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Special Issue Reprint

Novel Trends in Urban Planning for Building Urban Resilience

Edited by
Steffen Lehmann and Monika Szopinska-Mularz

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This is a reprint of articles from the Special Issue published online in the open access journal *Buildings* (ISSN 2075-5309) (available at: https://www.mdpi.com/journal/buildings/special_issues/3400SPRI72).

For citation purposes, cite each article independently as indicated on the article page online and as indicated below:

Lastname, A.A.; Lastname, B.B. Article Title. *Journal Name* **Year**, *Volume Number*, Page Range.

ISBN 978-3-7258-2375-8 (Hbk)
ISBN 978-3-7258-2376-5 (PDF)
doi.org/10.3390/books978-3-7258-2376-5

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About the Editors

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Preface

The future of humanity is undoubtedly urban. The global disruptions that have arisen in recent years have shifted the thinking on resilient urban planning, including compactness, mixed land use, density, diversity of built form and usage, sustainable transportation, and green space. Today, it is known that cities must adapt existing knowledge and develop novel tools to accommodate a growing number of residents and respond to ever-changing threats, such as climate change, supply chain disruptions and even armed conflicts over water supply. Natural disasters and human-made threats affect cities of various scales and densities. As urban growth in large metropolitan areas is expected to stabilise or experience a decline, small- and medium-sized cities are fast-growing and becoming increasingly important in the regional landscape. New trends in urban planning arise to address poverty and inequality, mitigate and adapt to climate change, develop resilient urban economies, secure green spaces, and reduce urban health risks.

This Special Issue aims to provide an overview of existing knowledge on novel trends in urban planning for building social, economic, and environmental resilience in cities of various scales and densities.

Original research (experimental and theoretical), case studies, and comprehensive review papers were invited for submission. Relevant papers were selected, and these include urban planning solutions, actionable recommendations, and future-oriented scenarios focused on enhancing urban resilience through:

- Governance and multilevel collaborations to confront future disruptions;
- Strengthening community resilience;
- Developing optimal compactness, density, and mixed land use;
- Innovative technologies and digitalisation in urban planning for a better urban life;
- Regenerative urban design for climate change mitigation, adaptation, and health;
- Nature-based solutions and biodiversity improvement for increasing resilience against climate change, extreme weather events, and other threats;
- Urban–rural interlinkages in urban planning and decision-making practices;

Strategies and guidance are now relevant to reduce adverse impacts of past planning decisions.

Steffen Lehmann and Monika Szopińska-Mularz

Editors

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Editorial

Research Methods in Urban Design: A Framework for Researching the Performance and Resilience of Places †

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† This article belongs to the Special Issue 'Novel Trends in Urban Planning for Building Urban Resilience'.

1. Introduction

> *Research is the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.* (Oxford English Dictionaries, 2020.)

What exactly is research in the broad field of performance of urban design, and what methods have proven to be appropriate and useful? There can be very narrow definitions of what constitutes "proper" research and natural scientists will most likely give a different answer from that provided by social researchers or engineers. Some may insist that research is only research when it proves or disproves a hypothesis and uncovers new facts, for example, about the performance of a specific neighbourhood, group of buildings or the work of a particular architect. Research is a systematic investigation and is likely to be an important factor in any urban design process. Geoffrey Makstutis [1] (2018; 20) notes, "It is seldom, if ever, that an architect begins to design without first undertaking some form of research". Urban design itself is an interdisciplinary research process in that, throughout the process, information from a variety of sources is gathered and evaluated continuously to develop an appropriate design proposition. Understanding the requirements for the future performance of a place or neighbourhood, gathering information, and understanding the local conditions of the site context or the history of the area all constitute elements of the initial research.

Research usually has its foundation in asking a pragmatic question. Aksamija [2] (2021) notes that "The ways in which the researcher asks that question are important, and if one applies the most appropriate and rigorous methods, the answers are likely to represent an original contribution to knowledge". Muratovski notes that research in the performance of a building or a particular public place is "the process by which one can understand the world in a verifiable and consistent manner" [3] (Muratovski, 2016). This means that merely collating existing information is not in itself enough to constitute research; the aim is to say something meaningful and new because of the data gathered and analysed. For example, a new interpretation or evaluation of the performance data collected. In this context, the term "originality" denotes examining material that has never been studied previously or providing new interpretations of well-known material [4] (Lucas, 2016).

This paper discusses the appropriate methods that can be used when researching place performance in urban design; thereafter, it explores the process of inquiry in the research-informed environmental design of green urban futures.

2. Appropriate Research Methods

> *The purpose of research is to learn what has never been known before; to ask a significant question for which no conclusive answer has previously been found; and by collecting data and interpreting relevant data, to find an answer to that question.* (Leedy & Ormrod, 2010.)

Citation: Lehmann, S. Research Methods in Urban Design: A Framework for Researching the Performance and Resilience of Places. *Buildings* **2023**, *13*, 1548. https://doi.org/10.3390/buildings13061548

Received: 1 June 2023
Revised: 12 June 2023
Accepted: 15 June 2023
Published: 17 June 2023

Research in urban design is closely connected to the challenge of innovation, e.g., to enhance a neighbourhood or building's performance and the effective integration of innovation into practice (a field that is still poorly understood). The growing role and importance of research in the field of urban design have been widely acknowledged [2,4–6] (Hensel & Nilsson, 2016; Lucas, 2016; Aksamija, 2021; Lehmann, 2021, 155f), and the strategic use of research in the urban design process will most likely lead to more effective and better-performing design solutions. However, there remains always the challenge of integrating the research findings meaningfully and effectively into the actual design process.

In the future, urban designers will need to be better trained in the skills with which to gather, assess, record and comparatively evaluate relevant information and data on the performance of different project scenarios to support conclusions for a specific project proposal, be it a place, a group of buildings or a proposed neighbourhood. Currently, most architects, designers and planners lack these skills and have received little or no training in thoughtful, considered data collection that could help their work be more innovative and perform better, including the synthesis of research findings for the development of meaningful conclusions that could inform and guide the performance of their projects positively and optimise positive impact.

There are two fundamentally different approaches that an urban designer might adopt [7,8] (Yin, 2013; Fraser, 2013):

- *Research through urban design*, including the creation of new knowledge and an improvement in design practice;
- *Research into urban design*, contributing new knowledge to the discipline's knowledge base.

The common characteristics of urban design research that focus on performance enhancement can best be described as follows:

- The research activity creates new knowledge, new information or a new interpretation of the environmental performance of a place or neighbourhood.
- With a focus on performance, it makes an original contribution to the knowledge of the operation of the place or project (e.g., assessing its operational and embodied energy).
- It is original, in that it is undertaken by a researcher, yet it also acknowledges other people's ideas and works appropriately and is cited clearly.
- It applies some interpretive or analytical framework and a rigorous method in exploring a particular performance theme (e.g., the whole-life-cycle carbon footprint of a new neighbourhood, the water management of a public space or the environmental performance of a particular construction system), asking very specific questions.
- It has the wider potential to influence future urban and architectural thinking and attendant culture.
- It explores measurable performance that can be replicated and scaled up in other cities and projects.
- It is widely disseminated and communicated through peer-reviewed publications, as well as being publicly presented at conferences, so that it has a positive impact on future thinking and transforms practice.

However, the creative process of urban design is often based more on intuition, assumptions and personal preferences. A more systematic and analytical approach that is evidence-based (using a clear research framework) will most likely improve the urban design process. Let us compare, for example, the natural cooling performance of different green spaces at varying urban densities, in a particular climate and in a specific city (this will be very different in Los Angeles compared to London, for instance). The benefits of such research are obvious, as regreening public spaces will help to future-proof urban settlements for an increasingly hot urban environment, which has been widely documented and discussed [9,10] (Wong & Yu, 2005; Sailor, 2014). Urbanism today aims increasingly to fuse the city with nature by reintegrating greenery into the public space network; however, there is still a knowledge gap in terms of which nature-based solutions are most effective

and perform best in different densities and climatic conditions. The term *nature-based solutions* refers to the use of nature in addressing environmental, cultural and societal challenges, while also increasing biodiversity and balancing urban temperatures. These solutions include green roofs, green walls and sustainable drainage systems [11–14] (Alberti & Marzluff, 2004; Meerow et al., 2016; Xing et al., 2017; Lehmann, 2018).

Cities are centres of consumption: 75% of our natural resources are consumed in and by cities, while cities are responsible for 50% of the world's waste and emit over 60% of global greenhouse gases. Moreover, by 2030, metropolises must meet the challenge of accommodating more residents, offering a better quality of life and buffering against the consequences of climate change. This is a considerable list of challenges. At the same time, urban ecosystems are increasingly under stress, as they must withstand more frequent and longer dry periods, with concomitant increasing heat, air pollution and water shortages [15,16] (IPCC, 2018, 2022). However, over recent years, the quality of life in many cities has declined. The reasons for this decline include many factors: air pollution, urban heat, increasing traffic and housing that has become unaffordable. Therefore, we must plan better, including a further increase in green spaces, so that we do not lose the liveability of our cities that we currently enjoy.

3. How to Get Started

The most basic starting point is the study and analysis of precedents (case studies) and the conducting of a literature review that identifies a possible knowledge gap, to formulate appropriate research questions, including ethical research questions, and a theoretical position regarding a complex design problem. Based on their training, urban designers and planners should excel in understanding, organising and visualising technical data and determining various parameters, e.g., by using urban diagrams, or the translation of quantitative and technical data into simple diagrams as a basis for better-informed decision making, as well as documenting observations and learning through drawings and diagrams.

Urban design is, by nature, an interdisciplinary activity, and the challenges of cross-disciplinary design research can inform any design process positively. It is key to formulate a compelling research question early that is based on a preliminary precedent analysis and a thoroughly conducted literature review. This can include comparative case studies that compare the effectiveness and performance of various types of neighbourhoods or buildings against an established benchmark (baseline).

Research in urban design refers to conducting a systematic investigation of some kind, which includes selecting the most suitable method from the different types of research, such as quantitative or qualitative research methods. A *method* is a particular procedure for approaching and accomplishing the research challenge.

Logical research is always based on valid procedures and principles. Some of the different types of urban research methods include:

- *Quantitative research*, which is the process of collecting and analysing numerical data (e.g., urban census or microclimate data for statistical analysis). It is highly structured and follows strict procedures and rigorous rules based on principles of validity, through experiments and statistical surveys.
- *Qualitative research*, which involves collecting and analysing non-numerical data (e.g., observations, texts, video or audio of interviews with users—what do they think?) to understand concepts, opinions or real experiences. There are no strict rules for this.
- *Empirical research*, which is based on direct experience and qualitative observation by the researcher.

Mcleod (2023) further explains the differences: "Quantitative research collects numerical data and analyses it using statistical methods. The aim is to produce objective, empirical data that can be measured and expressed in numerical terms. Quantitative research is often used to test hypotheses, identify patterns, and make predictions. Qualitative research, on the other hand, collects non-numerical data such as words, images, and sounds. The focus

is on exploring subjective experiences, opinions, and attitudes, often through observation and interviews. Qualitative research aims to produce rich and detailed descriptions of the phenomenon being studied, and to uncover new insights and meanings." Thematic analysis can be used to make sense of a large amount of qualitative data by defining and naming themes, as described by Braun and Clarke (2006) [17,18].

Therefore, the urban designer must be aware of the differences between the various methods available (e.g., qualitative, quantitative, experimental, visual, applied, historical and ethnographical—from desk research to action research to surveys to mixed methods) and select the most appropriate and useful method for a particular study. This includes decisions on data collection and analysis. For example, will the researcher conduct interviews with users, carry out archival research or find other ways to gather relevant new data?

Some of the key steps that the researcher has to follow include:

1. Framing the research problem (e.g., which type of environmental performance will be examined?).
2. Developing a compelling research question and hypothesis.
3. Conducting the literature review.
4. Compiling a glossary of key terms.
5. Selecting the methods: the different research approaches and multimethod research (by combining different methods), selecting the most suitable methods.
6. Structuring the research procedure and reporting on the findings.

The most common method in urban design and social science is qualitative research; it is a different approach and can be the opposite of quantitative research (which is mainly used in engineering and science). In a convincing qualitative study, the research question drives the purpose of the research through the identified knowledge gap and the selected methodology for collecting and analysing the performance data. Once the researcher has identified the research problem, the next step is to articulate the problem in a way that is carefully phrased and represents the goal of the research effort: the formulation of the research aims and objectives in order to produce results. The research question might be combined with a hypothesis. A hypothesis is a "logical supposition, a reasonable guess, and educated conjecture" to address the research problem [19,20] (Leedy & Ormrod, 2010; Lehmann, 2010).

Here, the researcher in urban studies will also need to develop a clear understanding of the limitations of the problem (the exact performance aspect). For example, some research problems might be overly ambitious, too complex or require unreasonable resources for their investigation in terms of time, funding, logistics, data or equipment. A statement is needed that explains how the researcher will deliver the results promised. If the problem is too large or complex, one can:

- Reduce the range of the problem to a point where the problem becomes feasible in terms of study, simply by setting narrow limits for the problem.
- Choose to focus on only a part of the problem instead.
- Break the problem down into several smaller subproblems.

Questions about the performance of places and public spaces have recently emerged at the forefront, as urban designers want to know how the performance and resilience of future urban places might best be predicted, analysed and measured. One might ask:

- What was the original intended use of the place and is it being used as planned? (e.g., does the place perform well?)
- What is its actual use and who are the different user groups? (e.g., one might conduct interviews with end users).
- What resources are used and what environmental impact do they have on the place?

The performance (or efficiency) of a place or neighbourhood is a measure of how well it functions according to certain designated criteria such as physical, social or environmental considerations. The effective use of the resources necessary to design and construct a particular place and whether it performs as intended can be measured. Urban design

performance standards aim to enhance the performance of different aspects of a place, neighbourhood or public park. These include the project's requirements regarding energy or water use, carbon emissions or user comfort during extreme climatic conditions (e.g., during heatwaves). The resilience of a place or neighbourhood is a measure of its adaptive capacity and how well it can recover from an unexpected major disruption or crisis.

High-performance urban design integrates and optimises on a lifecycle basis all major high-performance attributes (defined criteria), including resource efficiency, energy conservation, environment, safety, comfort, health and well-being, durability, accessibility, cost and benefit, productivity, sustainability, functionality and operational considerations. It is about how well a place or neighbourhood fulfils its functions, its resource efficiency when compared to other standard places or neighbourhoods, and the resilience (adaptive capacity) of the place to unexpected disruptions [21] (Lehmann, 2019). Thus, researching urban design performance is a way to describe and measure how well a place performs—or the benefits that it offers to residents, users, workers, owners and maintenance managers (to name just a few stakeholders)—regarding a variety of performance criteria (parameters) that the researcher has specified.

As researchers, we must ask relevant questions and test different scenarios. A rigorous assessment and evaluation of the performance of different urban density scenarios must follow: which one will deliver the most effective, sustainable and resilient outcome? Common themes on performance are urban health and opportunities for physical activity, urban form, ecology, mobility, connectivity and other urban design quality criteria [2] (Aksamija, 2021). Questions about the creation of new knowledge in the performance of urban design could also include critical explorations that discuss contemporary issues in urban studies, such as:

- The "meaning of place" and its relationship with nature and technology (e.g., the excessive surveillance of public space).
- The future role of public space and the notion of the "civic" in an increasingly privatised or commercialised city.
- The important role of urban informality versus the master-planned formal city.

In universities, there has been good progress in integrating research activities into the educational design curricula. In the context of urban design, it is common for design research studios to be devoted to an in-depth investigation of a defined design research project of the student's conception through an iterative structured methodology common in most graduate programmes. The research usually focuses on understanding design methodologies through a series of explorative projects based on precedent analysis and the comparison of cases. Advisors shape the research agenda, define milestones and play a supporting role in suggesting possible approaches, techniques, methods, directions or resources. New conceptual frameworks for design research are constantly evolving. With cities becoming hotter and experiencing heatwaves more frequently, the dangerous urban heat island effect has emerged as a serious research field that will have a direct impact on numerous future urban design decisions, such as density considerations and the use of greenery. Related to this is the question of the effective regreening of urban spaces to keep cities cool: for example, which tree species are most effective in cooling the urban microclimate? Therefore, the following part of this article looks at some metrics for performance measuring and quality criteria that are relevant for regreening strategies, urban resilience and ecology.

4. Practice-Oriented Research with Impact

> *Practices are always transforming due to changing needs, different conditions and circumstances to be met, emerging new design problems, and therefore new questions to be asked and new inquiries to be made. Practice must meet these new challenges, which now require advancement of, and through, modes of inquiry that differ from those employed thus far, which are frequently shown to be ineffective in addressing an increasing complexity.* (Hensel & Nilsson, 2016, ix.)

While a plurality of theories of scientific research have been articulated, these often lack relevance to practice and decision-making mechanisms to guide the profession. Applied research, today often termed "practice-oriented research-by-design", has become one of the most popular research approaches for urban designers as it promises to have a positive impact. The desired impact can vary and could include the following impact types:

- Scientific impact: knowledge creation and dissemination.
- Economic impact: a successful business model.
- Environmental impact: avoidance and reduction in CO_2 emissions.
- Instrumental impact: the formulation of new policies.
- Capacity building impact: skills development.
- Cultural and social impact: change in mindsets leading to behaviour change.
- Conceptual impact: uptake of new theoretical concepts.

While other approaches focus on understanding the problem and identifying a possible solution, applied research is more practice-related and focuses on developing a specific solution in detail. Integrating research into urban design practice is essential for developing and applying new knowledge and finding better-performing solutions. For innovation to take place, it requires a much stronger correlation between research per se and urban design strategies, and it is pertinent for the future of urban design practice that research becomes an integral part of the profession. Research can also give a practice a competitive advantage, regardless of a firm's size [22] (Lehmann, 2023).

For designers to develop themselves as professionals of broader significance, they will need to embark on a journey of lifelong learning and train how to incorporate scientific research into their practice [4,23] (Schoen, 1984; Lucas, 2016). Although scientific and analytical, design research has emerged as the basis of most good design work. Some professional firms are taking this seriously and have invested in research activities related to their projects and developed expertise within their practice—just think of leading firms KieranTimberlake, Perkins & Will, Renzo Piano Building Workshop, Foster and Partners or Kengo Kuma (to name but a few research-driven practices). This research expertise could be in materials research, the adaptive reuse of existing structures, the use of a particular construction method or other areas.

Philadelphia-based firm KieranTimberlake [24] offers the following statement on research:

> *KieranTimberlake takes a holistic view to designing for sustainability. It is our belief that current standards can result in a checklist approach to environmental design. We advocate designing for the integrity of the structure as a whole rather than a sum of individual parts, and we utilize integrated systems that work together for greater gains. Whenever possible, features serve multiple purposes: a pond on site may serve as a leisure amenity, a stormwater management strategy, and a source for landscape irrigation. We understand the need to balance the ideals of resource conservation, energy efficiency, and environmental stewardship with the realities of performance criteria, constructability, and budget.* (KieranTimberlake, website, 2022.)

5. Discussion: The Performance and Resilience of Urban Spaces

The performance and resilience of green spaces are a relevant research theme and an important topic to analyse. Trees provide cities with substantial potential for carbon capture, ecosystem services and shade. In the green city of the future, all flat roofs of buildings will need to become roof gardens and act as water reservoirs for plants. This requires knowledge from a series of experts, including landscape architects, ecologists and facility managers. In my own research, I always support cross-disciplinary approaches, as no single discipline can address the grand design challenges we face—we must combine environmental, economic and social concerns.

There are different definitions of performance in urban design research. While energy codes around the world get stricter every year, useful metrics for performance measurement of urban design projects include energy efficiency, energy use intensity (EUI measured in

kBtu/sqm or ft^2/year), water use intensity (WUI measured in gal/sqm or ft^2/year), and embodied and operational carbon emissions (both measured in kg or tonnes/CO_2e/year).

A project's EUI refers to the annual energy required to operate and sustain the project once it is occupied and in use, and an integrated research-informed design concept can lower operating and maintenance costs, improve thermal comfort and access to daylight and reduce water usage. When running energy simulations, one must understand the possible ramifications of each urban design decision on altering the EUI. By calculating the EUI of a project, urban designers can better predict the project's yearly utility cost.

The WUI determines how much water a project or public space design will require during its lifetime. It is important to design efficient water systems, as potable water consumption constitutes a large proportion of the world's finite freshwater reservoir. Collecting rooftop rainwater and stormwater runoff, treating wastewater and reusing greywater are all ways to reduce water consumption. Site strategies that allow for the greater infiltration and storage of stormwater enable water to be returned to the source, either with or without treatment.

The *waste generation and material flow* of a neighbourhood examines the amount of material that goes to landfill or incineration, instead of being sent to a recycling centre; it is measured in kg or tonnes/household/year. In 2010, to define the relationship between urban development and material flow and to better assess the impact of waste flows, I defined the term and parameters of a *Zero Waste City* [25] (Lehmann, 2011).

Embodied carbon emissions refer to the greenhouse gases emitted during the extraction, manufacture, transportation, assembly, replacement and deconstruction of the materials used for a project, together with the end-of-life profile. This is the most complete boundary condition, i.e., measuring from cradle to grave. If considered early in the design phase, up to 80% of a project's embodied carbon can be reduced. In the future, all construction materials should have a "material passport" that gives reliable information about their place of original extraction, sourcing, manufacturing, transportation to the site and other information relevant to assessing the embodied carbon.

Operational carbon emissions refer to the greenhouse gases generated annually during the operational or in-use phase of a project. This includes the use, management and maintenance of a district or structure, along with the energy consumed to use and run the project's systems.

Much research highlights how access to daylight can benefit the health, happiness and productivity of users and occupants. The geometry, orientation and compactness of a project play a key role in its efficiency and daylight autonomy. Shade and glare control is important, as too much direct sunlight can produce glare and overheating, creating discomfort. It can increase cooling loads due to the creation of overheating hot spots. The view from inside is also an important performance factor: building occupants and users who can visually connect with outdoor natural environments experience greater satisfaction and productivity. For example, in healthcare facilities, views and access to nature can shorten hospital stays, and reduce both stress and the use of pain medication, and this is also critical for school buildings and workplaces.

To ensure that cities work better for their residents, a people-centric approach with access to green space is essential. In post-pandemic times, urban living means people getting outdoors more to walk, cycle and spend time in nature. We have noted an increase in outdoor activities and people getting more physically active, with numerous health benefits that result from applying the concepts of renaturalisation and regreening. Nevertheless, more research is needed: Which are the most efficient solutions? How can cities use nature-based solutions to confront the challenges posed by unhealthy conditions effectively, including decreasing air quality, the loss of biodiversity and excessive urban heat?

Vegetation and, in particular, tree planting, green roofs, regreening and rewilding offer multiple benefits to the urban climate, health and personal well-being by helping to reduce levels of harmful pollutants in the air, ambient temperatures, the urban heat island effect and heat-related mortality. Evidence shows that people who live in neighbourhoods with

more trees and easy access to green spaces experience lower levels of stress and mental illness, affirming the concept of biophilia—the idea that humans have an innate desire to connect with nature [26–28] (Wilson, 1984; Roger, 1993; Kellert, 2011). Establishing and reinforcing people's connection with nature are recognised as critical to their mental and physical health.

The term *urban heat island* (UHI) is used to describe an urban area that is warmer than the rural areas that surround it. Local-scale temperature increases will accompany future population growth, putting more people in danger from the negative health effects of extreme heat [29] (Santamouris & Osmond, 2020). The main causes of the UHI effect are urban development, the loss of green space and building materials that absorb and trap heat (rather than reflect it). The cooling effect of urban parks, gardens and urban forests can be experienced easily during hot summer days in cities (see Figure 1).

Figure 1. A "good" urban place with significant tree cover providing shade and a comfortable microclimate. How can we measure the quality and performance of "good public space" quantifyably? (Image: by the author, 2023).

Post-occupancy evaluation (POE) has gained methodical significance among researchers. It leads researchers to visit, measure and monitor the "real" performance of built projects. Nevertheless, POE-related data can be difficult to interpret and easily skewed. Privacy concerns can also limit these kinds of investigations because no company wants to see a report published that says their headquarter offices are inefficient and making people sick, or some other negative report. Employees might be reluctant to correctly report problems or dysfunctional aspects at their workplaces. One of the goals is to remove the stigma, because there is a need for high-quality data to address important questions about workplace efficiency, health and comfort. Some researchers have faced misleading comments, hindering the scientific process or discouraging others to study this important subject matter, for example, covering up that the built project performs less well and not as it was promised. What is needed is a new era of research where these kinds of investigations are supported with a commitment to transparency in monitoring the operational efficiencies of the built cases.

6. Four Selected Examples of Regenerative Design Research

Over the past 30 years, the author has led numerous design research studios at different universities in six countries. A design research studio is based on the assumption that all good design is research-informed, applying research strategically. A considerable part

of teaching such studios includes principles of urban regeneration and the regreening of cities [21] (Lehmann, 2019). Students are asked to apply principles of regenerative design, which is an approach to designing systems and solutions that aims to work with the natural ecosystem processes. This approach goes beyond being restorative and self-sustaining; it aims to reverse and repair the damage made to the site's ecosystem.

Students in the graduate programme of the Master of Architecture degree are asked to design a significant urban design project and write a comprehensive 20,000-word research thesis related to the design project to demonstrate the depth of the investigation. In parallel to the design research studio, the author teaches the same cohort of students on research methods, which provides the theoretical underpinnings graduate students need to conduct a proper work of research. The thesis consists of a literature review, carefully considered research questions and a hypothesis (which the design project then either proves or disproves). A yearlong capstone project develops over two semesters, evolving from concept design to developed design and an in-depth technical study. All urban design projects must include a public space that contributes to the urban regeneration of the wider area. In the following part, four selected design research projects are introduced that deal with the urban regeneration of a substantial part of downtown Las Vegas.

- **Design Research Project 1:**

  A new public park, reconnecting two communities.

  This urban design research project creates a new public park and green space on top of a freeway tunnel. A clear landscape strategy identifies "windows" for the placement of five new buildings in a continuous cultural landscape. One research question was: How can one create a new public park, a resource-efficient place on top of a freeway tunnel that brings people together for community wellness? (See Figure 2; student: Mirella Garcia.) Research approach: As part of the design process, qualitative interpretations were constructed and various techniques were used in comparative case study and thematic analysis, to make sense of the data from numerous other precedents. It even allows for ambiguity and contradictions in the design, which reflects social reality.

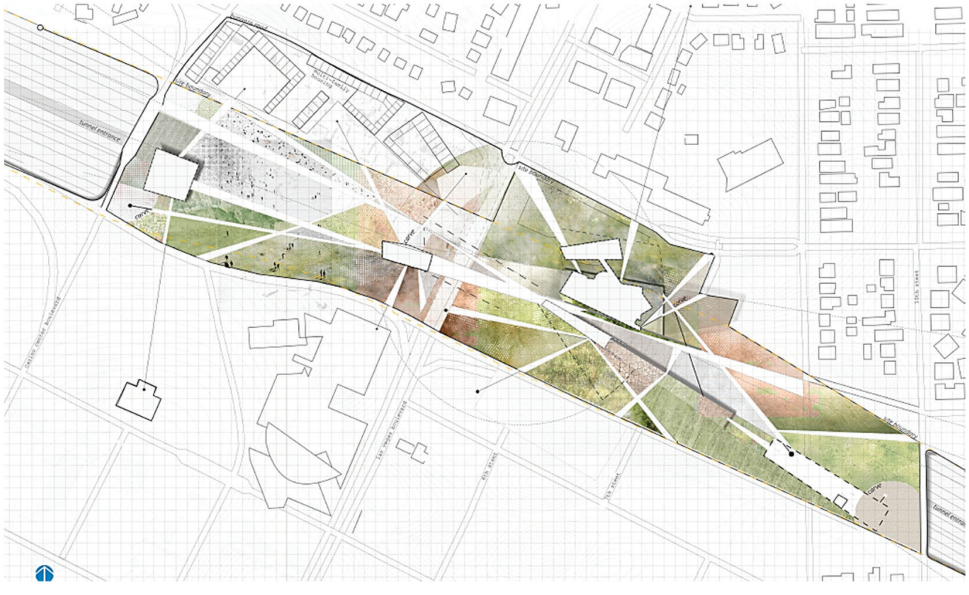

Figure 2. Master plan of a new park and cultural facilities on top of a freeway tunnel in downtown Las Vegas. (Image: courtesy of Mirella Garcia and the author, 2023.)

○ **Design Research Project 2:**

An urban food hub: vertical food production and distribution centre.

This urban design research project includes three growth towers and a drone delivery port. One research question was: How can the new technologies of urban farming help create a food distribution centre in downtown Las Vegas? The hypothesis: by using new technologies in robotics and AI, the integration of urban farming methods with a robust local delivery system can create a sustainable future-proof neighbourhood by reducing its carbon footprint of food transportation, while increasing access to fresh and healthy produce and creating a localised food system that promotes public health and food justice. (See Figure 3; student: Antonio Trejo.) Research approach: The design is based on extensive urban farming precedent studies and supported by personal experience and contextual observations. Because of the subjective nature of the qualitative data and its origin in a single context, it is difficult to apply conventional standards of reliability and validity. For example, because of the central role played by the design researcher in the generation of the data and project design, it is understood that it is generally not possible to replicate such a specific qualitative study elsewhere.

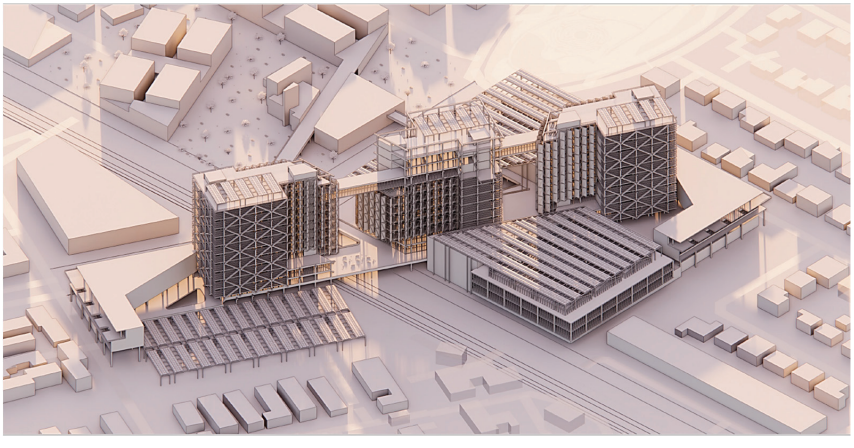

Figure 3. The three growth towers of the downtown food hub with a food distribution centre, drone port and bus terminal. (Image: courtesy of Antonio Trejo and the author, 2023.)

○ **Design Research Project 3:**

A new gateway to the Las Vegas Arts District.

This urban design research project proposes a significant new public plaza that serves as an outdoor events and exhibitions venue as well as the entrance to a new cultural facility. The research question: How can art and architecture, in unison, serve as a powerful catalyst in the revitalisation efforts in the Las Vegas Arts District? (See Figure 4; student: Andrya Mojena Cutie.) Research approach: Qualitative observational data were analysed to gain insights into social phenomena, such as human behaviour and social interactions at various art galleries and culture-led regeneration projects; suggesting possible relationships between urban space, circulation and the spatial organisation of the project.

○ **Design Research Project 4:**

Neo-Metabolism: a modular micro-housing system for urban infill.

