Newig, Thomas Schomerus, Ulli Vilsmaier, Henrik Von Wehrden, et al. 2016. "Leverage Points for Sustainability Transformation." *AMBIO* 46 (1): 30–39. https://doi.org/10.1007/s13280-016-0800-y

Bologna Living Lab

The city of Bologna is a northern medium-sized Italian city with almost 400,000 inhabitants. Due to its location at the intersection between the northern and southern sides of the Italian country, the city is the major junction of road and railway traffic in Northern Italy. The regional infrastructure network consists of 10,726 km of roads and 1,400 km of railways in continuous expansion to sustain the increasing mobility demand for private and public.[28] The mobility demand is absorbed for the major part by the private sector, with 65.2% of transfers occurring by private cars (increasing by 6.8% within the period 2001-2014), 8.3% by public transport (+0.4% within 2001-2014) and 21.9% by cyclo-pedestrian movement (-6.8% within 2001-2014). Previous studies suggested that the impact of a shift towards more sustainable mobility management will provide multiple co-benefits on air quality, especially in critical areas like the city center.[29]

Mani in Mappa!

The participatory approach adopted in the I-CHANGE project implements citizen science activities trying to trigger social innovation to foster changes in a wider context, based on new scientific and environmental consciousness. The promotion of a co-designed learning approach aims to improve citizens' knowledge of climate change impacts and help citizens understand how their behavior can make a difference and participate in a just and inclusive transition.[30] Involving a broader public in scientific projects, citizen science fosters a sense of community engagement and harnesses the collective intelligence of diverse participants.[31]

With this perspective, the gameboard-based activity MIM rethinks citizen science by enhancing public involvement in data collection, analysis, and discussion of results to better identify climate change-related phenomena, with a multi-dynamic point of view. It explores how the use of maps and the interaction with cartographic elements can assess climate awareness among participants, specifically to further developing and designing accessible, equal, and fair public transport in collaboration with urban planners and policymakers.

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28 Regione Emilia-Romagna. "Strategia di mitigazione e adattamento per i cambiamenti climatici della Regione Emilia-Romagna", *Regione Emilia-Romagna, DG Cura del Territorio e Ambiente* (2019a).

29 Silvana Di Sabatino, Erika Brattich, Francesca Di Nicola, Francesco Barbano, Muhammad Adnan, Shiraz Ahmed, Kristi Jylhä, Kimmo Ruosteenoja, Marco Deserti, Chiara Agostini, and Vanes Poluzzi. *Report on policy options for AQ and CC.* iSCAPE Project, 2019. https://www.iscapeproject.eu/wp-content/uploads/2020/06/iSCAPE_D4.5_Report-on-policy-options-for-AQ-and-CC.pdf

30 Stephen Williams, and John Robinson. "Measuring sustainability: An evaluation framework for sustainability transition experiments." *Environmental Science & Policy* 103 (2020): 58-66. https://doi.org/10.1016/j.envsci.2019.10.012

31 Christopher Kullenberg, and Dick Kasperowski. "What is citizen science? A scientometric meta-analysis." *PloS one* 11, no. 1 (2016): e0147152. https://doi.org/10.1371/journal.pone.0147152 ; Sarah-Kristin Thiel, and Peter Fröhlich. "Gamification as motivation to engage in location-based public participation?" In *Progress in location-based services 2016*, 399-421. (Springer International Publishing, 2017). https://doi.org/10.1007/978-3-319-47289-8_20

The MIM activity is designed as a tool to address the complexity of the urban mobility system, aiming to overcome the limitations imposed by the current power imbalance that often disadvantages citizens, leading to urban planning that is neither inclusive nor equitable. This research highlights the intricate dynamics of mobility systems, which integrate social, economic, and technological variables, intending to guide sustainable urban development initiatives. Although the mobility system involves citizens at individual, technological, and policy levels, citizens often take on passive roles, constrained by inadequate infrastructure and limited resources.[32] Despite their willingness to engage in eco-friendly behaviors, they are largely excluded from decision-making processes, which hinders the widespread adoption of environmentally conscious practices. The research underscores how top-down regulations and technological developments dictate citizens' mobility options, limiting their ability to make active choices and resulting in an urban environment that does not fully

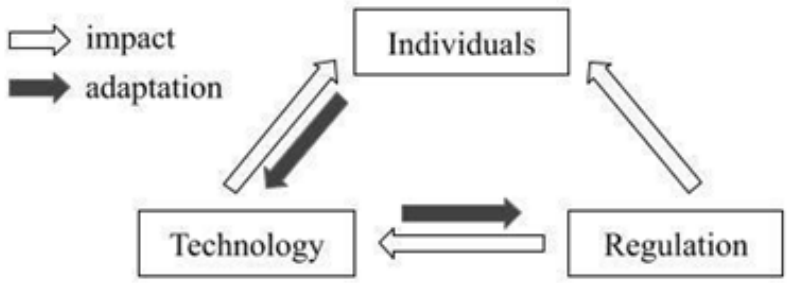

FIG. 1 Multilevel dynamics of the mobility system. Source: elaboration by Selene Tondini

address the needs and voices of its inhabitants.

We can grasp this dissonance through research efforts by engaging in participatory reflections with social groups within the urban setting. This engagement should involve the use of creative and participatory research tools, fostering reflective and chorographic processes on the specific topic. MIM generates a collective co-production of data; the data analysis grasps some dimensions of criticality and complexity, representing a central element in the construction of knowledge linked to the dimension of space,[33] less likely to be produced through conventional research methodologies such as in-depth interviews. The collaborative aim of MIM can be contextualized,[34] and embraces a dynamic approach aimed at engaging

32 Anja Kollmuss, and Julian Agyeman. "Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?" *Environmental education research* 8, no. 3 (2002): 239-260. https://doi.org/10.1080/13504620220145401

33 Federica Burini, *Cartografia partecipativa. Mapping per la governance ambientale e urbana.* (Franco Angeli, 2016). https://hdl.handle.net/10446/75688

34 Burini, *Cartografia partecipativa*.

communities, facilitating decision-making, and promoting empowerment.

Methodology
Phase 1: Mapping Activity

Between March 2023 and April 2024, 116 university students from four departments (Engineering, Service Design, Sociology, and Political Science), 30 local stakeholders and 20 middle school students participated in the MIM activities, resulting in 45 maps. Stakeholders were selected through an initial mapping of local civil society organizations, including NGOs, associations, and collectives focused on sustainable mobility, public space, and environmental issues. Students engaged in 8 hours of in-person activities with researchers during class, while stakeholders participated in a 3-hour evening workshop.

The "Mani in Mappa!" activity was developed to address the complexity of urban mobility systems by employing a methodological approach that integrates serious game and participatory mapping into citizen science activity in Bologna Living Lab.

Born in the field of design,[35] serious games are activities that combine "serious" objective -pedagogical, informational, or training - with playful elements. Usually, serious games refer to activities aimed at learning and training,[36] and are employed in educational and learning processes.[37] Serious games possess the potential to revolutionize citizen science by creating immersive and engaging experiences that motivate participants to actively contribute to scientific goals[38]. This integration aims to rethink citizen science by enhancing public involvement in data collection, analysis, and discussion of results to better identify climate change related phenomenon. Participants, engaged in mapping through a serious game conducted as a board game, overcome the passivity of simply representing data in a geo-referenced digital system exercising their judgment in structuring the map by incorporating the collective imagination of all participants.

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35 Ralf Dörner, Stefan Göbel, Wolfgang Effelsberg, and Josef Wiemeyer. Serious games. (Cham: Springer, 2016). https://doi.org/10.1007/978-3-319-40612-1

36 Jan Cannon-Bowers, and Clint Bowers. "Synthetic learning environments: On developing a science of simulation, games, and virtual worlds for training." In Learning, training, and development in organizations, 229-261. (Routledge, 2009).

37 Julian Alvarez, and Damien Djaouti. "An introduction to Serious game Definitions and concepts." *Serious games & simulation for risks management* 11, no. 1 (2011): 11-15 ; Nuri Kara. "A systematic review of the use of serious games in science education." *Contemporary Educational Technology* 13, no. 2 (2021): 295. https://doi.org/10.30935/cedtech/9608

38 Seth Cooper, Firas Khatib, Adrien Treuille, Janos Barbero, Jeehyung Lee, Michael Beenen, Andrew Leaver-Fay, David Baker, and Zoran Popović. "Predicting protein structures with a multiplayer online game." Nature 466, no. 7307 (2010): 756-760. https://doi.org/10.1038/nature09304; Sara Cravero. "Methods, strategies and tools to improve citizens' engagement in the smart cities' context: A Serious Game classification." Valori e Valutazioni 24 (2020) https://www.proquest.com/scholarly-journals/methods-strategies-tools-improve-citizens/docview/2529186058/se-2; Didone Frigerio, Anett Richter, Esra Per, Baiba Pruse, and Katrin Vohland. "Citizen science in the natural sciences." The science of citizen science (2021): 79-96. https://doi.org/10.1007/978-3-030-58278-4_5

Specifically, MIM participants were divided into groups and each group were assigned with fictional characters (personas), with specific socio-demographic characteristics such as gender, age, health status, family composition, employment status, and financial situation.[39] Specifically, personas were designed based on analytical dimensions that could play a role in mobility choices. Gender, age, ability can significantly impact the use of mobility choices in various ways, influencing individuals' access to transportation options, preferences, and experiences. These factors intersect and create complex dynamics that shape mobility patterns and opportunities for different segments of society.

Each persona is accompanied by a brief life story, with daily routine locations geolocated on the map (Appendix A). Using personas, each group was asked to address challenges related to urban mobility practices. Through route-tracking activities and transportation choices, each group had to complete a mobility agenda that reflected the personas' needs and also daily activities (going to work, shopping, getting to places for recreation) related to the personas' requirements. Each group could choose between three means of urban transport (private car, bicycle/foot, public transport) and have different policy scenarios (30 km/h areas, low emission areas).

The primary goal of the mapping activity is to identify barriers that prevent city inhabitants from shifting from private to public transport and sustainable mobility and drawing on map optimal routes (Fig. 4) based on speed, cost, and environmental sustainability, following urban mobility policies, including public transportation schedules. The activity has been conducted in two formats: as a competitive board game for stakeholders and a non-competitive exercise for students. Participants work to find the most suitable way to complete the personas' daily mobility agenda using the city's infrastructure and integrated systems, aiming for the most sustainable, fast, and economical route. In the competitive version, detailed in Appendix 2, participants earn or lose points based on their chosen mode of transport and the level of CO2 emissions during the journey. During the activity, participants can also test hypotheses directly in the field, developing various mobility solutions and gathering information using tools provided by interactive digital maps from Municipality of Bologna,[40] personal experience, and other digital maps (open street map or Google maps). At the end of each session, participants engage in a collective discussion of the most relevant issues that emerged during the mapping activity. This sharing moment allows them to propose strategies and interventions

39 Flore Vallet et al., "Tangible Futures: Combining Scenario Thinking and Personas - a Pilot Study on Urban Mobility," *Futures* 117 (January 13, 2020): 102513, https://doi.org/10.1016/j.futures.2020.102513

40 The maps used are available at the website http://sitmappe.comune.bologna.it/pugviewer/#!/app/map/default (last access September 2024).

FIG. 2 Stakeholders playing "Mani in Mappa!". Source: photo by Teresa Carlone

to mitigate difficulties related to public, sustainable, and shared mobility, thereby promoting a shift towards sustainable mobility habits.

Maps, conceptualized as a board game, serve as common shared workspaces where stakeholders with diverse skills and experiences come together leveraging their individual expertise to reproduce the urban complexity and co-create new dynamic solutions. This process is not merely an aggregation of ideas but an active engagement of all stakeholders, who, starting from individual analysis, collaboratively construct a new reality composed of multiple dynamics and solutions (Fig. 2). Moreover, role-playing further enhances their ability to reimagine reality while excluding cultural and social biases.

Eventually, participants are involved in the scientific process of creating "human data"[41] and identifying best practices or areas for improvement in

41 Giorgia Lupi, and Stefanie Posavec, *Dear data*. (Chronicle books, 2016). ; Giorgia Lupi, *Data Humanism, the Revolution will be Visualized*, (Medium press, 2017), available at https://medium.

FIG. 3 Example of map outcome from "Mani in Mappa!" session.
Source: photo by Teresa Carlone

Bologna's urban mobility system, fostering environmental awareness and stimulating innovative solutions for urban mobility. It links the adoption of sustainable mobility practices to the complexity of citizens' lifestyles, involving social, economic, and technological variables.

Phase 2: In-Depth Interviews

To gain insight into the effects of map use and serious game experience on participants, five people previously involved in the MIM activity were interviewed in depth. Despite the limited number of participants, efforts were made to include representatives from all degree programs and from a stakeholder group, with an effort to maintain gender balance. The interviews were conducted in January 2024, both online and in person, and represent the initial phase of a comprehensive investigation that will be conducted through focus groups, which are currently underway. The interview addressed two main topics: first, the frequency of interaction with maps by the interviewees and any previous knowledge of maps or cartographic mapping activities (crowd mapping, map design, etc.) for work or recreational purposes. Secondly, the focus was on the personal experience with the serious game and whether active interaction with the map tool accompanied a process of speculation on the complexity inherent in the concept of sustainable urban mobility. All interactions were recorded and transcribed verbatim. The findings from the interviews were subsequently analyzed through content analysis, identifying thematic areas to cluster the main points arisen from respondents. The following section will address the most pertinent issues, with a particular focus on the following four areas: a. the impact of the collaborative mapping process on

com/@giorgialupi/data-humanism-the-revolution-will-be-visualized-31486a30dbfb

awareness of critical issues and limitations related to sustainable urban transportation; b. comparative merits of digital maps and paper maps; c. the role of collaborative mapping as a research tool in citizen science; d. limitations and potential of collaborative mapping.

Discussion

In this section, we will discuss the main takeaways from the collective discussions that followed these cartographic activities, as well as insights from interviews with participants. Although the research is ongoing, preliminary observations suggest that mapping activities serve as valuable tools for collaborative research, education, and informed dialogue on complex issues. They also offer opportunities for engagement and empowerment, helping to raise awareness of urban mobility challenges and increase understanding on sustainable mobility practices.

Sustainable Urban Transport Critical Issues and Limitations

As for research purposes, it emerges that participation in citizen science activities in general has stimulated greater awareness of urban mobility related problems. During the discussion that followed each group's work participants stressed out that identifying with a citizen with specific socio-demographic characteristics led to reflection on physical, economic, and social limitations never experienced before. Using the serious game method, participants were immersed in alternative scenarios, requiring them to abandon cultural and cognitive preconceptions to address mobility challenges in an innovative and unusual way. The integration of personas in serious game development fosters a deeper understanding of the players' characteristics, preferences, and needs.[42]

Preliminary results show how in Bologna, the public transportation system does not consider the needs of the most fragile groups (people with disabilities, caregivers, the elderly, precarious workers) even then these categories tend to be the most represented among public transportation users. Moreover, all participants emphasized that gender is a highly discriminatory variable concerning mobility choices and constitutes a significant inequality, especially for those who oversee the reproductive and care work. Caregiving work turns out to be, along with disability, one of the main obstacles to sustainable mobility choices, such as urban public transportation or the use of bicycles. However, the responsibility for the solution is recognized to lie with administrations and governments in implementing integrated mobility policies that citizens can follow, aided

42 Francesco Bellotti, Bill Kapralos, Kiju Lee, Pablo Moreno-Ger, and Riccardo Berta. "Assessment in and of serious games: An overview." *Advances in human-computer interaction* 2013 (2013): 1-1. https://doi.org/10.1155/2013/136864; Luis De-Marcos, Adrián Domínguez, Joseba Saenz-de-Navarrete, and Carmen Pagés. "An empirical study comparing gamification and social networking on e-learning." *Computers & education* 75 (2014): 82-91. https://doi.org/10.1016/j.compedu.2014.01.012

by the provision of appropriate infrastructures and services.

Digital vs Paper Map

When confronting the research tool, differences between the use of paper and digital maps have been distinctly highlighted in the responses. While paper maps are seen as slower and more challenging to comprehend "*It was challenging to orient myself. The map is an additional difficulty(...) It's like knowing how to use a compass" (int.1)*, they offer an advantage presenting a more comprehensive view of the urban system and mobility, thereby fostering deeper critical reflection.

> *"The overall view that the paper map gives you, in my opinion, is less on the digital one(...) even on the digital map, I can see maybe the whole city of Bologna, but I don't have it all on the desk, I mean it's really a different thing, which is bigger, more immersive." (int.2)*

Using the paper map was deemed crucial in making the experience more tangible and facilitating comparison with digital platforms. It "adds a sense of reality" and is helpful in "getting a local perspective" compared to solely relying on digital tools, reflecting the concept of "imageability" of the mapping support to evoke a vigorous image postulated by Lynch (1964)[43]. Another benefit of paper maps emphasized by certain respondents is their clarity to a wider audience, facilitated by a standardized decoding method that enables anyone engaging with them to obtain consistent information.

> *"It's more convenient because it allows you to be intuitive even when talking to other people" (Int.5)*

> *"The map, although it should be an objective tool, actually becomes highly subjective at the moment it's represented." (Int.3)*

On the other hand, digital maps, like Google Maps, provide dynamic information which is not easily integrated into paper maps, such as bus schedules, city traffic simulations that change the travel times of a given route, or the calculation of costs and CO2 emissions.

> *"Google Maps is a very powerful tool that allows you to calculate everything you need to solve the challenges. I could have gone to the field to confirm the data found, for example, to measure distances and times, but Google Maps is reliable enough, even simulating schedules." (int.1)*

Collaborative mapping and citizen science process

A central aspect of the interviews was the ability of mapping activity to support a research process. Participants revealed that the serious game helped contextualize and represent as a visual tool the mobility system about the ideal citizen experiences of Bologna, identifying critical issues and difficulties among the city's neighborhoods. Using primarily online

43 Lynch, *The image of the city.*

navigation systems and maps (Google Maps, Via Michelin, Bologna Municipality), it was noted how online information is inaccurate or even missing, especially on some aspects related to the most vulnerable segments of the population. No apps efficiently indicate the presence of architectural barriers under the arcades, which bus stops are accessible, or which buses have ramps. Other missing information is related to architectural barriers on sidewalks or in some streets/squares in the city center. In some cases, to overcome the problem of missing information, some participants used Google Street View or directly explored the field to collect information.

> *"Maybe I try to understand, Ok, it's located in this area, so it means it's far from(...) a certain service, so that's why I have this problem, simply that, maybe, I mean if I see it on the map it stays in my mind compared to the study, but only because maybe I have more, I mean visually" (int.2)*

To explore the use of maps as a support for educational and training process, participants were initially prompted to undertake a thorough consideration of the nature of their relationship with maps, whether in paper or digital form, as well as their perceptions of spatial representations more broadly. Some participants initially found it challenging to acknowledge the pervasive influence of various forms of maps in their everyday lives. When asked about the frequency of map usage in their personal lives before the MIM activity, some participants spontaneously responded negatively. However, upon closer examination, it became evident that these participants, originally confining the concept of a "map" solely to the tool comparable to the one used in the activity, had indeed interacted repeatedly with the concept of maps in different contexts, pursuing diverse purposes and employing various forms and designations.

> *"At most, reference is made to company floor plans, primarily to building layouts rather than maps focusing on a broader portion of the territory." (Int.5).*

In this context, interaction with a graphic symbol delineating a space is not qualified as a "map", similar to what occurs when using a geographical map for orientation in a natural environment "*for example, during the summer season, on vacation periods, often using maps depicting forest or mountain environments" (Int.5)*. Other participants have stated they have used the map as a reporting tool for an investigation in research activity, activism or as support in the urban planning process to transpose geolocated data into a territorial dimension.

Exploratory questions have also shed light on the predominant theme of orientation, highlighting various ways in which people interact with maps, understood as the ability of individual parts of urban space to be recognized and organized within a coherent system.[44] Some prefer to deliber-

44 Ibid. 36

ately get lost and then find their way through map analysis, while others rely on prior studies or sports experiences (e.g., orienteering) to develop orientation skills. However, in general, the sense of navigating with a map, whether paper or digital, is seen on one hand as a means of representing oneself in space "*in terms of presence(...) I know where I am, I know how to move" (Int.4)*, and on the other hand, as a way of taking ownership of space:

> *"I really like to see, or maybe when you need to find a route, I mean I don't want to see it's one thing, but this is my thing, maybe I want, I want to study it, before crossing the city and then I do it without the phone" (Int.2).*

> *"I arrived in Bologna,(...) I don't use Google Maps anymore and so randomly I took a map, let's say, and(...) I spent a day getting lost in the middle of Bologna with the map and(...) it was the first time, in short, that I remembered the streets" (Int.4)*

In terms of training and learning, the group's experience was positively evaluated for the diversity of perspectives and the wealth of shared knowledge, to "*[…) have a vision that is not just the individual's personal one that we know better." (Int.3).* The collective aspect of MIM has been recognized as an additional asset, serving both to fulfill the challenge presented in the serious game and as an opportunity for engaging with diverse and complementary perspectives.