This urban design research project explores why the Metabolist designs of the 1960s have rarely worked. Modular construction using standardised components that can be assembled on-site can greatly reduce construction time and costs, while reducing waste and minimising the building's carbon footprint. Therefore, one research question was: what is the most efficient and flexible approach for revitalising vacant sites and parking

lots downtown to optimise their social, economic and cultural impacts? (See Figure 5; student: Bijan Damavandi.) Research approach: Since nothing was predefined or taken for granted, the researcher immersed himself during the design process in the field, in contextual surroundings. For the qualitative researcher, there is no single reality. This means that the study's design evolved during the research; it illustrates one of a variety of possible scenarios and was adjusted as it progressed.

Figure 4. A shaded public space with a cultural facility above that reorganises a currently neglected, left-over urban space. (Image: courtesy of Andrya M. Cutie and the author, 2023.)

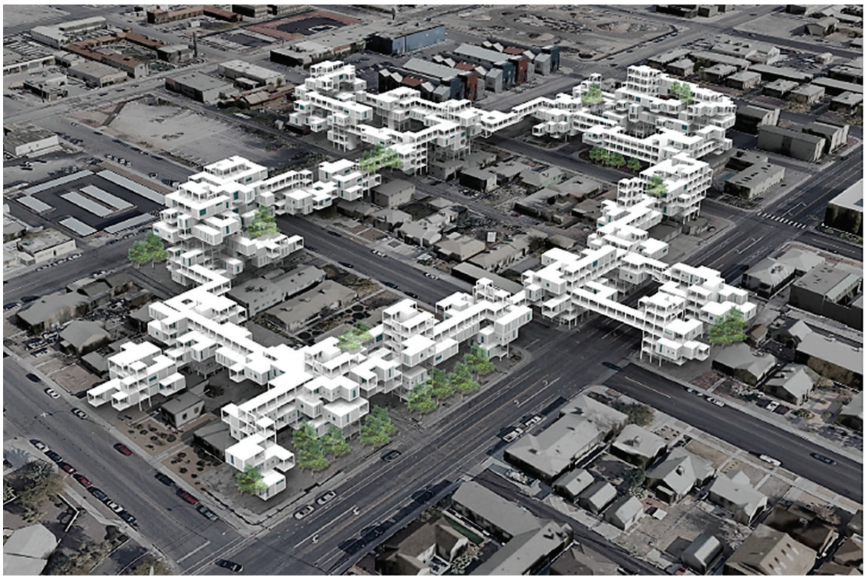

Figure 5. A perspective view of downtown Las Vegas illustrating the "new city built above the existing one", using a low-carbon, modular, off-site-manufactured construction system. (Image: courtesy of Bijan Damavandi and the author, 2023).

7. Conclusions

This article first explored methods used to research the performance of places in urban design and then introduced four examples of design research projects for such public spaces recently proposed for the urban revitalisation of downtown Las Vegas. There is now increased interest in new knowledge on resilient urban planning, density, affordability, sustainable transportation and green space. Cities must adapt existing knowledge and develop novel tools to accommodate a growing number of residents and respond to ever-changing threats, such as climate change, supply chain disruptions and other issues. Threats affect cities of various scales, and new research-driven trends in urban planning arise to address poverty and inequality, mitigate and adapt to climate change, develop resilient urban economies, secure green spaces and reduce urban health risks. More research in urban design and planning is required that strengthens the evidence base for better decision making and expands the knowledge of place performance. Research-led design and design-led research are very important approaches toward making the necessary improvements to our urban places and spaces. Critical analysis in design-led research is applied to develop new understandings and realise new opportunities, as exemplified by the four individual design research approaches. Comparative case studies are seen as a useful tool in qualitative and quantitative research [30] (Denscombe, 2010).

The four examples of urban design research projects are accompanied by deep and thorough research studies on the potential for the urban regeneration of downtown Las Vegas. In all four examples, research was used to test a theory, a hypothesis and ultimately support or reject it. Each of the projects explores a different area and aspect of regeneration. In urban design research, it is unlikely that any one study will provide a definitive, complete answer to all questions asked. Research in urban design is always part of a continuing journey of enquiry, analysis and scenario testing. At the outset, this paper discussed the various aspects and methods of applied research in urban design. There is now a growing awareness of the importance of new knowledge and innovation in practice and the need for its constant development. Therefore, one of the driving forces behind today's education of urban designers and architects is research-informed critical systems thinking, not the creation of "architectural objects". Relating theory to methodology and making informed design decisions will lead to evidence-based, research-informed urban design, rather than stylistic manoeuvres. Conducting research can make all the difference between a great design and a good design. Therefore, one of the conclusions is that the profession of the urban designer is one of lifelong learning and self-directed inquiry to kick-start a continuous cycle of self-improvement.

Funding: This research received no external funding.

Acknowledgments: The author has taught design research studios for the last 30 years and is grateful to the hundreds of highly motivated and talented students he worked with creating new knowledge in urban design. A special thank you to the students from the UNLV School of Architecture M.Arch. programme of Spring 2023 for providing the selected images: Mirella Garcia, Antonio Trejo, Andrya Mojena Cutie, and Bijan Damavandi.

Conflicts of Interest: The author declares no conflict of interest.

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Article

Balancing Increased Urban Density with Green Spaces: The Marketing of New Housing Estates in Poland

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Abstract: This study aims to analyse the transformation of urban greenery into greenfield housing development from 2019 to 2023 in the medium-sized city of Rzeszow (Poland) by evaluating the validity of references to the greenery in advertising texts on the developers' websites. Furthermore, to assess the impact of the proposed greenery-related changes on urban green infrastructure. Through web-based research, 13 greenfield housing developments were identified. Changes in land use of areas that were allocated to urban green infrastructure were highlighted by applying GIS spatial analysis. The written and visual content analysis identified references to greenery in advertising campaigns. Finally, status relations analysis was performed to assess whether the specific advertising website presents an added ecological asset that can be considered as a nature-based solution or should be interpreted as greenwashing. The study revealed that the advertising websites for greenfield housing development constructed from 2019 to 2023 in Rzeszow do not represent an additional ecological asset, but committed greenwashing. All analysed housing estates trigger irretrievable environmental damage. The advertising material does not define the environmental indicators of the housing estates, including how the new construction would compensate for the destruction of natural habitats.

Keywords: future-oriented urban planning; resilient communities; urban density; urban green infrastructure (UGI); greenfield housing development (GHD); nature-based solutions (NbS); study of conditions and directions of spatial development (SCDSD)

Citation: Szopińska-Mularz, M.; Lehmann, S. Balancing Increased Urban Density with Green Spaces: The Marketing of New Housing Estates in Poland. *Buildings* **2023**, *13*, 777. https://doi.org/10.3390/buildings13030777

Academic Editor: Nikos A. Salingaros

Received: 27 February 2023
Revised: 12 March 2023
Accepted: 14 March 2023
Published: 15 March 2023

1. Introduction

Since the beginning of the 2000s, planning policies in Poland have been gradually implemented which led to the intensification of urban developments while the overall urban densities decreased. Fast-paced urban growth, although necessary to provide for much needed housing and job opportunities, led to adverse environmental, social, and economic impacts [1,2]. The urban expansion of Polish cities and towns requires significant efforts in terms of planning and infrastructure investments to curb sprawl and reintroduce nature into the urban context. However, how can we re-naturalise cities without dropping urban densities? The problem is present in medium-sized cities with a population between 100,000 and 500,000 inhabitants, which must compete with larger metropolises on parallel issues, but are less equipped with resources and often lack institutional and planning capacity [3]. Since future disruptions are unpredictable but likely, these might affect urban areas where professional planning and management is considered an opportunity for more sustainable, resilient, and healthy urban futures [4]. City managers and councils must have the knowledge and tools to respond to ever-changing threats, including climate change, future pandemics, the risk of armed conflict and long-lasting supply chain disruptions [5]. In many medium-sized cities in Poland, urban densification became a crucial strategy and pretext for decision-makers to allow for more compact development, while introducing

urban greenery (UG) back into built-up areas. However, the continuation of the structural stability and functional security of this trend is not ensured [6]. Misguided territorial planning led to the construction of numerous greenfield housing development (GHD) and further development of low density, car-dependent sprawl. In the advertising campaigns for these new developments launched by the project developers, claims are frequently made that these housing estates would deliver significant social, economic, and environmental benefits. Furthermore, advertising campaigns highlight the location within the natural landscape as positive from the perspective of an urban dweller [7]. Here, landscape values become crucial elements of marketing strategies, which do not indicate any adverse impacts of GHD that are impossible to compensate for [8].

The question of urban density is closely connected to urbanisation models and how our cities may evolve in the future. Density and compactness are two closely related but different criteria, both relevant for sustainable urban development and the transformation of cities; however, their relationship is not always well understood. While a high degree of compactness is desirable, too much density can be detrimental to liveability, health, and urban well-being [9].

New urbanisation concepts should guide the inclusion and re-introduction of greenery and biodiversity in the urban built environment [10].

In this paper, a case study of Rzeszów, a medium-sized city in Poland, is analysed and conclusions are drawn that would be relevant to practitioners and researchers alike, especially those involved in urban densification, urban and architectural design, and greenery protection. The main aim of the study is to analyse the transformation of UG into GHD from 2019 to 2023 in the medium-sized city of Rzeszow (Poland) by evaluating the validity of references to the greenery in advertising texts on the developers' websites. Furthermore, to assess the impact of the proposed greenery-related changes on urban green infrastructure (UGI). The findings are used to provide recommendations to stakeholders to protect UGI and prevent negative impacts from GHD in medium-sized cities. Therefore, the objectives of the research article are threefold: (I) to highlight the changes in land use of areas that were allocated to UGI in the city of Rzeszow from 2019 to 2023; (II) to analyse the use of greenery in the written and visual content of the GHD marketing websites and to evaluate whether the applied strategy represents an added ecological asset that can be considered as nature-based solutions (NbS); or these claims should possibly be interpreted as greenwashing; and (III) to provide recommendations to decision-makers for the formulation of future policies relevant to protecting UGI and in order to prevent negative impacts from GHD from negatively transforming medium-sized cities.

In Europe, 67% of urban residents live in medium-sized cities and only 9.6% of dwellers live in large metropolises that have more than 5 million inhabitants [11]. Recent discussions on institutional conditions for an effective response to the environmental, social, and economic challenges that are evident in European cities revealed that medium-sized urban areas face more difficulties when planning sustainable and resilient urban growth [5,12,13]. Medium-sized cities are less equipped with resources and often with institutional and planning capacity [3]. Although UGI is recognised and acknowledged in planning strategies, its protection is at risk of haphazard urbanisation combined with pressure of modern life standards derived from large metropolises. Thus, strategic urban management, the protection of key sites, and the provision of funds and management mechanisms for restoration and rehabilitation are crucial themes for the sustainable future of medium-sized cities [13]. Contrary to large agglomerations, too little research attention has been paid to UGI protection and the prevention of transforming UG into a built environment in medium-sized cities.

2. Literature Review

Compactness, mixed land use, density, housing diversity, sustainable transportation, and green space represent essential planning strategies that contribute to social, economic, and environmental sustainability within an urban form [14]. Context-specific governance

and policy maintain a balance between these strategic elements, thus meeting the requirements of the three sustainability goals. However, the debate about urban evolution as a combination of rigorous development and planning practices indicates that implementing, improving, and maintaining all planning strategies simultaneously is difficult to achieve [15]. Stakeholders have been cherry-picking those elements that suit their needs and visions of a sustainable city [16]. In many urban areas, emerging economic opportunities overbalance social and ecological benefits when making planning and zoning decisions [14]. This phenomenon has various adverse impacts, and one of them, of interest to this study, is prioritising the construction of new housing estates at the expense of reducing natural landscapes [7]. Urban densification should be achieved through strict land use regulations aimed at revitalising brownfields to reduce land consumption in peri-urban areas, waste, energy use, air pollution, and avoid social segregation [17]. However, densification processes endanger UGI provision and protection [18].

UG includes areas in cities covered with vegetation, such as parks, urban forests, urban agriculture, private gardens, green roofs, or walls [19]. UG as a planned network of natural and semi-natural areas provides ecosystem services that support life in cities. UG improves social cohesion and inclusion [20,21], benefits life satisfaction and happiness [22,23], contributes to health by reducing stress and encouraging urban dwellers to be outdoors and walk [24], enhances biodiversity, and mitigates against adverse effects of climate change [25]. The provision of UGI is further supported by NbS, as systemic solutions that are inspired and supported by nature to provide environmental, social, and economic benefits and contribute to urban resilience [26,27]. Implementing NbS aims to bring natural characteristics and processes to the urban environment through locally inspired and resource-efficient interventions [28] that can be designed in symbiosis with urban structures [29] and to some extent compensate for the negative impacts of human activity on the natural environment [8].

UG provides cultural ecosystem services for leisure, cultural education, tourism, aesthetic appreciation, and spiritual needs [30], which constitute a large proportion of ecosystem services in UGI [31]. Previous research has established that residential satisfaction increases when the home is located in close proximity to greenery [32,33]. Natural elements, including green views from home and opportunities to access natural landscapes nearby, elicit positive emotions such as tranquility and peace, thus contributing to the well-being of residents [32,34]. The presence of parks and open space encourages neighbourhood interactions [32,35], opens opportunities to engage with nature [20], encourages physical activities [36], reduces stress and restores attention [37]. Residential satisfaction depends on the quantity and quality of UG [34], the size [38], accessibility [38], natural properties [39], biodiversity and the species composition of the green space [40]. For example, larger local greenery attracts more residents, including relatively far-away housing estates, than smaller neighbourhood greenery that more often does not meet user expectations [41,42]. Developers are aware of the role of nature in residential satisfaction; thus, plots within UG are in high demand for the construction of new housing estates [43]. The need for rapid development of multifamily housing, caused by the sharp increase in urban population, challenges land use management and increases concerns about the loss of UGI and ecosystem services [44,45]. Emerging economic opportunities for new construction often exclude green thinking [6,7]. Natural landscapes that are essential for ecological security are identified and acknowledged as UGI; however, their structural stability and functional security are not protected. There is a large volume of published studies describing the adverse impacts of new construction on natural cover, biodiversity, and the production of ecological services and goods [46–48]. Transforming UG to the built environment causes deforestation [49–51], habitat and land fragmentation [52], and loss of allotment gardens [53]. GHD, which includes all housing constructions built on land covered with vegetation, is a common phenomenon [54]. Previous research has established that the initial and operating ecological costs of GHD are higher than those of a brownfield development [55–57]. Several cities that have proclaimed themselves “green“, “innovative“,

"ecological", or "smart" have been criticised for greenwashing, due to the promotion of GHD as sustainable and ecological [55]. Caprotti, Springer, and Harmer (2015) examined Sino-Singapore, Tianjin, the urban megaproject in China that achieved the status of an eco-city (together with 259 other urban projects) [55]. The authors indicated that construction could cause irretrievable environmental damage that arises from the degradation of wetlands. Ecological indicators are vaguely defined within the project, which appears as an environmental—economic vision that will be difficult to validate after finishing the construction [55]. Shaw and Menday (2013) analysed Fibro Dreaming, a beach house development in Australia, and revealed that this housing estate, advertised as environmentally sustainable and integrated with nature, does not deal with the triggered environmental degradation and urban sprawl [58]. Cugurullo (2016) positioned Masdar City (Emirates) in the urban eco-modernisation context and argued that this high-tech development is more informed by market analysis than ecological studies [59]. Raco and Lin (2012) indicated that the policies and strategies, which guide sustainable urban development, are shaped by economic, environmental, and socio-political dynamics that often implement controversial changes that help to provide substantial financial income to elite groups [60].

GHD is driven by the availability of unprotected land in prominent locations and the willingness of urban dwellers to live close to nature [43]. Developers consider UG as the opportunity to build and sell apartments in desired districts, and refer to ecological values and proximity to green spaces in promotional campaigns [7,54]. Although green marketing positively influences the perception of developers and their investments [61], as well as generates a stronger intent to purchase the offered product [62], much published research has shown that advertisements produce misleading green claims [7,54]. Several studies have shown that greenwashing became a common marketing strategy in response to the growing emphasis on eco-climate issues [63,64]. Greenwashing is defined as a communication that misleads the audience (stakeholders, consumers) about environmental benefits/performance by disseminating positive information about a product, service, or organisation, without the complete disclosure of negative information on these dimensions [63,65]. Tateishi (2018) conducted a semi-content analysis of GHD ads in Nusajaya (Malaysia) to determine the dependence between the levels of green claims, deceptive green claims, and prices [54]. The study explored the relationship between green claim levels, deceptive green claims, and the level of loss of greenery. Green claims have been found to contradict each other due to initial adverse ecological costs that include cutting down vegetation and higher ecological costs in the next stages of the life cycle of the housing estate compared to similar brownfield developments. The larger the share of build-up to the project site, the greater greenwashing is practised [54]. Furthermore, developers adapt green marketing to improve market value and justify expensive prices. Gałecka-Drozda et al. (2021) investigated 73 multifamily housing advertisements in Poznań (Poland) with respect to written information and illustrations (plans and renderings) to assess whether green claims should be classified as greenwashing or NbS [7]. The study revealed greenwashing in all marketing campaigns. Some green interventions presented in the explored ads were identified as NbS (e.g., front gardens); however, elements of greenwashing were also observed. Although the study revealed examples of NbS, it has been highlighted that this concept is not well understood in urban development strategies in Poland. Thus, NbS appear implicitly in housing estate advertisements.

Little is currently known about the levels of green claims in marketing campaigns of ghd in medium-sized cities. This paper uses the case study of Rzeszow (Poland) to highlight the changes in land use of areas that were allocated to UGI in this medium-sized city from 2019 to 2023, to analyse the use of greenery in the written and visual content of the GHD marketing websites and to evaluate whether the applied strategy represents an added ecological asset that can be considered as NbS or these claims should possibly be interpreted as greenwashing. The findings are used to provide recommendations to stakeholders to protect UGI and prevent negative impacts from GHD in medium-sized cities.

3. Materials and Methods

3.1. Case Study

The case study is a qualitative approach that allows exploring a bounded system (a case) through in-depth data collection, which involves multiple sources of evidence, for example, documents, observations, focus groups, etc. [66,67]. Through case studies, researchers gain an in-depth understanding of phenomena and their meaning [68]. This research methodology is designed as an exploratory single case study that allows the analysis of the interaction between the context and the indicated phenomenon [69] within an urban organism. At the beginning of the research, the developers' approach to taking over UGI by GHDs and implementing natural elements in these projects to compensate for environmental losses is unknown. Thus, this paper focuses on one city to study it thoroughly, as recommended by Swanborn (2010) [70]. An exploratory approach offers openness and flexibility toward the phenomenon under analysis [70]. Merriam and Tisdell (2016) indicate that insights derived from case studies can influence procedures, policy, and future research [71]. This case study aims to develop results and conclusions that can be used by practitioners and researchers alike, when making planning and design decisions to protect UG, increasing compactness and density within compact cities. The selection of candidate cases was preceded by an analysis, the development of a protocol for the analysis, and the conduct of a pilot case study, as recommended by Yin (2018) [69].

3.2. Selection of Case Studies

The overarching goal of this paper is to analyse the transformation of UG into GHD from 2019 to 2023 in the medium-sized city of Rzeszow by evaluating the validity of references to the greenery in advertising texts on the developers' websites. Furthermore, to assess the impact of the proposed greenery-related changes on UGI. The crucial criteria for selecting an urban area in Poland for the exploratory case study were: a population between 100,000 and 500,000 inhabitants (medium-sized city), the positive natural increase in 2021 (the latest available version of the Demographic Yearbook of Poland), the need for greater compactness, density, and urban greenery to create a compact urban form that was highlighted in the latest development strategies, and the presence of GHD with available advertising websites. Potential cases were explored through documentation analysis, including online sources (e.g., the websites of municipal councils, planning departments, and Statistics Poland) and city plans through ArcGIS 10.8.2 Software and Geoportal 2 Software. The natural increase was investigated using the latest available version of the Demographic Yearbook of Poland [72]. Although many medium-sized urban areas were identified, only two cities with a positive natural increase in 2021 were determined: Rzeszow and Bialystok, both located in eastern Poland and with an advanced number of GHD. Finally, Rzeszow was selected, as GHD within urban borders significantly outnumbered those in Bialystok.

3.3. Study Area and Protocol for the Case Study

The study area is located within the city limits of Rzeszow (Poland). The first stage of the research was focused on analysing the Study of Conditions and Directions of Spatial Development (SCDSD) [73] formulated for Rzeszow to identify areas designated as UG in 2020, which have then been marked on the city map in ArcGIS 10.8.2 Software. Then, field observations were conducted to explore the state of the indicated sites, select GHD for the analysis, and the developers responsible for each of them. When considering buildings of relevance for this paper, we selected new multifamily housing with individual websites that present dwellings for sale. One potential challenge of web-based research is that internet data are not permanent [74]. When analysing online sources, it became prominent that the web data published before 2019 were not available. Therefore, the study had to be limited to these buildings, that construction started in 2019 and had been completed, or the housing estate is still under construction. The methods applied allowed the identification of 13 GHDs Finally, the specific locations of the buildings were obtained from the

Geoportal 2 software. Identifying the locations enabled drawing the 3D forms of the buildings in ArcGIS 10.8.2 software to respond to the first objective of this study; quantitative data on the transformed UGI area for GHD were calculated in the Geoportal 2 software. The square meterage of multifamily buildings above ground level was quantified for the purpose of this study. Utility buildings, car parking spaces, and hardstanding were not included in this quantitative investigation.

In the second stage, the study focused on web-based research, where developers' advertising websites were explored to collect data on the number of buildings constructed within each GHD, the number of floors, the number of dwellings, the start of the investment, and the end date. Once the basic data on the identified GHDs were collected, content analysis was conducted to investigate the written information on the advertisement websites. In content analysis, many words of a text are divided into defined categories, where words or phrases assigned to one category have similar meanings to draw conclusions [75]. According to Weber [75], problems in content analysis originate from the data reduction process, where texts are divided into words that are classified into content categories. An essential prerequisite for using content analysis is the reliability that comes from the stability, reproducibility, and precision of the results of content classification over time [76]. To address the second objective of this study, a qualitative and quantitative content analysis was conducted, followed by a visual content analysis. The first-stage coding categories were defined as outdoor activities in greenery, elements of greenery, and greenery as a building element. To explore the particular word use context, the complete sentence was coded. This approach provided structured information that allowed determining whether the meaning of specific words depends on their connection to certain phrases [69]. If so, the phrase was analysed as a single semantic unit. After the first stage of coding was completed, the second stage of coding was performed to examine the frequency of greenery-related words in advertising offers. The identified greenery-related words were named *keywords*. Coding categories were based on the use of greenery-related words or phrases in the text and were examined within the first stage coding categories. Therefore, the context of word use was crucial in assigning a greenery-related word to the coding category. The number of advertising texts that include the specific keyword and the number of instances where the keyword was used in these texts were coded in the NVivo 11 software. Accurate content analysis led to the distinction of 17 coding categories that were assigned as nodes, and this software provided the number of coded references.

Once the written content analysis was finished, the graphic information was examined using the visual content analysis method. Yet, visual products and immaterial visual traits dominate our culture [77]. Pauwels (2020) argues that the online environment is a highly productive and contemporary research field where scientists can explore the visual parameters of different graphic representations [78]. Visual techniques are suitable for nuance research methods to interpret, depict, and analyse the word [79,80]. However, visual material can be presented inaccurately on the Web, resulting in the reduction of data to draw conclusions [81]. Chaplin (1994) stated that the conclusions of visual studies might be limited to the realm of ideology [82]. In this study, architects investigate visual material presented on the web to promote GHD. As architects conduct this study, the subject focus, the modes of production, and the results belong to architectural knowledge [79]. Troiani and Ewing (2021) proposed the application of visual methods for architectural purposes and indicated the potential overlap with other disciplines, including mapping, digital drawing, or computation [79]. Wagner (2020) argued for designating research-specific categories for classification and analysis of graphics [83]. This paper analysis visual material, including renderings and plans, with respect to the level of depiction of outdoor activities in greenery, elements of greenery, and greenery as a building element. This investigation stage allowed the identification of potential NbS. Greenwashing indicators were adapted from Gałecka-Drozda et al. (2021) [7] as follows:

- GWI 1: The visual content presents unrealistic plans of green spaces: exotic plant species for the northern hemisphere, unfavourable or impossible growing conditions for the presented plant species (e.g., lack of soil, sun, or space);
- GWI 2: The visual content presents distorted greenery in the background of the housing estate;
- GWI 3: The visual content displays pre-existing trees that were cut due to the housing estate construction; and
- GWI 4: The visual content does not present greenery within the housing estate or/and in the background.

The final stage of the study analysed the interplay between the written and visual content of GHD advertising websites. Status relations analysis was conducted to assess whether text and visuals within an advertising website are consistent and complementary [84]. Specifically, correlations between written parts and visuals were investigated and assessed as equal, where the image and text are independent or complementary pieces of information; or as unequal, where the image is subordinate to text or text is subordinate to image [85]. The status relations analysis was extended by highlighting positive or negative presentation methods of greenery in texts and renderings. The positive relation was observed when the written and visual material extensively focused on greenery and indicated natural capital within and outside of the borders of GHD. The negative relation was identified when the texts and renderings presented unrealistic visions of greenery. Finally, the coherence in presenting graphic and written material was a basis for exploring whether the specific GHD advertising website presents an added ecological asset that can be considered as NbS or should be interpreted as greenwashing. The results were analysed to meet the third objective and to provide recommendations to decision-makers and the formulation of future policies relevant to protecting UGI and preventing negative impacts from GHD from negatively transforming medium-sized cities.

3.4. Brief Discussion of the Case Study's National and Urban Context

Rzeszow (50°2.4792′ N to 21°59.9406′ E) is a provincial city in Southeast Poland. The city occupies an area of 128 square kilometres, with more than 198,000 inhabitants. Rzeszow is the largest city in the Subcarpathian Voivodeship province. The natural increase per 1000 people in the first half of 2020 was 2.6%, making Rzeszow the second city in Poland with the highest birth rate [86]. At the same time, net migration to Rzeszow for permanent residence per 1000 population was the highest among provincial cities in Poland (3.6%) [86]. Rzeszow has a relatively young age profile with a median age of 39.1 in 2019, which is the lowest median age among provincial cities in Poland [86]. In 2012, Rzeszow had the highest proportion of students in higher education per number of inhabitants among all EU cities [87]. In 2020, the two public universities—Rzeszow University of Technology and the University of Rzeszow hosted together 27,500 students [88]. Since February 2022, when Russia invaded Ukraine, Rzeszow has become a strategic city that hosts refugees. Rzeszow is 100 km from the Polish—Ukrainian border crossing point in Medyka (Poland) and 170 km from the city of Lviv (Ukraine).

Rzeszow is a low-density city that consists of distinct urban and suburban neighbourhoods mainly of low- to medium-rise, with some tall buildings in the city centre. The city searches for new investment areas, mainly for housing and businesses. In 2020, building permits were issued for 4366 dwellings, and the construction of 3728 dwellings began between January and December 2020. There were 16.6% more dwellings completed in 2020 than in 2019 [86]. There are two strategies for urban growth: first, the densification of the existing urban fabric, and second, the city limits' expansion by incorporating neighbouring towns [89].

The first strategy consists of the recognition of vacant lots, which includes both greenfield and brownfield. Most greenfields within Rzeszow are not protected by law; therefore, there is no legal tool to block the issue of a construction permit [90]. Several natural landscapes have already been overbuilt with housing estates. The key greenery

located in the Wisłok Valley, actively used by urban residents for sport and recreation [91], became a location of interest for developers. Part of that green area is a designation for nature conservation that is home to a wide variety of common and rare animal and plant species. The green landscapes of the Wisłok Valley and the Wisłok Lagoon are essential to the health of the city, in terms of its ecosystem services, biodiversity, and opportunities for leisure and recreation [92].

Within the second strategy, the city limits started to expand from 2006 by incorporating neighbouring towns, to acquire new investment areas, and strengthen the role of Rzeszow as a metropolitan centre [89]. The lack of legal planning tools in these districts resulted in a haphazard urbanisation dominated by detached and terraced housing built within the farmland. The areas of suburban sprawl widen the spatial divide between the location of housing and jobs, thus increasing the demand for transport. UGI is not protected, resulting in the loss of precious agricultural land and natural habitats in peri-urban areas, leading to a poorer quality of life [4].

Considering both urban development strategies and the requirement to meet growing housing needs, the ecological security of Rzeszow faces a severe situation, such as loss of biodiversity and the heat island effect that affects human health and well-being [93]. Loss of ecosystem services due to urban development reduces cultural ecosystem values, biological and life-sustaining values [94]. The impact of the built environment on urban ecosystems and their ecological processes is now considered a crucial impediment to the sustainable development of cities [95,96]. In June 2000, the Rzeszow Development Office introduced SCDSD [73], which was updated several times, most recently in March 2020. The document conceptualises the land use zoning for the key urban areas within the administrative city boundaries from 2000 and the strategic sites incorporated later (e.g., Exclusive Economic Zones). Significant areas that were incorporated after 2006 were not included in the SCDSD. Our pilot study and preliminary field observations indicated a dramatic loss of intra-urban natural landscapes that were designated in SCDSD for UG, mainly for the development of multifamily housing. In May 2022, the Rzeszow Development Office presented an updated SCDSD and called for a public discussion before implementation. The new document encompasses the entire area of Rzeszów, accepts the transformation of UG into alternative functions, and establishes vast areas of UGI on private land located within the incorporated towns. Although public administration bodies did not respect the zoning designated in SCDSD, the municipal council asserts that the new SCDSD will be strictly obeyed when issuing land development decisions, and creates a foundation for a zoning plan that will encompass the whole city. This claim triggered protests and discussions on private land use rights, the reduction in the market value of private land, and the privileges offered by the city council to large developing companies.

4. Results

4.1. Loss of UGI Due to GHD in Rzeszow

The SCDSD analysis identified areas designated as UG in Rzeszow, which have been marked on the city map in ArcGIS 10.8.2 Software using the land use function. Field observation revealed 13 GHDs consisting of 36 multifamily buildings that had construction works carried out between 2019 and 2023 (Figures 1 and 2). Table 1 presents quantitative data on the UGI area transformed into GHD in Rzeszow from 2019 to 2023. From the data in Table 1, it is apparent that the transformed area of the UGI for GHD differs significantly from 760 square metres (single multifamily building) to 6083 square metres (seven multifamily buildings). In general, 43,852 square metres (4.3852 hectares) of land designated for UGI in SCDSD were converted to GHD between 2019 and 2023.

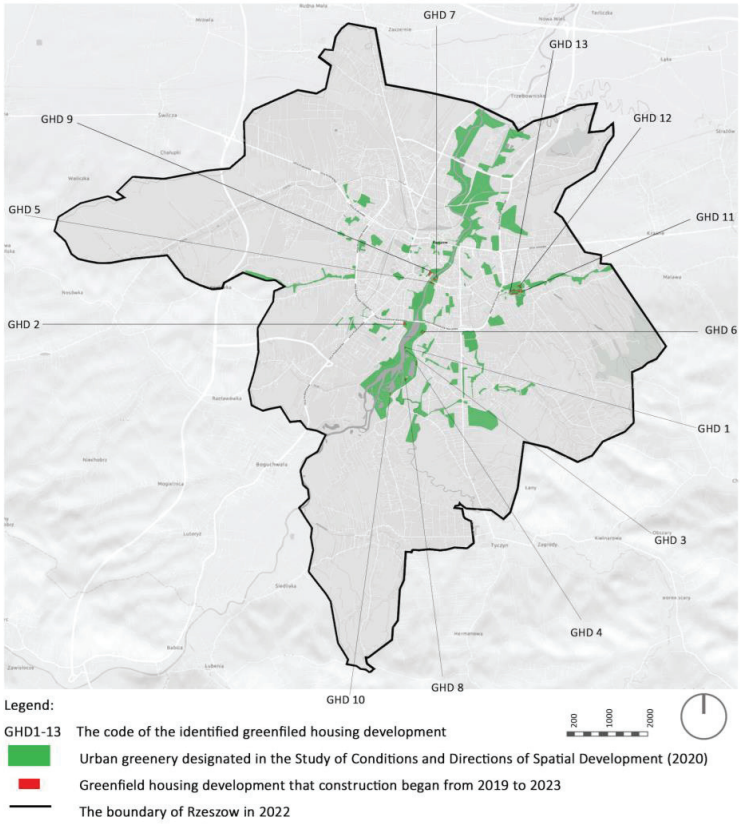

Figure 1. Map of Rzeszow: the distribution of UGI and the location of GHD that construction began from 2019 to 2023.

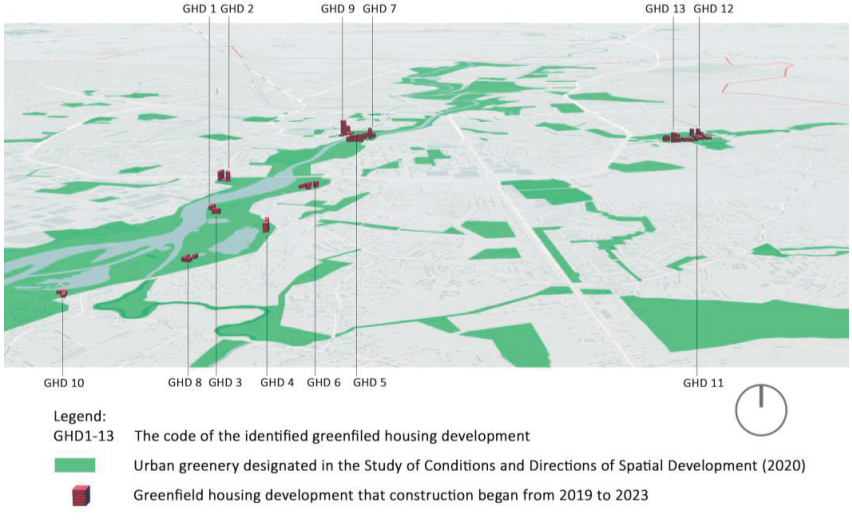

Figure 2. The distribution of GHD within UGI in Rzeszow in 2022—a perspective projection.

Table 1. Area of UGI transformed for GHD in Rzeszow (in m^2).

Housing Estate Code	Area of Transformed UGI for GHD [m^2]
GHD1	925
GHD2	4175
GHD3	760
GHD4	4050
GHD5	1822
GHD6	2244
GHD7	5256
GHD8	1355
GHD9	5226
GHD10	1270
GHD11	10,680
GHD12	3662
GHD13	2400
SUM	**43,852**

The second stage of the study focused on web-based research to gather data on the number of buildings constructed within a GHD, the number of floors, the number of dwellings, the start of the investment, and the end date (Table 2). Construction works of 30 buildings in 11 GHDs have been finished, and six buildings in two GHDs are under construction. Identified web advertising offers of 13 GHDs declared the developers would provide 3391 new dwellings for urban residents of a meterage from 24 to 300 square meters.

4.2. Using UGI in GHD Marketing Strategies in Rzeszow—Results of Web-Based Research

The reference to greenery was identified on each advertising website in the written information on GHD (100%). The frequency of reference to natural capital in advertising texts within the first stage category is presented in Table 3. The greenery-related word use context can be divided into two groups: greenery in the surroundings of the housing estate and greenery within the housing estate. The greenery in the surroundings of the housing estate was described as an asset in all advertising texts (100%). The references focused on existing UGI components (100% of the texts) and presented these components in the context of outdoor activities that are readily available to new residents (92.3% of the texts) or listed as UG elements that benefit the housing location (76.9% of the texts). Seven names of GHD (53.9%) refer to an element of the surrounding UG. Two names (15.4%) refer to a view of the surrounding greenery. One investment (7.7%) is named directly after the inner-city park which had its green cover reduced due to that GHD. Only the GHD4 advertising text (7.7%) pointed out greenery as a building element by claiming that nature is part of its architecture. However, the role and location of a specific NbS in the design were not specified.

When exploring references to natural capital within the housing estate, it was prominent that the sale offers refer to the new GI that has to be implemented due to the natural environment damage caused by the new development. Only one advertising text (7.7%) (GHD4) focused extensively on new vegetation within the housing estate. Written information included a list of potential plant species and recreational areas with specified functions, such as yoga, cycling, or walking a dog. The developer did not include data on the green cover prior to construction. Thus, based on written information, it cannot be assessed whether the greenery was expanded or minimised.

Table 2. Data on 13 GHDs that construction started from 2019 to 2023 in Rzeszow.

Housing Estate Code	Construction Date	Number of Buildings	Number of Storeys	Number of Dwellings	Meterage of Dwellings [m^2]
GHD1	2020–2021	1	8	71	40–80
GHD2	2017–2019	2	18-2 buildings	330	25–120
GHD3	2020–2022	1	9	61	39–114
GHD4	2022-under construction	2	15-1 building 15-1 building	112	35–91
GHD5	2021–2023	1	10–18	337	32–73
GHD6	2019–2021	6	11-2 buildings 6-4 buildings	300	29–109
GHD7	2017–2019	3	6-9-2 buildings 26-1 building	462	27–170
GHD8	2018–2019	2	5-1 building 5-1 building	80	37–120
GHD9	2020-under construction	2	18-1 building 36-1 building	292	40–300
GHD10	2018–2019	1	4	60	39–83
GHD11	2017-under construction	9	15-1 building, 10-1 building, 7-6 buildings, 6-1 building	800	38–120
GHD12	2017–2020	3	16-2 buildings, 11-1 building	264	24–85
GHD13	2019–2021	3	10-3 buildings	222	27–77

Table 3. The number of advertising websites that present greenery in a written material in the three coding categories.

	Coding Category (First Stage)	Number of Advertising Texts	Number of References to Greenery
1	Outdoor activities in greenery	9	20
2	Elements of greenery	12	49
3	Greenery as a building element	1	1

The second stage of the coding distinguished 17 coding categories that were assigned as keywords. Twelve advertising texts (92.3%) used keywords in the context of outdoor activities in greenery and referred to the identified keywords 20 times. Nine sales' offers (69.2%) listed keywords as elements of greenery and used the identified keywords 49 times. The data on the number of advertising texts that use specific keywords within the first stage of the coding category and the number of references to keywords in these texts are shown in Table 4.

"Greenery" and "recreational areas" were the keywords that were the most frequently used, with eleven mentioning each. Reference to "greenery" was made in four sale offers and to "recreational areas" was found in seven. Both terms were applied primarily within the "elements of the greenery" coding category, where "greenery" and "recreational areas" were listed as benefits arising from the location of GHD, thus relating to the existing UGI

in the neighbourhood. In one advertising text (GHD4), the word "greenery" was used to establish a connection between the architecture of a housing estate and nature. However, the sales offer did not specify which types or elements of greenery will be used to develop such a link; therefore, this claim is misleading and cannot be considered as introducing NbS into GHD.

Table 4. Results of the second-stage coding.

Coding Category			Number of Advertising Texts	Number of References in Texts
1	**Outdoor activities in greenery**		12	20
	1	Beach	2	3
	2	Boulevard	1	2
	3	Cycling route in greenery	6	6
	4	Greenery	1	1
	5	Harbor	1	1
	6	Jogging route through greenery	1	1
	7	Park	1	1
	8	Promenade	1	1
	9	Recreational areas	2	2
	10	River	1	1
	11	Walking route through greenery	3	4
2	**Elements of greenery**		9	49
	1	Beach	2	6
	2	Boulevard	1	1
	3	Cycling route through greenery	2	3
	4	Greenery	4	9
	5	Greenfield	3	4
	6	Harbor	1	1
	7	Lagoon	2	5
	8	Lake	4	7
	9	Nature	4	4
	10	Park	3	5
	11	Plant Species	1	6
	12	Promenade	1	2
	13	Recreational areas	6	9
	14	River	5	7
	15	Trees	1	6
	16	Walking route through greenery	1	1
3	**Greenery as a building element**		1	1
	1	Greenery	1	1

The other frequently used keywords include beach, cycling route through greenery, river, lake, park, plant species, trees, and walking route through greenery. These terms use context was outdoor activities in greenery or elements of greenery. Twelve advertisement texts applied these keywords as references to existing UGI in the neighbourhood. GHD4 extensively focused on the new GI that will serve residents and mentioned ten keywords in the context of different first-stage coding categories. The GHD4 sales offer has been identified as the one with the highest frequency of keyword coding. Table 5 presents the frequency of keyword coding in advertising texts, the total number of references and the percentage of keywords used in each first stage of the coding category.

Table 5. The frequency of keyword coding in advertising texts, the total number of references, the percentage of keywords used in each first stage of the coding category.

	Keywords	Number of Advertising Texts	Number of References in Texts	Outdoor Activities in Greenery [%]	Elements of Greenery [%]	Greenery as a Building Element [%]
1	Beach	3	9	33.3	66.7	0
2	Boulevard	3	3	66.7	33.3	0
3	Cycling route through greenery	6	9	66.7	33.3	0
4	Greenery	4	11	9.1	81.8	9.1
5	Greenfield	3	4	0	100	0
6	Harbour	2	2	50	50	0
7	Jogging route through greenery	1	1	100	0	0
8	Lagoon	2	5	0	100	0
9	Lake	4	7	0	100	0
10	Nature	4	4	0	100	0
11	Park	4	6	16.7	83.3	0
12	Plant species	1	6	0	100	0
13	Promenade	1	3	33.3	66.7	0
14	Recreational areas	7	11	18.2	81.8	0
15	River	5	8	12.5	87.5	0
16	Trees	1	6	0	100	0
17	Walking route through greenery	3	5	80	20	0

All GHD advertising websites (100%) used photorealistic renderings as the main graphic content that presented a housing estate from a human-eye view or a bird-eye view. Most renderings show greenery in a schematic, simplified manner in the form of a grass, trees of various sizes, flowers with intensive colours, and ornamental bushes. The graphic content of two advertising websites (GHD4 and GHD11) included site plans that present GI as part of the investment. The advertising websites of three GHDs (GHD1, GHD5, GHD9) provided animations that accurately showed the housing estate in the urban context.

Eight advertising websites presented greenery in the context of specific outdoor activities. The renderings show activities that use GI in the surroundings of the housing estate, including cycling (30.8% of GHD), jogging (46.2% of GHD), walking (53.9% of GHD), and boating (7.7% of GHD). Eight advertising websites show outdoor activities within the new infrastructure developed as part of housing estates investments, including cycling (15.4% of GHD), jogging (7.7% of GHD), and walking (61.5% of GHD). All sales offers presented natural capital in the *elements of greenery* coding category. Six websites (46.2%) that advertise GHD located in the Wisłok Lagoon have shown renderings that include a

view of the housing estate and its surroundings, especially UGI with recreational areas along the Wisłok River. Seven GHDs (53.9%) were advertised by presenting renderings without the vicinity, of which six were not located within the UGI along the Wisłok River. In six advertising websites (46.2%), the graphic content shows *greenery as a building element*: green walls, green roofs, and trees on roofs and balconies. The number of websites that present greenery in a visual material in the three coding categories is shown in Table 6.

Table 6. The number of advertising websites that present greenery in a visual material in the three coding categories.

	Coding Category	Number of Advertising Websites That Present Greenery in Visual Material
1	Outdoor activities in greenery	8
2	Elements of greenery	13
3	Greenery as a building element	3

The visual presentation of greenery implemented as NbS can be recognised in the two coding categories: *elements of greenery* and *greenery as a building element*. Within the category *elements of greenery*, NbS were applied at the site plan level in the visual presentation of two GHD (15.4%) as trees that prevent extensive sun access to glass elevations and flower fields. In the category *greenery as a building element*, green walls, green roofs, and balconies were identified as potential NbS that directly support architecture and were present in the graphic content of six GHD (46.2%).

The results of the visual content analysis on GWI have shown that the most common practice is to present distorted greenery in the background of the housing estate (69.2% of GHD) which was classified as GWI 2. In most cases, the background was falsely covered with large concentrations of trees and dense vegetation along busy roads. The second practice (53.9% of GHD), classified as GWI 1, is to show unrealistic plans for green spaces. The graphic content of 7 GHDs presented large trees planted in small pots or without soil on balconies and terraces. The renderings of 2 GHDs showed facades partly covered with vegetation without access to soil. GWI 3: the visual content displays pre-existing trees that were cut due to the housing estate construction was identified in three advertising websites (23.1%). GWI 4 was revealed in one sales offer (7.7%) that did not present greenery in the background of the housing estate despite the extensive presence of UGI. No GWI was found in the two offers (15.4%). The results of the visual content analysis on the greenwashing indicators are shown in Table 7.

Analysis of the interplay between the written and visual content of the GHD advertising websites with respect to existing and newly implemented greenery revealed that the visual content of the web sales offers focuses more on the presentation of greenery than the written content (Table 8). The strongest disproportion was observed with respect to the written and visual material that presents greenery as a building element. Although 53.8% of the websites showed GI as parts of facades or rooftops in the renderings, only 7.7% of the sales offers mentioned the interaction between architecture and nature in the written content. The crucial strategy to highlight the role of nature in GHD was to indicate elements of this greenery. Furthermore, 92.3% of the texts focused on listing greenery elements, and 100% of the renderings included greenery with a human-related context. Advertising material for four GHD (30.8%) was evaluated as having equal negative relations between written and graphic content. These sales offers include abstract green claims on UGI located outside housing estates as beneficial to potential residents; however, they did not include information on greenery within housing estates. Similarly, the renderings did not present vegetation within these GHDs but showed an extensive UGI that belongs to the public recreational areas. The web offers of three housing estates (23.1%) revealed an equal positive relation between written and graphic content. An extensive focus on greenery was noted in texts and renderings and included natural elements within housing estates and in the surroundings. Natural capital was presented mainly in the context of

outdoor activities in greenery and elements of greenery. Furthermore, the visual material of GHD9 and GHD11 (15.4%) presented nature as a building element. The status relation analysis showed an unequal relationship between the written and graphic content of six GHD (46.2%). For four GHD (30.8%), the attributes of greenery were loosely introduced in the texts (GHD1, GHD6, GHD12, GHD13), while the graphic material presented detailed vegetation within the housing estate, as elements of the buildings and the surroundings. The role of nature in GHD7 and GHD10 (15.4%) was not included in the written content, but UGI in the neighbourhood was recognised as beneficial for the location. The web graphic material of GHD7 and GHD10 (15.4%) showed greenery within the housing estate and as a building element; however, the surroundings of the lot were not presented.

Table 7. GHD: the results of the visual content analysis on GWI.

Housing Estate Code	GW Indicators				No of GWI
	GWI 1	GWI 2	GWI 3	GWI 4	
GHD1	-	+	+	-	2
GHD2	-	+	-	-	1
GHD3	-	-	-	-	0
GHD4	-	+	+	-	2
GHD5	+	-	-	-	1
GHD6	-	+	-	-	1
GHD7	+	+	-	-	2
GHD8	-	-	-	-	0
GHD9	+	+	-	-	2
GHD10	+	+	-	-	2
GHD11	+	+	+	-	3
GHD12	+	-	-	+	2
GHD13	+	+	-	-	2
%	53.9	69.2	23.1	7.7	

- GWI not identified in the visual advertising material of GHD. + GWI identified in the visual advertising material of GHD.

Table 8. The status relations analysis between the written and graphic content of GHDs' advertising websites regarding the three thematic categories: outdoor activities in greenery, elements of greenery, and greenery as a building element. (+ the presence of the indicator in the website content; - the absence of an indicator in the website content).

Housing Estate Code	Status Relation Analysis						Results of the Status Relation Analysis
	Written Content			Graphic Content			
	Outdoor Activities in Greenery	Elements of Greenery	Greenery as a Building Element	Outdoor Activities in Greenery	Elements of Greenery	Greenery as a Building Element	
GHD1	-	+	-	+	+	+	Unequal
GHD2	+	+	-	+	+	-	Equal Negative
GHD3	+	+	-	+	+	-	Equal Negative
GHD4	+	+	+	+	+	-	Equal Positive

Table 8. *Cont.*

Housing Estate Code	Status Relation Analysis						Results of the Status Relation Analysis
	Written Content			Graphic Content			
	Outdoor Activities in Greenery	Elements of Greenery	Greenery as a Building Element	Outdoor Activities in Greenery	Elements of Greenery	Greenery as a Building Element	
GHD5	+	+	-	+	+	-	Equal Negative
GHD6	-	+	-	+	+	-	Unequal
GHD7	-	+	-	-	+	+	Unequal
GHD8	+	+	-	+	+	-	Equal Negative
GHD9	+	+	-	+	+	+	Equal Positive
GHD10	+	+	-	+	+	+	Unequal
GHD11	+	+	-	-	+	+	Equal Positive
GHD12	+	-	-	+	+	+	Unequal
GHD13	-	+	-	+	+	+	Unequal
%	69.2	92.3	7.7	84.6	100	53.8	

5. Discussion

The first objective of the current study was to highlight the changes in land use of areas that were allocated to UGI in Rzeszow from 2019 to 2023. Research revealed that GHD in Rzeszow took 43,852 square metres (4.3852 hectares) of land designated for UGI. The advertisement material for 13 GHDs declared to provide 3391 new dwellings for urban residents of the size of 24 to 300 square metres. The second objective of this paper was to analyse the use of greenery in the written and visual content of the GHD marketing websites and to evaluate whether the applied strategy represents an added ecological asset that can be considered as nature-based solutions (NbS); or these claims should possibly be interpreted as greenwashing. Contrary to previous studies [7,97], the advertising materials were not structured around the natural asset, but stressed the quality of architecture and the inner-city location to highlight the prestige of the housing estate. The present investigation confirmed the findings of Maruani and Amit-Cohen (2013) who revealed that landscape values are important in presenting the prestige of the housing environment in advertising campaigns [97], among other elements, including the development of gated communities [98,99], the use of foreign languages [100,101], and the creative incorporation of various symbols of prestige [101,102]. In this study, keywords related to greenery were found in all web texts; however, in most cases, they did not play a significant role in written content, but were mentioned in relation to activities available to residents or listed among other elements of the vicinity. Twelve of 13 web texts (92.3%) focused on UGI outside of GHD in the context of outdoor activities within greenfields that are provided to all urban residents by the city. Nine out of 13 web texts (69.2%) focused on listing the elements of greenery, which in the majority belong to existing UGI. Only one GHD sales offer (7.7%) described green incentives exclusively for future owners. Greenery as a building element was mentioned in one GHD description (7.7%); however, no specific technology was provided. The visual content extensively focused on showing nature within GHD and in the surroundings in the context of outdoor activities in greenery (61.5% of GHD), elements of greenery (100% of GHD) and greenery as a building element (23.1% GHD). The study revealed a greater focus of graphic content on greenery than in texts. These results are in accord with recent studies indicating that graphic tools and methods

used to prepare renderings can trigger specific emotions, which is relevant for advertising purposes [103,104]. For instance, the lower colour saturation of pictures results in an eternal or romantic aura [105]. Visualising extensive greenery in the background of the housing estate triggers positive emotions in buyers and creates the vision of their future lifestyles as active and close to nature while still in the central urban districts. The presentation of greenery in visual advertising content contributes to the prestigious image of GHD, due to the presence of UGI in the vicinity, while the access to landscape values in new housing estates in other locations is not always obvious.

At least one of the four GWIs defined in the study was found in the visual material of 11 GHDs (84.6%). Two GHDs, which did not reveal GWI in graphic content, did not present extensive greenery within the project. In these two GHDs, the only natural element shown in the renderings was realistic or photorealistic UGI in the vicinity. Analysis of the use of greenery in the written and visual content of GHD websites revealed the lack of understanding of the concept of NbS and identified greenwashing in all advertising materials. As studies critically point out, GHD advertising campaigns present environmental—economic visions that are difficult to validate after the investment is completed [55,58]. The present investigation supports the findings of Tateishi (2018) who revealed that the greenwashing of the real estate market, especially GHD, restricts efforts to minimise the adverse environmental impacts of urban development by reducing global ecological capacity [54].

Claiming the benefits from the existing UGI, in the majority by using two keywords, greenery and recreational areas, showed that developers in Rzeszow do not consider the provision of natural capital and associated ecological values within the housing estate as an obligation that increases the prestige of the investment. At the same time, green marketing strategies have been implemented by using greenery-related keywords and an extensive presentation of greenery in renderings, indicating that developers understand the importance of the human—nature relationship in a housing environment and the willingness to live close to greenery. These results reflect those of Maruani and Amit-Cohen (2013) who found that the symbolic presence of nature-related terms in housing estate names supports their prestigious image as spaces of leisure, wellbeing, and good life in general [97]. As stated by Gałecka-Drozda et al. (2021) and Tateishi (2018), green marketing positively influences the perception of a housing estate and generates a stronger intent to purchase the product [7,54]. Developers claim that UGI in the vicinity is an opportunity for future owners to live near green landscapes and include outdoor activities in their daily routine. However, the location of the investment within the existing UG became a pretext for developers to reduce the greenery within the GHD limits in favour of increasing the density of buildings and the built-up share in the project area, resulting in higher financial profits. The construction of GHD is of interest to developers because of the UGI in the surroundings, which is readily available and can become a beneficial element of advertising campaigns without additional financial investment.

The limited presence of NbS on GHD websites has been identified in written and visual content. Only one GHD sales text claimed the supporting role of nature to architecture, but did not specify how such a relationship would be realised. In the visual material, NbS were shown in six GHDs (46.2%) using natural capital at the site plan level (two GHD) and with connection to architecture. The NbS related to architecture included green roofs, green facades, and plants on balconies and terraces, which belong to future owners of apartments. The study considers the presented NbS to be misleading green claims, which corroborate the findings of Gałecka-Drozda et al. (2021) who noted that maintenance of NbS within private areas is not a developer's responsibility, but depends on the acceptance of property owners and their involvement in maintenance [7]. Furthermore, the web offers analysed did not specify technologies that contribute to the environmental sustainability of GHD. The case study revealed that despite growing global environmental awareness, the housing estate market in Rzeszow is not progressive and does not contribute to urban resilience and sustainability. According to the report, "*Who pays for green? The economics of sustainable buildings*" [106], green buildings require 5% to 7.5% additional construction

costs. The higher initial investment may be the current barrier for developers in medium-sized cities to choosing outdated technologies and not applying NbS Zhang, Wu, and Liu (2018) noted that the inconsistency in economic viability can slow the construction of green buildings and suggested that increased comfort and health of residents should be included in the benefit analysis [107]. For medium cities, the lack of evidence on immediate opportunities arising from sustainable housing estate planning may be the crucial factor that limits the implementation of novel solutions. The general benefit of providing new dwellings for the growing urban population outweighs the environmental damage in a short-term perspective. Recent technological advancements and tools are recommended to test methods that support the decision-making process in choosing sustainable low-cost building materials and components [108] and creating a supportive relationship between existing UGI and new developments through NbS [109,110] as a socially inclusive process [111].

Misleading marketing material is commonly used for greenwashing of projects. The researchers have identified different types of greenwashing:

- Greenlighting occurs when company communications (including information on websites and advertisements) spotlight a particularly green feature of its operations or developments, however small, in order to draw attention away from environmentally damaging activities being conducted elsewhere.
- Greenlabelling is a practice where marketers call something green or sustainable, but a closer examination reveals that their words are misleading.
- Greenhushing refers to the act of corporate management teams' under-reporting or hiding their sustainability credentials in order to evade consumer, buyer, or investor scrutiny.

6. Conclusions

In our urban future, much will depend on how we develop, plan, design, build, and manage new housing estates; socially, economically, culturally, and environmentally. Our journey to identify better pathways for a circular transition of urban settlements is still in its infancy, where cities become drivers of future change using systemic thinking of the zero-waste concept, the circular economy, and regenerative design principles. We will not achieve the transformation toward the regenerative city of the 21st century if we keep applying outdated urbanisation models from the 20th century. Higher densities are unavoidable. However, 'quality density' is required, accommodating growth through careful densification, and developing first the vacant lots that are inside the existing city. New housing should be constructed in already built-up areas with existing infrastructure, rather than creating more GHD.

The main aim of the study was to analyse the transformation of UG into GHD from 2019 to 2023 in the medium-sized city of Rzeszow (Poland) by evaluating the validity of references to the greenery in advertising texts on the developers' websites. Furthermore, to assess the impact of the proposed greenery-related changes on UGI. The results of this investigation showed that GHD in Rzeszow took 43,852 square metres (4.3852 hectares) of land designated for UGI between 2019 and 2023. The GHD advertising websites do not represent an added ecological asset but committed greenwashing. All GHDs caused irretrievable environmental damage, including the degradation of wetlands, greenfields, and trees. The written and graphic content of the advertising websites do not define the environmental indicators of the housing estates, including how the GHDs would compensate for the destruction of natural habitats. Deceptive green claims were more often identified in visual material, which was prepared inaccurately, than in texts, which extensively used greenery-related jargon, however, vaguely. GHD marketing campaigns in Rzeszow are based on the lack of knowledge of potential buyers and their lack of understanding of the significant ecological costs of their potential place of living, which was intentionally unmentioned in the advertising material and replaced by deceptive green claims.

The research findings raise some critical points around integrity and correctness of the marketing texts. The act of making false and misleading claims about the environmental benefits of GHD to appeal to environmentally conscious buyers might be considered as greenwashing. Project developers engage in greenwashing to improve their image, boost sales, and avoid criticism from environmental organisations. Here are some key points on how they used greenwashing and made unsubstantiated claims in their promotional materials and websites:

- Misleading claims: Several developers made false or exaggerated claims about the environmental benefits of their projects, such as "carbon neutral" or "eco-friendly", without providing credible evidence to back up these claims.
- Lack of transparency: Developers used vague or ambiguous terms to describe their environmental practices, making it difficult for buyers of apartments to verify their claims.
- Hidden trade-offs: Developers promoted one environmental aspect of their project while ignoring other negative impacts, such as the loss of green space.
- Greenwashing of harmful materials and products: Some developers greenwashed products or construction materials that they have used for the building that have negative impacts on the environment, such as toxic paints and materials that impact the interior environment and indoor air quality.
- Non-compliance with regulations: Many countries, including Poland, have regulations in place to prevent greenwashing, but developers still engage in this practice by making false or misleading claims that are not prohibited by law.

The greenwashing activities can include: the use of seasonal jargon, push-to-sell by non-domain expert consultants (using sustainability buzzwords for PR with glossy brochures), fabrication of data, starting with high ambition but without tangible paths to an outcome, and self-congratulating "trust barometers".

The third objective of the study was to provide recommendations to decision-makers for the formulation of future policies relevant to protecting UGI and in order to prevent negative impacts from GHD from negatively transforming medium-sized cities. Such a list of recommendations might include:

- A clear list of possible actions that the local government and the development industry should pursue.
- Modifying building codes to make regenerative development practice for new urban neighbourhoods the norm.
- Demonstrating the benefits through exhibition and debate, highlighting the capabilities of NbS, enhancing awareness, educating the planning and design professions.
- Using the opinions of committed investors, and actively engaging owners and occupants of new housing developments to promote positive change.
- Accompanying the realisation of new types of urban neighbourhoods with performance data monitoring to provide scientific data as evidence base.
- Identifying the facilitators of and barriers to design/technology transfer with industry, university, and government partners, and produce a feasibility report for investors identifying the most commercially viable solutions for the determined market with a roadmap for implementation of regenerative planning.
- Ensuring longevity and impact of the implemented strategy for the creation of technical specification literature that lists practical and achievable solutions.
- Advancing evidence-based policy and planning practices through a user-centred approach to post-occupancy evaluation and effective understanding of feedback.
- Encouraging all levels of the government to take the lead in innovative urban development by implementing a scheme of incentives for the construction of regenerative housing developments (e.g., by allowing a higher plot ratio if the buildings follow and apply the principles identified, and if these are likely to become an important demonstrator project for other urban developments).

- Producing peer-reviewed publications to ensure market confidence including the wide dissemination of standardised information on regenerative urban development in different cities.

The study is limited to medium-sized cities and does not investigate the quality of housing estate investments, but focuses on the use of UG for advertising and raises questions on the impacts on urban sustainability. The paper focuses on these areas in Rzeszow that were allocated to UGI. The remaining UG transformed in GHD is not included in the analysis.

Future research should focus on implementing the defined recommendations for improving UGI. Indicators and evidence on the benefits of NbS in multifamily housing and brownfield regeneration for new neighbourhoods must be defined to implement research-based and regenerative design that responds to the context-specific needs of a medium-sized city. An interview study with developers is recommended to better understand their drivers and motivations for taking over UGI and greenwashing for advertising purposes. It is recommended to conduct a similar study in a different country or region to compare the results and provide more detailed recommendations that can be used as a starting point for strategies and policies aimed at reducing greenwashing in housing estate advertising campaigns.

Author Contributions: Conceptualization, M.S.-M. and S.L.; Methodology, M.S.-M.; Software, M.S.-M.; Validation, S.L.; Formal analysis, M.S.-M.; Investigation, M.S.-M. and S.L.; Resources, M.S.-M. and S.L.; Writing—original draft, M.S.-M. and S.L.; Writing—review & editing, M.S.-M. and S.L.; Project administration, M.S.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data available in a publicly accessible repository that does not issue DOIs. Publicly available datasets were analyzed in this study. This data can be found here: https://brmr.erzeszow.pl/studium-uwarunkowan-i-kierunkow-zagospodarowania-przestrzennego-miasta-rzeszowa/studium-uwarunkowan-i-kierunkow-zagospodarowania-przestrzennego-miasta-rzeszowa-obowiazujace/.

Conflicts of Interest: The authors declare no conflict of interest.

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Adopting Resilience Thinking through Nature-Based Solutions within Urban Planning: A Case Study in the City of València

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Abstract: The paper exposes the experience of València in applying climate-resilient thinking to the current revision of the city's General Urban Development Plan. A semi-quantitative, indicator-based risk assessment of heat stress was carried out on the 23 functional areas of the city sectorized by the Plan, including modeling and spatial analysis exercises. A data model of 18 indicators was built to characterize vulnerability. A thermal stress map was developed using the URbCLim model and a heat index was then calculated using Copernicus hourly data (air temperature, humidity, and wind speed) for the period of January 2008–December 2017 at a spatial resolution of 100 m × 100 m. General recommendations at the city level as well as guidelines for development planning in the functional areas at risk are provided, with specifications for the deployment of nature-based solutions as adaptation measures. From a planning perspective, the study positively informs the General Urban Development Plan, the City Green and Biodiversity Plan, and contributes to City Urban Strategy 2030 and City Missions 2030 for climate adaptation and neutrality. Applying the same approach to other climate change-related hazards (i.e., water scarcity, pluvial flooding, sea level rise) will allow better informed decisions towards resilient urban planning.