> *"Everyone had a piece of knowledge, a piece of practicality, some with the phone, some with the map, some with the means and so this helped us in the elaboration, let's say, of the path that we then proposed" (Int.3).*

Along with that, a crucial theme emerges from the interviews concerning the ability of the participatory approach of MIM to gather different and composite viewpoints and perspectives. As highlighted multiple times, those who engage in such activities are often already conscious of the topic. However, a cartographic serious game can serve as a valuable tool to collect data to describe the mobility system in a more human-centered and less "engineered" manner, while also increasing citizens' awareness of more sustainable mobility styles. Among participants, it has proven crucial to find ways to involve even the underrepresented categories of citizens.

> *"People who then participate are clearly more inclined to active engagement; those who attend but do not actively participate. Right? And so, in my opinion, this somewhat skews the discussion of achievable results and presents a limitation..." (Int.3)*

Limits and Opportunities of Collaborative Mapping

In this context, all participants have highlighted the lack of direct engagement with individuals embodying the characteristics presented through the personas and mobility agendas of MIM. This led to the need to verify the hypotheses developed during the workshop through field investigations (e.g., measuring the height of bus steps) or through personal experiences. The importance of involving underrepresented categories of citizens was emphasized by the interviewees, highlighting that those who participate are already willing to be engaged in the activity, making it necessary to adopt strategies to attract a broader audience.

> *"There could be all these problems, so since I don't know, because anyway I'm maybe distant at that moment to confront myself, maybe in a process where there are also many representative people" (Int.2)*

In some groups, this issue was resolved by going into the field to verify the hypotheses developed during the workshop, with measurements and sample interviews, or by relating them to personal experiences occurring in other contexts (e.g., through the experience of grandparents).

Finally, the future utility of MIM was considered in terms of its political and urban design potential. Participants suggested that the game could be dynamically used to identify immediate problems and engage citizens in urban planning, enabling a participatory vision rather than solely top-down approaches. Additionally, the importance of involving underrepresented categories was emphasized to ensure a more inclusive and accurate representation of city life.

> *"The obvious advantage is, I mean, putting people's vision into, I mean, into a design, maybe top-down. I mean, that then becomes not top-down anymore but participatory with other people. And so, it's not like, okay, I decide the line should pass here and here, but maybe I find out that the stop can be placed 100 meters earlier, benefiting 100 people who are much happier. Maybe nothing has changed for the bus itself, but I don't know, by listening to those people, I made it easier to go to school or to work." (Int.2)*

Final Remarks

As mentioned earlier, the "Mani in Mappa" activity is part of a series of initiatives promoted by the European I-CHANGE project. In this context, the data and reflections that emerged on the theme of sustainable mobility will be integrated into policy recommendations and then delivered to local administrators as guidelines for future planning, also based on the direct experiences of citizens. The presented preliminary results of the research can represent a good starting point for reflecting on the use of

maps in citizen science activities to enhance participatory research activities with a significant social and spatial dimension on issues related to climate change studies. Moreover, the study yields a systematization of tools to be employed in collaborative research and knowledge production processes, to promote critical reflection on the current state of knowledge and stimulate an individual and collective commitment to contribute to a social and cultural transition towards a more sustainable lifestyle.

However, some critical issues require further investigation. One potential concern arising from this work is that a "subjective" mapping process might appear dissonant with the objectives of citizen science, particularly due to possible issues like data inaccuracy. Contrary to this, it has been observed that the mixed use of online and offline tools leads to a data plateau that represents a scientific and shared description of reality. By involving the participants' personal experiences, a new "citizen" reality is created, revealing information that would otherwise be difficult to integrate into a standard investigation.

Another critical issue could be the scalability of the activity. The mapping activity in its competitive form was also tested with local administrators in the Porto area (Portugal), who were interested in developing a more participatory approach to their sustainable mobility choices. It emerged that with appropriate adjustments, especially regarding the personas (which must represent the local social fabric), "Mani in Mappa" can adapt to any context while maintaining its transformative power. The research underscores the potential of mapping activities to facilitate collaborative research, educational advancement, and community involvement in tackling complex urban mobility challenges. Through involvement in mapping activities, participants from diverse socio-demographic backgrounds found and discussed the physical, economic, and social barriers encountered by various community segments in accessing sustainable urban mobility, including individuals with disabilities, caregivers, the elderly, and those in precarious employment. MIM can be the chance for practitioners and policymakers to grasp experiences also from underrepresented and marginalized categories in mapping activities, even though it remains an ongoing challenge. The issue of digital maps and their relationship with paper maps reflects how digital tools may be perceived as complex and daunting by those less familiar with mapping activities, risking further processes of exclusion and alienation.

In conclusion, several significant future developments regard the implementation of mapping activities as instruments for collaborative research, educational goals, and informed discourse on intricate urban mobility matters. In discussions of mobility, the bond between the city and the surrounding territory is inseparable; hence, the utilization of maps in the activity has proved pivotal. Maps effectively pinpoint the issue, rendering it tangible rather than abstract.

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Appendix A

Name: Daniela Sandrelli	**Frequented places:**			
	**House**	via dello Scalo		
	School	IIS "Manfredi-Tanari", viale Felsina 40		
	Sport	Baratti Sports Facility, Via Irnerio, 4		
	Friends Hangout	Parco 11 Settembre 2001, via Azzo Gardino		
Bio:	**Means available:**			
Daniela, 17 years old, is a student at the IIS 'Manfredi-Tanari' in Bologna. Passionate about volleyball since she was a child, she spends most of her free time at the Baratti sports facility, where she trains with passion and perseverance. In the evenings and on weekends, when she has no matches, she goes out with her group of classmates, walking along Via Indipendenza and chatting at the 11 September 2011 Park.	Personal scooter, bicycle, free bus pass			
	Mobility Agenda:			
	7-8 am	Arrival at school	6-8 p.m.	
	8 a.m. -1 p.m.		8-9 p.m.	Return from the sports facility
	1-2 p.m.	Back from school		
	2-5 p.m.	Leisure		
	5-6 p.m.	Arrival at the sports facility		

Name: Daniele Sandrelli	**Frequented places:**			
	**House**	via dello Scalo		
	School	IIS "Manfredi-Tanari", viale Felsina 40		
	Sport	Baratti Sports Facility, Via Irnerio, 4		
	Friends Hangout	Parco 11 Settembre 2001, via Azzo Gardino		
Bio:	**Means available:**			
Daniele, 17 years old, is a student at the IIS 'Manfredi-Tanari' in Bologna. Passionate about volleyball since he was a child, he spends most of her free time at the Baratti sports facility, where he trains with passion and perseverance. In the evenings and on weekends, when he has no matches, he goes out with his group of classmates, walking along Via Indipendenza and chatting at the 11 September 2011 Park.	Personal scooter, bicycle, free bus pass			
	Mobility Agenda:			
	7-8 hours	Arrival at school	6-8 p.m.	
	8 a.m. -1 p.m.		8-9 p.m.	Return from the sports facility
	1-2 p.m.	Back from school		
	2-5 p.m.	Leisure		
	5-6 p.m.	Arrival at the sports facility		

Name: Maria Ancona	**Frequented places:**			
	**House**	via Pambera, Imola		
	Work	Via Pietralata, Bologna		
	Friends Hangout	Via Mascarella		
Bio:	**Means available:**			
Maria, 26 years old, is a financial consultant at an agency located in the center of Bologna. It is her first job with a permanent contract after graduating with a degree in economics. She decided to live in Imola as the cost of rent is lower than in Bologna and commuting is cheaper in comparison. Her working hours are flexible, but she always tries to be in the office before 9 a.m. to have time around 5 p.m. to have an aperitif with friends and colleagues in his favorite bar, LOrtica in Via Mascarella, before returning home.	TPer subscription for train and bus, private car, folding bike			
	Mobility Agenda:			
	7-9 a.m.	Arrival at work		
	9 a.m. - 5 p.m.			
	5-7 p.m.	Aperitif with colleagues		
	7-9 p.m.	Homecoming		

Name: Marco Ancona	**Frequented places:**			
	**House**	via Pambera, Imola		
	Work	Via Pietralata, Bologna		
	Friends Hangout	Via Mascarella		
Bio:	**Means available:**			
Marco, 26 years old, is a financial consultant at an agency located in the center of Bologna. It is his first job with a permanent contract after graduating with a degree in economics. He decided to live in Imola as the cost of rent is lower than in Bologna and commuting is cheaper in comparison. His working hours are flexible, but he always tries to be in the office before 9 a.m. to have time around 5 p.m. to have an aperitif with friends and colleagues in his favorite bar, LOrtica in Via Mascarella, before returning home.	TPer subscription for train and bus, private car, folding bike			
	Mobility Agenda:			
	7-9 a.m.	Arrival at work		
	9 a.m. - 5 p.m.			
	5-7 p.m.	Aperitif with colleagues		
	7-9 p.m.	Homecoming		

Name: Simona Panieri	**Frequented places:**			
	**House**	via Nosadella		
	Work	Strada Maggiore, 45		
	Supermarket	Conad, via Sant'Isaia, 67		
	Friends Hangout	Mercato delle Erbe, via Ugo Bassi, 25		
Bio:	**Means available:**			
Simona, 33, works as a researcher at the University of Bologna. Since she was a child, she has suffered from an illness that forces her to use a wheelchair or crutches to get around. However, she has obtained a driver's license and her private car is equipped with all the necessary systems so that she can drive it without using her legs. She enjoys cooking and hanging out with friends.	Bus pass with discounts, private car specially adapted according to the needs of the owner.			
	Mobility Agenda:			
	8-9 a.m.	Expense	6-8 p.m.	Aperitif with friends
	9 a.m. -10 a.m.	Arrival at work	8-9 p.m.	Homecoming
	10 a.m.-5 p.m.			
	5-6 p.m.	Homecoming		

Name: Simone Panieri	**Frequented places:**			
	**House**	via Nosadella		
	Work	Strada Maggiore, 45		
	Supermarket	Conad, via Sant'Isaia, 67		
	Friends Hangout	Mercato delle Erbe, via Ugo Bassi, 25		
Bio:	**Means available:**			
Simone, 33 years old, works as a researcher at the University of Bologna. Since he was a child, he has suffered from an illness that forces him to use a wheelchair or crutches to get around. However, he has obtained a driver's license and his private car is equipped with all the necessary systems so that he can drive it without using his legs. He likes to cook and hang out with friends.	Bus pass with discounts, private car specially adapted according to the owner's needs.			
	Mobility Agenda:			
	8-9 a.m.	Expense	6-8 p.m.	Aperitif with friends
	9 a.m. -10 a.m.	Arrival at work	8-9 p.m.	Homecoming
	10 a.m.-5 p.m.			
	5-6 p.m.	Homecoming		

Name: Francesca Neri	Frequented places:			
	House	via Rialto		
	Work	Via Marconi		
	School	"Carducci" Primary School, via Dante		
	Sports Centre	Energym Gym, via Scipione Dal Ferro		
Bio:	Means available:			
Francesca, 40 years old, is an employee at an accountant's office in Bologna. A former great lover of cycling, she now juggles work and her 8-year-old daughter, Rita. She takes her to school around 8 a.m., and then goes to work. Shortening her lunch break, Francesca leaves work around 4 p.m. to pick up Rita from school and take her to the gym where she practices artistic gymnastics. She then takes the opportunity to go shopping at the nearby "Coop" supermarket and returns home to prepare dinner. Her husband, Charles, picks up their daughter before dinner.	Own car, bicycle, moped. No bus pass.			
	Mobility Agenda:			
	7.30 a.m.-8 a.m.	Accompanying daughter to school	5-6 p.m.	Expense
	8-9 a.m.	Arrival at work	6-7 p.m.	Homecoming
	9 a.m.-4 p.m.			
	4-5 p.m.	Withdrawal of daughter from school, accompaniment to the Gym		

Name: Francesco Neri	Frequented places:			
	House	via Rialto		
	Work	Via Marconi		
	School	"Carducci" Primary School, via Dante		
	Sports Centre	Energym Gym, via Scipione Dal Ferro		
Bio:	Means available:			
Francesco, 40 years old, is an employee at an accountant's office in Bologna. A former great lover of cycling, he now juggles work and his 8-year-old daughter, Rita. He takes her to school around 8 a.m., and then goes to work. The evening before dinner he picks Rita up from the gymnasium, where she practices artistic gymnastics. Although he tries to help his partner Carlotta with the housekeeping, his work schedule does not allow him to go shopping during the working week.	Own car, bicycle, moped. No bus pass.			
	Mobility Agenda:			
	7.30 a.m.-8 a.m.	Accompanying daughter to school	7-8 p.m.	Daughter withdrawal from the gym
	8-9 a.m.	Arrival at work	8-9 p.m.	Homecoming
	9 a.m.-6 p.m.			
	6-7 p.m.	Homecoming		

Name: Gabriela Romero	**Frequented places:**			
	**House**	Via Fornasini		
	Work	A) Via Farini B) Via Manin		
	School	"Casaralta" Primary, via Dante		
	Supermarket	ALDI, Via della Liberazione		
Bio:	**Means available:**			
Gabriela, 38, moved to Bologna with her husband Marcus and their first child in 2017. They left the Philippines in 2010 and lived for a few years in Rome and then in the Milan hinterland. Her husband was then hired by a company based in Zola Predosa and for this reason they decided to move to Bolognina, a working-class district of Bologna. Gabriela is a domestic worker and has to move to two or three different houses every day. Since her husband's schedule is not flexible, she also takes care of the two children and the house. The children both attend the "Casaralta" primary school and are 6 and 10 years old. She has not yet acquired a total command of the Italian language, but she is very integrated into the social fabric, especially in her neighborhood.	Public transport pass			
	Mobility Agenda:			
	7-8 hours	Arrival at Job A	4 p.m. -5 p.m.	Withdrawal of children from school
	8-11 a.m.		5 p.m. - 6 p.m.	Expense
	11 a.m.-12 p.m.	Transfer from Job A to B	6 p.m. - 7 p.m.	Returning home with the children
	12 p.m. - 4 p.m.			

Name: Gabriel Romero	**Frequented places:**			
	**House**	Via Fornasini		
	Work	Zola Predosa		
Bio:	**Means available:**			
Gabriel, 38, moved to Bologna with his wife Maria and their first son in 2017. They left the Philippines in 2010 and lived for a few years in Rome and then in the Milan hinterland. Gabriel was then hired by an industrial cleaning company based in Zola Predosa and for this reason they decided to move to Bolognina, a working-class district of Bologna. He has to go to the workplace with his own vehicle and then move all day with the company's vehicle between the various tasks. He never manages to return home at a fixed time as the traffic between Zola Predosa and central Bologna is very variable, especially during rush hour.	Own car, bicycle. No bus or train pass			
	Mobility Agenda:			
	7.30 a.m.-8 a.m.	Arrival at work		
	8 a.m.-6 p.m.			
	6-7 p.m.	Homecoming		

Name: Giovanna Grandi	Frequented places:			
	**House**	Via Musolesi		
	Commissions	Cyrenaica District		
	School	Primary School "Mattiuzzi Casali", via Azzurra		
Bio:	**Means available:**			
Giovanna, 70 years old, was born and raised in Bologna. Married to Arnaldo, she has two grandchildren whom she takes care of. The eldest grandson is 8 years old and attends elementary school, while the 3-year-old stays at home with his grandparents all day. Giovanna takes the older man to school in the morning and picks him up in the afternoon. He usually goes to run small errands in the neighborhood shops: to the fruit and vegetables, to the baker and to the seamstress. After lunch, tidy up the house and prepare dinner for everyone. He is still able to drive the car, while on the bike and on foot he feels that he is starting to get tired.	Public transport pass, bicycle, own car			
	Mobility Agenda:			
	8-9 a.m.	Accompanying 8-year-old granddaughter to school	4 p.m. -5 p.m.	Withdrawal of the grandchild from school
	9-11 a.m.	Errands	5 p.m. - 6	Homecoming
	11 a.m.-12 p.m.	Homecoming		
	12 p.m. - 4 p.m.			

Name: Giovanni Grandi	Frequented places:			
	**House**	Via Musolesi		
	Mail	Via Carlo Alberto Pizzardi, 17		
	School	Primary School "Mattiuzzi Casali", via Azzurra		
	Bar	Via Sante Vincenzi, 2/A		
Bio:	**Means available:**			
Giovanni, 70 years old, was born and raised in Bologna. Married to Teresa, he has two grandchildren whom he takes care of. The eldest grandson is 8 years old and attends elementary school, while the 3-year-old stays at home with his grandparents all day. Giovanni takes the older man to school in the morning and picks him up in the afternoon. He usually goes to the post office and runs small errands at neighborhood stores. In the afternoon, after lunch, he often goes to the café near his home where he gets together with friends to play cards and talk about sports. He often takes his youngest grandson with him. He is still able to drive the car, while on the bike and on foot he feels that he is starting to get tired.	Public transport pass, bicycle, own car			
	Mobility Agenda:			
	8-9 a.m.	Accompanying 8-year-old granddaughter to school	4 p.m. -5 p.m.	Withdrawal of the grandchild from school
	9-11 a.m.	Mail	5 p.m. - 6	Homecoming
	11 a.m.-12	Homecoming		
	2 p.m. - 3 p.m.	Arrival at the bar		

Appendix B

HANDS ON MAP!

Game rules

Objective: The objective of Hand on Map is to efficiently plan and execute the daily mobility agenda of your persona, utilizing a combination of offline and online tools to minimize points spent on transportation.

Setup

- Form groups of 5 people
- Get your game kit: 1 map, sticky notes, color pen

1. Planning Phase

- Draw points of interest on a map representing the locations relevant to your persona's daily agenda.
- Analyze the agenda to identify the order of visitation and prioritize the points of interest.
- Consider the transportation options available for each part of the journey.

2. Execution Phase

- Each group must balance the use of transport modes private cars, public transport, bicycles, and walking to minimize the total points spent:
  - Private car trips cost = 30 points
  - Public transport trips cost = 20 points
  - Bicycle/foot trips cost = 10 points
- Participants can interact with real people for firsthand experiences (offline tool) or use public transport apps and online maps for information (online tool).

3. Balancing the Variables: speed, cost, and CO2 emissions

Optimize the route to achieve the best combination of speed, cost-effectiveness, and environmental sustainability. Consider trade-offs between variables and make strategic decisions to minimize overall impact.

- Speed (km/hours)

a. Participants must prioritize creating a fast route to complete the daily agenda efficiently.
b. Evaluate the time for each transport mode and choose the fastest option whenever possible.
c. Factor in traffic conditions, speed limits, and potential delays to optimize route speed.

- Cost of the Trip (euros/km)

a. Participants must consider the financial implications of each transportation choice.
b. Calculate the total cost of private car, public transport, bicycle, and walking trips based on ticket prices, fuel expenses, and any additional fees.
c. Aim to minimize costs while still meeting the speed requirement and minimizing CO2 emissions.

- CO2 Emissions (CO2 eq g/km)

a. Participants must take into account the environmental impact of their transportation choices.
b. Estimate the CO2 emissions associated with each mode of transport based on distance traveled and vehicle type.
c. Strive to reduce CO2 emissions by prioritizing eco-friendly transportation options such as walking, cycling, and public transport wherever feasible.

4. Scoring Phase

- Calculate the total points spent by each group based on the transportation choices made during the execution phase.
- Lower scores indicate more efficient route planning and utilization of transportation options.
- The group with the lowest - but reasonable - total points spent wins the challenge.

Teresa Carlone, PhD in Sociology, assistant professor in Tenure Track (RTT) at the Department of the Arts, University of Bologna. She works on cultures and practices of participation, co-design methodologies in public policy and cultural welfare, urban commons, and collaborative governance. Always locally engaged in citizen participation processes, she has been involved in interdisciplinary research projects at the intersection of climate change impacts, citizen engagement, and social and environmental justice. In recent years, she has focused part of her academic interests on gender and feminist perspectives in the study of public space, with a particular focus on data feminism and public policy through participatory and creative methodologies.

Selene Tondini, PhD in Sociology and Social Research, develops her work at the intersection of environmental sciences and environmental sociology, with a strong focus on climate change. She has been actively involved in several EU Horizon and Life projects, where her research centers on participatory approaches to scientific inquiry, stakeholder engagement, and inclusive decision-making. Her work pays particular attention to the involvement of marginalized groups in climate action and policy processes, with the aim of fostering more democratic and socially just responses to the climate crisis.

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Photo by Ivy Steijn, Laura van der Linden, Nora Allan, and Sanne Grommers

MAIN SECTION

Value Mapping as a Pedagogical Tool to Understand Complex Urban and Landscape Challenges

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ABSTRACT

The current work explores value mapping as a pedagogical tool to gain a better understanding of the role of values in addressing sustainability challenges and their implications across scales, disciplines, and time. First, we introduce a Master-level course where students use the city as a learning ecosystem and engage with situated creative practices tackling global sustainability challenges at a local scale. Then we discuss the developed value maps. It can be concluded that the value mapping process not only proved instrumental in offering valuable insights and contextual understanding into the intricate, and sometimes conflicting, values identified, but also fostered students' critical thinking skills, allowing them to identify potential areas of discord among stakeholders. The collaborative mapping approach, guided by shared values and facilitated by design expertise, holds the potential to overcome challenges, create a thriving ecosystem, and ensure a future where ecological well-being, shared responsibility, and informed decision-making go hand in hand.

KEYWORDS
Design Expertise, Ecology, Sustainability Challenges, Urban Transformations, Value Mapping.

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1. Introduction

The contemporary landscape of urban transformation recognizes the crucial role of value-based methodologies.[1] These approaches emphasize the importance of identifying, analyzing, and integrating diverse values into decision-making processes to address complex urban and landscape challenges. As Hein and colleagues[2] highlight, value mapping serves as a powerful tool to make implicit, unconscious, and seemingly self-evident values explicit, particularly in port cities. By visualizing these values, value maps aid planners and designers in both identifying and communicating the multifaceted value generated by projects or initiatives for various stakeholders.[3,4]

At its core, the concept of "values" encompasses fundamental principles, needs, and aspirations that influence decision-making.[5] The process involves crafting a visual representation of these values, their underlying principles, and their connections to real-world contexts.[6] This methodology helps to identify and illustrate the diverse values stakeholders attribute to different sites within a city or region.[7] By overlaying these values onto a map, urban designers gain a comprehensive understanding of the diverse aspirations and perspectives that shape the city's identity.

Value maps are particularly effective in acknowledging and managing a broad spectrum of values, encompassing cultural, economic, and environmental dimensions.[8] This holistic perspective empowers urban designers to make informed decisions aligned with the needs and aspirations of the community. For instance, values might include aspirations for ecological conservation, economic growth, or the preservation of cultural heritage, each carrying distinct implications for urban design.

The advantage of framing interests as "values" lies in their ability to reveal both alignments and tensions among stakeholders. Unlike isolated

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1 Carola Hein, Ingrid Mulder and Hilde Sennema. "A Call for Value Literacy in Port City Transitions." *European Journal of Creative Practices in Cities and Landscapes* 4, no. 2 (2021): 108-129.

2 Hein, Mulder and Sennema, "A Call for Value Literacy in Port City Transitions".

3 Joshua Radinsky et al. "How Planners and Stakeholders Learn with Visualization Tools: Using Learning Sciences Methods to Examine Planning Processes." *Journal of Environmental Planning and Management* 60, no. 7 (2017): 1296-1323.

4 Antje Kunze et al. "Visualization and Decision Support Tools in Urban Planning." *Digital urban modeling and simulation* (2012): 279-298.

5 Annika Manni, Karin Sporre and Christina Ottander. "Mapping What Young Students Understand and Value Regarding Sustainable Development." *International Electronic Journal of Environmental Education* 3, no. 1 (2013): 17-35.

6 Li Peng, Xuxi Wang and Tiantian Chen. "Multifunctional Land-Use Value Mapping and Space Type Classification: a Case Study of Puge County, China." *Natural Resource Modeling* 32, no. 4 (2019): e12212.

7 Gregory Brown. "Mapping Spatial Attributes in Survey Research for Natural Resource Management: Methods and Applications." *Society and Natural Resources* 18, no. 1 (2004): 17-39.

8 Andrea Rawluk et al. "Exploring Multiple Dimensions of Values and Valuing: a Conceptual Framework for Mapping and Translating Values for Social-Ecological Research and Practice." *Sustainability Science* 14 (2019): 1187-1200.

interests, values are inherently multidimensional, capturing not only current priorities but also aspirational goals. While benefitting from collaborative mapping techniques integral to the value mapping process, designers can synthesize diverse viewpoints into actionable insights, fostering shared ownership of outcomes, and aligning design interventions with stakeholder aspirations.[9] Collaborative mapping refers both to the participatory nature of the mapping exercise and to the role of designers as facilitators who mediate between stakeholder groups. Moreover, collaborative mapping approaches can be seen as a means towards collective sensemaking.[10]

Even so, the foundation of such mapping approaches lies in the ability of value maps to illuminate the underlying conditions, values, and mindsets that shape urban landscapes.[11] Design plays a crucial role in navigating the complexities of cities, acting as a tool for problem-solving and facilitating sustainable social innovation.[12] Cities concurrently represent both challenges and opportunities for tackling contemporary societal issues, such as climate change and environmental degradation.[13] How urban spaces are utilized reflects various stakeholders' diverse interests, aspirations, and values.[14] However, pinpointing and reconciling these values within the intricate context of cities can be a demanding task.[15]

In the current work, we explore value mapping as a pedagogical tool by moving away from a tool-and-methods-prescription-approach to train upcoming designers to become more value literate in their understanding of mitigating sustainability challenges and develop competencies to deal with the corresponding implications across scales, disciplines, and time.

2. Methodology

The study was conducted within a Master-level course titled "*Design & the City*", part of an Industrial Design and Engineering curriculum, allowing students to explore the emerging role of design in the public realm. Hence, cities are complex and challenging environments, asking for innovation to deal with large-scale societal challenges. This means going beyond more

9 Hein, Mulder and Sennema, "A Call for Value Literacy in Port City Transitions".

10 Aldo de Moor et al. "Collaborative Sensemaking of Design-Enabled Urban Innovations: the Mapping DESIGNSCAPES case." In *International Workshop on Measuring Ontologies in Value Environments*, (2020): 203-226.

11 Zuzana Harmáčková et al. "Linking Multiple Values of Nature with Future Impacts: Value-Based Participatory Scenario Development for Sustainable Landscape Governance." *Sustainability Science* 17, no. 3 (2022): 849-864.

12 Eduardo Staszowski, Scott Brown, and Benjamin Winter. "Reflections on Designing for Social Innovation in the Public Sector: a Case Study in New York City." In *Design for policy*, pp. 155-166. Routledge, 2016.

13 Aidan While and Mark Whitehead. "Cities, Urbanisation and Climate Change." *Urban Studies* 50, no. 7 (2013): 1325-1331.

14 Donizete Beck and Jose Storopoli. "Cities Through the Lens of Stakeholder Theory: a Literature Review." *Cities* 118 (2021): 103377.

15 Hein, Mulder and Sennema, "A Call for Value Literacy in Port City Transitions".

conventional market- or user-driven innovation towards mission-driven innovation. Cities are also contexts where design plays a key role in solving situated problems and where its adoption can be further fostered to address sustainability challenges. Please take note that the course does not derive from an urban planner or urban design perspective but aims to contribute to the current call for new inter- and transdisciplinary methodologies to tackle values in urban transformations. Therefore, the course refers to the city as a learning ecosystem and encourages students to develop their learning journeys and action repertoire while exploring the evolving role of designers in tackling real-world sustainability challenges, developing value-driven design practices, and/or addressing urban transformations.[16]

2.1. Transdisciplinary Collaboration

More specifically, the course is developed as a transdisciplinary learning space where students can participate in a timely discussion on the rapidly changing role of design in addressing sustainable development goals by working in close collaboration with pioneering creative practices and transdisciplinary programs that aim to push the envelope of design for the common good (e.g., New European Bauhaus[17]). In earlier editions of the course, students benefited from the pioneering European H2020 project DESIGNSCAPES: Building Capacity for Design-enabled Innovation in Urban Environments at the interplay of Design, Innovation, and the City[18,19] while more recent cohorts joined forces with the ongoing New European Bauhaus demonstrator Bauhaus of Seas Sails,[20] a New European Bauhaus lighthouse reimagining sustainable living through creative, interdisciplinary approaches. The project focuses on leveraging the sea as a critical natural resource, empowering cities near water bodies to achieve climate neutrality through innovative design interventions.

2.2. Course Setup and Structure

The course has run for eleven editions (n=236); the learning objectives and final assignment were similar for all editions; however, themes, challenges, local territories, and ecosystems as well as the values unveiled varied across cohorts and student teams. Each course spans ten weeks,

16 Ingrid Mulder and Alberto Magni. "A Collaborative Learning Infrastructure to Build Capacity for Urban Transformations." *Interaction Design & Architecture(s)* 52 (2022): 119-140.

17 EU. "New European Bauhaus." Accessed December 18, 2024.

18 Ingrid Mulder and Alberto Magni. "Design and Engineering as Agents of Change: a Capabilities." In *DS 117: Proceedings of the 24th International Conference on Engineering and Product Design Education* (E&PDE 2022), London South Bank University in London, UK. 8th-9th September 2022. 2022.

19 Grazia Concilio and Ilaria Tosoni. *Innovation Capacity and the City: The Enabling Role of Design*. (Cham: Springer, 2019).

20 Nuno Jardim Nunes. "The Bauhaus of the Seas: A Manifesto for the New European Bauhaus." *Design Issues* 40, no. 2 (2024): 90-97.

with students dedicating approximately twelve hours per week to lectures, workshops, and project work. The course's primary objective is to help students understand the significance of value-driven urban transformations and to develop design capabilities for addressing these challenges. The main deliverable is a value map, which refers to a visual placeholder enabling students to convey acquired insights. The purpose of such a value map is to articulate insights explicitly, revealing the conditions, values, and mindset within the selected context.

The course setup as a dialogical learning space,[21] combines theoretical grounding with hands-on mapping exercises, fostering students' understanding of value systems and their application in urban contexts. Several inter- and transdisciplinary viewpoints are brought in by guest lectures and supported by group assignments enabling students' reflection upon values and the emerging role of design in urban transformations. In this way, students gain insights throughout the course to construct a value map that identifies the ecosystem of actors and communicates value-driven pathways across multiple dimensions. For example, by engaging in hands-on value mapping exercises using value card methodology,[22] students gained a deeper understanding of the value systems at play within the designated locations and ecosystems. Other lenses presented referred to the use of open geodata encouraging students to connect values and data[23] to develop value maps that add a value-based narrative layer to the Bauhaus of Seas geospatial platform[24]. This platform is a tool designed to analyze coastal regions such as port-city territories, aimed at supporting sustainable development. The platform integrates open-access geospatial data with sustainability, aesthetics, inclusivity data, and narratives from land-sea interactions, enabling data-driven decision-making.

2.4. Mapping Beyond the Monodisciplinary Approach

As said before, the primary course deliverable is a visual representation of stakeholder ecosystems and value creation pathways, encompassing cultural, social, ecological, and economic dimensions. These maps act as tools for communicating complex insights and facilitating dialogue

21 Mulder and Magni. "A Collaborative Learning Infrastructure to Build Capacity for Urban Transformations".

22 Irene Conversano, Livia del Conte and Ingrid Mulder. "Research Through Design for Accounting Values in Design." In *Proceedings of the fourth biennial Research through Design Conference* (RTD 2019) "Method & Critique – Frictions and Shifts in Research through Design", 19-22 March 2019 | Science Center, Delft & Het Nieuwe Instituut, Rotterdam, The Netherlands.

23 María Elena López-Reyes, Birger Larsen, Ingrid Mulder, and Rikke Magnussen. 2024. "Navigating Open Data Ecosystems: Exploring Engagement in the Use of Local Governments Open Geodata". In *Proceedings of the 17th International Conference on Theory and Practice of Electronic Governance* (ICEGOV '24). Association for Computing Machinery, New York, NY, USA, 120–129.

24 Bauhaus of the Seas Sails Geospatial Platform. Accessed December 18, 2024. https://bauhaus-seas.app/

among an ecosystem of stakeholders pushing disciplinary borders.

The current study draws from the tenth cohort of the course, which focused on the Flemish-Dutch Delta, a region at the confluence of the Rhine, Meuse, and Scheldt rivers, which is one of the Bauhaus of Seas pilots. This Delta plays a vital economic and ecological role, with cities like Rotterdam and Antwerp serving as major ports. The students were grouped into six teams of three to four students each. They were asked to select a specific challenge such as water management, renewable energy, or urban biodiversity. Students were free in their choice as long as they motivated the relevance for the Bauhaus of Seas vision and the Delta context in particular. Students employed digital tools to create their maps. Data collection methods varied across teams. Some groups engaged directly with stakeholders (e.g., policymakers, NGOs, and local communities). Others relied on secondary sources, such as policy documents, academic literature, and datasets, to inform their analysis. Although the students were guided through the value mapping process, value mapping was not presented as a step-by-step process. Instead, the ability to produce a value map justifies the students' learning journey.

The following section presents the outcomes of the value mapping exercises conducted by the student teams.

3. Value Mapping Results

All groups explored themes of beauty, sustainability, and togetherness, aligned with the principles of the Bauhaus of the Seas Sails project. Their processes culminated in the development of value maps, presented through interactive tools and layered framework that invite the user to actively explore and engage with them.

A common focus was that values were locally groundedin in the urban setting, where students addressed values derived from the use of natural resources and urban spaces. They examined local initiatives and stakeholders in Rotterdam that demonstrated attention to sustainability, biodiversity, and liveability. A recurring theme was the potential of unused urban spaces to create new value for the city. Examples such as repurposing an old heliport or city rooftops illustrate how these underutilized areas can be returned to citizens, while fostering a deeper understanding of the interconnectedness between sea life, the environment, and the city.

Another shared theme across the value maps was the relationship with water. Water-centric environments are characterised by the complexity of holding together a diverse network of stakeholder, including the non-human ones, and conflicting interests. Students highlight the challenge of achieving balance between human activities, economic growth, and environmental preservation. The Borssele Wind Park at sea, was used as a case study bto address the "green dilemma", the urgent need for

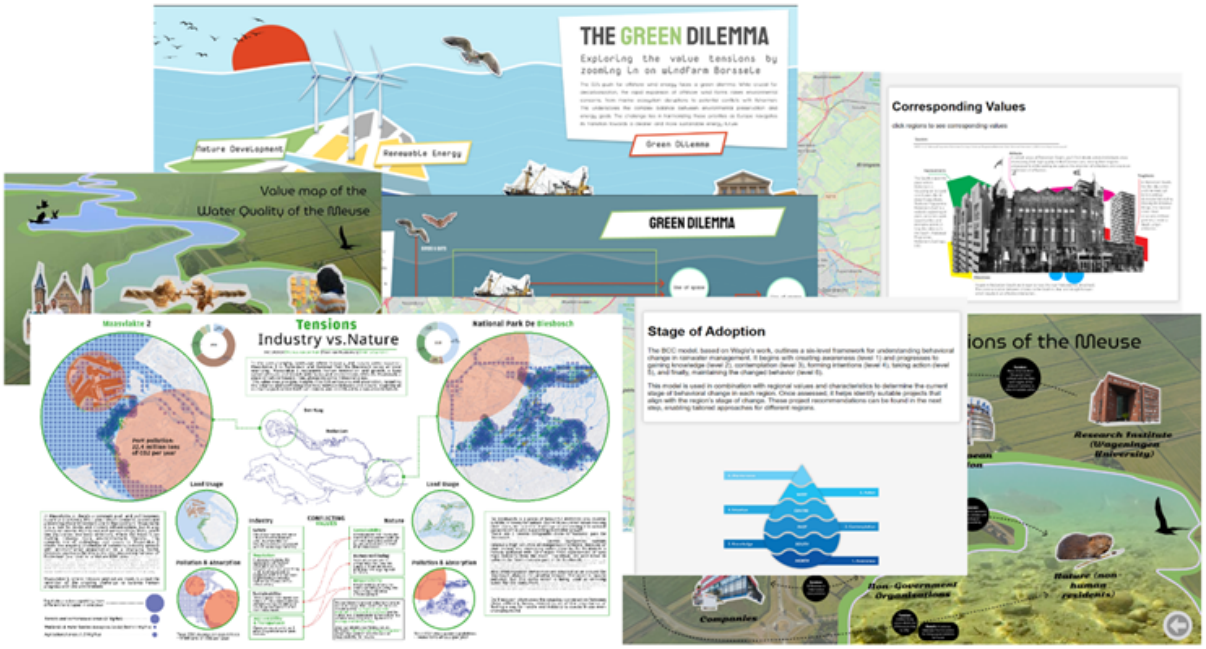

FIG. 1 A collage of resulting Value Maps. Jos van der Velden, Karel Hamburg, Maarten de Jong, Ivy Steijn, Laura van der Linden, Nora Allan, Sanne Grommers, Lori Lo, Rijk Roozenbeek, Siqi Chen, Ömer Taha Döver, Nicole Marques Morgado, Silke Rijcks, Florence Kao, Shervin Tjon, Federico Villa, Teun van Woudenberg, Andrija Stanković and Thomas van der Helm 2023.

sustainable energy solutions alongside the equally pressing goal of reconciliation with the sea, a core anchor of the Bauhaus of the Seas Sails project. This dilemma underscores the importance of sustainable development considering both ecological preservation and economic imperatives (see Section 3.2 for details).

Similarly, other groups looked into the intricacies of the river Meuse (Maas), where the need of preserving the water environment and its bio-diversity intersects with the importance of reconnecting with the local communities. Their value map encourages a deeper understanding of the complex interactions around the river, illustrating the challenges of balancing economic development, environmental protection, and societal well-being.

Figure 1 shows a collage of the value maps produced by the students, each addressing specific challenges such as water management, renewable energy, or urban biodiversity. An elaborate narrative of the students' work can be found here[25] and here.[26]

In the remainder, we elaborate upon the results from three student teams to illustrate different aspects of the value mapping process—conflict resolution, inspiring design opportunities, and stakeholder alignment. These examples demonstrate the utility of value mapping as a tool for addressing sustainability challenges and fostering collaboration among diverse stakeholders.

25 https://www.portcityfutures.nl/id5127-design-and-the-city

26 https://delftdesignlabs.org/news/reconceptualizing-the-agenda-of-design-in-port-cities-mapping-values-for-a-value-based-future-in-the-delta-region/

3.2. Navigating the 'Green Dilemma': Stakeholder Values in the Borssele Wind Park

The Borssele Wind Park[27] serves as a compelling example of conflict resolution within the context of renewable energy transitions. Located in the North Sea, this offshore wind farm faces the "Green Dilemma,"[28] balancing environmental conservation, economic interests, and societal needs. The value map created for this case highlights the intricate network of stakeholders—including energy providers, policymakers, conservation groups, and local communities—and visualizes their competing priorities.

Key values identified include: 1) Economic growth, driven by renewable energy production. 2) Ecological preservation, emphasizing marine biodiversity and sustainable practices. 3) Community engagement, focusing on equitable resource use and local benefits.

The value map revealed tensions between economic objectives and ecological concerns, such as the potential disruption of marine ecosystems by wind farm operations. By mapping these tensions, the process facilitated a nuanced understanding of stakeholder priorities and identified opportunities for compromise, such as incorporating seaweed cultivation within the wind park. This approach not only mitigates environmental impact but also generates additional value through innovative mariculture initiatives. The Borssele case underscores the role of value mapping in resolving conflicts by fostering informed dialogue and collaborative decision-making.

The value map's significance lies in its ability to visualize the interests, alignments, and tensions in values among diverse stakeholder groups within the Borssele Wind Park. It offers a visual representation of the intricate dynamics associated with the wind farm, emphasizing that it is not a universally applicable solution. The map acts as a visual synthesis of the complexities inherent to the "Green Dilemma," utilizing the wind park as its contextual framework (Fig. 2). Selecting the "green dilemma box" within the map reveals the various stakeholders involved, along with their associated values and the potential tensions arising between them (Fig. 3). Further details can be accessed by hovering over the different elements (Fig. 4).

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27 Golroodbari et al. "Pooling the Cable: a Techno-Economic Feasibility Study of Integrating Offshore Floating Photovoltaic Solar Technology Within an Offshore Wind Park." *Solar Energy* 219 (2021): 65-74.

28 Tanja Straka, Marcus Fritze and Christian C. Voigt. "The Human Dimensions of a Green–Green-Dilemma: Lessons Learned from the Wind Energy—Wildlife Conflict in Germany." *Energy Reports* 6 (2020): 1768-1777.