Keywords: resilience; climate change; risk; adaptative planning; nature-based solutions

Citation: García-Blanco, G.; Navarro, D.; Feliu, E. Adopting Resilience Thinking through Nature-Based Solutions within Urban Planning: A Case Study in the City of València. *Buildings* **2023**, *13*, 1317. https://doi.org/10.3390/buildings13051317

Academic Editors: Steffen Lehmann and Monika Szopinska-Mularz

Received: 29 April 2023
Revised: 15 May 2023
Accepted: 16 May 2023
Published: 18 May 2023

1. Introduction

In a scenario of population growth and usually limited municipal budgets, cities must face increasingly complex challenges, such as the management of land, waste, and energy, assurance of water quality and rainwater management, reduction of air, soil, and noise pollution, mobility management, creation of economic opportunities, maintenance and increase of biodiversity, food security, health and well-being, a progressively more inclusive, fair, and equitable society, as well as the more pressing need to fight and adapt to the effects of climate change [1].

The Intergovernmental Panel on Climate Change (IPCC), already in its fifth iteration and now with its sixth evaluation report, reaffirms climate change as a verifiable reality that entails a progressive change in climate variables as well as an increase in the frequency and severity of extreme events (i.e., floods, heat waves, storms). It also concludes that, even if there was the economic and political will to immediately stop all greenhouse gas (GHG) emissions that are causing the increase in global temperature and pollution, the damages to the functioning of the climate that generates the impacts already considered is, in many cases, irreversible and irreparable, such as the melting of the polar ice caps and the consequent sea level rise [2,3].

On the other hand, from a disaster risk management perspective, cities have a leading role to play in managing the risks [4] associated with climate change, such as those due to extreme temperatures. In this sense, the Sendai Framework for Disaster Risk Management [5] of the United Nations promotes the adoption of measures to limit exposure, reduce vulnerability, increase capacity, and attenuate hazards in order to reduce existing risks and prevent new risks.

Mitigation, understood as human intervention to reduce emission sources or improve GHG sinks, is therefore essential, since more than 40% of total GHGs are emitted by human activities [2], but insufficient. Adaptation, as the process of adjusting our socio-ecological systems to the current or expected climate and its effects, becomes imperative [1,6].

Urban areas can be understood as complex socio-ecological systems that are directly and/or indirectly co-responsible for global change through their contribution to GHG emissions and, at the same time, receptors of the usually adverse climate impacts [7]. Currently, the share of the urban population in the world's population has reached 56%, which is expected to increase to 9.7 billion by 2050, with 68% of inhabitants living in urban areas [8]. Despite the fact that estimates of global urban land stated in various sources vary widely from less than 1% to 3%, mainly due to different definitions of urban land [9], urbanization processes affect the sustainable use of natural resources and put important pressure on ecosystems. Moreover, cities are supposed to be responsible for most of the emissions. The World Resources Institute Global identified greenhouse gas emissions by sector in 2016 as follows: energy use in buildings: 17.5% (commercial: 6.6%, residential: 10.9%); transport: 16.2%; energy use in industry: 24.2%; agriculture, forestry, and land use: 18.4%; waste disposal: 3.2%; and industry: 5.2% [10].

The artificialization process, motorized mobility, energy demand, and loss of soil permeability cause important changes in the water cycle, and thermal stress derived from the intensification of the urban heat island effect may also cause environmental, economic, and social damages. These damages include impacts on health conditions, especially to elder generations [11], harm to housing and infrastructure, loss of business or loss of productivity, and increased household and public service energy demand, among others. Given this situation, despite essential efforts at the global level with large-scale international agreements, certain decisions and actions can and should be conducted at the local level.

In this context, urban planning and management can be seen as a powerful instruments through which climate action could be effectively integrated from both mitigation and adaptation perspectives, combining coping, adaptive, and transformative capacities to build more resilient territorial and city models [1,7].

Depending on the administrative structure and the distribution of powers and responsibilities, many local authorities have robust resources and capacity for climate action, especially relevant from the perspective of adaptation, through the articulation of local policies such as urban planning, drinking water supplies, sanitation networks and wastewater treatment, the management of roads and public spaces, environmental protection, and public health [1,12].

In this context, it is worth noting that the European Strategy for Adaptation to Climate Change 2021 [13], like the previous 2013 strategy, recognizes spatial and urban planning as the main disciplines through which climate action should be implemented due to their ability to coordinate sectoral policies and land use decisions. Additionally, in the same direction, the European Commission's proposal for the first European Climate Law aims to turn into law the goal set out in the European Green Deal: that the European economy and society become climate neutral by 2050 [14]. Spatial and urban planning have a relevant role to play in achieving this goal.

In Spain, the potential of spatial and urban planning to address climate change was recognized at the state level by Law 7/2021 on 20 May, entitled the Climate Change and Energy Transition Law [15]. In its fourth and final provision, the law modifies the consolidated text of the Land and Urban Rehabilitation Law, approved by Royal Legislative Decree 7/2015 on 30 October, incorporating the need to consider the risks arising from climate change in land use planning [16]. Although it is too soon to really evaluate the impact of this modification of the Land and Urban Rehabilitation Law, it is expected to be a remarkable catalyst towards more resilient planning in the Spanish context.

The renaturing of cities through increased emphasis on the use of nature-based solutions (NbS) has been gaining significance in the climate change context in recent years,

since it offers urban areas the opportunity to deliver multiple environmental, social, and socio-economic benefits with blue and green non-regret interventions [7].

NbS are conceived as interventions that use natural ecosystems or incorporate elements inspired by nature and its processes, such as green roofs and facades or natural lamination rafts, among others, to help society cope with climate change. This approach values multifunctionality and the environmental, social, and economic co-benefits of NbS being able to simultaneously respond to different urban challenges, as well as with good cost-effectiveness ratios [7,17–20].

To successfully deploy NbS to address climate change, it is important to have a good understanding of the existing environmental conditions and evaluate the spatially explicit distribution of risks and vulnerabilities within the city in order to identify the areas in need of priority action [1,21–24].

1.1. Context and Description of the Case Study

València is the capital city of the Autonomous Community of València. The city is located on the eastern Mediterranean coast of Spain and is the third largest city in the country demographically and economically. In 2021, the population was 800,180 inhabitants, which amounted to 1,581,057 inhabitants if its metropolitan area was included, thus being the third most populated city in Spain after Madrid and Barcelona. Its climate is characterized by hot summers and low rainfall, with episodes of heavy rain. Climate change predictions suggest that higher temperatures, less precipitation, and more extreme weather episodes associated with rainfall and heat wave events are likely.

The vision and development principles that guide the municipal public policies and the plans and strategies developed by the city of València are those of a 21st century city: healthy, free of emissions and pollution, green and natural, participatory, supportive, and inclusive, tailored to people. This vision and these principles emerge in the city's Urban Agenda 2030 [25], for which the design, proposed by the municipal government, followed a co-participatory process in which almost all municipal departments and the representatives of the civil society were actively involved. Within Urban Agenda 2030, València also launched València Climate Missions 2030, which proposed four axes—healthy city, sustainable city, shared city, and entrepreneurial city—to develop strategic lines that cover the objectives of sustainable development, with an important focus on addressing climate change and energy transition [26].

At the regional level, València has a mature territorial and urban planning system that is specified in Law 5/2012, entitled Territorial Planning, Urbanism and Landscape of the Valencian Community. This law describes the articulation of multi-scale planning instruments, including the Territorial Strategy of the Valencian Community, Territorial Action Plans, the General Urban Development Plan, and other multisectoral strategic territorial actions. The Territorial Strategy of the Autonomous Community of València also includes specific formulas for territorial governance, which allow administrative and public–private cooperation and coordination to develop dynamic projects in the territory, with a complementary distribution of powers between public administrations at regional, provincial, and local levels. Law 6/2022 was approved on 5 December 2022, entitled Climate Change and Ecological Transition of the Valencian Community, which was considered a very relevant step towards resilience in the region [27].

From the early 2000s, the city of València has joined a series of climate action initiatives, starting with the Covenant of Mayors signed in 2009, with the commitment to reduce GHG emissions by 20% by 2020 through the approval of a Sustainable Energy Action Plan (SEAP) 2010, followed by the Strategy Against Climate Change València 2020 in 2011. The integration of two previous plans, the Environmental Action Plan—which formed part of the Local Agenda 21 process—and the SEAP itself, led to new commitments in 2014 and the Covenant of Mayors for Climate and Energy 2015. In 2017, the València 2050 Plan for Adaptation to Climate Change was published in collaboration with the different areas of the City Council involved. In April 2019, the municipal plenary session approved the

Sustainable Energy and Climate Action Plan (SECAP). In September 2019, the municipal plenary session approved the Climate Emergency Declaration. In August 2020, the City's Energy Transition Board, made up of representatives from all social sectors of València (NGOs, academia, public, and private), was created to develop a participatory roadmap towards decarbonization. In September 2020, the municipal plenary session approved the València 2030 Strategic Framework Agreement, an urban agenda tool aimed at accelerating the transition towards a more sustainable, healthier, more shared, and more prosperous city. In February 2021, the municipal plenary session approved the 'València neutral city' mission aimed at achieving climate neutrality in three city neighborhoods by 2030. In March 2021, the municipal plenary session approved adherence to the Green City Accord, a commitment by European cities to the conservation of the environment, agreeing to take measures to improve air quality, the use of water, and the conservation of urban biodiversity, moving towards a circular economy, circular urban planning applying retrofitting approaches and multifunctionality of spaces, and reduction of noise pollution, as objectives to be met by 2030.

1.2. Climate Change Related Hazards in València

The most relevant climate-related hazard in València is heat stress, with an extraordinary impact on human health and well-being that is foreseen to worsen in the coming decades due to climate change. The historical data collected for average temperature in València in the period 1951–2022 showed an increasing trend (Figure 1). The period 1994–2021 was among the warmest years on record for surface temperature (except 2010).

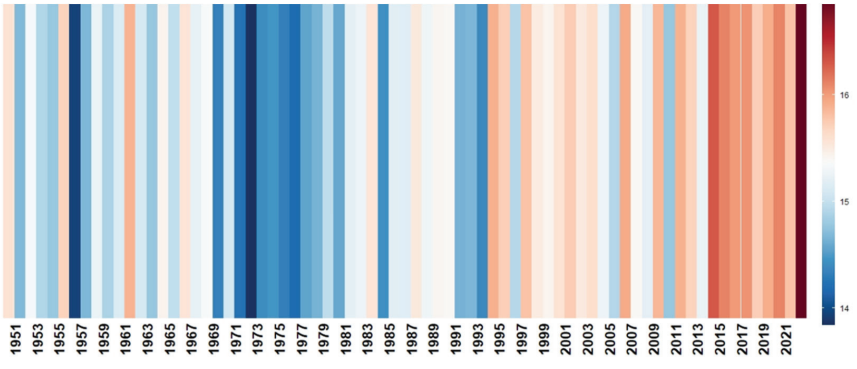


Figure 1. Representation of the average temperature of the València observatory in the period 1951–2022 through "warming stripes." Source: Spanish Meteorological Agency AEMET Comunitat Valenciana.

The following figures show temperature projections (based on Euro-CORDEX) for the future climate change scenarios RCP 4.5 and 8.5 as well as observational data. The evaluation of all of the indicators analyzed in relation to temperature indicated a positive trend. Notably, this increase in temperatures was even greater for the RCP 4.5 climate scenario from 2040 onwards.

As shown in Figure 2, by the end of the century, the maximum annual temperature may rise between 1.8 and 3.2 °C, with respect to the reference period (RCP 4.5 and 8.5, respectively). In addition, climate models show that this increase would be greater for annual minimum temperatures rising between 2.1 and 4.0 °C.

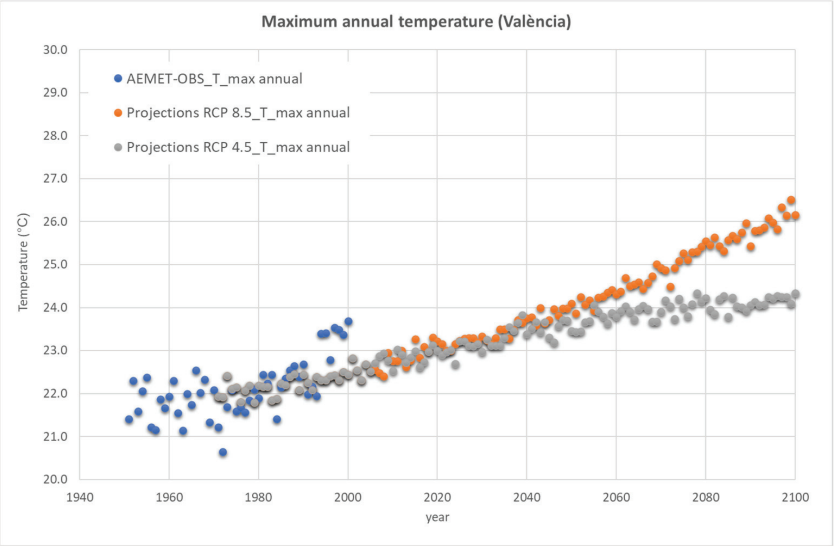


Figure 2. Maximum annual temperature in València. Reference period 1971–2000. Source: Processed from data from Adaptecca's climate scenario viewer.

In addition, climate models show a decrease in the number of days below freezing (Tmin < 0 °C) that, together with the decrease in duration and frequency, predict the disappearance of cold waves in the RCP 8.5 scenario for the last half of the XXI century.

Regarding temperature-related extreme events associated with thermal comfort and the well-being of the population, projections show an increase in the duration of heat waves as well as an increase in the number of warm nights (number of days in a period in which the minimum temperature exceeds the 90th percentile of a reference climatic period), which may be between 2 and 3 times more frequent by the end of the present century.

On the other hand, in the last decade there has been a slight increase in the duration and frequency of heat waves (Figure 3). This increase in the maximum duration of heat waves may mean an average duration of heat waves of around 17 days between the years 2010 and 2039, i.e., double the average duration of the historical period 1971–1980.

1.3. The Revision of the General Urban Development Plan of València: An Innovative Approach

In 2018, the València city council started revising the General Urban Development Plan using an innovative approach, which was awarded a prestigious national award by the Spanish Training and Urban Development Foundation.

The revision of the General Development Urban Plan applied an innovative approach with a strong spatial component that materialized in the delimitation of 23 functional planning areas, as described in the Special Plan of Urban Quality Guidelines of València [28] (Figure 4).

The 23 functional areas resulted from an analysis of historical development, physical support, as well as administrative division of the city. However, some areas, specifically the outermost areas, exceeded the administrative boundaries of the municipality, so existing interactions with the adjoining municipalities of Mislata and Xirivella should be studied.

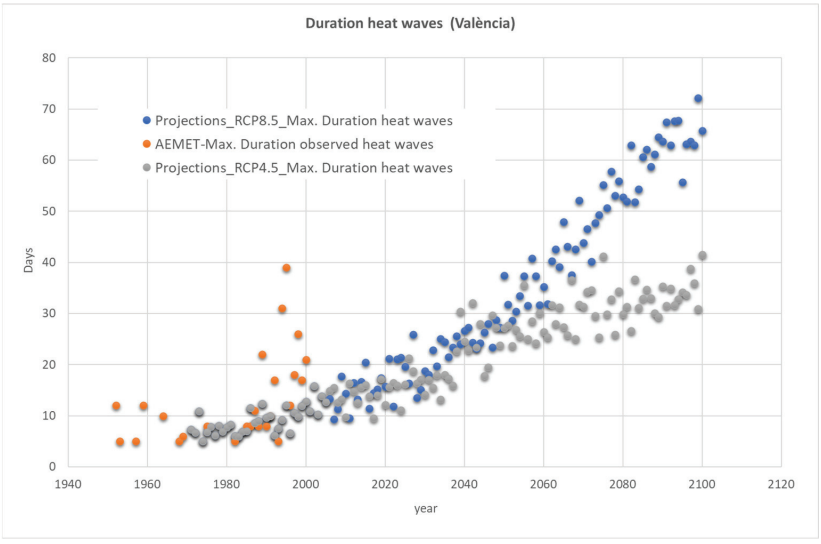
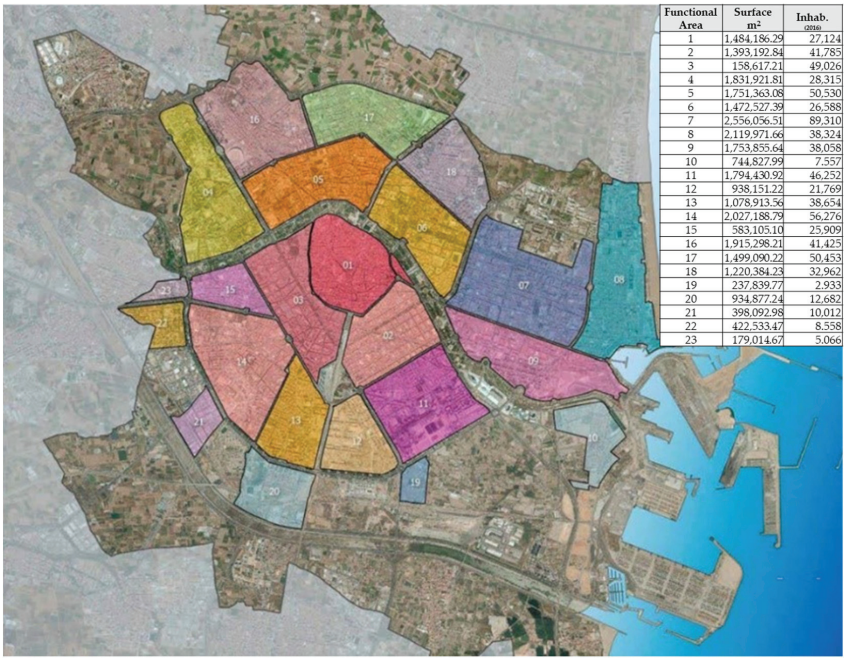


Figure 3. Maximum duration of heat waves in València. Reference period 1971–2000. Source: Proceeding from data from Adaptecca's climate scenario viewer.



Functional Area	Surface m²	Inhab. (2016)
1	1,484,186.29	27,124
2	1,393,192.84	41,785
3	158,617.21	49,026
4	1,831,921.81	28,315
5	1,751,363.08	50,530
6	1,472,527.39	26,588
7	2,556,056.51	89,310
8	2,119,971.66	38,324
9	1,753,855.64	38,058
10	744,827.99	7,557
11	1,794,430.92	46,252
12	938,151.22	21,769
13	1,078,913.56	38,654
14	2,027,188.79	56,276
15	583,105.10	25,909
16	1,915,298.21	41,425
17	1,499,090.22	50,453
18	1,220,384.23	32,962
19	237,839.77	2,933
20	934,877.24	12,682
21	398,092.98	10,012
22	422,533.47	8,558
23	179,014.67	5,066

Figure 4. The 23 functional areas that sectorize the city of València for urban planning purposes in the revision of the General Plan for Urban Planning. Source: Adapted from the Special Plan of Urban Quality Guidelines of València [28].

The functional areas were characterized based on indicators of a physical, urban, social, and environmental nature (Figure 5), which were organized around thematic fields (land, built heritage, social identity and culture, facilities, public space, housing, and mobility) in which urban planning has the capacity to act. Under comparable parameters,

functional imbalances could be found and corrected between functional areas, improving accessibility to services on foot and optimizing the land, thus responding to the guidelines of sustainability, efficiency, and satisfaction of citizen demand. The two fundamental parameters on which the functional balance of residential areas was built were: (a) the availability of land for pedestrians, and (b) the accessibility to public services.

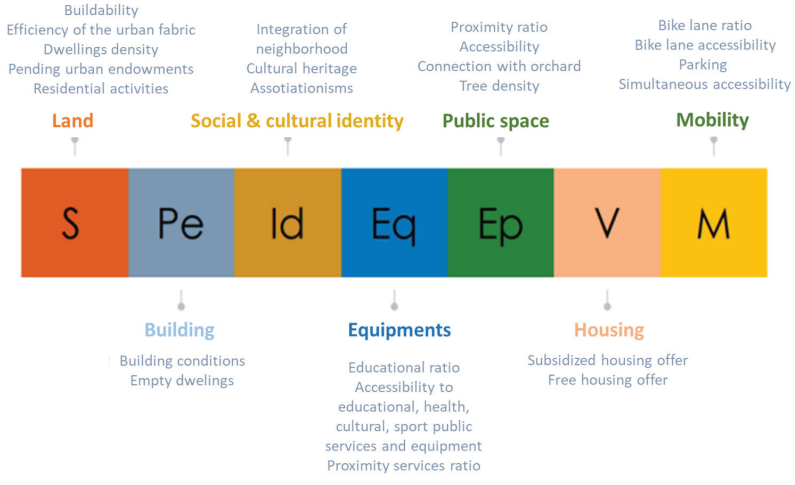


Figure 5. System of indicators used to characterize the functional areas in the revision of the General Urban Development Plan. Source: Special Plan of Urban Quality Guidelines of València [28].

This functional delimitation generated a new structure of the city and increased the degree of influence of its neighborhoods, which acquired the category of centrality of each functional area and was the starting point of the green infrastructure of the area and around which superblocks would be available. Only a few neighborhoods, such as Mestalla (distributed between areas 6, 7, and 9), Grao, and San Llorens, exceeded the scope of the functional areas. In the case of Mestalla, the barriers of Avenida de Aragón and Avenida del Puerto have historically divided this neighborhood, as they are rail traffic axes and provide access to the port.

The characterization of the functional areas was then completed with an analysis of urban green infrastructure accessibility and connectivity, and on this basis, detailed planning guidelines were drawn up for each functional area.

Through the functional areas, the entire city was connected at two scales: that of road traffic, supported by the main infrastructure of the city, and that of the pedestrian, based on the urban green infrastructure. Thus, the city was viewed as a network that connects public services and neighborhoods.

In these functional areas, the concept of neighborhood was recovered as a space in which the interventions for the improvement of urban quality would be most effectively implemented.

The innovative approach and planning process described above were used as a basis for the applied research work described in this paper in the following sections.

The revision of the General Urban Development Plan represented an opportunity to strengthen the consideration of climate risks, thus allowing better informed decision-making with regards to urban planning and risk management and the deployment of green and blue infrastructures and NbS as climate action measures.

The operationalization of climate action in the urban planning of València anticipated the requirements of climate change laws at the state and regional levels reinforced in 2021 by the institutional Climate Emergency Declaration and the commitments made by the local government.

2. Materials and Methods

2.1. Study Design and Data Sources

The incorporation of the climate change perspective into the revision of the General Urban Development Plan of the city of València constituted a step forward in the city's pathway towards climate action and resilience.

In this context, the Plan stands out as one of the pioneer formal planning instruments in Spain, applying spatially explicit vulnerability and risk assessment in the planning process. The novelty of the Plan relies on the fact that the characterization of functional areas was complemented with an indicator-based risk assessment, which allowed the prioritization of areas with the most significant risk. For those functional areas at risk, guidelines and recommendations for detailed planning were defined, promoting NbS as adaptation measures.

The vulnerability and risk assessment was carried out for thermal stress and its effect on the population, as it is one of the priority climate hazards in Mediterranean cities, and València is not an exception [29,30]. Thermal stress on the population was identified in the city's Strategic Agenda 2030 as well as Missions València 2030 [25].

The analytical framework for the evaluation of vulnerability and risk was that suggested in the "Guide for the elaboration of local plans for adaptation to climate change in Spain" [29] (Figure 6), which was based on the approach proposed in the IPCC's Fifth Assessment Report on Impacts, Adaptation and Vulnerability [2].

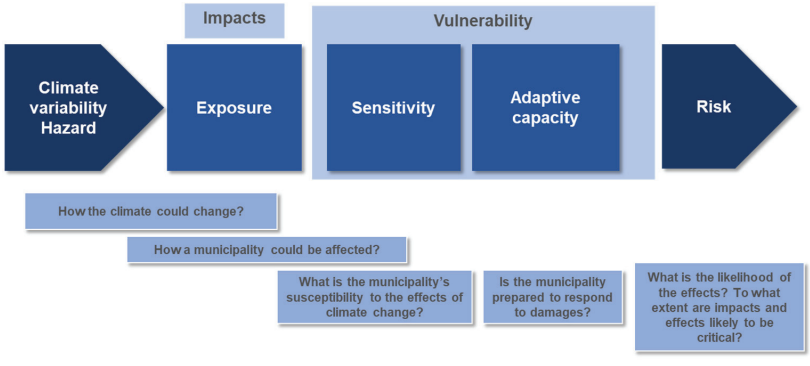


Figure 6. Process of adaptation to climate change at a local scale. Guide for the preparation of local plans for adaptation to climate change in Spain. Source: [2,31].

2.2. Procedures

In this study, the climate hazard was characterized by means of the heat index indicator [32], which was derived from multiple regression analysis and considered the impact of air temperature and relative humidity on human comfort (Equation (1)) [30,32,33]. For this, data provided by the urban climate model UrbClim [34] based on the Copernicus EU program were taken as a reference, with a spatial resolution of 100 m × 100 m and an hourly temporal resolution for the period between January 2008 and December 2017. The day with the highest heat index score within the period was selected as a representative day of the future climate in a climate change scenario [33].

$$\begin{aligned} \text{ST\_c} = \; & -8.78469476 + 1.61139411\ \text{T} + 2.338548839\ \text{HR} - 0.14611605\ \text{T HR} \\ & -0.012308094\ \text{T2} - 0.016424828\ \text{HR2} + 0.002211732\ \text{T2 R} \\ & +0.00072546\ \text{T HR2} - 0.000003582\ \text{T2 HR2} \end{aligned} \quad (1)$$

As already stated, the evaluation of the risk due to thermal stress on the population used an indicator-based approach (Table 1). A semi-quantitative, indicator-based risk assessment was applied. For each risk component, a series of indicators was selected.

Table 1. List of indicators used in the vulnerability and risk assessment of functional areas for thermal stress on human population. HZ = Hazard; EX = Exposure; VU = Vulnerability; SE = Sensitivity; AC: Adaptative Capacity. Source: Own elaboration.

Component	Dimension	Type	Indicator	Definition
HZ			Heat index	Heat index
EX		Population	Total population	Number of inhabitants per functional area
VU	SE	Land	Buildability	Building coefficient per functional area
VU	SE	Land	Efficiency of the urban fabric	Compacity: building volume by the total surface of the functional area
VU	SE	Population	Population > 65 years old	% of inhabitants > 65 years old in the functional area
VU	SE	Population	Population < 15 years old	% of inhabitants < 15 years old in the functional area
VU	SE	Public space	Artificialized areas	% of impervious land by the total surface of the functional area
VU	SE	Housing	Old residential buildings	% of residential buildings > 50 years (reference year 2020)
VU	AC	Social and cultural identity	Associationism	Existing associations in the functional area
VU	AC	Public services/equipment	Accessibility to health centers	Coverage by radius of distance from health centers
VU	AC	Public services/equipment	Proximity to public facility ratio	Area of local public facilities per inhabitant
VU	AC	Public services/equipment	Global ratio of public facilities	Global area of public facilities per inhabitant
VU	AC	Public space	Proximity to free spaces ratio	Area of free spaces in proximity per inhabitant (gardens)
VU	AC	Public space	Proximity to free spaces ratio	Global area of free spaces per inhabitant (parks, boulevards, and gardens)
VU	AC	Public space	Simultaneous accessibility to free spaces	Circles of coverage by radius of distance (simultaneous accessibility to several types of free spaces)
VU	AC	Public space	Connectivity to the orchard	Percentage of land covered by the areas of influence of the orchards and pedestrian routes
VU	AC	Public space	Density of trees	Number of trees per road surface (urban comfort)
VU	AC	Mobility	Bike lane ratio	Linear meters of bike lanes by length of urban road
VU	AC	Social well-being	Household income	Average household income per functional area calculated from the average data in 2017 assigned to buildings.
VU	AC	Public spaces	Public fountains	Number of fountains in each functional area per hectare

Risk was understood, following the IPPC approach, as the result of the combination of hazard, exposure, and vulnerability, the latter being divided in turn into sensitivity and adaptative capacity [35].

The exposure was analyzed using the indicator of total population exposed to thermal stress in the functional areas of the city [36].

For the assessment of vulnerability, a series of indicators of sensitivity and adaptative capacity was defined [37].

In the first step, the system of indicators used for the characterization of the functional areas for the General Urban Development Plan (Figure 5) was analyzed to determine which ones could be used to estimate the sensitivity and adaptative capacity to heat stress under analysis.

Subsequently, a database was structured with the selected list of indicators and completed with additional indicators and variables of a social, economic, environmental, and physical nature, selecting the information available in the Open Data portal of the city of València and in the Spatial Data Infrastructure of the city of València.

Once the database was structured and completed with the indicators' values, the approach by Tapia et al. [37] was used for the vulnerability assessment. A series of treatments and statistical tests was undertaken (i.e., normalization, standardization, and rescaling) using R data analysis software. These statistical treatments were needed to generate the respective aggregated indexes of sensitivity and adaptative capacity, and later, by the aggregation of these, to obtain the aggregated vulnerability index of each functional area.

A weighting process was applied to obtain the aggregated indexes of sensitivity and adaptive capacity by assigning different weights to the respective individual indicators. These weights were obtained dynamically using statistical methods (principal components analysis and factor analysis, mainly) to eliminate any potential redundancy in the data used.

Once the weights were generated, the last step was aggregating the different indicators in the sensitivity and adaptative capacity indexes of each functional area. As a form of aggregation, weighted geometric aggregation (multiplicative aggregation) was used instead of weighted arithmetic aggregation (additive aggregation) [38]. In this way, specific aggregated indexes were finally obtained for each functional area. This allowed comparative analysis among the functional areas, identifying which areas had the highest relative vulnerability, thus providing additional information in order to propose local actions aimed at reducing their sensitivity or enhancing their adaptative capacity to climate change.

Finally, the risk was obtained by combining the hazard, exposure, and vulnerability using an equally weighted geometric mean. That is, multiplying these components with a weight of one-third for each of them.

Based on the results of the risk assessment, guidelines and recommendations were then drawn up at two planning levels: (a) structural planning at the city level aimed at refreshing the General Urban Development Plan, and (b) development planning in the functional areas in which significant risk was observed, with specific proposals to reinforce the deployment of NbS as adaptation measures.

Figure 7 shows the sequence of analysis for the incorporation of NbS as adaptation measures in the urban planning of València.

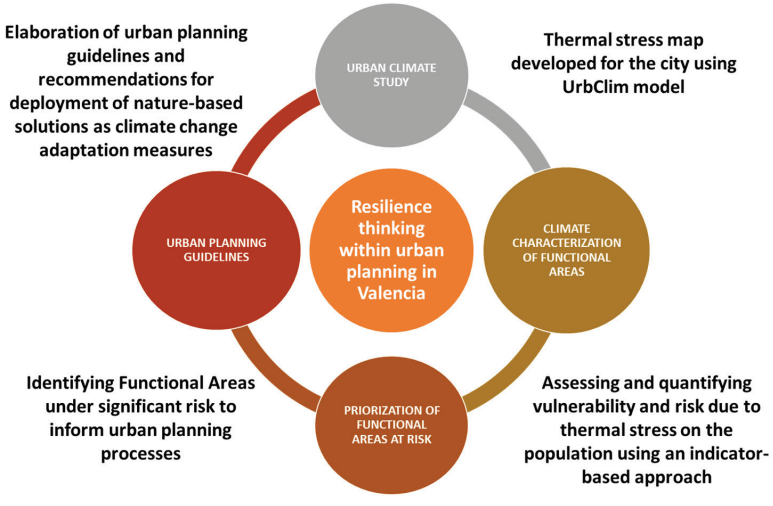


Figure 7. Logical sequence for the consideration of NbS as adaptation measures in the urban planning of València. Source: Own elaboration.