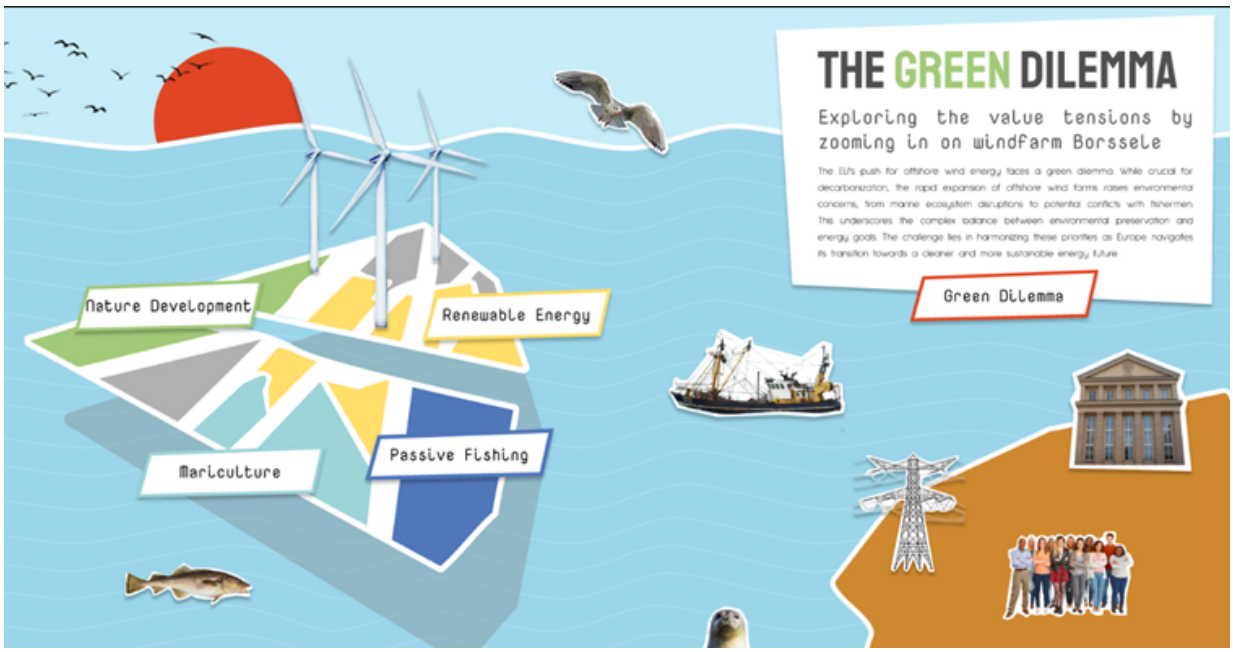

FIG. 2 The green dilemma value map. Ivy Steijn, Laura van der Linden, Nora Allan, and Sanne Grommers 2023.

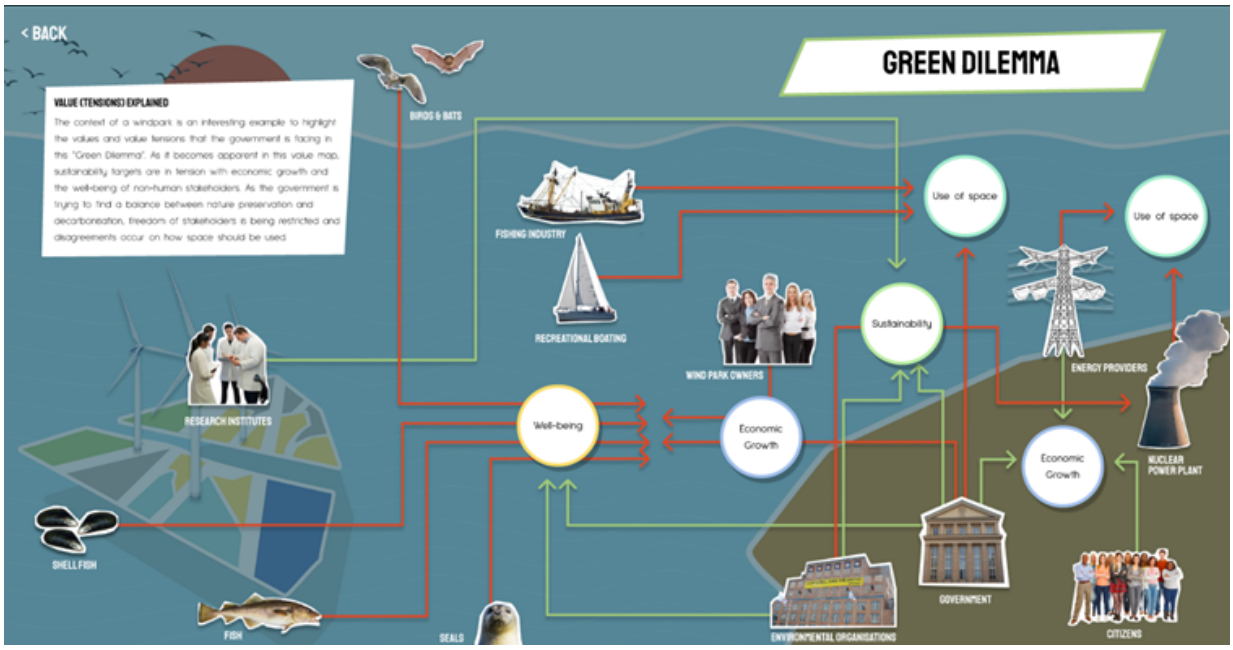

FIG. 3 Stakeholder's values and tensions. Ivy Steijn, Laura van der Linden, Nora Allan, and Sanne Grommers 2023.

Returning to the initial map view (Fig. 2), we observe the wind farm segmented into four distinct categories: Nature Development, Renewable Energy, Mariculture, and Passive Fishing. Clicking on each section reveals a corresponding detailed description (Fig. 5), providing a deeper understanding of the activities and interests within that specific domain.

Further exploration through the "values of this area" section triggers another interactive value map, focusing exclusively on stakeholders associated with the chosen category (Fig. 6). Employing the same intuitive

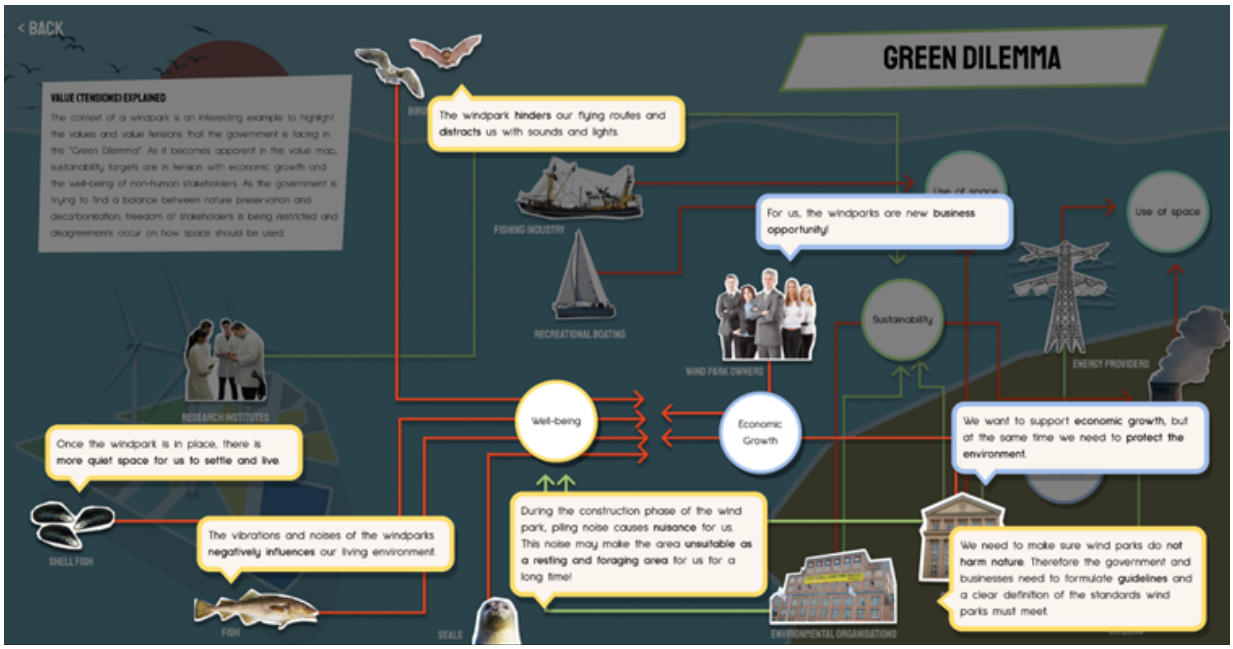

FIG. 4 Additional information. Ivy Steijn, Laura van der Linden, Nora Allan, and Sanne Grommers 2023.

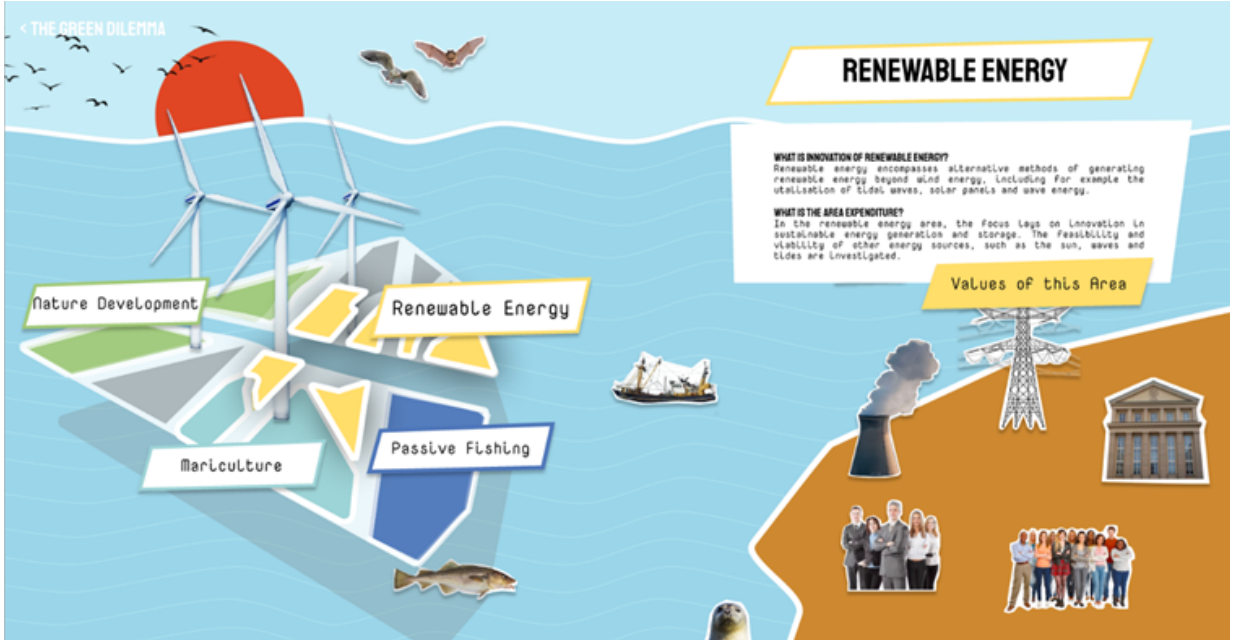

FIG. 5 Renewable energy in the area. Ivy Steijn, Laura van der Linden, Nora Allan, and Sanne Grommers 2023.

hovering mechanism, users can access further explanations regarding the values held by diverse stakeholders and the potential tensions arising between them. This layered approach facilitates a nuanced comprehension of the complex interplay between competing interests and shared values within the wind farm ecosystem.

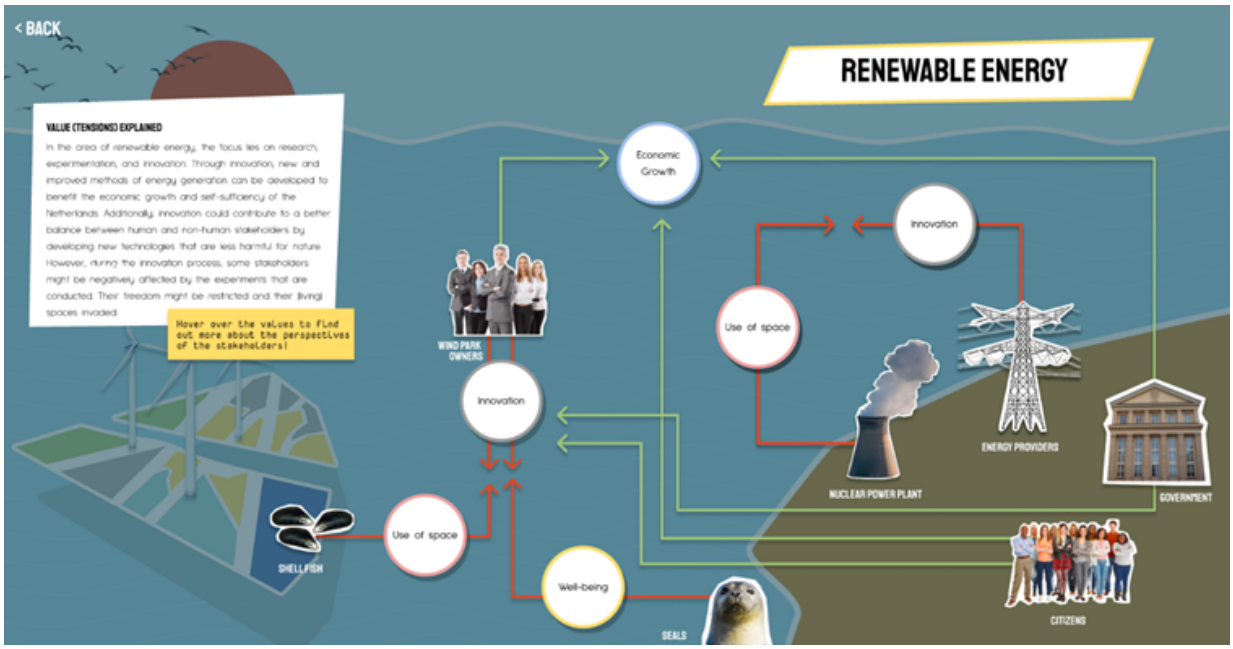

FIG. 6 Additional information about renewable energy in the area. Ivy Steijn, Laura van der Linden, Nora Allan, and Sanne Grommers 2023.

The Borssele case study offers a compelling example within the global quest for renewable energy solutions. In the face of the "Green Dilemma," the value map serves as a guiding framework, facilitating the navigation towards an optimal balance that accommodates the diverse interests of stakeholders. It ensures that the voices of both human and non-human entities are represented and heard. Furthermore, a comprehensive understanding of stakeholder values and their interactions is critical for effectively addressing the "Green Dilemma" and constructing a more equitable future. The Borssele wind park value map emerges as a valuable resource in tackling this complex issue, illuminating the intricate dynamics that shape energy transitions worldwide.

3.3. Stakeholder Alignment in the Blue Economy: The Alga.farm Project

The Alga.farm project in Rotterdam highlights value mapping's role in fostering stakeholder alignment within a circular economy framework. This initiative repurposes the former Tropicana swimming pool into a facility for cultivating spirulina, demonstrating how abandoned urban spaces can be revitalized through innovative ecological practices. The value map categorized the project's impact into three scales: 1) Local (Drop-Pilot): Enhancing community engagement and environmental awareness. 2) Citywide (Ripple-City): Promoting collaborations between businesses and local governments. 3) Global (Wave-Wider): Advancing sustainable production practices and knowledge sharing. The "Drop, Ripple, Wave" metaphor illustrates how a single action or process can grow and influence outcomes over time, much like a drop of water creates ripples that expand

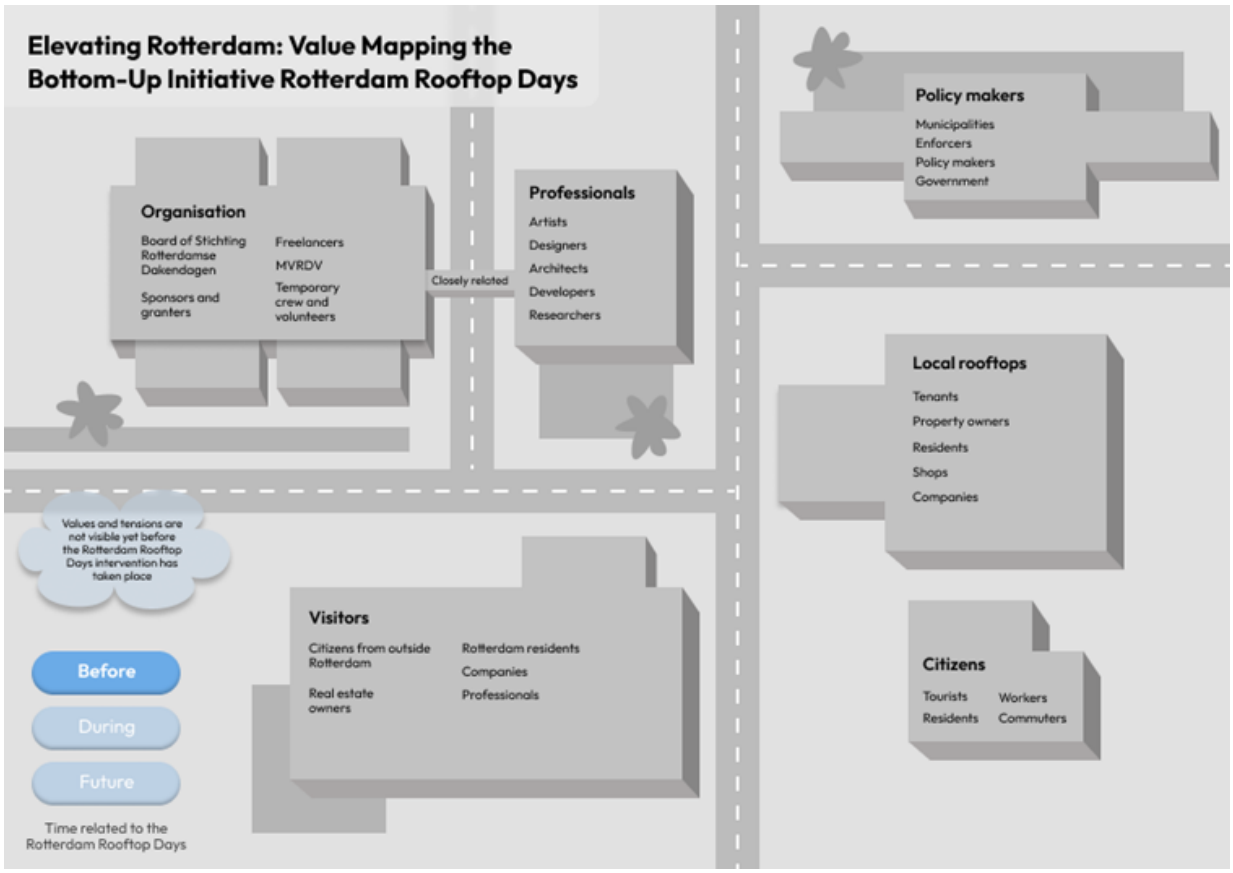

FIG. 7 Period before the initiative Rotterdam Rooftop Days. Ömer Taha Döver, Nicole Marques Morgado, and Silke Rijcks 2023.

into larger waves. This concept is applied in the Bauhaus of the Seas Sails[29] project to describe the phases of development and the broader impact of its initiatives.

Key values visualized include environmental sustainability, economic innovation, and social responsibility. For instance, the project's focus on algae cultivation not only supports renewable materials and food production but also fosters connections between stakeholders, such as companies, citizens, and research institutions. The map revealed opportunities for expanding the initiative's reach, such as integrating algae-based technologies into building materials or urban energy systems.

By aligning diverse stakeholder interests, the Alga.farm value map underscores the importance of collaboration in achieving sustainability goals. This case illustrates how value mapping can bridge gaps between ecological, economic, and social priorities, driving collective action toward a blue economy.

3.4. Reimagining Urban Spaces: Rotterdam Rooftop Days

The Rotterdam Rooftop Days is an annual event showcasing the potential of underutilized urban rooftops to address sustainability and livability

29 Bauhaus of the Seas Sails. Accessed December 18, 2024. https://bauhaus-seas.eu/

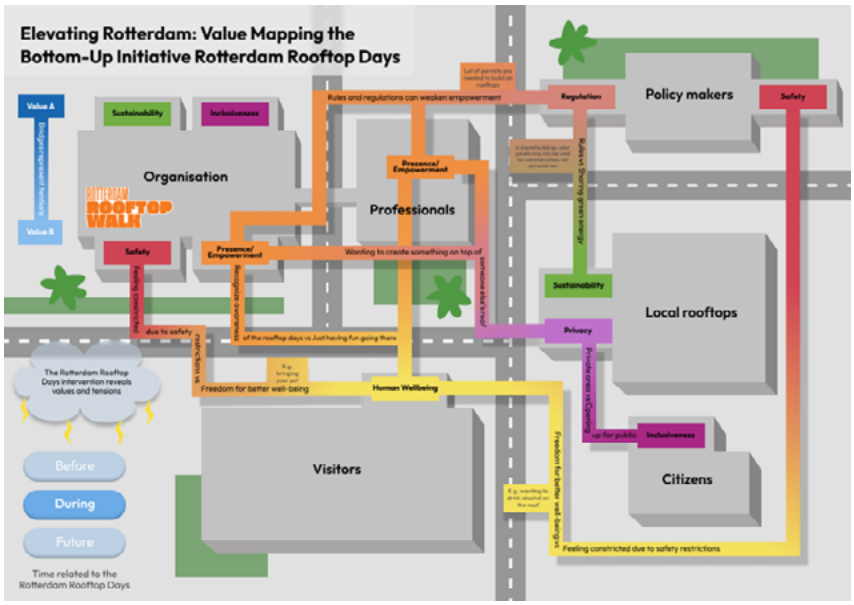

FIG. 8 Period during the initiative Rotterdam Rooftop Days. Ömer Taha Döver, Nicole Marques Morgado, and Silke Rijcks 2023.

challenges. The value map for this case exemplifies how value mapping can inspire innovative design opportunities. Specifically, it explores three temporal phases—before, during, and future—to illustrate the evolution of stakeholder engagement and value creation.During the event, rooftops were transformed into spaces that foster biodiversity, renewable energy, and community interaction. The value map identified key guiding principles: 1) Sustainability, promoting green roofs and energy-efficient installations. 2) Inclusivity, ensuring accessibility and diverse community participation. 3) Empowerment, encouraging residents to envision new uses for urban spaces.

For example, the map revealed trade-offs between sustainability and inclusivity, such as balancing green infrastructure development with the need for equitable access. By visualizing these dynamics, the value map enabled stakeholders—from policymakers to local residents—to align their efforts toward a shared vision. The initiative demonstrates how value mapping can inspire actionable design solutions that address urban challenges while fostering collaboration and creativity.

Figure 7 depicts the "before" phase of the value map, presenting a spectrum of stakeholders, from policymakers to residents, who influence the city's dynamics but lack cohesive collaboration. The roofs themselves are shown as underutilized and vacant spaces, symbolizing unrealized potential. The grayscale rendering emphasizes the stark reality of this underutilized urban resource. The "during" phase of the Rotterdam Rooftop Days value map (Fig. 8) delves into the transformative influence of key values on stakeholders and the urban environment. It highlights seven critical values: Sustainability, Inclusivity, Presence/Empowerment, Safety, Human Well-being, Privacy, and Regulation.

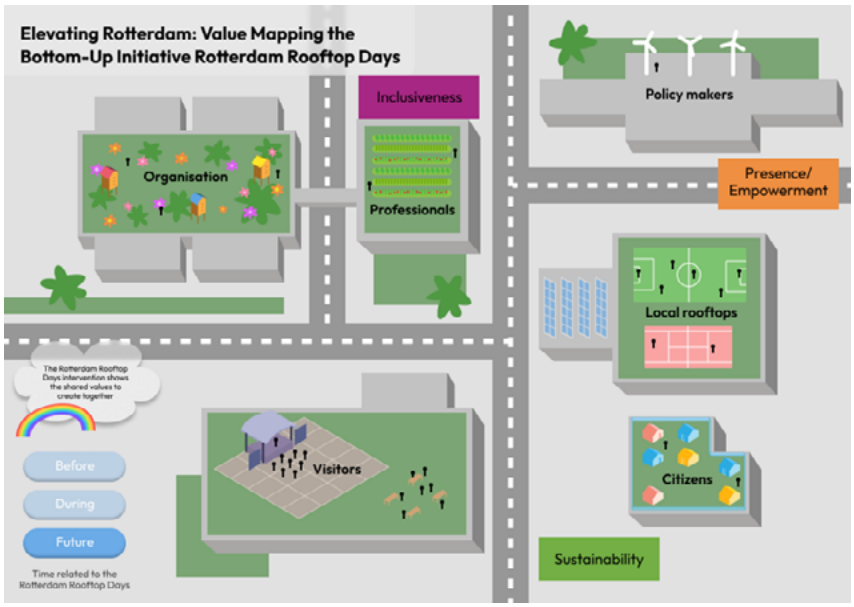

FIG. 9 Period after the initiative Rotterdam Rooftop Days. Ömer Taha Döver, Nicole Marques Morgado, and Silke Rijcks 2023.

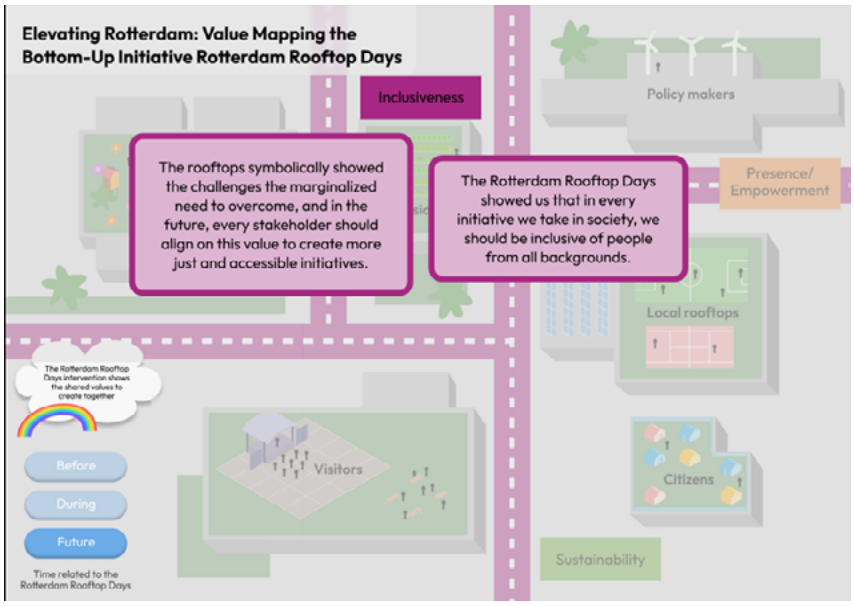

FIG. 10 Example of additional information. Ömer Taha Döver, Nicole Marques Morgado, and Silke Rijcks 2023.

The map utilizes a vibrant color scheme to visually represent the inherent trade-offs and conflicts associated with value-driven transitions. This reflects the dynamic nature of the initiative, where competing priorities and concerns must be negotiated to achieve successful implementation. For instance, the value of "Sustainability" might conflict with "Inclusivity" if accessibility considerations necessitate additional construction, potentially impacting environmental footprint. Similarly, "Presence/ Empowerment" through resident participation may require balancing it with "Privacy" concerns regarding rooftop activities.

The "future" phase of the Rotterdam Rooftop Days value map (Fig. 9)

embodies a collaborative vision of a more sustainable, inclusive, and empowered urban environment. This aspirational future rests upon three core values: Sustainability, Inclusiveness, and Presence/Power. These values serve as guiding principles for stakeholders as they strive to transform the city's rooftop landscape. Clicking on each value within the map reveals further details and explanations (Fig. 10).

Inspired by the Rotterdam Rooftop Days initiative, the "future" phase emphasizes the critical role of aligning stakeholders with these core values. This alignment serves as a catalyst for enduring and positive transformations within port cities. By fostering collaboration and a shared understanding of these values, stakeholders can move beyond individual interests and work towards a collective vision for a more vibrant and equitable urban future. This collaborative approach, informed by the insights gleaned from the "during" phase, allows for the identification of potential synergies and the mitigation of potential conflicts between competing values.

The presented analysis delves into the multifaceted role of design within mission-driven innovation, examining both the professional practices of expert designers within the Rotterdam Rooftop Days organization and the diffuse design skills and mindsets exhibited by other collaborators, including visitors. By exploring this spectrum of design capabilities, we gain insight into the various layers, classifications, and manifestations that design can assume in the realm of urban innovation. Stakeholder mappings further illuminate these aspects, emphasizing the importance of diverse collaborative design approaches such as co-design and participatory design.

4. Discussion

The student-created value maps of the Flemish-Dutch Delta offer insights into the complex challenges of urban sustainability as well as the opportunities for interventions driven by shared values. These maps underscore three key contributions of our introduced value mapping methodology while also pointing to its broader applications, limitations, and future directions.

A primary contribution of value mapping lies in its ability to bridge diverse stakeholder values with actionable design opportunities. By visualizing cultural, social, and ecological values within a specific context, the maps highlight alignments, conflicts, and areas for intervention. For instance, the Borssele Wind Park case revealed tensions between economic development and environmental conservation. By mapping these competing values, the exercise provided a clearer understanding of the trade-offs and helped inform more balanced design solutions.

Connecting stakeholder values through value-mapping has the potential to inform decision-makers and practitioners by helping them to prioritize

interventions that maximize benefits while minimizing trade-offs, as exemplified by the Rotterdam Rooftop Days initiative, which shows how underutilized urban spaces can be repurposed to tackle sustainability challenges. Furthermore, integrating data-driven insights with value mapping can enhance collaborative decision-making.

This approach is aligned with findings from the open data ecosystem literature[30], which emphasizes the importance of collaboration through transparency and accountability. Practitioners can leverage data-driven insights within value maps to foster a shared understanding among stakeholders and improve access to critical urban data. Meanwhile, decision-makers can use these insights to structure their arguments and support evidence-based policy formulation, ensuring that urban planning decisions are transparent and grounded in a comprehensive understanding of stakeholder ecosystems

Another essential strength of value mapping is its capacity to recognize and accommodate regional diversity. The Flemish-Dutch Delta, with its varied landscapes and unique social-ecological dynamics, requires location-specific approaches. This diversity is evident in cases like the Maasvlakte, which illustrated the tension between industrial activity and ecological preservation, and the Rotterdam rainwater initiative, which highlighted the importance of localized, community-focused interventions. By visualizing the specific needs and challenges of each region, value mapping enables a nuanced approach to urban design and planning.

The ability to facilitate context-specific solutions is another significant strength of value mapping. The Borssele Wind Park case, for instance, demonstrates how this approach reveals the intricacies of local contexts, which can help practitioners tailor their interventions to address specific regional or cultural challenges effectively. Policymakers can leverage value maps to develop regulations accounting for the unique social, ecological, and economic dynamics within different areas, as illustrated in the Maasvlakte and Biesbosch case studies.

Perhaps most significantly, value mapping inspires forward-looking, aspirational futures by aligning shared values with innovative possibilities. For example, the Rotterdam Rooftop Days value map demonstrated how underutilized urban spaces like rooftops could be reimagined to enhance sustainability and well-being. By projecting future opportunities, value mapping fosters long-term planning and innovation, making it a powerful tool for envisioning transformative urban interventions. Additionally,

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30 van Loenen, Bastiaan, et al. "Towards value-creating and sustainable open data ecosystems: A comparative case study and a research agenda." *JeDEM eJournal of eDemocracy and Open Government* 13. no.2 (2021): 1-27. María Elena López-Reyes, Birger Larsen, Ingrid Mulder, and Rikke Magnussen. 2024.
"Navigating Open Data Ecosystems: Exploring Engagement in the Use of Local Governments Open Geodata". In *Proceedings of the 17th International Conference on Theory and Practice of Electronic Governance* (ICEGOV '24). Association for Computing Machinery, New York, NY, USA, 120–129.

driving innovation through interdisciplinary collaboration helps align the goals of various stakeholders. This methodology encourages cooperation among practitioners from different fields, such as urban designers, ecologists, economists, and social scientists. This interdisciplinary approach has the potential to generate innovative solutions that utilize diverse expertise, as seen in initiatives like Alga.farm.

The current demonstrations of value mapping extend across a range of urban design contexts. It can guide ecological interventions by emphasizing the interconnectedness of human and natural systems, as seen in the prioritization of green infrastructure in port cities like Rotterdam. Additionally, value mapping promotes shared responsibility among stakeholders by visualizing collective challenges and opportunities, a feature particularly relevant in multi-stakeholder projects like water management in the Meuse. Furthermore, the process enhances transparency by making explicit the values and trade-offs at play, as demonstrated in the Borssele Wind Park case, where it facilitated dialogue by clarifying the tensions between renewable energy objectives and community concerns.

In summary, value mapping not only helps to identify and bridge stakeholder values—it also empowers practitioners and policymakers to create more sustainable urban environments through informed decision-making, context-specific solutions, and collaborative innovation. However, despite its potential, value mapping is not without challenges. The process of defining and mapping values may introduce subjectivity, particularly when certain stakeholders dominate the narrative or when designers unintentionally impose their interpretations. Reconciling competing values also requires careful facilitation to avoid reinforcing existing power imbalances.[31] Moreover, creating interactive and accessible maps often necessitates advanced digital tools and expertise, which can pose significant barriers in resource-constrained settings.

To address these limitations and enhance the effectiveness of value mapping, future efforts should prioritize participatory approaches that actively involve stakeholders in the mapping process. This inclusion fosters trust, improves the accuracy of the maps, and ensures that diverse perspectives are represented. Additionally, innovations in software and data visualization techniques can make the process more intuitive and accessible, expanding its usability. Finally, embedding value mapping within policy frameworks and urban planning practices can ensure its long-term relevance as a tool for strategic decision-making.

By addressing these challenges and building on its strengths, the proposed value mapping methodology has the potential to transform urban design and planning. It provides urban designers and planners with a

31 Fabiana Tomasini Giannini and Ingrid Mulder. "Towards a Power-Balanced Participatory Design Process." In *Proceedings of the Participatory Design Conference* 2022-Volume 2, pp. 111-117. 2022.

methodology to foster inclusivity, sustainability, and value-driven transformation, ensuring that future urban interventions align with the aspirations and needs of diverse communities.

5. Conclusion

The elaborate value mapping process has proven to be an effective pedagogical and methodological tool for gaining value literacy and understanding of complex urban and landscape challenges. Conducted within the Flemish-Dutch Delta, the student-generated value maps underscored the critical importance of understanding and visualizing diverse stakeholder values to foster sustainable and inclusive urban development. By illuminating regional complexities and stakeholder interconnections, the maps offered valuable insights into aligning design interventions with local needs and aspirations.

Beyond its use in educational settings, value mapping demonstrates significant practical applications for urban design and planning. By bridging the gap between stakeholder values and design opportunities, this approach supports informed decision-making and fosters collaborative solutions. It promotes ecological well-being, shared responsibility, and transparency, aligning with the broader goals of sustainability and inclusivity in urban transformation.

However, while the method shows promise, it is not without limitations. Reconciling competing stakeholder values requires careful facilitation to avoid bias and subjectivity. Moreover, the technical demands of creating interactive and accessible value maps may pose challenges, particularly in contexts with limited resources or expertise. These issues highlight the need for continuous refinement to improve the applicability of value mapping across diverse contexts. To address these challenges and maximize its potential, future efforts should prioritize the integration of participatory methods that actively engage stakeholders in the mapping process. Such an approach would ensure greater accuracy and relevance while fostering a sense of shared ownership among participants. Furthermore, advancements in digital tools and data visualization techniques could enhance the accessibility and impact of value maps, making them more effective for communication and collaboration.

In conclusion, our value mapping methodology provides urban designers and planners with the means to act as facilitators and mediators, guiding collaborative transformations rooted in shared values. By addressing critical urban challenges through this approach, value mapping holds the potential to create thriving ecosystems and inclusive urban futures. It exemplifies how design expertise can contribute to advancing sustainability, inclusivity, and resilience in response to contemporary societal challenges.

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PRACTICES

Mapping Scenarios for the Netherlands in 2050

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ABSTRACT

Maps are powerful tools to communicate and discuss the content of spatial scenarios with policymakers, planners and the public. Scenario projects become more accessible when visually presented by maps, thereby fostering greater understanding of the spatial features and differences. This, in turn, leads to more inclusive and well-informed discussions about possible futures and spatial choices. In 2023, PBL Netherlands Environmental Assessment Agency published a research study including four scenario maps showing what the Netherlands could look like in 2050. This article describes how the scenarios and associated maps were developed and reflects on the multiple functions the maps had in different phases of the scenario study.

KEYWORDS

Mapping; Spatial Planning; Scenario Method; Research by Design; Multidisciplinary Approach

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Introduction

In March 2023, PBL Netherlands Environmental Assessment Agency published the scenario study Ruimtelijke Verkenning 2023 (Spatial Outlook 2023), containing four spatial scenarios for the Netherlands in 2050.[1] In this multidisciplinary scenario study, a combination of storylines, maps and other visualizations was elaborated on to explore and describe what the country could look like following a transition towards a climate-neutral and circular society (Fig. 1).

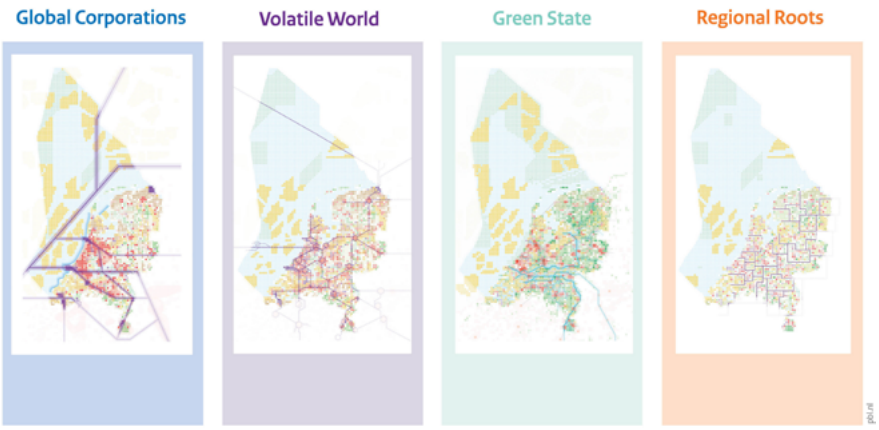

FIG. 1 Conceptual maps of the four spatial scenarios of the Spatial Outlook 2023, source: PBL and PosadMaxwan

The four scenarios presented in the Spatial Outlook 2023 have enabled policymakers and planners to understand, explore and discuss advantages, disadvantages and possible conflicts of spatial choices.[2] Maps played an important role during the scenario development process and were crucial in the presentation of the four scenarios upon publication. Maps, with their ability to convey spatial relationships and patterns,[3] are powerful tools to help develop spatial scenarios and to help communicate and discuss the content of the given scenarios with policymakers, planners and the public.[4] This article describes how the scenarios and associated scenario maps were developed by applying a multidisciplinary and participatory approach and by combining geospatial modelling

1 PBL – Netherlands Environmental Assessment Agency. Ruimtelijke Verkenning 2023. (The Hague: PBL, 2023).

2 Kersten Nabielek, David Hamers and Rienk Kuiper "Spatial Scenarios as a Tool For Future-Proof Spatial Planning in the Netherlands" (Proceedings of the AESOP Annual Congress 2024): 2320-2333. https://www.pbl.nl/system/files/document/2024-07/pbl-2024-spatial-scenarios-as-a-tool-for-future-proof-spatial-planning-in-the-netherlands-5593.pdf

3 Carola Hein and Yvonne van Mil. "Towards a Comparative Spatial Analysis for Port City Regions Based on Historical Geo-spatial Mapping," PORTUSplus. 8 (2019), https://portusplus.org/index.php/pp/article/view/189.

4 Christian Salewski. Dutch New Worlds, Scenarios in Physical Planning and Design in the Netherlands, 1970-2000. (Rotterdam: 010 publishers, 2012).

techniques with creative methods of research by design.[5] Moreover, this article reflects on the multiple functions the maps had during the research phase, in the publication phase and in the post-publication, dissemination phase.

Spatial Challenges in the Netherlands

Before describing the development of scenarios and the maps in more detail, it is important to provide more insight into the Dutch situation and context regarding spatial planning. The Netherlands faces major challenges in the field of the living environment, such as building houses and creating space for industry, mobility and nature.[6] Additionally, there is the ambition to realize several transitions (fundamental system changes) towards a more sustainable economy and society. This includes making the energy supply climate-neutral, making the economy circular and adapting cities to climate change. Meeting the environmental challenges and realizing the sustainability transitions will require major spatial interventions, such as the construction of wind and solar parks and the redevelopment of rural and urban areas.

Scenarios as a Tool in Policymaking Processes

Although the scenarios of the Spatial Outlook 2023 were created to support national policies, they are also useful for provincial, regional and municipal policies. Dutch provinces and municipalities are in the process of making or updating their spatial and environmental strategies. In all these trajectories, scenarios can help policymakers to develop more coherent and future-proof spatial and environmental policies.