3. Results

After calculating the wind chill index for the entire modeled period, the evolution of the heat index was analyzed and the day with the maximum wind chill value, 27 August 2010, was selected (Figure 8).

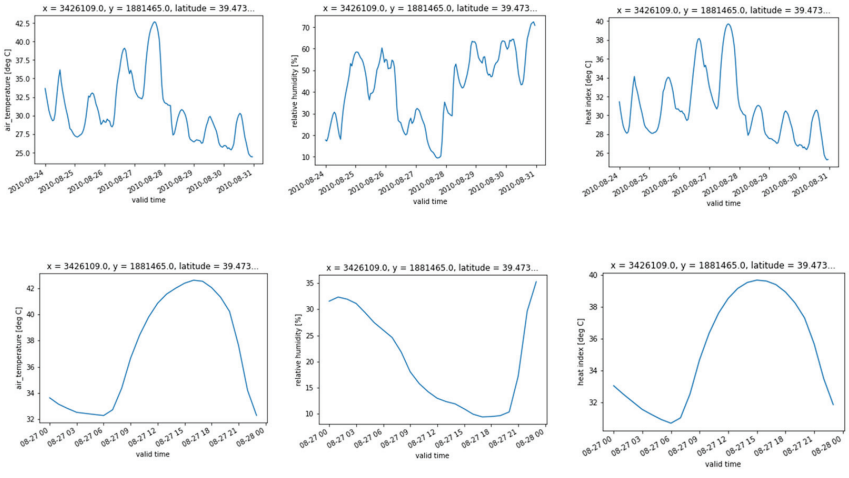


Figure 8. Thermal stress index in València. Source: Own elaboration.

The spatial distribution of the thermal stress is shown in Figure 9. The map revealed that the heat index values obtained for most of the city corresponded to extreme precaution, only 1 °C away from entering the danger zone according to the European Environment Agency and the National Oceanic and Atmospheric Administration rankings.

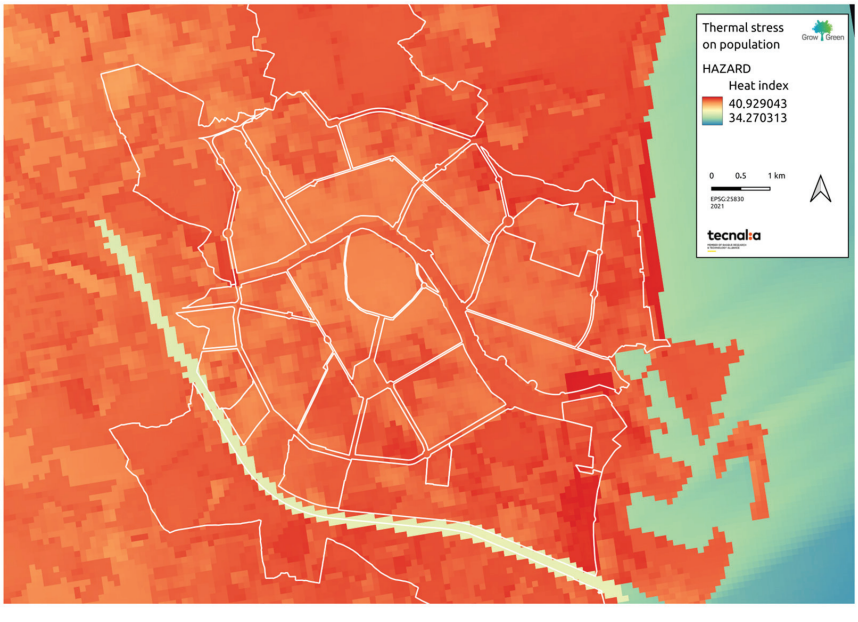


Figure 9. Spatial distribution of thermal stress in the city of València. Source: Own elaboration.

The resulting maps of the analysis of exposure, vulnerability, as well as the subcomponents of sensitivity and adaptative capacity are shown in Figures 10–13. The functional areas with the highest exposure were 07, 03, 05, 14, and 17, while those with the greatest vulnerability were 02, 03, 13, and 23 due to their high sensitivity and low adaptative capacity.

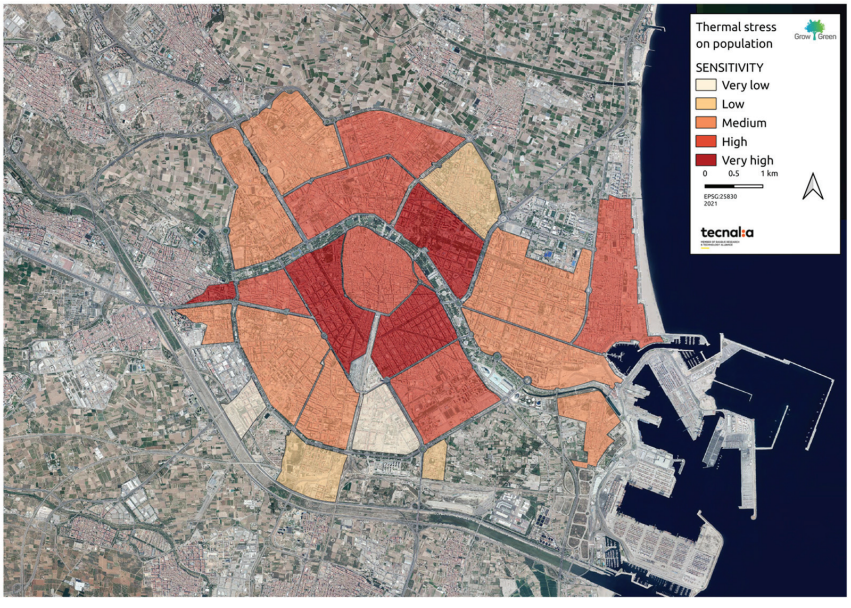


Figure 10. Results of the vulnerability assessment of the functional areas of València against thermal stress—Sensitivity. Source: Own elaboration.

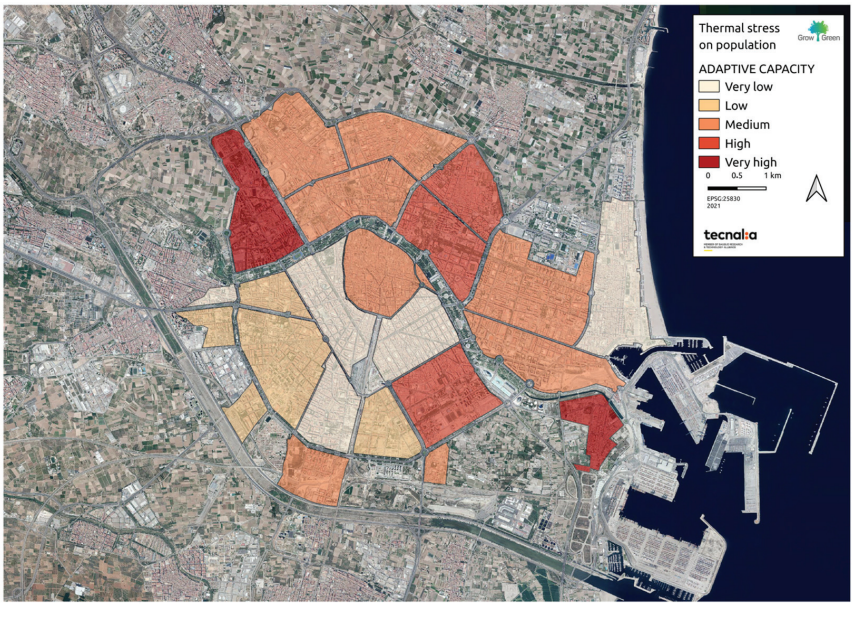


Figure 11. Results of the vulnerability assessment of the functional areas of València against thermal stress—Adaptive Capacity. Source: Own elaboration.

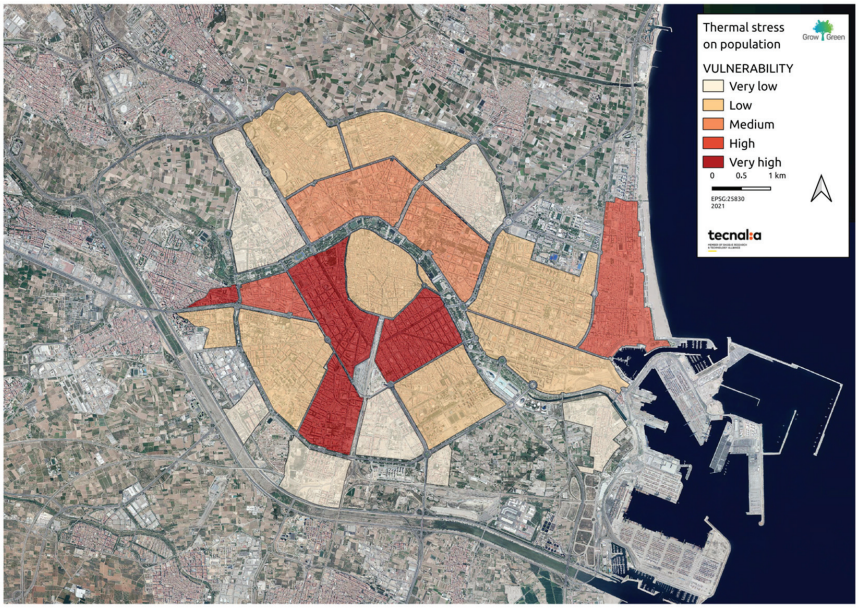


Figure 12. Results of the vulnerability assessment of the functional areas of València against thermal stress—Vulnerability. Source: Own elaboration.

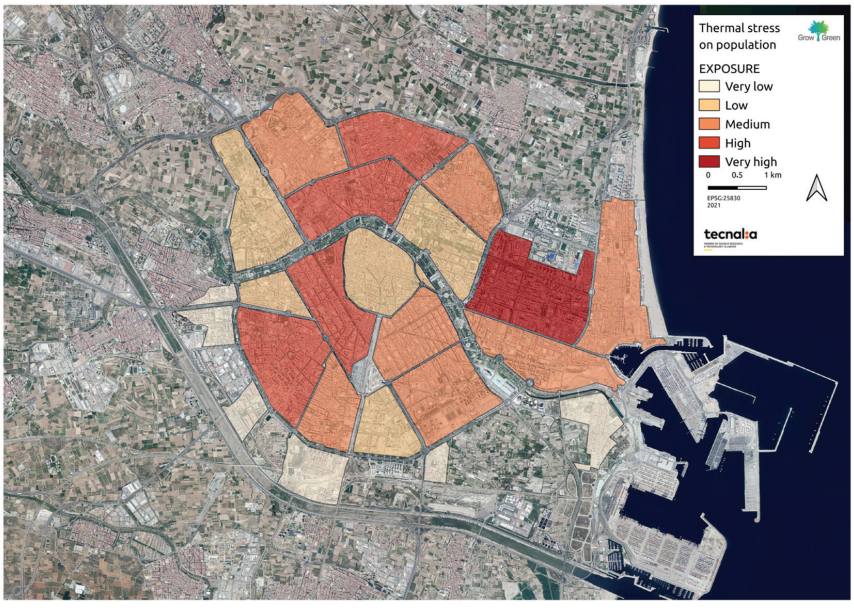


Figure 13. Results of the vulnerability assessment of the functional areas of València against thermal stress—Exposure. Source: Own elaboration.

Finally, the risk level was obtained after integrating the components of hazard exposure and vulnerability, as shown in Figure 14.

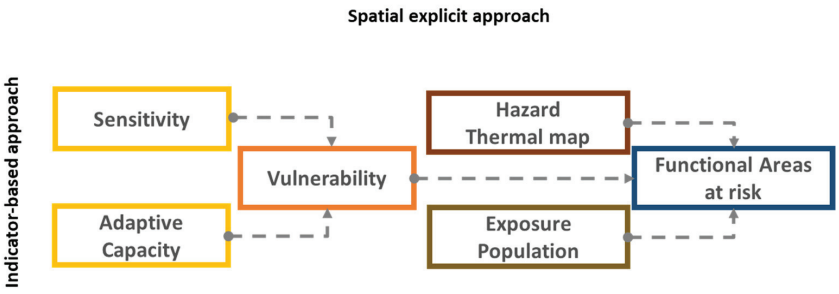


Figure 14. Integration of the different components of risk. Source: Own elaboration.

Five out of the 23 functional areas presented high risk due to thermal stress on the population: 02, 03, 07, 08, and 13 (Figure 15).

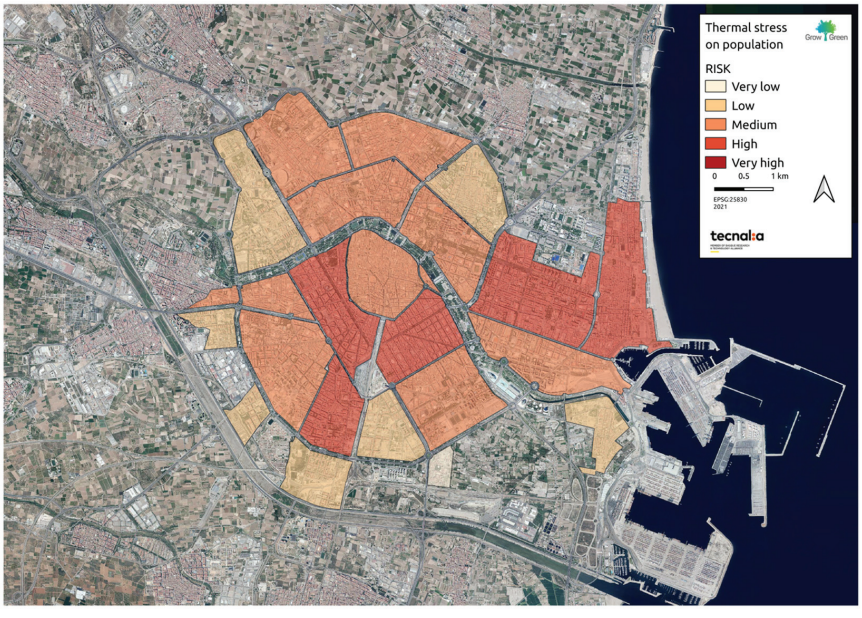


Figure 15. Risk assessment of the functional areas of València against thermal stress on human population. Source: Own elaboration.

For these functional areas in which the assessment revealed significant levels of risk, an analytic summary sheet was prepared (Figure 16) describing the contribution of each indicator to the components of risk and the values obtained in the area.

This analytic summary sheet was a valuable tool that qualitatively examined the intrinsic features of the functional areas and the neighborhoods within, explaining their risk so that tailored actions could be designed to successfully reduce the risk and increase resilience.

The results of the spatially explicit risk assessment facilitated the elaboration of guidelines and recommendations to inform structural (city wide) and detailed urban planning.

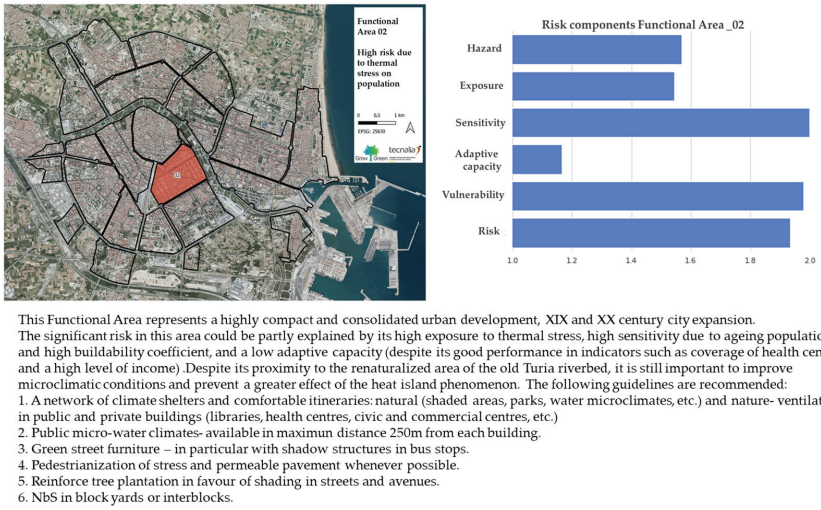


Figure 16. Example of a risk analytical summary sheet by functional area. Source: Own elaboration.

The guidelines and recommendations for city-wide structural planning could be summarized as follows:

- Perform tailored studies at the city scale for the analysis of climate-related hazards and the associated risks, prioritizing the following: flash floods, water scarcity, and forest fires.
- Define and include in the General Urban Development Plan the minimum content and basic orientations for undertaking vulnerability and risk assessments when elaborating development planning instruments (partial plans, special plans, etc.), in new development areas and/or regeneration projects.
- Identify the priority areas of action for the implementation of NbS, considering their vulnerability and climate risk as well as their maximum potential for deployment of NbS. The priority areas of action can be included in the progress documents of the General Urban Development Plan as well as the related strategic environmental reports.
- Elaborate opportunity mapping of green infrastructure and NbS deployment in the city, including the capacity to implement different types of NbS for climate resilience [37].
- Define synergetic actions between adaptation and mitigation measures.
- Emission proof the adaptation measures to identify potential mal-adaptations or conflicts with mitigation measures.
- Identify areas in the city with increasing energy demand due to climate change-linked climatization/household or industry air conditioning.

Specific recommendations were also defined to inform the development planning guidelines in functional areas for which the assessment of thermal stress revealed more significant risk in order to reduce their vulnerability and increase their adaptative capacity, considering NbS as the main adaptation options (Table 2).

Table 2. Summary of recommendations for detailed planning in functional areas with significant risk for the consideration of NbS as adaptation measures against thermal stress. Please note that the recommendations for detailed planning of the functional areas with significant risk do not address the role of albedo, emissivity, and other physically measurable quantities of used or proposed materials and surface of buildings. This was beyond the scope and objective of this research. Source: Own elaboration.

Functional Areas	Diagnosis	Recommendations for NbS Deployment
Historic centre, high-density urban consolidation, compact, residential, commercial, administrative development	 These areas represent the historical centre of the city, with a compact urban fabric. The aims in these areas in relation to climate resilience are to improve microclimatic conditions and prevent the deterioration of green spaces. These aims also apply to future construction and renovations.	Design a network of climate shelters and comfortable, cool, and shady pedestrian routes. Cold islands: water microclimates—publicly available at a maximum distance of 250 m from each building. Green urban furniture—for example, conditioning of public transport stops.
High-density consolidated urban, compact, residential, commercial, administrative development	 These areas represent compact urban fabric. The aims in these areas in relation to climate resilience are to improve microclimatic conditions and prevent the deterioration of green spaces. These aims also apply to future construction and renovations.	Pedestrianization of streets and permeable pavement on roads, sidewalks, parking spaces. Wooded—shading elements. Intensive cooperation with local actors.
Consolidated urban-residential garden environment	 In the case of the city of València, this is a critical area due to its need for permeability with the surroundings of the orchard, city parks, farmland. Natural areas (forests, watercourses, alluvial plains).	Implementation of green and blue adaptation measures as a priority to increase connectivity in the urban–rural interface. Energy efficiency measures and sustainable building in new developments including material selection during the construction and renovation of buildings and public spaces to minimize secondary heat generation and maximize environmental cooling. Effective green management—preservation of high-quality areas (i.e., orchard) and restoration of green areas that allow connectivity with the peri-urban and rural environment of the orchard. Guarantee the connection between urban and rural areas, specifically with the orchard area. Use of the re-naturalization of linear infrastructures as ecological connectors. Promote ecosystem services in protected natural areas. In areas where the functional use of the area allows further construction, this should be done on the condition that it does not negatively affect the microclimate in surrounding areas with higher levels of risk.
Peri-urban facilities, infrastructures	 Mainly residential areas, single-family houses, equipment.	Local construction/change of functional use must not reduce thermal comfort, so NbS must be prioritized. Energy efficiency measures and sustainable building in new developments including material selection during the construction and renovation of buildings and public spaces to minimize secondary heat generation and maximize environmental cooling. Permeable pavements in surface car parks.

4. Discussion

The vulnerability and risk assessment undertaken on the functional planning areas for the city of València provides relevant information for the planning process in the revision of the General Urban Development Plan, which was still under the approval process at the time of the writing of this research, in order to prioritize those areas that may require special attention as they show significant levels of risk in the face of adverse climatic events. In these areas, planning could condition certain land uses and activities to reduce their exposure or deliver NbS aimed at improving thermal comfort, therefore guaranteeing the health of the population, mainly of the most vulnerable groups.

This applied research work focused on heat stress in urban areas, being one of the priority areas identified by the Climate Adaptation Strategy of the city of València. The spatial information on the climate hazard due to an increase in temperature made it possible to generate spatial distribution maps of climatic indexes with a resolution that allowed vulnerability and risk studies to be conducted at the urban and suburban (district) scales, thus providing data to inform appropriate adaptation and urban intervention decisions.

Five out of the 23 functional areas presented high risk due to thermal stress on the population. This high risk was explained by the combination of high levels of hazard, exposure, and vulnerability. Indicators related to buildability, the efficiency of the urban fabric, and the population over 65 years contributed to the sensitivity of these areas. On the other hand, the level of civic association involvement, ratio of public facilities, free spaces, connection with the garden, and income per household partially explained their low levels of adaptative capacity.

Our results, together with those of other studies related to health [6,17,24,36,39], suggest that increasing the tree coverage should be combined with other interventions to produce larger temperature reductions, thereby having greater beneficial effects on health—particularly for cities with low cooling capacity, where increasing the tree coverage would not substantially reduce the temperature. This implies changing ground surface materials, structural interventions, land use, mobility, and interventions in buildings. At both the structural and development planning scales, the deployment of NbS through planning could determine the scope of content anchored in regulations and/or ordinances or as guidelines and recommendations.

Having said that, we recognize some limitations in the data used and methods applied. In relation to the characterization of hazard, other climate indexes could have been used, such as heat waves, which would allow better assessment of extreme events. However, considering the purpose of this research, which was the inclusion of climate change considerations into the urban planning process, the consideration of heat stress distribution was considered more appropriate.

The lack of data on air temperature at the district level (<100 m resolution) prevented making decisions on the heat impact on buildings, indoor comfort, and energy demand.

The database of indicators used in this research for the vulnerability assessment could have been enhanced by including additional physical, social, and socio-economic indictors beyond those in the Spatial Planning Guidelines, but this would have required gathering and processing of high-resolution data, which was beyond the scope of the research.

The city of València currently lacks a comprehensive, spatially explicit climate risk study that addresses, in addition to heat stress, other climate-related hazards. This comprehensive analysis would allow better informed planning and urban management decision-making, both in general and development planning, as well as the prioritization of climate adaptation actions. It is suggested that studies be conducted on climate vulnerability and the risks around the main hazards identified in the city using a spatially explicit approach, either the functional areas defined in the PGOU or neighborhoods, districts, or others, such as:

- Combined hazard studies: air quality and urban climate on population health.
- Water stress and footprint on economic activities (e.g., tourism)

- Flooding due to surface runoff associated with extreme precipitation events affecting population, transportation, and economic activities.
- Flooding due to sea level rise and waves in the urban environment.
- Forest fires in urban–rural fringe.
- Vulnerability and risk studies at the suburban level for the different impact chains associated with climate change would allow the identification of priority action areas, which would require municipal resources and urbanization, or regeneration interventions aimed at reducing vulnerability and risk by implementing better informed adaptation measures.

The assessment was carried out at a time of opportunity, not only due to the revision process of the Plan itself but also in light of the new Green and Biodiversity Plan, which is currently under development. In this sense, the vulnerability and risk assessment can contribute to València's strategic, in-depth reflection on its climate action roadmap towards adaptation.

The experience in València shows that, to ensure growth towards a more pluralistic approach, it is indisputable that urban planning teams are well positioned to assume the role of facilitators and determinants of change. Not only do they have a broad spatial understanding of the urban area in question, but they often work at the interface of both the environment and the market and are therefore able to explore new forms of green investment.

The renaturation of cities through a greater emphasis on the use of NbS also potentially offers urban areas the opportunity to generate multiple environmental and socioeconomic benefits.

Local governments, therefore, have a key role in designing projects that can help transform urban areas through more sustainable solutions. However, new pathways for NbS adoption will require substantial government commitment.

5. Conclusions

This case study, which was developed hand-in-hand with the involvement and validation of municipality officers of different departments, clearly exemplifies how urban thermal stress maps combined with spatially explicit socioeconomic data can provide useful information for assessing and quantifying vulnerability and climate-related risk. Applying this approach to benchmark a given sample of suburban-scale spatial units offers crucial facts to inform urban planning processes, allowing the prioritization of where to apply different type of measures. Among other climate adaptation options, NbS offer a cost-effective approach that additionally provide multiple co-benefits [40]. Predefining NbS classes for better integration into different urban typologies could orient urban interventions in prioritized areas.

In the context of climate change, heat stress has high importance to many cities worldwide and specifically in Europe [41]. This systematic approach, therefore, could be transferable and of use in other geographies and contexts facing the same climate challenges.

Further research could be developed in relation to: (i) applying this same approach to address other climate hazards in urban planning; and (ii) better understanding of formal planning mechanisms that could facilitate the deployment of this approach in different planning frameworks.

Both the results of this research as well as the further research suggestions could feed key current policies in Europe, such as the implementation of the EU Adaptation Strategy and the EU Mission on Adaptation to Climate Change [42].

Author Contributions: G.G.-B. Conceptualization, methodology, formal analysis, writing—original draft preparation, review and editing, visualization. D.N.: Data acquisition, processing, programming, analysis, validation, writing, review, and editing. E.F. Conceptualization, supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the GrowGreen Project, under the European Union's Horizon 2020 Research and Innovation Programme (grant agreement number 730283).

Data Availability Statement: All the data in this study were routinely collected and contained no information about specific people. Our data are available upon request to the corresponding author, subject to the agreement of the trial steering group.

Acknowledgments: To José Ignacio Lacomba, Ernesto Faubel, and Fernando Balaguer from the València City Council and Francisca Hipólito from Las Naves for their trust. To José Vicente Gregori from AUMSA for his generosity and openness to collaboration. To all of those involved in the Horizon 2020 GrowGreen Project. The project has constituted a trigger for incorporating NbS into the city's urban planning as measures to adapt to climate change using an innovative spatial approach, through which València has accelerated the process towards defining its NbS strategy.

Conflicts of Interest: The authors declare no conflict of interest.

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Financing Brownfield Redevelopment and Housing Market Dynamics: Evidence from Connecticut

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Abstract: Brownfield redevelopment projects are often perceived as more risky than greenfield investment, and financing opportunities may be more limited and expensive. Different financial support projects have been developed to support regeneration projects, and empirical evidence has shown that all buildings near the intervention area may benefit from an increase in prices once the brownfield project is complete. The article considers the Connecticut market and evaluates the characteristics of the brownfield projects that had access to a financial support program (loan or grant), the impact of the regeneration process on the liquidity of the housing market, and the gap between the price and the appraisal value of the residential unit. Target areas for this type of financing program are mainly characterized by low income, a high density of population, a high incidence of homeowners, and a high crime rate. Once completed, the brownfield requalification has an impact on the housing market because the brownfield recovery reduces the number of house sales due to the increase in the average price in the surrounding area and makes the selling price more consistent with the appraisal valuation. The empirical evidence provided may be useful for public institutions that are suffering from budget constraints and have to prioritize areas for financial support solutions.

Keywords: brownfield; regeneration process; spillover effect; housing market

Citation: Gibilaro, L.; Mattarocci, G. Financing Brownfield Redevelopment and Housing Market Dynamics: Evidence from Connecticut. *Buildings* **2023**, *13*, 2791. https://doi.org/10.3390/buildings13112791

Academic Editors: Steffen Lehmann and Monika Szopinska-Mularz

Received: 28 September 2023
Revised: 22 October 2023
Accepted: 5 November 2023
Published: 7 November 2023

1. Introduction

The real estate market is exposed to distortions arising from environmental liabilities [1], as is the case for brownfield sites, that may affect land or premises that have previously been used or developed and are not currently entirely in use. As a consequence, old sites may be partially occupied or used, and, in extreme cases, they can become vacant or derelict [2]. The existence of brownfield sites can determine spillover effects on nearby property values when potential buyers fear that the contaminants may migrate to surrounding properties or, in any case, create a hazard to the neighborhood [3]. Brownfields may negatively affect the prices of surrounding real estate, and several homeowners will suffer capital losses, (especially those with little home equity) which may prevent them from leaving the area [4].

Brownfield projects face critical financing gaps that can foil efforts to assemble a complete package as lenders and investors will not finance beyond the current market value of the asset [5]. These gaps typically involve capital shortages for three activities specific to brownfield sites: early-stage site assessment to determine precisely what contamination needs to be addressed; defining a site remediation plan, which owners need to take the site through a voluntary cleanup program (VCP) that allows the use of institutional controls or provides some finality on liability; and implementing cleanup [6]. The attention of the public authorities to brownfield redevelopments has grown in the last decades, and nowadays land and building revitalization represent a national priority [7].

Many financial tools are available to brownfield developers. Nevertheless, brownfields almost invariably have to pledge a higher rate of return to their investors or lenders to persuade them to assume the higher perceived risk associated with the project [6]. Additional underwriting costs can also significantly add to the costs of loan processing and review procedures. Lenders usually require developers to have a non-relevant percentage of equity in the project to ensure that the borrower has sufficient capital at risk [8]. Consequently, brownfield redevelopment is increasingly driven by the availability of development grants and subsidies to compete with greenfield programs [9].

In light of the wide range of federal, state and local level programs [10] and given the importance of grant funding more than property values, private investment, and public investment in redevelopment programs [11], the paper analyzes the public database of brownfield redevelopment created by the state of Connecticut over a 13-year time horizon (2008–2020) (The choice of the time horizon is constrained from the availability of the data about the brownfield redevelopment that are available only from 2008) to evaluate the stock of brownfields existing in the area and the number of redevelopment projects in progress or already completed focusing the attention on the role of grants and financing solutions to support private intervention. Results provide evidence about the main target areas for brownfield refinancing, the impact of the completed intervention on house sales, and the difference between the selling price and the appraisal value. The main results are mostly relevant for government and public administrators that have a lack of resources for supporting all the brownfield redevelopment and have to prioritize the areas in which the benefits are maximized for the citizens that are living nearby.

The paper is organized as follows: Section 2 describes the literature on the impact of brownfield refinancing on the value of housing stock, and Section 3 describes the relevance of brownfield areas in Connecticut and values the characteristics of the areas for which the state program for brownfield refinancing exists and the impact of the refinancing on market liquidity.

2. Literature Review

Brownfield areas represent an issue for the value of houses in the surrounding areas due to the real or perceived contamination that may affect all buildings nearby [12]. Literature has shown that simple disclosure of environmental issues related to abandoned or derelict buildings has an impact on the values of the entire neighborhood [13]. The economic impact for the nearby houses depends on the size, location, and level of contamination, and the decrease in value for existing houses will happen every time the alarm related to the brownfield is considered sufficient by the citizens [14]. Literature shows that the impact of brownfields does not increase proportionally to the number of nearby properties or areas, and the negative could be maximized even if they are nearby residential areas only with one or two derelict and/or abandoned buildings or sites [15].