However, applying scenarios in a policy context can be challenging and most policymakers are not used to working with scenarios. Therefore, PBL offered support to organize workshops to put the scenario method into practice after the publication of the scenario study. Between Spring 2023 until the end of 2024, the PBL project team organized more than 200 activities to raise awareness of the scenarios involved and to promote the use of the scenario study in general. These activities were named 'Spatial Outlook on Tour' and included giving presentations, organizing workshops and participating in conferences and exhibitions.[7]

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5 PBL. Vier scenario's voor de inrichting van Nederland in 2050. Ruimtelijke Verkenning 2023, Achtergrondrapport. (The Hague: PBL, 2023).

6 PBL – Netherlands Environmental Assessment Agency. Grote opgaven in een beperkte ruimte. (The Hague: PBL, 2021).

7 Ed Dammers, Rienk Kuiper, Kersten Nabielek and Leo Pols, Scenario's voor beleidsvisies: een handreiking. (The Hague: PBL, 2025).

About the Making of the Scenarios

The Spatial Outlook 2023 builds on societal values developed in PBL's Rehearsing the Future report.[8] Whereas the report Rehearsing the Future did not include maps of possible future spatial land use, the ambition of the Spatial Outlook 2023 was to create four integral maps of what land use in the Netherlands could look like in 2050. Four scenarios were developed, reflecting diverse societal preferences, and focused on five key themes **(Fig. 2)** aligned with the Dutch national spatial and environmental strategy (NOVI).[9] Created over two years (2021–2023) by PBL and several advisory research partners, the scenarios emphasize the transition to a circular, climate-neutral society by 2050 and are based on demographic projections and GIS modeling.

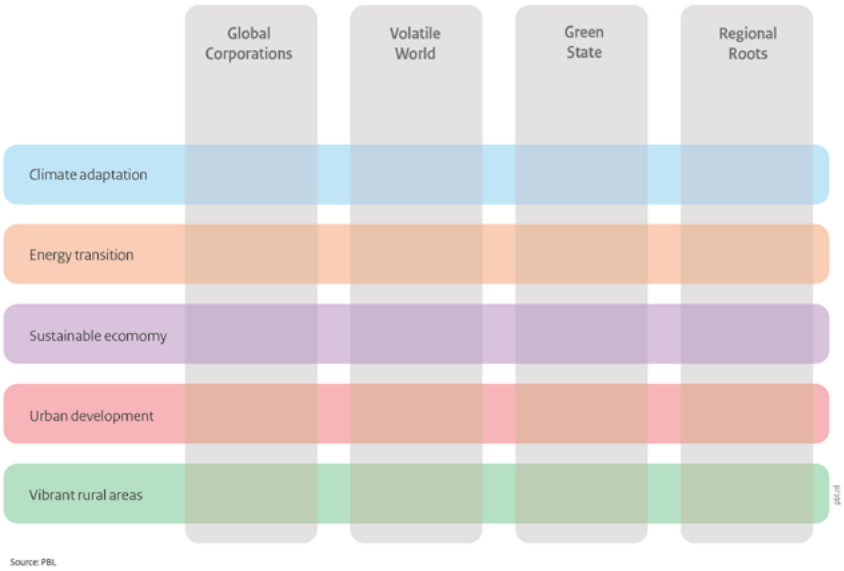

FIG. 2 Four scenarios and five main themes of the Spatial Outlook 2023, source: PBL

An interactive process with experts and stakeholders, including policymakers, shaped the scenario narratives and maps. Workshops with policymakers and stakeholders helped refine the maps, later published in a book and online with an interactive maps viewer.[10] While the maps are not prescriptive blueprints, they inspire policymakers and adapt to various spatial contexts **(Fig. 3)**. After the publication, PBL conducted lectures and workshops, using the maps to clarify planning concepts, explore scenarios, and promote understanding of spatial patterns.

8 PBL, Rehearsing the Future. (The Hague: PBL, 2020).

9 BZK, Nationale Omgevingsvisie. (The Hague: PBL, 2020).

10 https://themasites.pbl.nl/scenarios-inrichting-nl2050

FIG. 3 Translating national scenario maps of the Spatial Outlook 2023 to regional scenario maps in a workshop with stakeholders and spatial designers, source: PBL

About the Making of the Maps

As mentioned earlier in this article, the process of mapping and the final maps themselves played an important role in the different phases of the scenario study. Spatial scenarios can be visualized in various ways: through maps, but also through collages, artist impressions, photo editing and the like. The visualizations are especially suitable for analyzing and depicting the future use of space according to the scenarios. In addition, the visualizations help to make the content of the scenarios visible in concrete terms, which helps to communicate with the users of the scenarios. For instance, well-chosen and appropriate visual language can make the essence of the scenarios clear even at a glance. Furthermore, a vivid visualization can increase the imaginative power of the scenarios, which equally enhances communication.[11]

The design process of making the maps for the four scenarios started with the ambition to create integral and legible maps with a certain level of detail for the Netherlands in 2050. The challenge while making the maps was to find a good balance between making the maps easy to understand for national policymakers and the general public and, at the same time, making the maps detailed enough to be useful for regional and local policymakers and planners. As spatial planning in the Netherlands has been decentralized from the national government to provinces and municipalities in the past decades, spatial planning decisions are mostly taken a decentral level.[12]

11 Christian Salewski. Dutch New Worlds, Scenarios in Physical Planning and Design in the Netherlands, 1970-2000. (Rotterdam: 010 publishers, 2012).

12 Kersten Nabielek, David Hamers and Rienk Kuiper. "Spatial planning in times of uncertainty," Informationen zur Raumplanung 4/2022 (Bonn: BBSR, March 2023): 134-145.

Netherlands Now as Design (NNAO 1987) | The Netherlands 2030 (RPD 1997) | The Netherlands in the Future (MNP 2007) | Spatial Outlook 2023 (PBL 2023)

FIG. 4 Four national spatial scenario studies from 1987 to 2023, source: PBL

A Dutch Tradition of Mapping Scenarios

Since 1987, a national scenario study with spatial maps has been published more or less every ten years in the Netherlands **(Fig. 4)**. With the publication of Spatial Outlook 2023, PBL participated in this tradition.

The study The Netherlands Now as Design (NNAO)[13] was the first design-based scenario study to explore the spatial development of the country in a comprehensive way. The scenario study succeeded in developing four desirable scenarios based on underlying values, thereby enabling the possibility of discussing a desirable future rather than propagating a specific future. While the maps in NNAO (1987) and The Netherlands 2030 (1997)[14] were manually drawn in explorative and artistic manners, the maps in The Netherlands in the Future (2007)[15] were the result of precise GIS-based land use modelling. Whereas the maps of NNAO were criticized for being too artistic and not always readable,[16] the maps of The Netherlands in the Future were criticized for being too technical and overly precise, making them look like plans rather than exploratory scenarios. Reflecting on the methods of mapping in earlier scenario studies, the project team of the Spatial Outlook 2023 therefore decided to develop detailed maps based on GIS land use modelling and to complement and improve the readability of the maps with creative and participatory methods of research and design.

13 Stichting Nederland Nu als Ontwerp. Nieuw Nederland: ontwerp van ontwerp – Nieuw Nederland 2050. (The Hague: Staatsuitgeverij, 1987).

14 RPD. Nederland 2030 – Perspectieven. (The Hague: VROM, 1997).

15 MNP. Netherlands in the Future. Second Sustainability Outlook, the physical living environment in the Netherlands. (Bilthoven: MNP, 2007).

16 Christian Salewski. Dutch New Worlds, Scenarios in Physical Planning and Design in the Netherlands, 1970-2000. (Rotterdam: 010 publishers, 2012).

Sketch Maps, Detailed Maps and Conceptual Maps

At an early stage of the research, sketch maps for the four scenarios were drawn with coloured pencils on top of printed base maps of the country. These initial rough sketch maps helped to communicate basic spatial developments and features related to the storylines of the scenarios in meetings with the project team and in the national workshops with stakeholders. After the initial phase with the sketch maps, detailed maps were generated based on land use modelling by applying the models Land Use Scanner (PBL) and the Model for Nature Policy (WUR). Finally, the detailed maps derived from the GIS modelling were enriched, edited and graphically stylized by a team of urban designers to create comprehensive and readable maps.

The central ambition for the scenario maps was to give general input for the national spatial and environmental planning strategy as well as more detailed map information for local and regional planning strategies. Therefore, the decision was made to create two types of maps for the publication: detailed maps and conceptual maps. After the detailed maps were produced by a combination of GIS land use modelling and research by design methods, the designers made a strongly simplified and stylized version of the maps (Fig. 1). These conceptual maps have a more iconic character and only show the most important spatial elements. That makes them easier to read and more accessible for both policymakers and the general public.

GIS-Based Land Use Modelling

The Land Use Scanner is a GIS-based spatial allocation model containing an extensive database of maps of existing land use in Nederland (infrastructure, buildings and other land use), ownership and spatial and environmental law provisions.[17] From the database, the local availability and suitability of specific locations for possible transformations for each scenario were derived, for example, from industrial sites or agricultural land to new residential neighborhoods (Fig. 5). Based on the scenario and model logic, the Land Use Scanner quite literally maps the most probable transformations and their effects on land use. This is done very precisely on a grid with a resolution of 25 x 25 meters.

17 Jip Claassens, Eric Koomen and Bart Rijken. "Actualisering landgebruiksimulatie Deltascenario's: Achtergronddocument bij Ruimtescanner inzet," Spinlab Research Memorandum, Volume 12. (Vrije Universiteit Amsterdam, 2017).

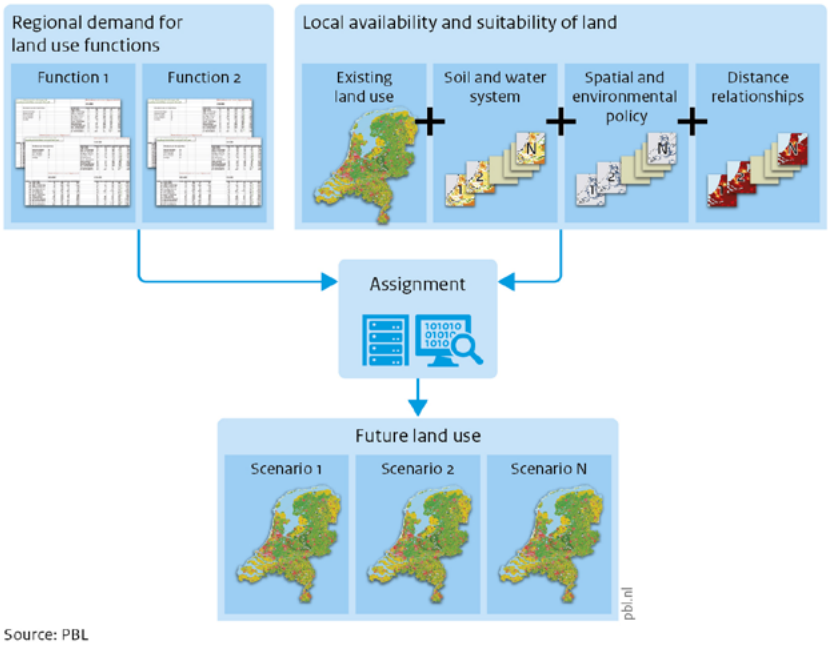

FIG. 5 Work process of the PBL Land Use Scanner, source: PBL

Research by Design

The Land Use Scanner is a very capable tool to create maps for the development of housing areas, business areas, wind parks and solar parks. However, other topics, such as the spatial effects of a circular economy, spatial interventions related to climate adaptation and the spatial development of the North Sea, cannot be modelled by the Land Use Scanner. Therefore, additional map layers were added using research by design methods. Central to research by design is the use of empirical evidence to inform options and decisions for spatial planning processes. Planners gather data, analyze trends and assess case studies to understand the context, challenges and opportunities of a specific area. This evidence-based approach enhances the quality and effectiveness of the design solutions. To add additional map layers, we collaborated closely with the urban design office PosadMaxwan which helped us to develop additional maps based on various existing scenario studies and additional expert judgment. PosadMaxwan also edited the maps of the Land Use Scanner to make them look less technical and visually more coherent with the other layers. The different versions of the detailed maps in development underpinned the national and regional workshops. This was done to feed discussions on the different options for future spatial planning and to provide insight into the spatial effects of the policy scenarios. In turn, the feedback from the internal sessions and the national and regional workshops was used to adjust and enrich the national scenario maps.

Superimposing Layers

Finally, the five thematic layers, which were based on the outcomes of the GIS land use modelling and research by design methods, were superimposed to produce the detailed maps of the four scenarios (Fig. 6). In doing so, we have chosen a particular order. The layer of water, nature and agricultural areas serves as underlay for the maps. The next map layer is that of residential areas, working areas and main infrastructure (roads, railways). This is followed by the layer of energy network and the layer of climate adaptation. The integral detailed maps as well as the separate thematic map layers can be viewed via the online map viewer. The viewer makes it possible to show or hide layers, to display them separately or in various combinations, to zoom in or out and to compare the scenarios.

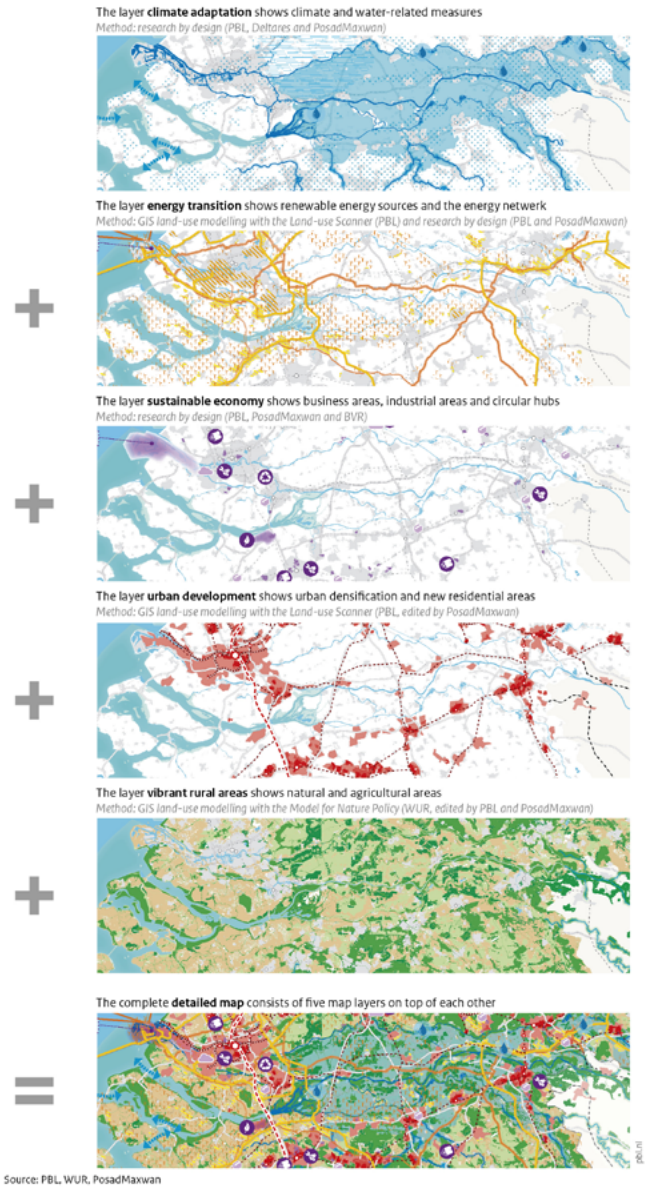

FIG. 6 Layers and methods of mapping of the detailed scenario maps, source: PBL and PosadMaxwan

Reflections on the Value of Mapping in the Scenario Study

As described in this article, a specific mixed methods approach has been applied for the development of the maps for the Spatial Outlook 2023 scenario study. The mixed methods approach combines participatory and multidisciplinary scenario development, GIS-based land use modeling and creative tools of research by design. The mapping process, from preliminary to final maps, has played a central and essential role during the development, for the publication and after the publication scenario study. In the different phases of the project, three main functions of the maps can be distinguished:

- Firstly, the maps served as 'conversation piece' during the development of the scenarios;
- Secondly, the maps served as 'communication tools' for the publication of the project, and;
- Thirdly, the maps were used as 'boundary objects' in workshops with policymakers and planners after the publication scenario study.

These functions are described in the following three paragraphs, respectively.

Maps as Conversation Pieces for Research and Design

During the development of the project, preliminary sketch maps had the function of a 'conversation piece' for the multidisciplinary project team as well as for stakeholders with different backgrounds. The sketch maps were important tools for discussing the content and the spatial specificities of the scenarios in an early phase of the research process. That was relevant for developing the story lines of the scenarios by the research team, as well as for discussions and reflections in workshops with national and regional stakeholders. Next to the early sketch maps, GIS-based land use modelling was important to set the ground for a more detailed investigation of the possible future land use. At the same time, the feedback from the research team and the stakeholders on the maps were used to improve the quality of the maps and to create plausible spatial interpretations of the storylines and underlying societal values.

Maps as Communication Tools to Explain Future Options

Based on GIS land use modelling and the outcomes of the participatory research and design approach, the design office created two sets of maps of graphically consistent maps for the printed publication of the Spatial Outlook 2023: a set of detailed maps and a set of conceptual maps that are easier to read for the general public. These maps were important 'communication tools' to attract the attention of policymakers, planners and any interested parties, including the broader public. The conceptual maps show the most relevant spatial features of the four scenarios at a glance and were used for publications and press releases. The detailed maps, on the other hand, show the results of the thorough GIS land use modelling and design research processes and are the fundamental basis for in-depth discussions of spatial options for future land use with policymakers and experts in the field of spatial planning. Alongside the printed publication, the detailed maps were also made available on an interactive website with a map viewer, as high resolution image download files as well as printed on banners that to be used for workshops. Furthermore, the maps were also used for an exhibition about spatial future studies in the Netherlands.

Maps as Boundary Objects to Bridge Gaps Between Groups and Disciplines

In scenario workshops involving multiple disciplines, the maps functioned as 'boundary objects', allowing for different meanings to different people, but having the potential to integrate different types of expertise, norms, and values[18] and to bridge gaps between different groups or disciplines.[19] By using maps, actors can co-create and participate in complex spatial and environmental policy and planning processes.[20] Visual representations through maps are universally understood and serve as a shared reference point, transcending sectoral and interdisciplinary barriers. As such, maps have an important function to help in the knowledge integration process and to facilitate effective communication between planners, policymakers and the public.

Conclusions

18 Paul Carlile. "View of Knowledge and Boundaries: Boundary Objects in New Product Development," Organization Science, 13 (4), (2002): 442–455, https://doi.org/10.1287/orsc.13.4.442.2953.

19 Maarten Hajer and Peter Pelzer. "2050 – An Energetic Odyssey: Understanding 'Techniques of Futuring' in the transition towards renewable energy," Energy Research & Social Science, Volume 44 (2018): 222-231, https://doi.org/10.1016/j.erss.2018.01.013.

20 Tamara Metze. "Visualization in Environmental Policy and Planning: a Systematic Review and Research Agenda," Journal of Environmental Policy & Planning, 22:5 (2020): 745-760, https://doi.org/10.1080/1523908X.2020.1798751

As described in this article, maps can have different functions in different phases of a spatial scenario study. Mapping allows for the creation and comparison of multiple planning scenarios. Moreover, mapping empowers researchers, planners and policymakers to make informed recommendations and decisions by providing a clear understanding of the existing conditions and potential consequences of various choices. However, tensions can arise when creating and using maps. Indeed, for the analyses, it is important to have detailed and data-based maps, which accurately indicate locations and specific spatial features. For the communication of scenarios, however, it is relevant to have stylized conceptual maps, which only show the essence and avoid false accuracy. In the development of the maps for the Spatial Outlook 2023, GIS-based land use tools and research by design techniques have been combined to produce 'new' knowledge that supports future-proof spatial decision making. In the study, the use of maps has enabled effective communication between researchers, planners and policymakers on various scales. Complex spatial developments become more accessible when presented visually by maps, fostering greater understanding of the scenarios and spatial planning choices. This, in turn, leads to more inclusive and well-informed discussions on possible future-proof spatial and environmental policies.

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The PBL Netherlands Environmental Assessment Agency is the Dutch national institute for strategic policy analysis in the fields of the environment, nature, and spatial planning. The institute contributes to improving the quality of political and administrative decision-making by conducting outlook studies, analyses, and evaluations in which an integrated approach is considered paramount.

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PBL – Netherlands Environmental Assessment Agency. Netherlands in the Future. Second Sustainability Outlook, the physical living environment in the Netherlands. Bilthoven – The Hague: PBL, 2010.

PBL – Netherlands Environmental Assessment Agency. Rehearsing the Future. The Hague: PBL, 2020.

PBL – Netherlands Environmental Assessment Agency. Grote opgaven in een beperkte ruimte, Ruimtelijke keuzes voor een toekomstbestendige leefomgeving. The Hague: PBL, 2021.