Externalities related to brownfield proximity are normally negatively related to the distance of the house from the contaminated site, even if there is no consensus about which proxy fits better for measuring the distance, and the relationship could be not linear but exponential [16]. The impact is economically significant for the wealth of households, and the loss can be recovered only if a successful clean-up process takes place in the area and the family is not obliged to sell the building before the area is requalified [17].

The existence of brownfield areas and the risk of additional costs related to the clean-up process may represent a significant disincentive to invest in the area, and developers may prefer to avoid the risk related to an investment in areas exposed to this type of risk [18]. Moreover, revenues from the regeneration project are not easy to forecast because the expected selling price of the refurbished assets will be affected by the gap between demand and supply once the project is completed [19].

During brownfield redevelopment, the influence of financial, legal, regulatory, and policy incentives leads to uncertainty about redevelopment costs and land values [20]. As a consequence, uncertainty can affect the development of a well-functioning finance

market for brownfield remediation investments [21] because financial risks are difficult to predict due to uncertainties about social responsibilities under land reuse plans [22]; furthermore, the trade-off between land value and the environmental health impact of brownfields makes banks and private developers reluctant to support the programs [23] without implementing a flexible land management approach [24]. In light of the relevance assigned by developers to financial, market, and site-specific risks [25], the solution adopted in several countries is to enact a set of rules that allow the creation of a limited liability program that, under some circumstances, may avoid responsibilities related to unexpected events that may occur during the demolition or construction stage [26].

Urban recovery has higher and less predictable costs and execution times than real estate properties in ex novo areas, and the relevance of this difference increases with the costs of land reclamation and the administrative and community constraints on the urban recovery intervention [27]. Greenfield investments, on the other hand, allow the costs of the intervention to be cut and profit margins to be potentially maximized, given the lower constraints on the construction of new buildings in areas not previously intended for development [28].

The execution of the clean-up process of real estate assets has normally a positive effect on the building value, and after the brownfield recovery process, all the real estate assets nearby may increase their value over time due to the better living conditions in the surrounding area [29]. In particular, brownfield areas characterized by a risk of contamination have a significant effect on prices [30] and frequently have a contagion effect on all nearby areas [31]. When the risk of contamination is lower or there is a program to reduce liability and risk for owners, the impact on the price of surrounding buildings is lower because the brownfield area will be redeveloped faster [28].

On closer inspection, the impact on urban areas of brownfield remediation may be different concerning the average of the market, as it is significant on surrounding housing prices in low- and middle-income neighborhoods [32]; moreover, because the consumer attitude is the main factor explaining the intention to acquire [33], stigma negatively affects the value of housing even after the brownfield recovery process with a long-term potential [34] or, in contrast, it can determine gentrification of the area due to improvement of quality of life quality [35].

Fundraising for brownfield intervention is limited due to the additional risks that characterize these projects with respect to greenfield developments. Issues are related not only to the cost estimate (such as clean-up cost, site preparation, and time for the development process) but also to the revenue forecast for areas that are in decline and that are normally characterized by low volumes of sales [36]. Lenders are normally reluctant to offer loans for brownfield investment, and the loan-to-value offered could be significantly lower than the average amount offered for greenfield projects [37].

Uncertainty related to time and costs for the brownfield recovery process makes the projects less appealing for lenders that would prefer safer real estate investments [38]. The high risk of regeneration projects is frequently unsustainable for private investors (debt holders or equity holders), and public support is necessary to make the financial burden more sustainable [39].

The literature has shown that public financial support may never represent the only solution to support brownfield redevelopment due to the high expenditure related to real estate projects and the large number of potential areas of intervention. The issue is to measure the externalities that may be driven by a successful clean-up process and to identify area features that allow one to maximize the return for the community [40]. Although public investments in brownfield redevelopment may not result in an economic endeavor, they positively affect nearby communities, leading to increased property values that ultimately result in increased tax revenue [41]. Therefore, the capitalization effect produced by the remediation on the housing prices approximates the lower bound of the return for the community [42].

The main incentive for brownfield recovery is always the grant, but in some markets (main cities), a public entity can create an incentive for urban recovery by using a mix of grants and lending instead of offering a full, non-refundable grant, giving rise to the popular public-private partnership contract form [5]. The brownfield refinancing project has localized impacts on the real estate market, affecting market liquidity by modifying the frequency of trades and the gap between appraisal values and housing prices [43].

Empirical evidence on the impact of completed projects on the characteristics of the housing market is still limited, and the paper will test the following research hypothesis:

Hypothesis 1. *Less developed city areas are most likely to benefit from a brownfield recovery financial support program.*

Less developed areas are normally characterized by lower housing prices and worse living conditions, and so the public and private interest in brownfield redevelopment is maximized.

Hypothesis 2. *The volume of house sales is not growing immediately after the brownfield recovery intervention.*

The brownfield intervention determines an increase in average prices, and so until the quality of the services (private and public) provided in the area does not improve, the number of house trades will not change significantly.

Hypothesis 3. *Houses are traded at a lower discount on the appraisal values once the recovery process is complete.*

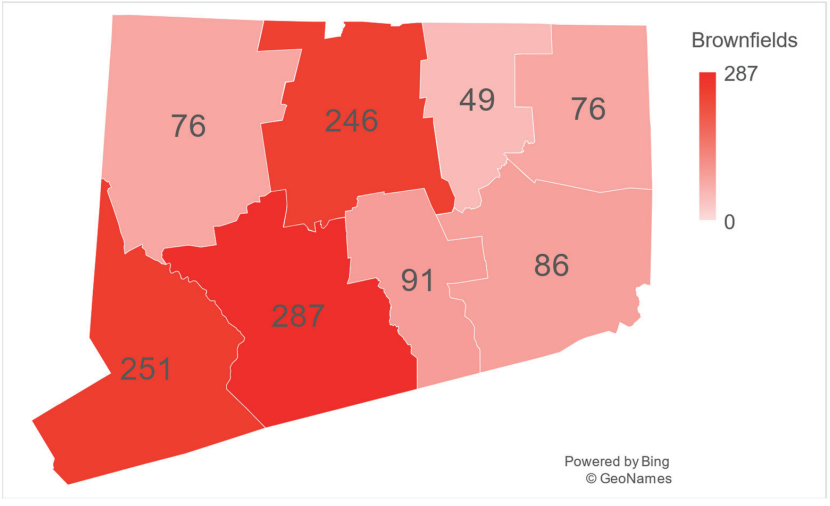
The existence of derelict or abandoned areas does not allow the sale of houses at their appraisal value due to the negative externalities of these assets. Brownfield recovery will increase the quality of life for people living in the surrounding areas, and so the price of the houses for sale will be revised upwards by the landlords.

3. Empirical Analysis

3.1. Sample

At the beginning of the twentieth century, Connecticut was already one of the tenth-most industrialized states in the USA, and the main specialization areas were highly polluting productions (such as brass casting and finishing, shipbuilding, and the iron and steel industry) [44]. During the First and Second World Wars, Connecticut's industries were converted into war productions for all the suppliers necessary for the US Army [45]. As for all the countries characterized by the development of the hard industry, a lot of brownfield sites exist in the area, and the United States Environmental Protection Agency has established a regional office in the area since 1994 [46].

The brownfield area sample was constructed by the Department of Energy and Environmental Protection of Connecticut. The data available allows for identifying for each town in the state the number and address of areas that are classified as brownfields and other contaminated sites in Connecticut. The inventory considers both hazardous waste disposal sites and the comprehensive environmental response compensation and liability information system at the end of 2020 and provides information about the address and the company or individual that started the recovery process (Figure 1).



Source: Connecticut Department of Energy and Environmental Protection data

Figure 1. Brownfield location in Connecticut.

In Connecticut, we have 1347 areas that are classified as brownfields, and the majority of them are in the counties of Fairfield (251), Hartford (246), and New Haven (287), but the brownfield areas are widespread throughout the state, and it is not a phenomenon that matters only for the big cities.

Connecticut has developed several programs for supporting the brownfield recovery process for areas or buildings that, without public financial support, cannot represent a convenient investment opportunity for developers (e.g., [47]). To evaluate the impact of refinancing brownfield recovery, we collected from the Department of Economic and Community Development the data on brownfield assets financed by the state of Connecticut and the percentage of financing (loan or grant) for each project selected for the program (Table 1).

Table 1. Brownfield location in Connecticut.

County	N° of Towns	N° of Towns with Brownfield	Average Percentage Financed by the Special Programs
Fairfield	23	19	15.33%
Hartford	29	18	19.08%
Litchfield	26	17	8.16%
Middlesex	15	15	11.56%
New Haven	27	25	15.92%
New London	21	13	33.92%
Tolland	13	11	13.64%
Windham	15	11	7.38%
Overall	169	129	15.64%

Source: Connecticut Department of Energy and Environmental Protection data.

Brownfield sites are widespread in the state, with 129 towns with at least one contaminated site. The county of Middlesex has no town without brownfield sites. On average, less than 16% of brownfields have access to financial support for redevelopment, with counties

such as New London, Hartford, and New Haven having an above-average percentage of contaminated sites that obtained a grant or loan for the regeneration project.

For each town, data on macroeconomic and social features are collected in order to identify the most relevant characteristics of the social environment of towns with or without brownfields and to highlight the main characteristics of areas that are targets of brownfield redevelopment financing (Table 2).

Table 2. Summary statistics of the characteristics of the macroeconomic and social district classified according to the existence of brownfields.

	Formula	Towns without Brownfields	Towns with Brownfields	Towns with Brownfields Redevelopment
Income	$\frac{Income_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Income_{Town_i}}$	0.71 (0.17)	0.65 (0.23)	0.57 ** (0.17)
Population	$\frac{Population_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Population_{Town_i}}$	1.00 (1.85)	1.83 (2.00)	2.60 ** (2.41)
Homeownership	$\frac{Homeownership_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Homeownership_{Town_i}}$	0.32 (0.07)	0.31 (0.07)	0.31 (0.07)
Housing value	$\frac{Housing\ value_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Housing\ value_{Town_i}}$	1.21 (0.42)	1.17 (0.76)	0.98 ** (0.37)
Vacancy rate	$\frac{Vacancy\ rate_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Vacancy\ rate_{Town_i}}$	0.14 (0.09)	0.10 (0.07)	0.10 (0.05)
Rent value	$\frac{Rent\ value_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Rent\ value_{Town_i}}$	1.12 (0.33)	1.07 (0.26)	1.03 (0.18)
Crime rate	$\frac{Crime\ rate_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Crime\ rate_{Town_i}}$	1.00 ** (0.97)	1.54 (1.08)	1.97 ** (1.18)
Housing permits	$\frac{Housing\ permits_{Town_i}}{\frac{1}{n}\sum_{i=1}^{n} Housing\ permits_{Town_i}}$	0.99 ** (1.79)	3.48 (5.92)	4.09 (6.67)

Notes: the table reports average values and standard deviations (in brackets) and the results of a mean comparison test for the subsamples of towns with respect to the full sample (** statistically significant at the 99% level). Source: Census 2010 & 2020 data available at www.ctdata.org.

The simple existence of a brownfield is not associated with a significant impact on the town's socio-economic features, with the exception of the criminality rate and the number of new construction permits that are below average. Conversely, areas that are targeted for brownfield refinancing projects are those with a lower average population income, a higher density of citizens living in the area, a lower percentage of homeownership, and a higher crime rate.

3.2. Methodology

The analysis of the role of financing opportunities for brownfield redevelopment considers the impact of socioeconomic features on the probability of being financed by using the following formula:

$$Financing(D)_i = \alpha + Distance\ from\ CBD_i + \sum_{k=1}^{n} Area_k^i + \varepsilon_i \quad (1)$$

where the dependent variable ($Financing(D)_i$) is a dummy, assuming value one for brownfields financed and zero otherwise.

Since brownfield recovery interventions determine the greatest positive reaction to commercial services [48], the independent variables are the distance from the central business district of the town where the brownfield is located ($Distance\ from\ CBD_i$) and, additionally, a set of socio-economic factors that describe the town are considered [49]. On the basis of the availability of data, the socioeconomic variables are the average income of

citizens, population number, percentage of homeownership, average housing value, the vacancy rate, average rent value, the crime rate, and the number of housing permits. To obtain a comparable value for large and small towns, all data are rescaled on the basis of the average value at the county level. The data analysis is performed using a panel logit regression model, and all the control variables are considered on the basis of the last available census.

The analysis of the subsample of brownfields refinanced allows for the study of the impact on the percentage of different financial supports of the same independent variables plus the value of contribution to brownfield development. In formulas:

$$GTC_{it}(\%) = \alpha + Distance\ from\ CBD_i + \sum_{k=1}^{n} Area_{kt} + Financial\ support_i + \varepsilon_i \quad (2)$$

$$LTC_{it}(\%) = \alpha + Distance\ from\ CBD_i + \sum_{k=1}^{n} Area_{kt} + Financial\ support_i + \varepsilon_i \quad (3)$$

$$FTC_{it}(\%) = \alpha + Distance\ from\ CBD_i + \sum_{k=1}^{n} Area_{kt} + Financial\ support_i + \varepsilon_i \quad (4)$$

where the dependent variables are the percentage of the overall investment necessary for the brownfield re-development financed with a grant ($GTC_i(\%)$), with a loan ($LTC_i(\%)$), or with both the solutions available ($FTC_i(\%)$). The independent variables are the same as used in Equation (1) plus a variable related to the size of the financial support given ($Financial\ support_i$) and the choice of including the variable related to the size is necessary because some type of brownfield refinancing may be used only up to the maximum amount. The data analysis is performed by using a linear regression model only for the brownfields that were financed, and the control variable values are assigned based on the last census data available before the brownfield recovery project.

The analysis of the impact of brownfield redevelopment on real estate prices is performed considering both the number of housing trades [50] and the gap between prices and appraisal value [49] for each town. In formulas:

$$Sales\ \%_{it+k} = \alpha + \sum_{k=1}^{n} Area_{kt} + Brownfield\ Financing_{it} + \varepsilon_i \quad (5)$$

$$Sales\ ratio_{it+k} = \alpha + \sum_{k=1}^{n} Area_{kt} + Brownfield\ Financing_{it} + \varepsilon_i \quad (6)$$

where the dependent variables are respectively the percentage of sales in the town i with respect to the overall sales in Connecticut ($Sales\ \%_{it+k}$), the yearly growth in the number of sales in the town i, and the average ratio between the appraisal value and the selling price of houses sold in the town i at the time t ($Sales\ ratio_{it+k}$). (Data about the number of sales by town and the ratio between the appraisal value and selling price are provided by the open-access database provided by the State of Connecticut, Office of Policy and Management (https://data.ct.gov/ accessed on 1 June 2023)). The analysis is performed by using a panel linear regression model and by considering the effect in the same year of the brownfield refurbishment ($k = 0$) and in the following two years (k equal to 1 and 2).

The independent variables related to the area ($\sum_{k=1}^{n} Area_{kt}$) are the same as in the previous Equations (1)–(4) but computed year by year over the full time horizon 2010–2020, and the Brownfield financing ($Brownfield\ Financing_{it}$) is a dummy variable assuming value one when at least one brownfield redevelopment project was financed in the town i, in the year t or before.

3.3. Results

The analysis of the refinancing policy of the brownfield areas in Connecticut shows some interesting results about the areas that are more interested in the redevelopment financing support and the type of grant offered (Table 3).

Table 3. Brownfield refinancing and town features.

	$Financing\ (D)_i$	GTC_i (%)	LTC_i (%)	FTC_i (%)
Distance from the CBD	0.01	0.01	0.01	0.01
Income	−1.54 **	0.08	0.56	0.07
Population	0.06 **	−0.01 *	−0.03 *	−0.01 *
Homeownership	0.62 *	0.01 *	0.87 *	0.10
Crime Rate	0.11 *	−0.01	−0.01	−0.02
Housing Value	−0.09 *	−0.06 *	−0.10 *	−0.02
Vacancy rate	−0.75 *	−0.37 *	−1.04 *	−0.07 *
Rent Value	0.21	−0.11	−0.14	0.06
Housing permits	−0.03 **	−0.06	−0.01	0.01
Financial support	-	−0.02 *	−0.14 **	−0.17 **
Constant	−0.53	0.24 *	0.28 **	2.94 **
Pseudo R^2	10.48%	28.55%	33.52%	22.09%
N° Observations	1347	291	291	291

Notes: ** statistically significant at the 99% and * statistically significant at the 95% level. Source: Census 2010 and 2020 data and Connecticut Department of Energy and Environmental Protection data processed by the authors.

Brownfield refinancing does not target the central areas of the city, where market-based financing solutions may normally represent an economically reasonable solution available for redevelopment projects. The areas that are more interesting for this type of project are those with lower incomes, a higher density of population, a higher incidence of homeowners, and a higher crime rate. Markets where brownfield redevelopment projects are financed more frequently are those in which the value of housing, the vacancy rate, and the number of housing permits are lower.

When considering the type of financial support, the main drivers of the grant and the loan amount are the population, the percentage of homeownership, the value of the home, the rate of vacancy, and the overall amount of the contribution. Data show that the percentage of grants and loans is lower when the population is higher, homeownership is higher, the value of the home is lower, and the vacancy rate is lower. The percentage of support given by the brownfield refinancing program is normally larger for towns that are overcrowded, where the house renting market is residual, the value of the real estate investment is not high, and there is not an excessive supply of housing units already vacant in the market. Furthermore, independently of the town considered, the larger the financial support requested, the lower the weight on the overall resources necessary for the project.

The analysis of the sales trend before and after brownfield refinancing shows some interesting differences among the proxy variable related to sale concentration $(Sales\ \%_{it})$, and the ratio between selling price and appraisal value $(Sales\ ratio_{it})$ (Table 4).

After brownfield refinancing, the concentration of sales in one town with respect to the overall market is decreasing, showing a higher interest in areas that were considered not appealing before the requalification project, and the average price is significantly increased for all houses in the area, even if there are significant differences town-by-town that confirm the localized effects of brownfield redevelopment [13]. On average, appraisal values are revised upwards after the brownfield recovery, and so the selling price is better proxied by the expert valuation. The evidence related to the price dynamics is coherent with other evidence related to the US [51] and European [52] markets that showed that the proximity to brownfield areas affects negatively the price of the houses in the nearby areas until the area is refurbished.

The analysis of the sales proxies for the sample shows some interesting results related to the brownfield refinancing project that allow one to evaluate more effectively the impact

of positive externalities related to the requalification project for all houses in the same town (Table 5).

Table 4. Summary statistics of sales proxies.

	$Sales\ \%_{it}$		$Sales\ Ratio_{it}$	
	Before Brownfield Refinancing	**After Brownfield Refinancing**	**Before Brownfield Refinancing**	**After Brownfield Refinancing**
Average	0.87%	0.55%	89.89%	96.29%
St. Dev.	0.73%	0.59%	18.16%	17.58%
Minimum	0.05%	0.00%	18.16%	17.58%
Maximum	3.97%	4.11%	167.08%	220.36%

Source: Census 2010–2020 data and Connecticut Department of Energy and Environmental Protection data processed by the authors.

Table 5. Brownfield refinancing and the impact on housing sales.

	$Sales\ \%_{it}$			$Sales\ Ratio_{it}$		
	t + 0	**t + 1**	**t + 2**	**t + 0**	**t + 1**	**t + 2**
$Income_{it}$	0.00	0.00	0.00	−0.32 **	−0.36 **	−0.34 *
$Population_{it}$	0.00 **	0.00 **	0.00 **	0.01 **	0.01 **	0.01 **
$Homeownership_{it}$	−0.01 **	−0.01 **	−0.01 **	0.42 **	0.50 **	0.48 **
$Crime\ rate_{it}$	0.01 **	0.01 **	0.01 **	−0.04 **	−0.04 **	−0.04 **
$Housing\ value_{it}$	0.03	0.01	0.01	0.03 **	0.03 *	0.02
Vacancy rate	0.01	0.01	0.01	0.38 **	0.33 **	0.34 **
$Rent\ value_{it}$	0.01	0.01	0.01	0.00	0.00	0.00
$Housing\ permits_{it}$	0.01 **	0.01 **	0.01 **	−0.00 **	−0.00 **	−0.00 **
$Brownfield\ financing_{it}$	−0.01 **	−0.01 **	−0.01 **	0.02 **	0.07 **	0.07 **
Constant	0.01 *	0.01 *	0.01	0.82 **	1.01 **	1.01 **
Pseudo R^2	0.75	0.76	0.76	0.21	0.11	0.11
Fixed effects for the town	☑	☑	☑	☑	☑	☑
Fixed effects per year per year	☑	☑	☑	☑	☑	☑
N° towns	169	169	169	169	169	169
N° Observations	2197	2018	1849	2197	2018	1849

Notes: ** statistically significant at the 99% and * statistically significant at the 95% level. Source: Census 2010–2020 data and Connecticut Department of Energy and Environmental Protection data processed by the authors.

Areas that are increasing the volume of sales are those with higher population density, lower homeownership, and a higher crime rate, for which the frequency of new construction permits is higher, and so new houses will be available in the market year-by-year. Financing brownfield regeneration projects decreases the frequency of new trade because the average price of houses in the surrounding areas increases [28,31]. Brownfield regeneration process impacts on the volume of sales are persistent over time, even after two years from the completion of the real estate project.

Looking at the ratio between appraisal values and selling prices, the areas that have values more coherent with the expert valuation (values close to one) are highlighted by lower income, higher population density, a higher percentage of homeownership, and a lower crime rate. In addition, normally, the house value is higher, the vacancy rate is higher, and the number of new construction permits is below the average of the market.

The choice to finance a brownfield redevelopment has a positive impact on the sales ratio and increases the number of house trades at prices similar to or higher than the appraisal estimate, ensuring consistency in the process of valuation [53]. The impact on the price-to-appraisal ratio after one or two years from the brownfield regeneration is even stronger than in the year when the refurbishment was completed.

4. Conclusions

Brownfield represents a unique opportunity to make land use flexible [26], but such flexibility comes at costs and risks related to the clean-up process, representing a significant disincentive to invest in the area and inducing developers to prefer greenfield projects [9]. Through public financial support, investors can be attracted by a not otherwise economically sustainable initiative, and developers can apply their know-how in redeveloping a land, determining multiple-level benefits for different stakeholder categories [54].

The benefits following brownfield redevelopment justify the public financial support received by those programs over years in many countries, but the features of the brownfield area affect the public finance support and the achieved results on the real estate market depending on the type of facility selected to finance the program (grant, loan, or both). Looking at Connecticut brownfields, areas that are the target for refinancing support are those with a lower average population income, a higher density of citizens living in the area, a lower percentage of homeownership, a higher crime rate, and a depressed housing market. When it comes to the type of financial support, the main drivers of the grant and the loan amount are the population, the percentage of homeownership, the value of the house, the vacancy rate, and the total amount of financial support. Additionally, it appears that a substitution effect between public and private funds holds because the larger the financial support requested, the lower the weight on the overall resources necessary for the project. The impact of the financial program on the real estate market trades determines a lower concentration because of a wider urban area to satisfy housing demand, and the average price is increased in the surrounding area, even though local effects emerge. Lastly, financially supporting redevelopment refinancing favors the consistency between market prices and expert valuation.

Empirical evidence is focused on a developed market in which the price and volume of trades may react better to a brownfield recovery due to the higher demand for houses in the area. Literature has already shown that developing countries and markets behave differently on this issue [55], and the results cannot be generalized to small markets on a worldwide scale. Moreover, the analysis is focused only on residential real estate and does not consider the spillover effect that may happen in commercial real estate (e.g., [56]), especially for the retail sector that is servicing new citizens that will live in the area.

The results obtained contribute to the understanding of the financing determinants of brownfield redevelopment intended to reduce urban sprawl [57]; nonetheless, the increase in the prices of the houses close to the re-developed area raises the issue of gentrification [45]. Results could be useful to evaluate opportunities related to regeneration projects in brownfield areas, and this evidence will be even more important in EU countries and other historical countries in which millions of brownfield areas are still to be recovered. Government budgets do not allow the recovery process for more than a few thousand projects by country [58], and it is necessary to prioritize intervention in areas that will maximize the benefits for the population and homeowners.

The increasing attention to the ESG principles by investors and regulators points out that the housing supply cannot be based only on greenfield projects, and a lot of local administrations are currently applying density constraints and reducing the number of new construction permits [59]. The development of green mortgages will represent, in the near future, a solution for making the regeneration projects of brownfield areas more affordable, and the analysis provided may represent a useful benchmark for prioritizing the area of interest for private special loans [60].

Future research developments concern delving into the relationship between the public financial program and the affordability of the housing market after the redevelopment [61]. More detailed datasets on the building features and transaction data will allow identifying houses' and owners' features that matter the most in accessing the financial support program.

Author Contributions: Conceptualization, L.G.; Methodology, G.M.; Formal analysis, G.M.; Writing—original draft, L.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

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Ethics of Climate Change Adaptation—The Case of Torrential Rains in Norway

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Abstract: This article analyses adaptation to climate induced challenges in form of torrential rains hitting urban landscapes in Norway with increased frequency. Specifically, it investigates the influence of the industry structure on ethical challenges when the climate changes. A meta-analysis of the scientific output from a major multi-disciplinary research program is carried out. In addition, the methods include use of expert opinions, literature review and document studies. Climate change adaptation challenges disciplines within civil engineering and natural sciences. Following this, established practices need alteration as specialists face new ethical challenges. Practical climate change adaptation requires the ability to overcome silo mentality among the involved disciplines. Challenges involve acknowledging responsibility, transparency, and information quality. Engineering takes place in an environment of incomplete knowledge. In addition, there is a high degree of decentralised decision-making and directives, and laws and regulations are often lagging after the experienced challenges. Consequently, individual experts experience increased ethical challenges. Systemic circumstances apprehension is necessary for reducing societal risks within climate change adaptation. Both education of engineers and cooperation between specialists from different disciplines is needed to master the altered framework conditions.

Keywords: professionalism; silo-thinking; information asymmetry; problem of many hands; knowledge abuse

Citation: Lohne, J.; Solheim, A.; Muthanna, T.M.; Time, B.; Hauge, Å.L.; Kalsnes, B.G.; Lædre, O.; Kvande, T. Ethics of Climate Change Adaptation—The Case of Torrential Rains in Norway. *Buildings* **2023**, *13*, 1111. https://doi.org/10.3390/buildings13051111

Academic Editor: Rafik Belarbi

Received: 21 March 2023
Revised: 14 April 2023
Accepted: 20 April 2023
Published: 22 April 2023

1. Introduction

Climate change exposes societies to radical change [1]. Categorisations of the responses to the changes observed mostly vary between climate change mitigation and climate change adaptation (CCA) e.g., [2]. At the heart of CCA lies ethical concerns (ibid.) and responding to climate change is one of the gravest ethical challenges facing humanity today [3]. Indeed, these authors underline that CCA impacts not only a need for technical solutions, but also encompasses major changes in the way societies operate. Such major changes will inevitably have significant ethical implications. These include most notably questions about who will bear the burdens of the changes (that is, key ethical concerns such as equality issues, gender issues, geographical distribution issues, and socio-demographic issues).

The ethical concerns are multiple [4,5]. Ethical analysis concerning CCA needs to take place at several levels, since "[e]thics [within this context] encompasses evaluative thought that extends from noble visions and high ideals to the more immediate and constrained assessment of options that face people in the here and now" [6], p. 847. The literature

indicates that within the field of CCA, more effort has been invested in ethical analysis on an overall level than in the here and now.

Climate change leads to a concern for the actors that carry out concrete CCA measures, in particular engineers within the architecture, engineering, and construction industry [7]. In this article, ethical challenges posed by CCA enforced by intense precipitation in the form of torrential rains affecting urban landscapes are scrutinized. In several regions, but in Norway in particular, torrential rains are pointed out as being a key challenge inflicted on the built environment by climate change. Torrential rains are also worth paying particular attention to, given that they are very challenging in terms of CCA [8]. The results outlined here are thus based on analyses of the Norwegian context; they are, however, applicable in regions where an increase in torrential rains is expected.

The literature review preceding the research presented in this paper showed, however, that little is known concerning the implications for the actors addressed—and in particular the ethical challenges that surface during this work. As such, the analysis presented pertains not only to CCA, but also to the more general question of adaptation to altered framework conditions by industry professionals such as engineers. The ambition is to illustrate how altered framework conditions expose engineers to ethical challenges by answering the following research questions:

1. What are the main systemic circumstances shaping CCA measures?
2. What ethical challenges do these measures entail for individual experts?
3. What measures can be envisaged to overcome these challenges?

2. Theoretical Framework

The definitions of ethics are notoriously diverse [9]. The contrasting features and overlapping of these definitions can be illustrated in several ways [10]. For instance, Davis ([11], p. 718) depicted three separate concepts labelled ethics, notably (1) ordinary morality, (2) a field of philosophy, and (3) special standards that go beyond ordinary morality. Engineering ethics fall into this third category, as it "applies only to members of the relevant group (engineers)" ([11], p. 719). While resembling aspects from other ethical perspectives, engineering ethics is generally more stringent. For instance, the National Society of Professional Engineers [12] is very specific in detailing ethical conduct and unethical practices, where the safety of others, truthfulness, trustworthiness, and a long list of similar topoi from the literature on ethics are listed.

Even though occurrences of such practices are treated in the following, the present article rather treats the dynamics driving the occurrence of or potential for unethical practice.

2.1. From Ethics in the Built Environment to Ethics in CCA

Reviews aiming at mapping unethical practices within the built environment in general—be they broad in approach e.g., [13,14], focusing particularly on corruption e.g., [15,16] or particularly exposed individuals [17]—have remarked the small interest in questions related to ethics. As Walker [18] notices, there is no reference to ethics in the index of PMI's Guide to the Project Management Body of Knowledge [19] and generally "a dearth of papers related to ethics".

Associations such as the Project Management Institute (PMI), Royal Institute of British Architects (RIBA), American Institute of Architects (AIA), American Society of Civil Engineers (ASCE) and International Project Management Association (IPMA) have codes of conduct [20]. These codes are typically general in nature. In addition, studies of higher levels of education have shown that little if any ethics are included in the curriculum of engineers e.g., [21–23].

Exploratory studies reveal a widespread idea of professional ethics existing in the form of tacit knowledge [24,25]. Tacit knowledge is typically anchored in deep-rooted practices. As climate changes and the responding adaption measures change, pressure is put on established perceptions of ethics in the industry.

2.2. Ethics of CCA—Previous Analyses

Further, the approach of Heyward, for whom "adaptation aims to deal with the potential or manifested effects of the physical changes associated with global climate change. It does not attempt to reduce GHG concentrations [e.g., mitigation] or avert temperature increase" [2], p. 483, is followed. The main advantage of this definition is that it opens the question of CCA to all fields of potential interventions.

The moral worthiness of CCA has been contrasted with that of mitigation, resulting in that "[t]hose who advocated mitigation regarded talking of adaptation, variously, as (1) defeatist [. . .], (2) as an indication or creating unwillingness to participate in mitigation efforts, and (3) as a distraction from mitigation" [2], p. 475. Having such a promised cure should make us more likely to procrastinate and less likely to address the root problems causing climate change in the first place e.g., [26,27].

The need for adaptation has, however, been recognized more prominently in the 2010 Cancun agreement, maintaining that "adaptation must be addressed with the same priority as mitigation and requires appropriate institutional arrangements to enhance adaptation action and support" [28], p. 3.