PBL – Netherlands Environmental Assessment Agency. Ruimtelijke Verkenning 2023. Vier scenario's voor de inrichting van Nederland in 2050. The Hague: PBL, 2023.

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MISCELLANEA

Computer-Aided Decision-Making for the Highest Sustainable Reuse of Historic Buildings

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ABSTRACT
The adaptive reuse policy aims to extend the functional life of the historic building in a way that suits its physical age. Recently, computer software has been utilized in decision-making processes as an assistant and accelerator to attain the best results. This paper seeks to create a program to achieve the Highest Sustainable Reuse - HSR of the historic building. The software is created by specifying two categories of urban and architectural requirements and restrictions. The first relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the needs and conditions of the proposed function. By performing an algorithmic comparison, the program is able to provide percentages for a set of proposed functions based on the case study. The paper concluded the effectiveness of the proposed methodology by conducting it on the historic Al- Barood Khanah building in Mosul.

KEYWORDS
Preventive conservation, Adaptive reuse, decision-making, Highest Sustainable Reuse, MAROHB.
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Introduction

Historic buildings are distinguished by their prominent importance in understanding and appreciating the past and present.[1] They face a range of threats that weaken their capabilities and reduce their lifespans.[2] The goal of preservation, as stated in the Burra Charter, is to retain, recover, or reveal as much as possible of the historic significance of the heritage element, whether it is a building or an archaeological piece[3]. The challenges of urban conservation are divided into three levels: the physical condition level, which includes material behavior and structural systems, causes and mechanisms of deterioration, possible interventions, and long-term effectiveness of treatments, etc.; the management level, which includes resource availability and utilization, including finances, trained staff, technology, political and legislative conditions, land use issues, etc.; and the cultural significance and social values level, which includes the importance of the place, reasons for its preservation, and the impact of interventions on its understanding or perception, etc.[4] The fundamental principle of preserving historic buildings lies in the fact that the higher the level of intervention, the greater the risk of damage to the historic building. Due to their unique importance and irreplaceability, extreme caution must be exercised in selecting and implementing preservation strategies.[5] The required degree of intervention is determined in relation to the building's condition, and the minimum intervention is always preferred in the preservation process.[6]

Adapting historic buildings for sustainable preservation involves either within-use adaptation, modifying the building while keeping it in the same function, or across-use adaptation, modifying the building while changing its function.[7] This includes the policy of adaptive reuse, aiming to adopt a new and s function for the historic site or structure that enhances cultural, social, and economic values.[8] Reuse is often sought due to the aging of single-purpose structures or their inability to achieve suitable economic gains, as well as changes in the demand for construction based on social

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1 ICOMOS, Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance (Australia: Australia ICOMOS, 1999).

2 Cristina Garzillo et al., Adaptive Reuse of Cultural Heritage: An Examination of Circular Governance Models from 16 International Case Studies (Synthesis, California: ICLEI Europe, 2020).

3 ICOMOS, Burra Charter, 1999.

4 Erica Avrami, Randall Mason, and Marta de la Torre, Values and Heritage Conservation (Research Report, Los Angeles: The Getty Conservation Institute, 2000).

5 Ehab M. Okba and Mohga E. Embaby, *"Sustainability and Heritage Buildings,"* International Journal of Engineering Research & Technology 2, no. 8 (2013): 1682–90.

6 Bernard M. Feilden, Conservation of Historic Buildings, 3rd ed. (Rome: Elsevier, 2007).

7 G.D.R. De Silva, B.A.K.S. Perera, and M.N.N. Rodrigo, *"Adaptive Reuse of Buildings: The Case of Sri Lanka,"* Journal of Financial Management of Property and Construction 24, no. 1 (2019): 79–96.

8 Imad Hani Al-Allaf, Ahmed Youssef Al-Omari, and Mumtaz Hazem Al-Diwaji, *"Alternatives to the Reconstruction of Al-Hadbaa Minaret in Old Mosul,"* Sulaimani Journal for Engineering Sciences 6, no. 2 (2019): 13–24.

and economic transformations and aligning them with the nature and density of settlements in desired areas.[9] The most sustainable level of reuse is the highest and optimal level of adaptation, relying on the installation strategy, which involves adding new parts or elements to the current building without changing the basic structure. This allows for the removal of these new parts later and restoring the building to its original state. This strategy is often used in historic buildings for preservation purposes.[10] Finding the appropriate use is often necessary to prevent the deterioration or destruction of the building, posing one of the most challenging problems in architectural preservation practice.[11] Contributing to the enhancement of historic buildings and the preservation of their social, historic, and cultural values, highlighting the role of financial and governance models in heritage preservation, increasing opportunities for collaboration between multiple stakeholders, reducing resource usage, and renewing values, capital, and knowledge.[12]

This study initially analyzed previous studies to provide a theoretical framework for a comprehensive methodology for the most sustainable reuse mechanism, addressing the cognitive deficit in finding the most sustainable alternative for reusing historic buildings. After identifying the research gap, the study explored the use of computer capabilities to find the most sustainable alternative for reusing historic buildings. The aim of this study is to design a computer program based on a multi-criteria decision-making methodology. The program is created by defining two categories of urban and architectural requirements and constraints. The first relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the proposed function's needs and conditions. Through algorithmic comparison, the program can provide percentage scores for a set of proposed functions based on a case study. This study assists decision-makers in making the most accurate, timely, and effective decisions for reusing historic buildings, contributing to prolonging the physical and functional life of the building without causing harm due to incorrect reuse decisions.

9 S. Mutal, "Adaptive Reuse for the Future Development of the Historic Centres: Some Thoughts and Considerations," Handout 7 (2015): 1–7.

10 Graeme Brooker and Sally Stone, Re-readings 2: Interior Architecture and the Principles of Remodelling Existing Buildings (London: RIBA, 2018).

11 Feilden, Conservation of Historic Buildings, 2007.

12 Lucia Della Spina, "Adaptive Sustainable Reuse for Cultural Heritage: A Multiple Criteria Decision Aiding Approach Supporting Urban Development Processes," Sustainability 12, no. 4 (2020): 1363.

Preventive Conservation and Decision-Making Management

The foundation of the current interest in preserving urban heritage is a result of increased awareness of history and the recognition of cultural diversity. Preservation has gradually become accepted as the modern approach to protecting historic buildings and artworks, serving as the primary reference for maintenance and restoration policies.[13] The conservation of heritage buildings contributes to the sustainability of the built environment and urban diversity, shaping the character of the city.[14] The fundamental principle of urban preservation is that the higher the level of intervention, the greater the risk of damage to historic buildings. Due to their unique importance and irreplaceability, extreme caution must be exercised in selecting and implementing preservation strategies.[15] The required degree of intervention is determined in relation to the building's condition, and the minimum intervention is always preferred in the preservation process.[16] Preventive conservation is indirect preservation that includes proactive preventive operations and non-intrusive activities on the structure. These efforts contribute to delaying or preventing the deterioration and disappearance of historic buildings. Preventive conservation involves information management and organizing data for appropriate decision-making purposes.

The reuse of historic buildings for contemporary purposes is a multifaceted and complex design process. Therefore, a multi-criteria decision-making process can enhance decision-making by providing a transparent and efficient selection process among design alternatives.[17] The Multi-Criteria Decision-Making (MCDM) process is a cognitive and organized approach developed to address decision-making problems in various fields, seeking the most suitable alternative. It aims to improve the quality of decision-making to become more rational and efficient, involving steps such as problem identification, stating the problem in clear and measurable terms, developing alternatives, summarizing the advantages and disadvantages of each alternative, and evaluating them to ultimately choose the best alternative that achieves the goals.[18] [19] [20] One of the objectives

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13 Jukka Jokilehto, A History of Architectural Conservation (England, UK: Routledge, 1999)

14 Buildings Department, Practice Guidebook for Adaptive Re-use of and Alteration and Addition Works to Heritage Buildings 2012, 2019 ed. (Hong Kong: Buildings Department, 2019).

15 Okba and Embaby, "Sustainability and Heritage Buildings," 1682–90.

16 Feilden, Conservation of Historic Buildings, 2007.

17 Beser Oktay Vehbi, Kağan Günçe, and Aminreza Iranmanesh, "Multi-Criteria Assessment for Defining Compatible New Use: Old Administrative Hospital, Kyrenia, Cyprus," Sustainability 13, no. 4 (2021): 1922.

18 Rahul Misra, Introduction to Management: Principles of Management (India: KMRO, 2015).

19 Fatma Eltarabishi, Omar Hassan Omar, Imad Alsyouf, and Maamar Bettayeb, "Multi-Criteria Decision Making Methods and Their Applications – A Literature Review," International Conference on Industrial Engineering and Operations Management, Dubai, UAE, 2020.

20 Maria Rita Pinto et al., "Building Reuse: Multi-Criteria Assessment for Compatible Design," International Journal of Design Sciences and Technology 22 (2017): 165–93.

of decision-making processes is pre-assessment, determining the consequences of different actions before implementation. Multi-criteria analysis is a useful tool for evaluating various alternative options in the field of cultural heritage preservation.[21]

Adaptive Reuse

It is the process of upgrading and enhancing the performance of a building to meet modern standards and adapt to changing user requirements while retaining the original structure as much as possible.[22 23 24 25] This involves the transformation of an inefficient structure and modifying it into a new form that can be used for a different purpose while preserving its good structural condition and safeguarding it from damage. It often includes significant changes in usage, renewing a historic building with both material and economic values. This entails alterations to the structure or spaces to meet new needs, helping to rehabilitate the building and integrate it into the economic and social environment of the city rather than leaving it as a closed and abandoned place.[26 27 28 29 30] The goal of these modifications to the current building is to make it compatible with contemporary use while preserving parts of the building and its valuable characteristics. Successful heritage reuse projects are usually those that respect the heritage values of the building, preserve them, and add contemporary advantages that provide sustainable value for the future. Adaptation and new uses for the building may be the only way to preserve its heritage significance, resulting in environmental, social, economic, and creative benefits. The assessment and strengthening of heritage building

21 Pinto et al., "Building Reuse," 165–93.

22 De Silva, Perera, and Rodrigo, "Adaptive Reuse of Buildings," 79–96.

23 Yasmine Sabry Hegazi, Heidi Ahmed Shalaby, and Mady A. A. Mohamed, "Adaptive Reuse Decisions for Historic Buildings in Relation to Energy Efficiency and Thermal Comfort—Cairo Citadel, a Case Study from Egypt," Sustainability 13, no. 19 (2021): 10531.

24 Despo Parpas and Andreas Savvides, "Sustainable-Driven Adaptive Reuse: Evaluation of Criteria in a Multi-Attribute Framework," WIT Transactions on Ecology and the Environment 217 (2018): 29–37.

25 Shreya Chandrakar and Sandeep Singh, "Adaptive Reuse of Heritage Building," International Journal of Creative Research Thoughts (IJCRT) 10, no. 5 (2022): C330–C336.

26 Markus Kip and Heike Oevermann, "Neighbourhood Revitalisation and Heritage Conservation through Adaptive Reuse: Assessing Instruments for Commoning," The Historic Environment: Policy & Practice 13, no. 2 (2022): 242–66.

27 Kripa Shakya and Sudarshan Raj Tiwari, "Sustainability Assessment of Adaptive Reuse Buildings in Kathmandu – A Study of Three Cases in Patan," Proceedings of 10th IOE Graduate Conference, Kirtipur, Nepal, 2021.

28 Buildings Department, Practice Guidebook, 2019.

29 Marika Gaballo, Mecca Beatrice, and Francesca Abastante, "Adaptive Reuse and Sustainability Protocols in Italy: Relationship with Circular Economy," Sustainability 13, no. 14 (2021): 8077.

30 Fenk D. Miran and Husein A. Husein, "Introducing a Conceptual Model for Assessing the Present State of Preservation in Heritage Buildings: Utilizing Building Adaptation as an Approach," Buildings 13, no. 4 (2023): 859.

structures for comprehensive reuse are evaluated throughout the duration of addition, modification, and post-operation. [31 32 33 34 35 36]

The policy of reuse plays a crucial role in building sustainability by extending the productive life of the current building. It assists communities, governments, and developers in reducing costs. This policy can develop old or historic buildings for their cultural value by giving them new sustainable uses and preserving the historic building stock and urban fabric. It contributes to finding and enhancing values related to history, continuity, affinity, identity, and sustainable human development. Additionally, it acts as an economic stimulus for the region and the city as a whole, promoting dynamic relationships within cities by transforming old buildings while introducing new architecture into old settings, achieving a balance between preserving the building and enhancing its role in the urban environment. This approach reduces energy waste, construction and maintenance costs, and land consumption, making it more sustainable. Heritage buildings are locally and internationally appreciated by current and future generations and tourists, providing an effective method for self-financing that contributes to the economic foundation of sustainable development. The transformation of heritage buildings into accessible and usable places is executed by setting clear guidelines with a vision for clear and long-term projects to avoid the destruction of heritage instead of its development. [37 38 39 40 41 42 43 44 45 46]

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31 Hegazi, Shalaby, and Mohamed, "Adaptive Reuse Decisions for Historic Buildings," 10531.

32 Yan Zhang and Qi Zhang, "A Model Approach for Post Evaluation of Adaptive Reuse of Architectural Heritage: A Case Study of Beijing Central Axis Historical Buildings," Heritage Science 11, no. 1 (2023): 1–17.

33 Royal Australian Institute of Architects, Adaptive Reuse: Preserving Our Past, Building Our Future (Australia: Department of the Environment and Heritage, 2004).

34 Buildings Department, Practice Guidebook, 2019.

35 Chiara Bertolin and Arian Loli, "Sustainable Interventions in Historic Buildings: A Developing Decision Making Tool," Journal of Cultural Heritage 34 (2018): 291–302.

36 Act No. 645, National Heritage Act (Malaysia: The Commissioner of Law Revision, 2005).

37 Parpas and Savvides, "Sustainable-Driven Adaptive Reuse," 29–37.

38 Itohan Esther Aigwia, Jason Ingham, Robyn Phipps, and Olga Filippova, "Identifying Parameters for a Performance-Based Framework: Towards Prioritising Underutilised Historical Buildings for Adaptive Reuse in New Zealand," Cities 102 (2020): 102756.

39 Gaballo, Beatrice, and Abastante, "Adaptive Reuse and Sustainability Protocols," 8077.

40 Hegazi, Shalaby, and Mohamed, "Adaptive Reuse Decisions for Historic Buildings," 10531.

41 Chandrakar and Singh, "Adaptive Reuse of Heritage Building," C330–C336.

42 Miran and Husein, "Conceptual Model for Assessing Preservation in Heritage Buildings," 859.

43 Mutal, "Adaptive Reuse for the Future Development," 1–7.

44 Rawan Abdullatif Alhojaly, Abeer Abdulaziz Alawad, and Noura Abdulrahman Ghabra, "A Proposed Model of Assessing the Adaptive Reuse of Heritage Buildings in Historic Jeddah," Buildings 12, no. 4 (2022): 406.

45 Okba and Embaby, "Sustainability and Heritage Buildings," 1682–90.

46 Ayman Ahmed Ezzat Othman and Heba Elsaay, "Adaptive Reuse: An Innovative Approach for Generating Sustainable Values for Historic Buildings in Developing Countries," Organization, Technology & Management in Construction: An International Journal 10, no. 1 (2018): 1704–1718

Previous Studies

Previous studies have focused on the effective contributions of the Highest Sustainable Reuse in enhancing the importance of historic buildings, preserving them from disappearance, and reducing demolition and damage operations while utilizing the built environment to achieve investors' goals. High attention has been given to the physical, cultural, social, economic, financial, environmental, and political aspects in the analysis of buildings proposed for reuse or with suggested functions for several buildings. The analysis process is conducted according to a set of criteria and indicators, studying their availability in historic buildings that are being reused.

Yildirim study[47] concentrated on presenting a methodology to determine the Highest Sustainable Reuse for historic buildings and has been applied to Khan Diyarbakir Hassan Pasha by applying the proposed methodology in six steps: assessing the state of the historic pattern, the state of the environment, the safety of the place, the reuse of alternatives and their advantages and disadvantages, the requirements of owners and users, and evaluating the results to determine the best re-use of the structure. Its unique methodology was applied, and decisions were made using interviews, with a primary focus on physical, cultural, social, economic, financial, and environmental aspects. Alallaf study[48] aims to explore and analyze several reuse practices in the ancient city of Mosul using the REs4 methodology, which combines topics that highlight embodied energy, including the reduction of consumption, reuse, rehabilitation, and recycling, and the possibility of preferring a new type of use to propose to different buildings. on applying the REs4 methodology using Microsoft Excel. It emphasized physical, cultural, social, economic, financial, environmental, and political aspects. Elsorady study[49] concentrated on providing a methodology to assess and determine the Highest Sustainable Reuse for historic buildings. The Alexandria National Museum was taken as a case study, focusing on three objectives: to assess indicators derived from literature; the second is to investigate the museum's sustainable adaptation; and the third is to assess the heritage building's ability to meet reuse standards. Its methodology was applied through interviews, with a primary focus on physical, cultural, social, economic, and environmental aspects. Tan, et al.

47 Mücahit Yildirim, "Assessment of the Decision-Making Process for Re-Use of a Historical Asset: The Example of Diyarbakir Hasan Pasha Khan, Turkey," Journal of Cultural Heritage 13, no. 4 (2012): 379–388.

48 Emad Hani Alallaf, "The 4res Procedure for Preserving the Built Heritage of Old Mosul: A Sustainable Conservation Policy," Second Engineering Conference for the Golden Jubilee of Engineering College, University of Mosul (Mosul, Iraq, 2013).

49 Dalia Abdelaziz Elsorady, "Assessment of the Compatibility of New Uses for Heritage Buildings: The Example of Alexandria National Museum, Alexandria, Egypt," Journal of Cultural Heritage 15, no. 5 (2014): 511–521.

study[50] discussed the Highest Sustainable Reuse of industrial buildings in Hong Kong. By focusing on applying the Fuzzy AR fuzzy logic method to measure the suitability of the building for proposed uses through expert interviews. as this model provides decision-makers with multiple options according to their different preferences over standards. Their opinions on the Highest Sustainable Reuse were considered regarding physical, social, economic, environmental, and political aspects. Islami, et al. study[51] aimed to identify factors influencing the Highest Sustainable Reuse of historic buildings in Tehran. The study demonstrates the importance of the participation of different stakeholders in the decision-making process on the reuse of historic homes and the need to preserve the original form and context of historic buildings, as it is an important decision-making factor. Its methodology was applied using Multi-Attribute Decision Making (MADM) methods, with a primary focus on physical, cultural, social, and economic aspects. Pinto, et al. study[52] was applied to the monastery of Santa María del Geso at the historic center of Ragusa in Italy, which aims to help select the Highest Sustainable Reuse design among the many alternatives compatible in four phases: identifying future user needs; identifying obstacles to the building's transformation determined by its historic and artistic characteristics; designing alternative solutions to restore the building; and evaluating alternative design solutions concerning preservation and adaptation needs for new use. By focusing on applying the AHP and EVAMIX methods to evaluate the suitability of the building for the proposed use and select the most appropriate design using multi-criteria decision-making (MCDM) methods regarding physical, cultural, and environmental aspects. Barakat & Goriel study[53] concentrated on determining factors influencing the Highest Sustainable Reuse of historic buildings of the Qabhan School in Dohuk governorate in Iraq. The study used analysis at two different levels, the first by analyzing cultural, environmental, and architectural characteristics, and the second by analyzing the functional planning of the Space Syntax building. By focusing on physical and cultural aspects. Haroun, et al. study[54] applied the AHP methodology to assess the Highest Sustainable Reuse of Aziza Fahmi Palace in Alexandria Egypt. using Microsoft Excel, with a focus on physical, cultural,

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50 Yongtao Tan, Liyin Shen, and Craig Langston, "A Quantitative Approach for Identifying Adaptive Reuse Option for Industrial Buildings," in Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate (Berlin: Springer, 2015), 505–495.

51 Seyed Gholamreza Islami, Davood Dehghan, and Hasan Sadeghi Naeini, "A Model Development to Adaptive Reuse of Iranian Qajar Houses: An Approach to Sociocultural Concept (A Case: Nasir Al-Din Mirza House)," American Journal of Civil Engineering and Architecture 4, no. 3 (2016): 84–89.

52 Pinto et al., "Building Reuse," 165–93.

53 Armange Ismael Barakat and Wafaa Anwar Goriel, "Factors Affecting the Adaptive Reuse Process for Historical Buildings in Kurdistan Region: An Analytical Study of Qubahan School as Historical Case Study," Sulaimani Journal for Engineering Sciences 6, no. 3 (2019): 29–46.

54 *Hebatu-Allah Abdul Fattah Haroun, Ali Fouad Bakr, and Asmaa El-Sayed Hasan, "Multi-Criteria Decision Making for Adaptive Reuse of Heritage Buildings: Aziza Fahmy Palace, Alexandria, Egypt," Alexandria Engineering Journal 58, no. 2 (2019): 467–478*

social, economic, and financial aspects. Ribera, et al. study[55] focused on applying AHP methodology to evaluate the Highest Sustainable Reuse for historic buildings using the AHP Priority Calculator, emphasizing physical, cultural, social, economic, and financial aspects. Joudifar & Türker study[56] focused on applying the Reuse Projection Framework methodology to determine the Highest Sustainable Reuse for architectural monuments in general and Othello Castle in the particularly walled city of Famagusta in Cyprus. The first step of the framework covers analytical and practical research based on the survey of literature and observation on the site. Then he explores the architectural and historic advantages of identifying architectural layers and modifications over time, finally looking at heritage values and evaluating importance, with a focus on physical and cultural aspects. Vehbi, et al.study [57] concentrated on applying AHP methodology to evaluate the Highest Sustainable Reuse of Kyrenia Administrative Hospital in Cyprus using 11 Choice Expert, emphasizing physical, cultural, social, economic, financial, environmental, and political aspects. Farjami & Türker study [58] focused on applying grounded theory methodology to evaluate the Highest Sustainable Reuse of historic buildings using collecting data from the survey of the literature and reviewing the common features of ARM and ERS to produce the outline of the proposed PCS basic preliminary standards, concentrating on physical, social, economic, environmental, and political aspects. Finally, El borolosy study[59] concentrated on applying the AHP methodology to assess the Highest Sustainable Reuse of Chamblion Palace in Egypt using the Analytic Hierarchy Process, focusing on physical, cultural, social, economic, and environmental aspects.

After analyzing previous studies, methodologies and measurement tools, their application levels, and the most influential aspects studied were extracted. Most studies relied on unknown methodologies, using interviews to verify their effectiveness on buildings in addition to Multi-Criteria Decision-Making (MCDM) methodologies. Based on various aspects, it can be noted that there is a research gap in the importance of selecting the appropriate use to prevent the failure of the building reuse process, which often occurs due to inappropriate choices for the new function of the building, leading to increased damage to the historic building. The

55 Federica Ribera, Antonio Nesticò, Pasquale Cucco, and Gabriella Maselli, "A Multicriteria Approach to Identify the Highest and Best Use for Historical Buildings," Journal of Cultural Heritage 41 (2019): 166–177.

56 *Farnaz Joudifar and* Özlem *Olgaç Türker, "A 'Reuse Projection Framework' Based on Othello's Citadel and Cultural Tourism," The Historic Environment: Policy & Practice 11, no. 2-3 (2020): 202–231*

57 Vehbi, Günçe, and Iranmanesh, "Multi-Criteria Assessment for Defining Compatible New Use," 1922.

58 Elnaz Farjami and Özlem Olgaç Türker, "The Extraction of Prerequisite Criteria for Environmentally Certified Adaptive Reuse of Heritage Buildings," Sustainability 13, no. 6 (2021): 3536.

59 Lobna Abd El Aziz El Borolosy, "Use Multi-Criteria Analysis MCDM to Determine the Most Appropriate Funding for the Adaptive Reuse of Heritage Buildings (Case Study of the Champollion Palace)," International Journal of Multidisciplinary Studies in Architecture and Cultural Heritage 5, no. 2 (2022): 1–29.

current study aims to provide a comprehensive methodology for the Highest Sustainable Reuse mechanism for historic buildings to extend their operational and functional lives.

Highest Sustainable Reuse

The highest and optimal level of adaptation relies on the installation strategy, which involves adding new parts or elements to the current building while avoiding changes to the fundamental structure. This approach allows for the later removal of these new components, returning the building to its original state. Often employed in historic buildings for preservation purposes, this strategy aligns with environmental, economic, and social sustainability.[60] It requires profitability, flexibility, energy efficiency, and environmentally friendly materials.[61] Moreover, it contributes to enhancing the historic building, preserving its social, historic, and cultural values, and highlighting the role of financial and governance models in heritage conservation. However, historic buildings face challenges in achieving sustainable use. Challenges include the potential loss of architectural authenticity due to a lack of clear distinction between the original elements and modern additions. Achieving self-funding for projects is possible but may be unsustainable without considering the proper financial balance between building operation technology and expected financial funding. An effective management process involving stakeholders is required, as without active community participation, historic buildings struggle to fully express the cultural identity of the community.[62]

The highest sustainable reuse mechanism is defined as the one where the building is compatible, enhances, and increases understanding of the cultural significance of the historic place.[63] Selecting the appropriate use is crucial to reducing potential conflicts between heritage preservation and modifying the building to meet current standards for new usage.[64] This process considers the heritage classification of the building to determine the allowed intervention extent, preserving architectural elements, details, and finishing materials that give the building a distinctive character.[65] Additionally, attention is given to community needs and desires, emphasizing the importance of buildings, protecting them, providing long-term management, using dismantlable and switchable systems, and offering

60 Brooker and Stone, Re-readings 2, 2018.

61 Elsorady, "Compatibility of New Uses for Heritage Buildings," 511–521.

62 Imane Djebbour and Ratiba Wided Biara, "The Challenge of Adaptive Reuse Towards the Sustainability of Heritage Buildings," International Journal of Conservation Science 11, no. 2 (2020): 519–530

63 Yıldırım, and Turan. "Sustainable development in historic areas: Adaptive re-use challenges in traditional houses in Sanliurfa, Turkey."

64 Buildings Department, Practice Guidebook, 2019.

65 *Mohannad Tarrad and Salam Mtawea Husban, "The Creation of Guidelines for Adaptive Reuse of Heritage Buildings in Jordan, Case Study Palace of the Ali Alkaid Basha (Jordan)," Architecture and Modern Information Technologies 3, no. 56 (2021): 64–78*

comfortable facilities. It is closely related to the main urban plan, involving design consultations with stakeholders to enhance the understanding of local housing practices[66]. The more significant the importance of the historic building, the more crucial it becomes to find the Highest Sustainable Reuse to minimize damage during the transformation process, maintain vitality, and enhance its significance.[67] [68]

The constraints of the Highest Sustainable Reuse include the need to differentiate new additions and ensure they do not impact the distinctive features of the heritage building. Changes, expansions, or internal and external additions should be minimal, avoiding alterations or damage to parts and spaces, maintaining compatibility with the new function, and allowing easy user access to all building facilities. The usage of the building throughout the day and its full utilization of all its floors are preferred. The process involves a combination of integrated operations, including restoration, renovation, maintenance, and infrastructure improvement, without compromising its artistic and historic value, with the approval of necessary internal modifications by relevant administrative authorities.[69]

MAROHB

The establishment of a decision-making management system for the reuse of historic buildings in the Old City of Mosul involves several stages. After extracting aspects, criteria, and indicators directly impacting this mechanism within the theoretical framework, the process begins by identifying and analyzing the essential system requirements. This ensures a comprehensive understanding of what the proposed Most Appropriate Reuse of Historic Buildings (MAROHB) system should offer in the current study and how it operates. Data is then collected and analyzed, followed by the design of detailed specifications. This phase aims to transform the acquired data into an interactive design that can identify user requirements and achieve their goals of finding the most suitable alternative. This stage includes the design of backend system operations, focusing on processes that will occur in the background to activate the system for the intended purpose. Data processing involves establishing relationships and equations to connect the impact of user interface entities with the basic data for indicator weights. The final result is derived by processing the linkage of requirements, building capabilities, and functions with indicator values. When inputting data into the user interface, it is transformed

66 Mücahit Yıldırım and Gizem Turan, "Sustainable Development in Historic Areas: Adaptive Re-Use Challenges in Traditional Houses in Sanliurfa, Turkey," Habitat International 36, no. 4 (2012): 493–503.

67 *ICOMOS, Principles for the Conservation of Heritage Sites in China (China: The State Administration of Cultural Heritage, 2015).*

68 Sara J. Wilkinson, Hilde Remøy, and Craig Langston, Sustainable Building Adaptation: Innovations in Decision-Making (United Kingdom: John Wiley & Sons, Ltd., 2014).

69 Yildirim, "Re-Use of Diyarbakir Hasan Pasha Khan," 379–388.

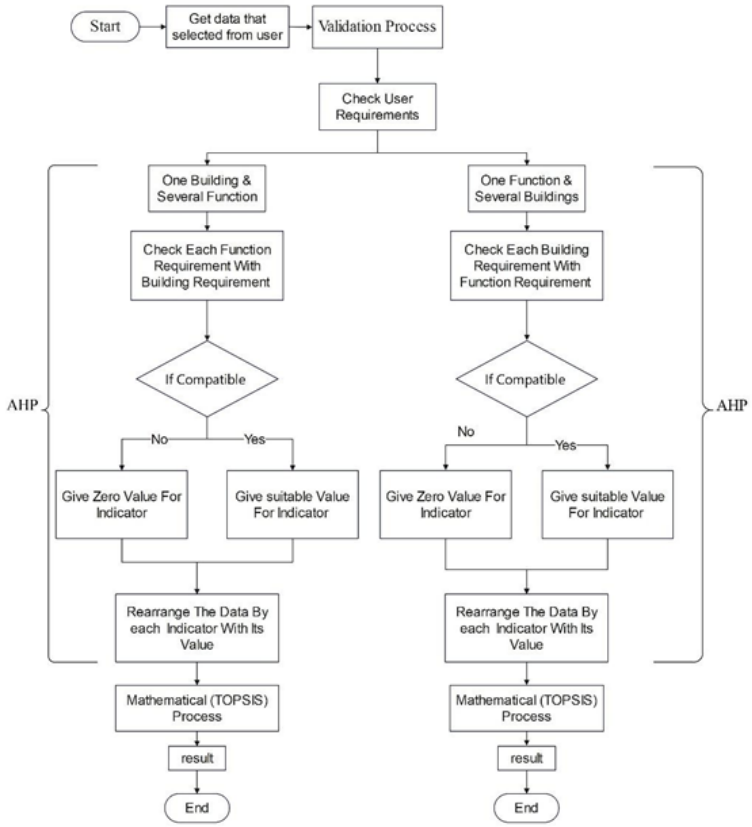

FIG. 1 MAROHB system process design algorithm. Imagine by authors

into system operations for analysis, uncovering relationships using equations and algorithms to reach the final result. This result is then clearly presented to the user on the interface, allowing for easy and clear understanding, as shown in Figure 1.

Following this, the user interface design is developed as shown in figure 2, to create what the user will see and how they will interact with the details. This includes designing pages, windows, menus, buttons, and other control elements for user interaction. This contributes to making the user experience smooth and logical, providing guidance and instructions through images and interactive explanatory texts to help users perform tasks. The system interface is designed to be responsive across various devices and screens (computers or mobile phones), allowing easy access from anywhere. The goal in this part is to ensure a comfortable and effective user experience, guiding them efficiently towards achieving their goals and successfully reaching the final result. The program provides the option to download the final results in both CSV and PDF formats.

The study outlined the most sustainable reuse mechanism for preserving historic buildings, prolonging their operational lifespan, and enhancing their value. Recognizing the actual need for a comprehensive and effective methodology to implement the most sustainable reuse, this study aims to design a computer program based on a multi-criteria decision-making approach. The program was created by identifying two categories of urban and architectural requirements and constraints. The first

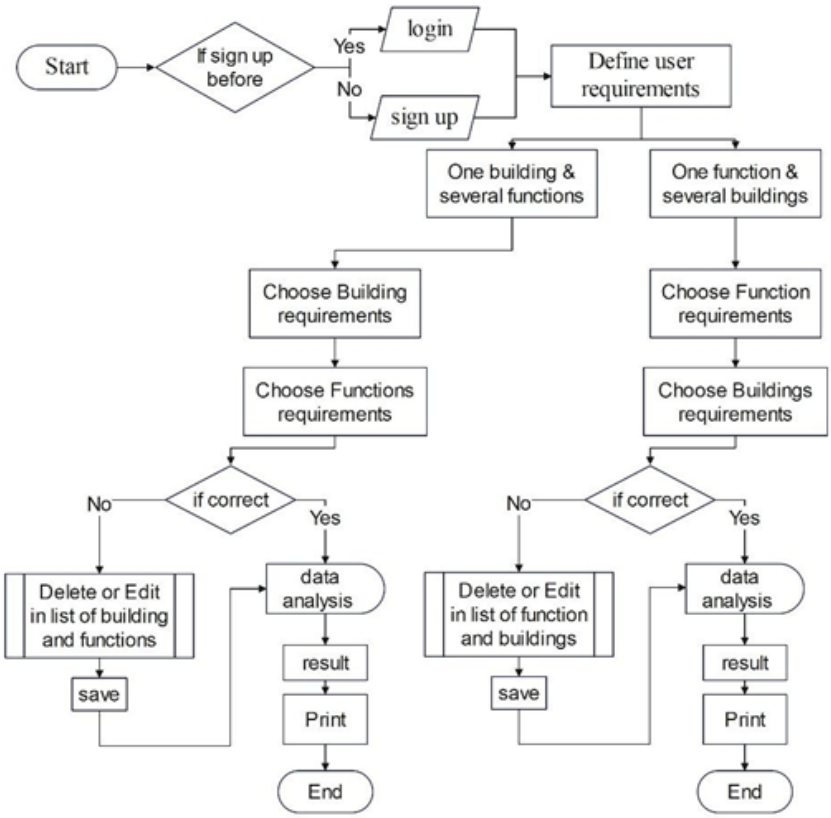

FIG. 2 User interface algorithm in the MAROHB system. Imagine by authors

relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the proposed function's needs and conditions. Through algorithmic comparison, the program can provide percentage scores for a set of proposed functions based on a case study. This study helps decision-makers make more accurate decisions for the reuse of historic buildings in a more efficient manner, contributing to the extension of the building's physical and functional lifespan and avoiding damage resulting from incorrect reuse decisions.

The next section will analyze a historic building in the Old City of Mosul, testing its capacity to accommodate various proposed functions, including a museum, heritage restaurant, library, and a training center for the maintenance and restoration of antiquities.

Case Study Old City of Mosul

The Old city of Mosul is situated at a historically significant location, bordered by the right bank of the Tigris River to the east and surrounded by old walls. It is positioned on a gradually sloping plateau towards the Tigris River, constituting 5% of the current city's area. The Old City of Mosul holds a pivotal status as a cultural and historic center with substantial influence on regional history throughout old times. Mosul boasts a rich and diverse history, representing a multifaceted historic and cultural significance

ohat has witnessed various influences over the ages.[70 71 72] The city faced destruction during military operations from 2014 to 2017, resulting in the disappearance of many of its landmarks. Currently, international organizations and local efforts are directed towards revitalizing and preserving the city's heritage, aiming to restore it to its former glory.

Al-Barood Khana 1834 AD

The building dates back to the year 1834, during the reign of Mosul's governor, Muhammad Enjah Birqdar. The term 'Al-Barood Khana' translates to the Gunpowder Depot, and it stands as one of the most important structures from the Ottoman era. It is located in the Al-Shifaa district, in the northwest of the old city. The structure consists of three parts: the main building for storing gunpowder (Al-Danat), which still stands and has two metaphorically rectangular floors with two protruding wings on each side. It covers an area of 2374 square meters and has a height of 11 meters. The building is characterized by its thick walls and the presence of semi-cylindrical towers at its corners, supported externally by buttresses with dimensions of 5.5 meters, a height of 8 meters, and a thickness of 1.1 meters. As for the second building for the workers' residence and the third building for the officers, they are not currently present. The building was previously used as a cooperative society and later transformed into a museum for folk heritage.

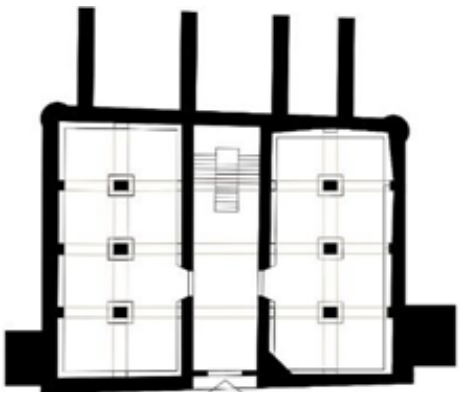

FIG. 3 Ground floor of Al-Baroud Khana

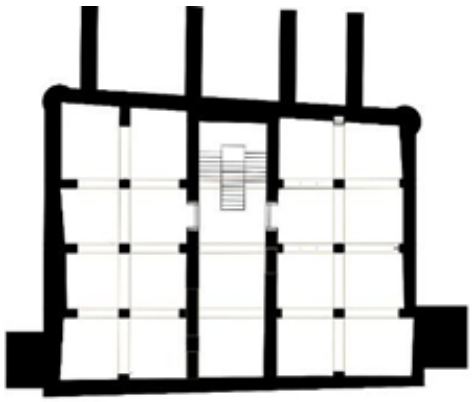

FIG. 4 First floor of Al-Barood Khana

Discussion

The results of applying the capabilities of the Al-Barood Khana building and job requirements in the MAROHB system indicate that the most suitable alternative is selected due to achieving the highest percentage of

70 Ahmed Qasim Aljumaa, The Old Arab City of Mosul Is Undergoing Reconstruction and Development (Mosul-Iraq: Mosul House, 2020), accessed September 1, 2023, https://www.baytalmosul.com/.

71 University of Mosul, Mosul Civilizational Encyclopedia, vols. 1–4 (Mosul-Iraq: Ibn Al-Atheer House for Printing and Publishing, 1991).

72 Saeed Al Diwaji, History of Mosul, vol. 1 (Mosul-Iraq: Iraqi Scientific Academy, 1982).

FIG. 5 Al-Barood Khana building. Irfaa Sawtak, Irfaa Sawtak, January 27, 2023, accessed September 28, 2023, Facebook.

Building Function	Museum	Library	Heritage restaurant	Training center
Barood Khanah Building	74%	48%	60%	45%

TABLE. 1 The most appropriate function for Al-Barood Khana from a set of proposed functions. By authors

compatibility conditions with job requirements. These requirements hold high importance and include factors such as space, capacity, number of rooms, ventilation, lighting, and required materials, among other less impactful requirements. The selection of Al-Barood Khana for the study was based on field documentation, referring to other sources, whether books, articles, or interviews with individuals directly related to these buildings, to fully understand their details. After completing the process of identifying the building's capabilities, heritage experts were consulted in the practical field to provide their opinions on the credibility of determining these capabilities. As for the functions to be tested, a set of functional programs was proposed within the current study and presented to architectural design experts, professors in the Department of Architecture at the University of Mosul, for review, criticism, and approval as suitable and efficient programs for the proposed functions, meeting the requirements of stakeholders and aligning with global standards for each. Based on this, several functions and a specific building in the MAROHB system were implemented to verify its efficiency in finding the most suitable alternative. The results showed that the museum with the highest percentage function is the most suitable, with a percentage of 74%, as it achieves the highest compatibility with the job requirements.

It is evident that the closer the capabilities of different buildings are, the higher the likelihood of multiple buildings getting the same function if their requirements match the building's capabilities. The degree of proximity or distance from the ideal alternative is measured, and a percentage is assigned to this proximity. The results of the application may change as a result of changes in the requirements and capabilities of the buildings and their proposed functions.

Conclusions

The most sustainable reuse mechanism is considered the most suitable for preserving and enhancing historic buildings, giving the structure or site a higher likelihood of protecting its construction and architectural characteristics. The effective contributions of sustainable reuse emphasize the importance of historic buildings, preserving them from disappearance, reducing demolition operations, and utilizing the built environment to achieve investors' goals. The current study proposes a computer program aimed at analyzing the detailed details of the system and how to transform user requirements into a practical and visual design in an easy and efficient manner for implementing its functions. The data processing in the system operations design led to the creation of relationships and equations to connect the impact of user interface components with the basic data for the weights of aspects and criteria and how to find the final output by processing the link between requirements and possibilities for buildings and functions with indicator values. After completing the system design process, it was applied to the historic Barood Khanah building, classified among the highest values in the Old City of Mosul, proving the effectiveness and accuracy of the system in finding the most suitable alternatives. The program is created by specifying two categories of urban and architectural requirements and constraints. The first relates to the characteristics, capabilities, and limitations of the historic building, while the second describes the needs and conditions of the proposed function. Through algorithmic comparison, the program can provide percentage ratios for a set of proposed functions based on the case study. The use of the MAROHB methodology facilitated sound decision-making by decision-makers, in addition to reducing the time required to complete the process of selecting the Highest Sustainable Reuse for the historsic building. The comprehensiveness of the information significantly contributed to covering and managing the process as thoroughly as possible.

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