Following this, ethical debates have been raised on analytic and political levels. Institutional arrangements e.g., [29], policy-making processes e.g., [30,31] and administrator role challenges e.g., [32] are typical examples of this. Thematically, these debates include concerns for indigenous populations particularly exposed to the effects of climate change e.g., [33]; vulnerable populations e.g., [34,35]; the implications of the use of global-reaching adaptation tools such as geoengineering e.g., [36]; climate diplomacy e.g., [37,38]; non-linear risk potentials, such as exceptional tipping-points e.g., [39], etc. Similarly, the identified approaches to ethics of adaption vary from normative e.g., [40] via framework-oriented e.g., [5] to exploratory e.g., [3]. The debates include terms such as justice (for a discussion hereof from a financing perspective, see e.g., [41]; transparency (e.g., [42]; responsibility (e.g., [43]; obligation to act (e.g., [44]), etc.). It seems, thus, that the main body of the literature addresses challenges occurring within the spheres of politics and policy-making.

Equally interesting is what is not debated. Questions about practical concerns such as conflict resolution [45], analyses porting on those carrying out practical CCA work, or crucial subjects such as project delivery methods are rare (a notable exception can be found in [46]; see also [47]). Considering this, it is easy to agree with Schmidtz [45], for whom "[e]nvironmental ethicists need to start with conflict on the ground rather than visions". Even more sharply, Holland [34] underlines that "adaptation efforts are largely treated as a technical enterprise [. . .] while marginalizing issues of social justice". It can be added to this that there is a real lack of the literature on what van de Poel et al. [48] and van de Poel et al. [49] denote the problem of too many hands. Within the Norwegian context, this "conflict on the ground" has several aspects, with challenges driven in particular by geographical factors that vary greatly.

2.3. Torrential Rains in Norway

Norway's varied topography, long north–south extent, and location at the edge of the North Atlantic result in highly variable climatic conditions over short geographical distances. The seasonal variations are significant. Generally, the climate is milder in Norway than in other areas at the same latitude, mainly because the North Atlantic Drift transports warm water from the Gulf of Mexico northwards along the Norwegian coast. Prevailing south-westerly winds carry warm, moist air towards the coast [50].

Annual precipitation in Norway has increased by ca. 18 % over the last ca. 100 years, and climate prognosis shows that average precipitation will increase by 10–18% through this century, relative to the reference period 1971–2000, depending on the emission scenario [8]. In addition, both the frequency and intensity of extreme precipitation events are increasing. The increase is seen for all regions and all seasons, causing large damage to infrastructure and buildings. The effects of heavy rainfall—most notably with high intensity over a few hours—are particularly challenging to adapt to, both due to their amplitude and the

relative lack of predictability concerning where they will occur [8]. In addition, as buildings and infrastructure assets have expected lifetimes from 40 to more than 100 years, they are exposed not only to the climate at the time of construction but also to climate variations over decades [51,52].

The increase in torrential rains—both in frequency and impact—challenges existing systems established to tackle precipitation. In other words, altered framework conditions impose altered technical solutions and the new ethical challenges that come with them.

2.4. Industry Characteristics Moulding Ethical Challenges

As debated by several authors e.g., [53], projects carried out within the context of the built environment have certain characteristics that distinguish them from other industrial ventures. Vrijhof [54] has typified the industry as a "project-based industry with specific characteristics such as location-bound design, one-off production, changing production coalitions per project, outdoor and environmental circumstances, multiple clients and multiple suppliers involved in a single project. In comparison to many other industries, the production environment in building is relatively complex and unstable". This definition can with minor alterations be extended to all endeavours discussed here.

Not surprisingly, these characteristics reflect how the industry operates, so "actual operations in the industry can be interpreted as responses to its inherent complexity" [55], p. 3. A key point is that the characteristics foster decentralized decision-making. This means that executive powers and corresponding ethical responsibilities are put in the hands of those carrying out CCA-related work.

The challenges involved in decentralised decision-making are exacerbated by another characteristic of the contemporary AEC industry, notably that of information silos.

2.5. Silo Mentality

An information silo can be defined as an insular information system incapable of exchanging information with other systems. In a field characterised by information silos, information is not adequately shared.

The influence of industry structures on knowledge sharing between engineering disciplines within the built environment is a surprisingly little-scrutinized theme. Working within a fragmented structure, with project-based work and between different engineering disciplines involves results in information silos [56]. Challenges can—for instance—be directly observed in the lack of cohesion in the new teams that take on the different phases of a construction project [57].

Technologies such as BIM have for decades held the promise of enhancing integration and reducing the fragmentation of the industry [58]. Still, this development is far from reaching a point of maturity permitting for effective combatting of existing information silos [59].

For what concerns decision-making within the context of CCA, it seems that silo mentality will expose more actors that carry out concrete CCA measures, in particular engineers within the architecture, engineering, and construction industry [7], to ethical challenges. Not being able to involve other disciplines and actors with differentiating concerns in the decision-making will expose those making decisions to the dangers of not being able to fully appreciate the consequences of decisions.

2.6. Knowledge Gap

As commented by Nair and Bulleit, "[e]ngineering is a practice that must function in an environment of incomplete and uncertain knowledge" [7], p. 65. Alterations to complex adaptive systems predictably produce highly uncertain results. The incompleteness and uncertainty of knowledge manifests at two analytically distinct levels—practically, in that the engineering challenges encountered are new, and ethically, since the tacit knowledge developed over time will be outdated.

Such consequences of systemic alterations need, as illustrated above, to take into account the nature of the system that is changing—in this case, the AEC industry exposed to climate change. As illustrated above, climate changes will inflict major stress on the built environment. To meet future climate conditions, CCA efforts need to be made. These efforts, however, need to be conceived of within constraints that are very much present in the AEC industry, notably its project-based nature and the information silos characterising the industry. To a certain extent, the consequences of this have been discussed at a policy level.

Yet, neither the consequences of alterations to practical solutions nor the consequences this will have for the ethical deliberations of those carrying out work on a practical level are properly understood.

3. Methods

3.1. The Research Object

The research object under investigation here is the built environment at large as this is influenced by changes in climate that necessitate CCA measures. Emphasis lies on water-triggered landslides, stormwater management, blue–green solutions, building structures, socio-economic incentives and decision-making processes.

3.2. Research Design

The present article results from a meta-analysis of the outcomes of an eight-year research project, Klima 2050, with the main objective of "risk reduction through climate adaptation of buildings and infrastructure". Meta-analysis is here not to be taken in any very technical sense, but rather in its original meaning, as the "analysis of analyses" [60].

The analysed studies were based on laboratory and field measurements, simulation techniques, as well as semi-structured interviews and observation studies. This covers the entire width of the centre activities and therefore a broad range of methods and techniques within building sciences, geosciences, hydrology, civil engineering, and social sciences [61–66].

In addition, pilot projects have constituted a main arena for product and process development, as well as for validation of previous research. Collaborative research through PhD projects, master theses, partner participation and stakeholder groups constitutes the core of all research activities.

3.3. Literature Review

The main search engine used was Google Scholar. Complementary searches were conducted in the Norwegian library database Oria. Search words included "ethics", "virtue", "professionalism", "silo mentality", "urban landscapes", "information asymmetry", "problem of many hands" and combinations of these using Boolean operators.

3.4. Document Study

In addition to the published research, the centre has produced a series of documents such as strategy documents, communication plans and summaries of the research conducted. These form part of the background material for the analysis, following Bowen's [67] prescriptions for document analysis.

4. Results

4.1. Precipitation and Awareness in Norway

Over the last decades, several extreme weather events have been observed in Norway. The common denominator of these events is water. As described by Sandberg et al. [68], the chronological development of CCA strategies in Norway from 2009 to 2019 illustrates that extreme events have led to increased awareness of climate change consequences.

The national budget for 2009 marked the commencement of the Government's adaptation-related work [69]. This resulted in a report outlining the consequences of climate change (i.e., [52]). In 2013, a government report on the status of CCA in Norway [50] recommended

addressing surface water flooding in particular. The ensuing report was published in 2015 [70].

Reporting to the Intergovernmental Panel on Climate Change (IPCC) entails the continuous assessment of risk factors and adaptation needs [71]. As part of the Paris Agreement, all countries are committed to preparing a climate change adaptation plan [72]. In 2018, a governmental report [73] was published setting out climate-related risk factors and their significance for the Norwegian economy. The year 2018 also saw the publication of adaptation guidelines for use in planning, directed at the municipalities, county councils and national authorities. These were subsequently incorporated into the statutory provisions accompanying the Municipal Planning Act [74]. However, climate change adaptation was only referred to in Norway's national budget in 2020 under the items research and foreign aid [75].

With two exceptions, the documents described above do not mention ethical issues. The first exception [52] refers twice to the need to respect the inherent ethical value of nature, whilst the second exception [73] refers to moral hazard in the context of actor behaviour. No mention can be found of CCA-related ethical challenges.

4.2. Ethical Challenges following the Effects of Torrential Rains

The following sections illustrate on a practical level that challenges stemming from the increase in torrential rains have ethical implications for individual experts.

4.2.1. Torrential Rains Lead to Landslides

Most debris slides and flows in Norway are triggered by precipitation. The precipitation occurs mostly in the form of rain, but sometimes it occurs in combination with the melting of snow [76–78]. Milder winters with more frequent rain-on-snow events lead to an increased frequency of slush flows, which often develop into debris flows as the flows entrain debris and sediments downslope. Increased levels of human activity, such as uncontrolled land use, urbanization and deforestation increase the probability of release and the consequences of landslides. The changing precipitation patterns may also lead to landslides in areas not usually affected by landslide activity.

The development exerts increased pressure on infrastructure. Transport infrastructure such as roads and railways are particularly vulnerable to landslides. Climate change is identified as one of the main challenges to the safety of transport infrastructure [79]. Examples of this appeared in the village of Kvam in central southeast Norway in both 2011 and 2013, when main roads and railroads were closed for long periods due to flooding and debris flows, with huge economic losses as a result.

Structural risk-reducing measures for landslides include barriers and check dams. Non-structural measures include early warning systems, evacuations, and road/railroad closures. Lately, nature-based solutions that usually involve vegetation have gained importance. Proper land use planning is however crucial for the establishment of new infrastructure and buildings. This planning is regulated by the Norwegian Planning and Building Act (Plan-og bygningsloven) [80].

For existing buildings and infrastructure, however, the challenges are multifaceted. Many houses and much infrastructure are built in areas which already are, or will be, exposed to landslide hazards. The hazard is difficult to assess, and the assessments are often based on the expertise and judgement of individual specialists. Furthermore, the knowledge of landslide hazards is largely missing in the general public.

Assessments of landslide hazards require frequently updated knowledge and frequently updated directives, laws and regulations. In addition, the hazards entail ethical challenges, for instance, pertaining to political decision-making, the responsibility for variations in insurance premiums, and questions regarding the balance between individual and collective responsibilities. A hazard assessment by a specialist may lead to dramatic changes in property values. Today, specialists already face ethical challenges in addi-

tion to traditional engineering challenges, and these ethical challenges do not disappear when ignored.

4.2.2. Torrential Rains Lead to Pluvial Floods

The construction of traditional drainage systems (mainly underground) will not suffice to address the challenges ahead. Nature-based solutions and floodways are proposed as measures for tackling such challenges [70].

Following this line of thought, the overarching strategy for tackling flood water stemming from torrential rains in Norway today is outlined by Lindholm [81]. The main approach described there consists of a three-step strategy for infiltration, delaying, absorption and safe flood roads. The principle is that the first subsection in most cases manages to infiltrate or withhold the water in all rains with a smaller amount of precipitation than a defined threshold value. When precipitation above this threshold falls, the excess drains to open facilities that delay and absorb runoff. In a few events, the volumes of water are so extensive that the normal systems cannot handle runoff alone. For these, floodways can be constructed to safely divert the resulting pluvial floods [81]. The above illustrates what challenges those responsible for reducing the effects of flood water are facing.

One challenge stems from the system boundaries for Norwegian urban streams. Paragraph 20 in the Natural Damage Act (Naturskadeloven) [82] requires downstream protection against flood-triggered landslides [nedstrøms sikring er påkrevd]. It is unclear how far downstream measures are to be implemented. The text of this act leaves a fuzzy boundary between measures protecting against floods and downstream measures protecting against landslides caused by such floods. This fuzzy boundary is particularly felt in urban areas, where effects on the built environment can be substantial. In areas with quick clay, which are common in Norway, the balancing between measures poses significant ethical challenges.

Another challenge concerns the overlap between disciplines when it comes to the use of maps. Several frameworks for tackling parts of the challenge exist, but there is a limited exchange of information between users of these different frameworks. Good maps are available for flood and landslide hazards, respectively, but they are rarely combined. As such, the problem of the engineer—typically coming from one of the disciplines involved, such as hydrology or geotechnics—is to understand what to do within one's field of expertise without resulting in an action that conflicts with the concerns of those involved in other disciplines.

The third challenge comes with the dimensioning of the intervention. As outlined by Skrede et al. [83], the use of streets as floodways is an illustrating example. Streets as floodways require additional hydraulic performance criteria and safety criteria. They are demanding structures to establish. Skrede et al. [83] determined that, when planning safe floodways, planners must choose between the level of safety and the hydraulic performance of the floodway. As such, steep urban streets as floodways cannot be recommended without substantial flood safety measures, such as levees, elevated pedestrian crossings, and elevated curbs. The balancing acts are left to the actors carrying out work on the ground to address. This dimensioning challenge is especially valid when deciding what maximum level of flood events should be accounted for; there is a large difference between planning for events with a 5-year return period and those with a 100-year return period.

For all three challenges, the question of who should act remains open. This is a typical problem of too many hands, and this problem is enforced by the plurality of actors from different disciplines. The lack of judiciary boundaries proves problematic. As of the writing of this article, no concrete cases illustrating the above challenges have been put to test before a Norwegian court of law.

All solutions have consequences, such as restricting usable area and high costs. Goal incongruities are almost guaranteed to arise between those who abide the measures and those who do not. The recourse to new floodways is telling; whose street is to be exposed to what levels of torrents of water is no innocent decision. In the end, many such deliberations

should be determined on a political level; yet the technical analyses and other documents on which decisions are based need to be elaborated by engineers. These analyses are to a significant degree left to individual judgement.

In the examples discussed above, one of the main characteristics is the difference in specific knowledge by the engineer (the agent) compared to that of the commissioning party (the client). The recourse to the individual judgement of the engineer facing concrete problems exacerbates the potential for the inhibited use of this—and as such, opens the potential for dishonourable behaviour. In the Project Management literature, information asymmetry has been identified as one of the "hot spots" for potential corruption or analogous challenges. With the advent of increased intensity and frequency of torrential rain following climate change, it is predictable that the challenges will be greatly exacerbated.

4.2.3. Torrential Rains Lead to Damage to Buildings and Infrastructure

Two major sources of information concerning damages to buildings and infrastructure in Norway provide grounds for analysing both trends in and root causes for water-related damages. These are data from Finance Norway, concerning trends in insurance pay-out for water-related damages and the SINTEF Building defects archive [Byggskadearkivet], mapping building damages and their causes.

Finance Norway is the organization for the financial and insurance businesses in Norway, and their figures show that the trend in insurance payments is on the rise. The consumer price indexed figures increased from NOK 1.032 billion in 2008 to NOK 1.831 billion in 2019 [84].

An overview of the cost development of insurance paying outs after damages on buildings/inventory as a consequence of precipitation in the years 2008–2020 in Norway shows that urban stormwater damage is the most expensive factor, more so than floods and other natural disasters [84]. Data shows a drastic increase in the number of stormwater damages, from 18.000 in 2008 to 26.000 in 2016. According to Finance Norway [85], this increase cannot be explained by a significantly higher number of buildings nor infrastructure; it rather expresses the increased climate loads.

The SINTEF Building Defects Archive documents cases of building defects for the past 60 years. Since 1964, more than 5000 cases have been investigated. Detailed information regarding these investigations has been collated and filed in this building defects archive. A thorough investigation into the process-induced building defects collected in this archive revealed that few new types of damage occur, but they occur more often and with larger consequences [86].

This aggravation of damages leads to a need for more robust constructions. Buildings are, for instance, exposed to maceration over longer periods than before. Adaptation measures must address such concrete challenges. Masonry is a good example here, where research shows that an alteration in the wetness of the concrete employed can provide a more resilient masonry [87,88]. In addition, the altered precipitation patterns following frequent occurrences of torrential rains lead to novel needs for maintenance, e.g., where gutters formerly needed cleaning each autumn, they now ought to be cleaned before the rains of the summer season as well. Such small details typically have significant consequences for the built environment. Rather than the problem consisting of defective assemblies on a large scale, small parts of the construction might be exposed to stress levels exceeding their potential. CCA through the addressing of such small details challenges the ethical stance of individual experts.

Kvande and Time [89] maintain that current building regulations do not treat CCA measures as an ensemble, but rather as dispersed entities. Whether an area is suitable for development purposes is assessed in the form of a risk and vulnerability analysis, in accordance with the Plan and Building Act and Chapter 7 in the Building Regulations TEK17 [90].

For land to be developed, there are requirements concerning groundwater and flood water in both the Plan and Building Act and the Building Regulations TEK17. For the

building's ability to withstand moisture, wind and snow, the relevant requirements are discussed specifically in the Building Regulations TEK17. Chapter 7 of Building Regulations TEK17 describes the effect of climate change and the fact that this may have consequences for the localisation of buildings and for loads. An increased risk of flooding and landslides is described. After this, it is pointed out that "the Planning and Building Act with regulations shall contribute to ensuring that new buildings and structures are adapted to a changed climate". The Plan and Building Act specifically states that "to ensure that any measure has a proper and intended lifespan, special consideration shall be given to geographical differences and climatic conditions on site" (our translation). However, how the future climate is to be considered is not specified.

For an actor planning or carrying out actual work on site, assessing the implications and interplay of these regulations will prove inherently challenging. The level of detail can pose problems. Andenæs et al. [91] outline that unsurmountable levels of dispersed information in SINTEF building design guides relevant to blue–green roofs are inducing a selective reading of design guides. The SINTEF Building Research Design Guides are a series of reputed and widely used building technical recommendations in Norway. The selective reading leaves a significant and largely unaddressed human factor in play, and with corresponding risks and responsibility issues following thereof. Sticking to well-proven solutions will thus be highly tempting, even if these solutions are not the recommended ones.

This penchant for choosing well-proven solutions is exacerbated by questions pertaining to goal incongruity. Economic factors are at play, since altering the modus operandi of operations typically inflicts extra costs. Equally important, however, are temporal aspects. According to The Housing Construction Act (Bustadsoppføringsloven) [92], for instance, the warranty time for dwellings in Norway is limited to five years. Many of the damages inflicted by altered climatic conditions occur in a temporal horizon significantly longer than this. This means that the contractor has a strong incentive to consider the construction according to another timeframe than the client, who typically uses the built object over a period of decades.

Finally, adapting to new climate conditions typically leads to increased complexity in projects. As outlined by Engebø et al. [93], to meet the challenges of projects with high sustainability ambitions, new collaborative working processes need to be implemented, with the explicit ambition of breaking down discipline silos. To achieve this, emphasis is placed on heightened levels of trust among participants. Furthermore, according to Engebø et al. [46], achieving the requisite collaboration depends on contractual, cultural, and organisational elements, of which the latter two are under the direct influence of individual experts. Trust is of the essence, yet questions about responsibility and blame for breaching trust remain [47]. It seems reasonable that the actors most in contact with the other project parties—that is, the individual experts—will be most exposed to blame.

The numbers show that insurance payments are quickly raising. The knowledge about ways to make the buildings and infrastructure more robust partly exists, but the dissemination of this knowledge requires more effort than is provided today. The result is that those carrying out work on the ground are tempted to apply well-proven solutions suited for previous climate conditions before the more costly and robust solutions.

4.2.4. A Reactive Rather Than Active System

The above has identified ethical challenges following the effects of torrential rains as relatively discrete entities. Such an approach may hide possible cascading effects of the events. Flooding can, for example, lead to landslides, increased risk for landslides can influence the security classification of building sites, and runoff from buildings challenges the capacity of the urban drainage systems.

The possible cascading effects imply ethical challenges at an aggregated systems level. From the research carried out within the context of Klima 2050, at least three systems with challenges can be identified.

First, network activities are needed for practical dissemination of knowledge about the reactive nature of CCA measures. In a series of papers, Hauge et al. [94–96] discuss the nature of existing guidelines for CCA and the need for knowledge network activities as a strategy for dissemination.

Second, the directives, laws, and regulations within the context of CCA are dispersed and not holistic. For an actor planning or carrying out actual work on site, assessing the implications and interplay of building regulations will prove inherently challenging. The level of detail in the regulations can pose problems as well.

Third, damage of data in the form of insurance payouts has been of interest to the researchers involved in Klima 2050 (e.g., [97]. Previous research has shown that municipalities benefit from damage of data on an address level from the insurance companies [98]. Data contribute to an improved understanding of the risks involved, and consequently to prioritizing measures. As described by Hauge et al. [95], the data provided made possible a public–private cooperation between regulatory bodies and insurance companies. The Norwegian Directorate for Civil Protection (Direktoratet for samfunnssikkerhet og beredskap) and Finance Norway implement common measures to prevent undesirable nature events. The closer one gets to those responsible for CCA, the clearer it becomes that such increases in data quantity and quality imply ethical challenges. If the insurance companies provide the municipalities with detailed loss data, claiming a lack of knowledge is challenging. The latter thus increases their exposure to impoverishing regress claims. The question is if small municipalities can manage such responsibility for access to loss data. As such, questions of responsibility arise on a systems level.

In sum, the pattern of action is reactive rather than proactive. The regulation of measures carried out does not adapt well to the challenges encountered and the question of who is taking on risk when information flows are altered is not well understood. The reactive systems leave the individual experts with ethical challenges when carrying out their work.

5. Discussion

The Results section addressed (1) the main systemic circumstances shaping CCA measures, (2) ethical challenges these measures entail for individual experts and (3) what measures can be envisaged.

First: A general insight from the results presented is that reactions to climate change adaptions (CCA) within the Norwegian context are largely pushed forward through major natural incidents such as hurricanes, floods, etc. This implies a certain lag in regulatory responses to such events. Directives, laws and regulations do not keep pace with the needed changes in the built environment that the physical conditions impose.

Second: Concrete CCA is highly specialised. Such specialisation is prone to foster silo mentality among the involved engineering disciplines. The specialisation underlines the need for decentralised decision-making, as the specialists are best in place for deciding what to do with encountered challenges. The specialists will typically have superior knowledge to the regulator about CCA issues, and there is a corresponding risk of abuse of knowledge.

Third: As Coecklebergh [99] suggests, there are two mutually exclusive ways to manage challenges within contexts similar to the ones discussed here; "by imposing external constraints on engineers or by engendering their feelings of responsibility and respect their autonomy". The results presented above suggest that the latter of these two ways is the most viable. The individual expert needs to rely more on professional virtues than directives, laws and regulations. There is a clear need for working towards less silo mentality and increased cross-disciplinary work. This, in effect, underlines the need for professional virtues.

6. Conclusions

On basis of the analysis, the following conclusions can be made:

- CCA challenges boundaries between civil engineering disciplines.

- Established practices need to be altered, and individual experts face new ethical challenges.
- On-the-ground CCA requires an increased ability to overcome silo mentality among the involved disciplines.
- Prevalent challenges concern acknowledging responsibility, transparency, and information quality.

The key point underlying the above points is that engineering with a high degree of decentralised decision-making occurs in an environment with incomplete knowledge and regulations. It follows that knowledge and regulations lag after the experienced challenges. As a consequence, individual experts experience situations that challenge their ethical judgements. The analyses presented above illustrate the concrete challenges met by actors within several contexts.

Systemic circumstance apprehension is necessary for reducing societal risks within climate change adaptation. To master the altered framework conditions, both education of engineers and cooperation across disciplines is needed. Education and professional standards must respond to these alterations. Increased attention to ethics in engineering education will be a good start.

Several directions of future research can be envisaged in light of the analysis presented here. It seems, however, that concern exists for the actors that carry out concrete CCA measures, in particular engineers within the architecture, engineering, and construction industry [7]. The role of these—be they consultants, project managers, technical experts, etc.—can be expected to increase in the near future. Given the limited literature on the field, observations of actual practices with recommendations for the improvement of these should be carried out. CCA is in its nature very concrete and tangible; future analyses ought consequently to be more oriented towards operational challenges and the ethical concerns these entail than towards solely desktop studies.

Author Contributions: Conceptualization, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K., O.L. and T.K.; methodology, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K. and T.K.; validation, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K., O.L. and T.K.; formal analysis, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K., O.L. and T.K.; investigation, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K. and T.K.; resources, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K. and T.K.; data curation, J.L., A.S., T.M.M., B.T., Å.L.H., B.G.K. and T.K.; writing—original draft preparation, J.L.; writing—review and editing, J.L. and O.L.; visualization, J.L. and O.L.; supervision, B.T. and T.K.; project administration, B.T. and T.K.; funding acquisition, B.T. and T.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: No new data were created or analysed in this study. Data sharing is not applicable to this article.

Acknowledgments: This paper was written within the Klima 2050 Centre for Research-based Innovation. The authors gratefully acknowledge all our partners and the Research Council of Norway.

Conflicts of Interest: The authors declare no conflict of interest.

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Integrating Aerial and 3D Data into a Data-Driven Decision-Making Workflow for Nature-Based Stormwater Solutions

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Abstract: Urbanization and climate change have increased the need for stormwater management and nature-based solutions. Decisions made at the project level impact the emergence of the systemic traits of the stormwater network and the functionality of the catchment areas in urban planning. To that end, it is vital to introduce the decision-making tools for analysing both the utilities and amenities of nature-based solutions (NBS) to increase their adoption to reduce the peak loads in the stormwater system and, to that end, mitigate the impacts of climate change. There is a deficiency in employing a software-based approach to analyse the qualitative and quantitative aspects of NBSs to back up design decisions. This paper demonstrates a workflow using drone-based photogrammetry, 3D modelling, and simulation software to generate visual and functional models assisting in informed decision-making in the design of stormwater systems as functional landscape architecture. Using aerial data from drones and modelled design solutions, the proposed workflow simulates rain events, infiltration, evaporation, water flow, and the accumulation of stormwater in a way that allows the visual and quantified analysis of detailed landscape architecture designs. The paper provides an example of a rooftop site simulation demonstrating the infiltration and flow of water to the drainage. The visual decision-making method provided can aid in investment decisions for functional landscape design in support of stormwater management.

Keywords: data; drones; urban; nature-based; photogrammetry; design; software; decision-making

Citation: Edelman, H.; Rosén, L.; Nyman, E.; Leskinen, P. Integrating Aerial and 3D Data into a Data-Driven Decision-Making Workflow for Nature-Based Stormwater Solutions. *Buildings* **2023**, *13*, 2983. https://doi.org/10.3390/buildings13122983

Academic Editors: Steffen Lehmann and Monika Szopinska-Mularz

Received: 29 October 2023
Revised: 23 November 2023
Accepted: 28 November 2023
Published: 29 November 2023

1. Introduction

Urban stormwater runoff is a significant environmental challenge that threatens human and ecological health across cities worldwide and calls for urban stormwater management (USM) [1–5]. The continued urbanization and changing climate have exacerbated the problem [6], highlighting the need for effective stormwater management solutions [7]. However, conventional engineered stormwater systems commonly lack combined functionality and design quality, leaving much to be desired in terms of visual and architectural quality in the artful rainwater design (ARD) [8]. The concept of ARD shares common objectives with an earlier approach of "infra-garden" to support ecological and social values in stormwater management [9]. Both approaches aim at combining functional performance and artistic, visual, and emotional qualities with architectural experiences that promote liveable and resilient cities.

Novel trends in stormwater management suggest the use of nature-based solutions (NBSs) in the planning of urban rainwater systems, mainly in the European Union since 2015 [10]. Apart from the functional performance, the social benefits with aesthetic and place-making qualities are considered as quintessential properties of NBSs [11]. However, small-scale NBSs associated with the urban fabric are effective only in large numbers and with a systemic implementation [12]. To that end, there is a need to investigate how to increase and encourage the adoption of NBSs as part of the urban drainage system. Here,

NBSs are considered as nature-based and inspired design interventions in the urban fabric, being part of the design of the built environment.

The objective of this paper is to provide a demonstration of a drone-based data-collection and design workflow delivering an approach for assessing both the amenities and utility performance of a design for a specific project area. A green roof of a campus building was used in this study as a test and demonstration location for the workflow. The analysis of amenities of NBS is grounded in subjective and project-specific design aspirations while the investigation of utilities offers parameters with metrics, such as the infiltration capacity of the ground to absorb stormwater, to analyse the functionality of the stormwater system through a computational approach.

This study consisted of two phases: (1) the current applications of drone data to the design of stormwater management systems were investigated, and (2) the implementation of a design workflow was investigated. The aim of the first phase was to find out to what extent the current practice and workflows support the decision-making of the functionality and aesthetic quality of the stormwater systems in small and medium urban scale projects typically subject to real estate investments. In the second stage, a design workflow was investigated to provide prescriptive advice for design practitioners, the software development community, and researchers for further development of workflows based on aerial imaging, modelling, and design software to achieve more informative design methods for decision-making in projects having the potential to involve a small-scale urban NBS.

The paper aims to explore the use of aerial imaging to support the analysis of amenities and utilities of smaller-scale urban NBSs by answering the following research questions:

1. In what ways has aerial data been used in support of designing small-scale urban NBSs?
2. Is there a way to use aerial data as a rapid assessment method of the amenities and utilities of urban NBSs?
3. How could a computational workflow be established combining aerial data and 3D design information to create a visual and functional representation of a prospect NBS for decision-making purposes in urban projects?

Current Trends of Using Drone-Based Aerial Data for NBSs and Stormwater Design

The performance of stormwater systems has been under scrutiny for an extended period of time due to impairments and knowledge gaps in stormwater management actions and impacts of the urban landscape and grey infrastructure on local and regional hydrology [13,14] and pollution in the runoff waters [15,16]. At the same time, the municipalities commonly work under constrained resources for stormwater management resulting in the need to target the measures with the most impact on the water quality, which is a complex task to accomplish [17]. The effectiveness of the measures may not fully comply with the design intentions, and to that end, active monitoring has been suggested to ensure compliance [18]. However, laborious active monitoring and data collection on the properties of water, such as the surface flow or water quality, have limited capacities to provide direct prescriptive advice and guidance for designing stormwater solutions in other areas and specific sites. In turn, aerial data can offer a means for data-driven decision-making in the local design context. MacDonald [17] has proposed the following taxonomy for drone applications in the emerging field of using Unmanned Aerial Vehicles (UAVs) in stormwater management and system design:

1. An asset management tool. This category involves data collection and analysis of both built environments, such as sewer inlets [19], and green infrastructure, enabling, for example, the monitoring of plant health [20].
2. A water measurement tool, including both sampling [21] and imaging approaches such as fusion of RGB and multi-spectral imagery [22].
3. A vehicle for better model parametrization. Aerial data can provide spatial data on demand for higher spatial accuracy than other georeferenced data with low resolution and granularity for the improved performance of models [23,24]. More-

over, thermal imaging can produce fine resolution estimates on the ground surface temperatures [25] and surface imperviousness [26]. The detailed properties of the ground can significantly contribute to the development of the modelling approaches from the viewpoint of functional landscape architecture.

4. A way to support smart and connected stormwater systems. UAVs are considered as tools for generating data and improving situational awareness [27]. The advantage of emerging autonomous and frequent drone operations can be real-time and can frequently update aerial data as a side product of other smart city solutions such as drone logistics or first responders' operations. The increased availability of detailed and high-resolution data supports the adoption of data-driven stormwater design and management approaches.

The above taxonomy supports the aims of this research in three ways. First, aerial imagery and photogrammetry were investigated as asset management tools to (i) establish a mesh model created through photogrammetry that can be used as a preliminary model to study the stormwater features of the location by altering the assigned mesh properties, such as colour and texture, and functional properties, such as imperviousness and roughness of the surface impacting water flow, and (ii) deliver the surrounding context data of the design area to which the 3D model of the nature-based design solution can be inserted for analysing the utilities and amenities of the solution. The above approach helps to estimate the qualitative and quantitative performance of the intended design solution.

Second, for the aim of better parametrization of physical model parameters, it is possible to use measurement-based estimations of imperviousness for each soil and surface type and assign those values to corresponding areas of the surface mesh to simulate the infiltration and flow of the stormwater. For smaller surface areas, the approach can be applied manually by selecting the desired parts of the mesh. However, for efficiency and larger surface areas, machine learning using semantic segmentation could be applied [28]. The aerial data of UAVs can aid in this task, namely, by providing more detailed and unobstructed imagery in comparison to high-altitude aerial imagery. The tree canopies often prevent the surface analysis from aerial images taken from higher altitudes. Furthermore, in such aerial images, the resolution or point cloud densities are insufficient for determining very precise geometries of the surface, such as inclined surfaces or detailed curb sides, to analyse precise surface water flows and pooling of water in detail. To that end, the evaluation of functional landscape architectural design calls for more detailed data about the surroundings.

Third, smart and connected stormwater systems have their roots in individual projects and investment decisions concerning NBSs. To that end, each project and related nature-based design is part of a larger evolving network of site-specific stormwater solutions and contributes to the reduction of loads on the network. Therefore, the decision-making process at the project level should provide an informed process to consider the increased adoption of NBSs in support of creating the network in a coordinated manner.

In summary, drones can effectively collect data for creating 3D models of urban locations for the modelling of surface flows and the infiltration of stormwater in a detailed architectural context. Further, the paper aims to introduce a design software-based workflow to support such decision-making processes. The research problem of the study stems from the notion that there is a shortcoming in the available design workflows for analysing the visual and functional stormwater qualities of architectural nature-based solutions.

To conclude, the aim of the work is to investigate the ways drones are currently used for collecting data in support of designing and adopting nature-based stormwater management solutions in urban development projects. Moreover, the 3D models can be used as preliminary design tools by changing the parameters of the mesh to measure and visualize the functional properties of the design. Lastly, a detailed architectural design can be integrated into the 3D mesh model to provide a visual and functional simulation of the nature-based solution to support the decision-making in investment projects opting for implanting nature-based solutions.

2. Materials and Methods

2.1. Target of the Research

The research targets are urban sites and locations that become objects of urban development and investments. The scale of the site is not limited, but rather, it is connected to the investment decisions and ways to provide the stakeholders with the means for informed decision-making for the adoption of nature-based stormwater management techniques.

For the aims of the research, a test site was selected consisting of a green roof of a campus building. The size of the selected sedum green roof is 25 m × 25 m (625 m^2), and it is surrounded by terrace areas and hard roof surfaces. The size of the area fits well with the aims of the research to study the solutions as nature-based landscape architecture solutions applicable to areas other than green roofs, such as courtyards of residential blocks. Additionally, the compact size of the demonstration site helped in the development of the workflow while using limited computational resources.

2.2. Research Approach

First, the study used a literature search to investigate the current use of drones in support of stormwater management and design, covering peer-reviewed journals and using Google Scholar for the initial investigation of the literature and the Scopus search engine for refining the investigation by using the search terms described in Tables 1 and 2.

Table 1. The results of the Google Scholar literature search.

Search Terms	Results
"drones smart and connected stormwater systems"	6290
"drones for water measurement"	61,800
"drones monitoring plant health"	36,900
"drones surface imperviousness"	6120
"drones land surface temperature"	36,000

Table 2. The results of the Scopus literature search.

Search Terms	Results
drones AND stormwater	8
drones AND water AND measurement	347
drones AND monitoring AND plant AND health	71
drones AND surface AND infiltration	9 [1]
drones AND land AND surface AND temperature	45

[1] Search term "imperviousness" provided zero results.

Second, based on the findings of the literature search, the investigation used action research to discover and demonstrate a workflow that could fill the identified gap in the design methodology, supporting an increased adoption of nature-based stormwater management techniques. Action research is an approach commonly used in discovering workflow and software approaches to solve a practical need [29]. The method was used to investigate the functionality of NBSs in simulated rain events in 3D models that were prepared based on aerial data.

2.3. Creation and Application of 3D Mesh Models

2.3.1. Data Collection for Photogrammetry

The objective of the data collection was to create a visually high-quality mesh of the demonstration site. The creation of the mesh model needs to produce a unified mesh surface without any holes in it for the rain event simulations to perform properly. A DJI Mini 3 Pro drone was used to collect 550 aerial images of the test site. The images were post-processed into a 3D mesh model using WebODM 1.9.15 software. The demonstration

site, illustrated in Figure 1, included diffused objects such as perforated steel structures to increase the complexity of the small-scale urban space.

Figure 1. Demonstration site. The area subject to investigation is marked with a dotted line.

2.3.2. Fast-Track Analysis with Photogrammetry 3D Models

After producing the 3D mesh of the site, the 3D mesh was processed using Blender 4.0 to initially develop and test the workflows that could later be developed inside Blender into more user-friendly design applications with user interfaces or software solutions using other applications, such as game engines.

The first workflow tested aimed to use the model with minimal interventions for analysing the amenities and utilities of an NBS. The test site contained an existing NBS comprising an extensive sedum green roof. After the initial tests without interventions, the following interventions were tested:

1. Changing the colour of the mesh surface and altering the topography of the surface. This approach can be used to analyse in a streamlined fashion the changes in the appearance of the demonstration site caused by desired amenities and the desired functional properties, such as the impact of adding a stormwater reservoir to the design (Figure 2). The deviation of the surface levels can provide liveliness and functional properties to the design such as a retaining pool for stormwater, without having to fully design and model the NBS. Later, if the design process is desired to be continued in more detail, the same volumes of stormwater retention pools can be adapted to a more detailed and realistic 3D model, which is also more time-consuming to produce. In a similar fashion, the existing hard surfaces such as terrace pavements can be re-coloured to provide an initial appearance of the NBS that can be later designed and modelled in detail.
2. Assigning physics properties to the surface. The last application is the most crucial one from the functional point of view as it enables the analysis of the utilities of the applied solutions. Physics properties of the surface may contain the following variables: (i) permeability as the property of the surface to prevent or allow the infiltration of stormwater, (ii) stickiness/surface roughness as the feature impacting the speed of surface flow and transfer through the structural ground layer. The assignment of the above properties to the mesh model is illustrated in Figure 3. Additionally, the rainwater particles may be assigned a parameter-estimating feature for evaporation by reducing the lifetime of the particles in the simulation. Finally, the stormwater outflow from a single NBS to the stormwater piping network can be simulated through the accumulation of rainwater particles in the stormwater tank (Figure 4).

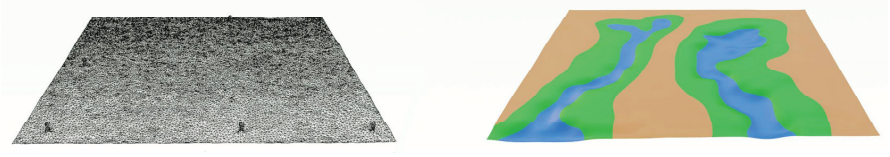

Figure 2. A rapid method for visualization by changing the colour scheme and topography of the mesh model. On the left side is the original 3D mesh of the test site based on photogrammetry. On the right side is the illustration of a surface water reservoir by altering the surface topography of the mesh. Further, the colour scheme has been enhanced to highlight the wider adoption of a green roof.

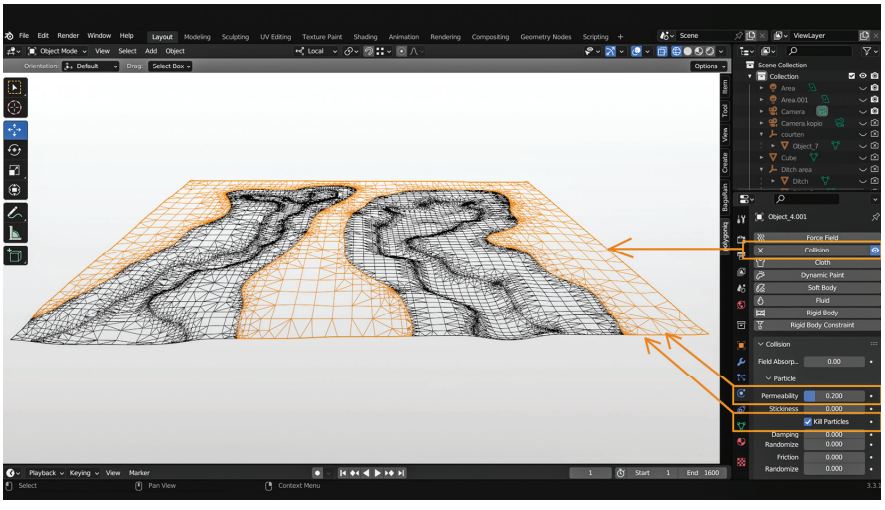

Figure 3. Illustration of the mesh surface with assigned physics properties.

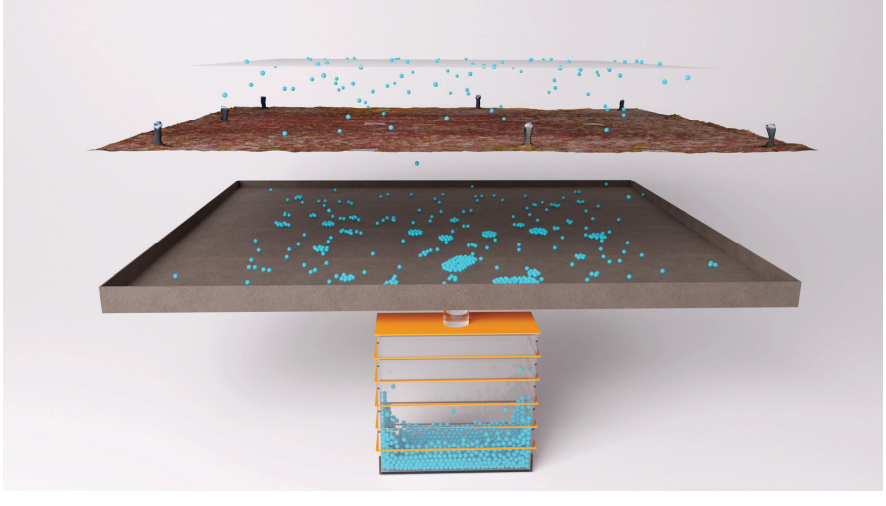

Figure 4. The principle of the system for the stormwater tank with a volume of 9.0 m^3.

2.3.3. Photogrammetry 3D Models for Creating Context Data for the Design

The created photogrammetry 3D model was used as context data for a proxy design of an NBS in the rooftop test location. The approach allows a fast-track design review in the urban context, that is, a rooftop location in the current study. The method is applicable to other locations such as, e.g., residential courtyards. The scale of the analysis is mainly limited by the available high-quality aerial imagery and computing capacity. To enable the analysis of the amenities of an NBS, a proxy design of an NBS was created for the demonstration location and inserted into the photogrammetry 3D model (Figure 5). The model was turned into a single unified mesh model with assigned physics variables for the functional mesh areas. Next, we will discuss the workflow for the analysis of the NBS designs based on the integration of a 3D NBS design and a 3D photogrammetry model.

Figure 5. Integration of a detailed 3D NBS design with the context of a photogrammetry model.

2.4. Workflow to Analyse NBS Designs

2.4.1. Parametrization and Features of the Model

The 3D NBS model was parameterized according to Figure 2, showing the applied physics parameter and the selected value for it. The surface areas of the mesh were selected manually and stored as selection values in Blender to maintain the option to edit both the selection itself as well as the physics properties assigned to the selection.

2.4.2. Simulation Settings of Rain Events

Next, a rain event was created over a selected period based on the efficient use of the available computing resources. The number and duration of rain events can be increased based on demand and the desired detail of the simulation. For efficiency and illustrative purposes, only one rain event is used here. Table 3 describes the rain event.

Table 3. Description of the rain event used in the simulation.

Number of the Rain Event	Start (min: s)	End (min: s)	Amount of Rain (mm/m^2)	Volume of Total Precipitation (mL)
1	0:00	1:06	34.23	5,230,000

2.4.3. Simulation

The simulation was implemented using the physics and Cycles render engine inside Blender. The hardware used consisted of a custom-built PC with Intel®Core™ i7-9700K CPU @3.60 GHz and 32 RAM by Jimmy's PC Store, Turku, Finland.

2.4.4. Analysis of the Utilities

The analysis of the functional performance of the design was enabled in two ways. First, the topography of the design with depressions allowed the pooling of the run-off water. The maximum capacity of the reservoir is achieved when the water starts to overflow from the designated pool area to the surroundings. This is an indication of a lack of infiltration capacity, the small size of the reservoir, or insufficient piping systems allowing excess water to run off.

Second, the functional performance of the utilities can be measured by modelling a stormwater tank to the system (c.f. Figure 4). The piping solutions correspond to the design requirements of each specific system. For example, the stormwater inlets of the current test site have been modelled and connected to the virtual stormwater tank. In different phases of the simulation, the volume of the run-off water can be measured in the tank. The objective of the approach is to provide a model for comparing different design solutions with different parameters, such as the infiltration capacity of the surface, against the same rain events. In other words, the simulations show the accumulation of stormwater in the tank over the same period and rain events under different design parameters, allowing for the analysis of, e.g., the retention capacity and rain event-related maximum flow peak reduction effects.

2.4.5. Analysis of the Amenities

The simulation can provide a highly visual presentation of the chain of events, depending on the selected approach. To that end, the ARD becomes possible when the design analysis is combined with integrated negotiation techniques. The aim of such techniques is to enable consensus building and lasting agreements on the selection of design alternatives [30].

3. Results

Based on the findings of the literature investigation, there is a shortage of applications for using drone-based aerial data in support of visual and functional analysis of the performance of architectural NBSs at a detailed design level. Grounded in the findings of the first research question, the second research question aimed to discover a way for rapid and agile use of aerial imagery to investigate the amenities and utilities of urban NBSs. Here, an approach to post-producing the 3D mesh based on photogrammetry was presented. The third research question targeted finding a software-based workflow to integrate detailed NBS architectural design solutions to the photogrammetry model and perform an analysis of the utilities of the solution. To that end, the paper has described an approach to simulate the rain events and their stormwater impact in a visual fashion while analysing the performance of the test site. The approach was tested with a selected rain event described in Table 2, and the results will be shown next using three different design solutions as the targets of the simulation.

Results of the Analysis with Design Solutions Integrated into the 3D Model

Three different design versions were analysed through a simulation: (i) a bitumen hard roof, (ii) an extensive sedum green roof (existing situation in the test site), and (iii) an intensive green roof with an NBS design. The run-off coefficients were 0.33 for the extensive green roof and 0.83 for the intensive green roof, and they were used as pessimistic values for the performance, drawing from a comparison of mineral-organic and mineral substrate-based extensive green roofs [31].

The three design alternatives were tested with the same simulated rain events, lasting 1:06 min with a total precipitation of 34 mm/m^2. The results are illustrated in Figures 6–8 (start stage and end stage of simulation shown) showing the amount of accumulated water on the ground and in the stormwater tank at the end of the rain event.

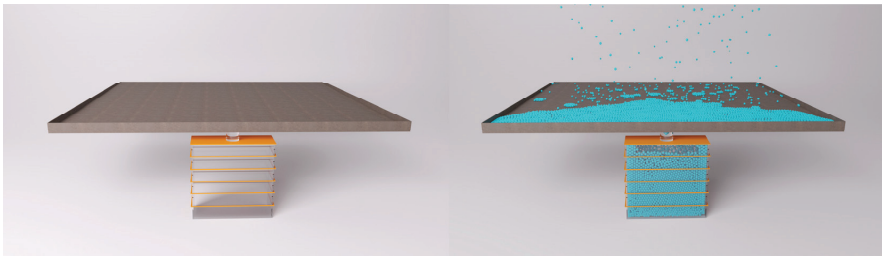

Figure 6. Visualization of the bitumen roof before and after the simulation. The total accumulated amount of runoff water to the stormwater tank is 8.5 m^3.

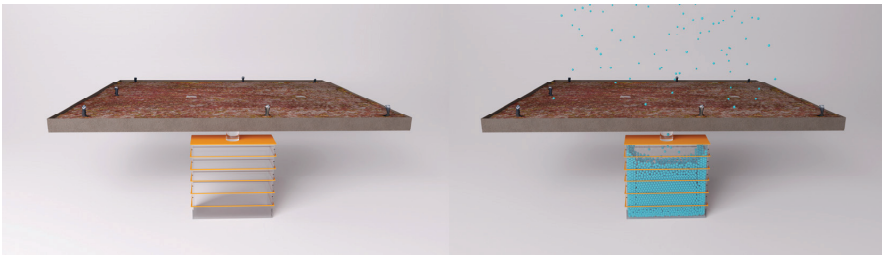

Figure 7. Visualization of the extensive green roof before and after the simulation. The total accumulated amount of runoff water to the stormwater tank is 7.25 m^3.

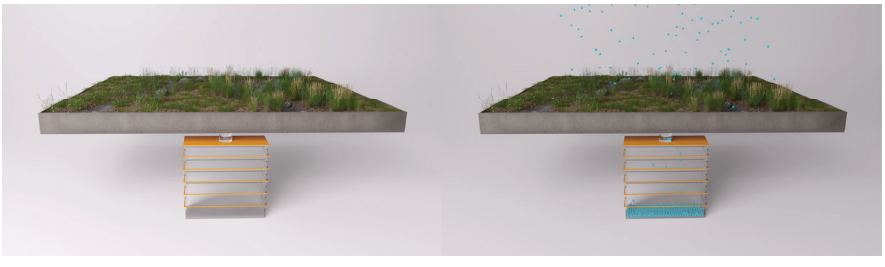

Figure 8. Visualization of the intensive green roof before and after the simulation. The total accumulated amount of runoff water to the stormwater tank is 0.25 m^3.

4. Discussion

The study investigated an analysis approach to the functional and aesthetic properties of roof designs. The utilities and amenities of three different roof typologies were studied as a demonstration of the approach, including (i) a bitumen hard roof, (ii) an extensive green roof with sedum, and (iii) an intensive green roof.

The study investigated the applicability of aerial imagery for the purposes of analysing and communicating nature-based solutions for stormwater management. Earlier taxonomies were reviewed in the research. Most of the earlier identified taxonomies focus on the use of drone data for direct measurement and near real-time monitoring [17]. The proposed approach in this study suggests a new taxonomy for strategic design and decision-making through data-driven design. The approach of data-driven design can be achieved by combining the aerial data with 3D modelling and simulation software.

The results of the study suggest that aerial imagery and powerful modelling tools can effectively be used for analysing the utilities and amenities of NBSs in urban developments at various scales. The use of drones enables the collection of high-resolution aerial images

on demand, thus filling the gap in the availability of data as the satellite imagery fails to provide sufficient resolution for design analysis on a detailed urban scale. Further, the imagery collected at the street level provides little or no information on the rooftop level. Therefore, drones can provide a powerful tool for novel approaches to design analysis.

There are two hindrances to a larger-scale adoption of the approach. The first is the need to own and operate a drone to collect the data. The second is the availability of affordable photogrammetry software for occasional users. Both hindrances suggest that the approach is currently applicable mainly to professional users. The change may be introduced along the availability of autonomous drone services, such as data collection as a service, and machine learning-based tools enabling the reconstruction of 3D information, for example, through neural radiance fields (NeRFs), an emerging powerful tool to create 3D content from imagery [32]. Such an approach may provide new ways of illustrating the designs to a higher level of visual quality than the photogrammetry-based approaches.

In its current stage, the workflow presented supports the practical implementation of the ARD and fills the gap in the professional design and communication tools supporting the decision-making in the adoption of NBSs in urban contexts. Specifically, the smaller-scale solutions required a detailed study of the surface water flows and urban elements impacting the functionality and architectural quality of the design.

The results of the simulations in three different designs demonstrate the benefits of the NBSs, allowing for the quantification of the design alternatives. Importantly, the analysis of the visual and architectural qualities can be done within the same metrics; that is, the numeric performance of the designs can have the realistic representation of the design simultaneously available. To that end, complementary research on the functional properties of versatile green roof implementations is essential for gaining additional evidence-based knowledge for the parameters that can be used for setting the parameters of simulations.

5. Conclusions

This research investigated a method and a Blender 4.0 workflow to analyse the qualitative architectural content and the quantitative functional performance of NBSs within the same comparable and visual framework. The findings suggest that the workflow using aerial data for 3D modelling could be developed into a practical tool for supporting the decision-making and analysis of the impacts and functionality of NBSs in urban development projects.

Limitations of the study include the investigation of the workflow in a single software stack for demonstration purposes. Future studies should consider using different simulation and game development platforms. Additionally, what kind of classification of ground surface types is needed to address the relevant differences in the infiltration capacities of the ground should be investigated. For building automated and more easy-to-use applications with a high capacity for analytics, future research should also look at the applicability of machine learning-based solutions such as semantic segmentation to automatize the workflow and detection of surface properties.

Author Contributions: H.E., Conceptualization, methodology, investigation, writing—original draft preparation; L.R., Investigation, visualization; E.N., project administration, writing—review and editing; and P.L., funding acquisition. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Finnish Ministry of Culture and Education, a grant for the Intelligent and Smart Stormwater Management Project (ISMO).

Data Availability Statement: The data presented in this study are openly available in the service provided by the CSC-IT Center for Science (csc.fi) at https://etsin.fairdata.fi (accessed 29 November 2023).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Article

Investigating the Effect of Transit-Oriented Development (TOD) on Social Equity—Examining the Displacement of Footscray, Melbourne

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Abstract: As Melbourne faces exponential population growth, the necessity for resilient urban planning strategies becomes critical. These strategies include mixed land use, density, diversity, and sustainable transportation through transit-oriented development (TOD). While TOD promises to accommodate growing populations and address environmental concerns, it also raises issues regarding its unintended consequences on poverty and inequality, notably through residential displacement and gentrification. This study investigates the impacts of TOD construction on inequality in Footscray, employing spatial analysis techniques like the hedonic price model (HPM), robust regression analysis, and Pearson correlation analysis. It aims to understand how spatial factors influence housing prices and their correlations. Additionally, the study uses observational spatial analysis via Google Street View (GSV) to examine indices such as housing development type, traffic signage, sanitation facilities, and house beautification. This approach seeks to build an evaluation framework to assess the extent of TOD street reconstruction and its impact on gentrification and displacement. The research adapts existing knowledge to create a tool for reviewing past planning decisions and assessing the fairness of TOD planning implementation. By providing assessment and guidance to mitigate the potential adverse impacts of TOD, this study contributes to the advancement of urban-planning practices, offering insights into mixed land use and effective strategies to balance economic development and social equity, thereby enhancing community resilience. Ultimately, this research deepens our understanding of the impacts of TOD on urban inequality and offers practical tools and insights for more equitable and sustainable urban development.

Keywords: TOD; gentrification; displacement; spatial analysis; mixed land use; social equity

Citation: Wang, X.; Xie, Y.; Xia, L.; He, J.; Lin, B. Investigating the Effect of Transit-Oriented Development (TOD) on Social Equity—Examining the Displacement of Footscray, Melbourne. *Buildings* **2024**, *14*, 824. https://doi.org/10.3390/buildings14030824

Academic Editors: Steffen Lehmann and Monika Szopinska-Mularz

Received: 7 January 2024
Revised: 13 March 2024
Accepted: 15 March 2024
Published: 19 March 2024

1. Introduction

1.1. Transit-Oriented Development: An Urban Sustainability Strategy

As urban populations expand, the imperative for sustainable urban development intensifies. Transit-oriented development (TOD) plays a crucial role in this context, offering a comprehensive strategy to improve access to goods, services, and employment through efficient public-transport systems [1]. TOD focuses on transit accessibility and promotes a sustainably built environment by integrating mixed use, density, and walkability around public-transport stations [2]. Despite its advantages, such as reduced air pollution and car dependency, TOD may introduce challenges like increased noise, vibration, and crime, potentially affecting community acceptance and quality of life [3]. The impact on displacement and justice is particularly significant in discussions on urban development.

1.2. The Australian Context: Challenges and Opportunities

In Australia, urban sprawl and congestion have led to economic, social, and environmental issues, including reduced productivity, social exclusion, and increased carbon emissions [4]. TOD emerges as a salient solution to these challenges, advocating for high-density development proximate to major transit stations to alleviate congestion and foster sustainable urban growth [5]. Although successful international TOD examples exist, its adoption in Australia has been slow. Nonetheless, the Melbourne metropolitan region has begun embracing TOD principles, as is manifest in the Policy Melbourne 2030 and the conceptualization of 'Central Activities Districts', '20 Minute Cities', and 'Activity Centres' [6].

1.3. Footscray Detailed Overview

Footscray, known for its diverse community and proximity to Melbourne's city centre, along with recent public-transport infrastructure improvements, was selected as the focus of this study. Footscray stands out due to its diverse community, its prime location close to Melbourne's city centre and recent advances in public-transport infrastructure. The suburb's unique characteristics make it an ideal case for examining TOD's impact on urban neighbourhoods [7]. Following TOD implementations such as the 20-min cities scheme, activity centres, and transit cities, Footscray has seen significant changes in housing prices, demographics, and urban redevelopment. This study aims to reveal how TOD influences urban neighbourhoods in Footscray and beyond.

1.4. Research Objectives and Questions

This study explores the impact of TOD policies on redevelopment in transit station areas, employing HPM, robust regression analysis, Pearson correlation analysis, and GVS in Footscray. It aims to develop an evaluation framework for displacement and gentrification. The research questions are the following: How does TOD affect house prices, and what is its relevance to displacement? The study synthesizes evaluation-framework results for house prices and redevelopment, offering recommendations for planning-policy development.

2. Literature Review

2.1. The Role of TOD in Urban Planning

The academic definition of TOD is the development of mixed density, mixed-use housing within a pedestrian-friendly radius, with transport hubs as the core, encouraging active transport and providing more convenient access to basic services [1]. Originally, the concept of TOD was proposed by Peter Calthorpe, an American urban designer, in order to provide ideas to address suburban sprawl and to balance the development of urban centres and suburban infrastructure in the context of the new urban liberalism [8]. Specifically, TOD is an urban-development model that addresses the problems of urban sprawl and environmental issues in order to develop a compact city with sustainable communities [9]. When the TOD is built, the density of the surrounding commercial and residential areas will increase from outward to public transport stations. And land prices within the TOD service area continue to rise as the TOD is improved. More importantly, as Cruits [10] point out, a successful TOD may not only save residents' commuting time, but also benefit the urban society, urban environment, and urban economy.

In urban planning, TOD is more about planning and comprehensive urban design strategies to achieve a sustainable, compact, and climate-resilient urban vision [9]. Therefore, it can be seen from different TOD city government documents that government policies tend to propose TOD-related policies from different planning aspects, such as housing-planning policies and transportation-planning policies, etc., to form a comprehensive transportation-oriented strategic framework with specific requirements to ensure TOD implementation [11,12]. Furthermore, as Scheurer and Porta point out, TOD can also be a strategy for generating more urban economic revenue initially [13]. Therefore, TOD is not only the development of transit facilities, but also the policies or strategies on other

credentials of development that need a "multi-bench" to commence as well [14]. Policies and strategies that support TOD are given in different kinds of urban policies to determine the specific requirements and standards for the implementation of TOD in different aspects.

For example, in Charlotte, North Carolina, the infrastructure policy and living amenity strategy mentioned developing transit infrastructure and encouraging development along five major transportation corridors for the integration of transit and land use [15]. In addition, accessibility to public transportation is another thing that the government always considers, so different urban policies will provide different guidelines to ensure the accessibility of the TOD region. The Planyc housing strategies mentioned building more new housing within the 0.5-inch radius of the transit station [16]. In addition, the Portland Community Development Strategy states that community development is to be accomplished with the hope that community members can access amenities within 20 min [17]. Furthermore, the Strategic Framework of Cape Town points out that it is needed to guarantee Cape Town's TOD Strategic Framework, which has set targets to improve access to transit by 12% by 2032, and to reduce kilometres travelled by passengers by 23% [18].

The above three examples all link the construction of TOD with accessibility and use accessibility as an indicator to manage the construction of TOD suburbs. These common characters are valuable and can be used as a reference for studying similar policies in Australia. Additionally, it can be seen that TOD is a widely implemented urban development-planning strategy [19].

Melbourne's TOD strategy and policies are comprehensive at both metropolitan and state levels, referring to different strategic approaches to TOD implementation and expected outcomes. As Melbourne 2030 mentioned, better management of metropolitan growth [20] will concentrate urban growth areas into growth areas dominated by public transportation [21]. In the state's PPF, it is also mentioned that the area close to the bus station should be encouraged to develop in medium and high density, and the infrastructure should be improved to create a city with TOD characteristics [22]. Melbourne, as the targeted city, has developed TOD cities by encouraging high-density development along transport routes [23]. Therefore, according to the above policies and strategies, the TOD concept plays an important role in the strategies of Melbourne and has been given the expectation bringing about more positive impacts on the future development of the city.

2.2. The Concept of Gentrification and Displacement

Gentrification describes the process by which wealthier people move into areas of lower socio-economic areas, attracting new business and improving housing, then displacing current inhabitants. The term 'gentrification' originally referred to a practice of the English gentry during the 19th century. They kept an inner-city flat in addition to their country home [23]. The original use of the term originated in the mid-1960s when Glass observed the changes in the inner city of London. The social and housing market in the city centre was changing as the middle class moved back from the suburbs and drove out the working class who lived there. There is still no universally accepted definition of gentrification, and research continues to try to better understand it.

The effects of gentrification are more complex than the factors that cause it. For most planners and sociologists, gentrification is a negative social problem. It displaces relatively poor, disadvantaged groups in the areas where they usually live, especially renters [24]. Gentrification thus disrupts social life and has the inevitable consequence of displacement [25]. Conversely, other commentators have praised gentrification, arguing that it can lead to urban regeneration, boost the economy of a site, and increase local property values. From blighted and derelict neighbourhoods, they are transformed into safe and vibrant new communities with good and beautiful homes and attractive commercial services, all without the need for generous new investment from the public [26]. In short, displacement is a necessary consequence of gentrification.

Displacement is an analytical perspective that can be used to understand the impact of various urban-development policies on local communities [27]. Social displacement is a term to describe residents' movement, from the inner city to outer suburbs, or just the loss of their original housing due to several reasons [28].

In most developing countries, like China and India, most kinds of displacement are caused by urbanism and the redevelopment of inner-city spaces, so that there are some policies indirectly causing the residents to leave [29,30]. In developed countries, displacement might not be affected by policy directly, but gentrification and infrastructure investment may cause this social phenomenon [29]. For example, after Watt surveyed London residents, it was found that behind the policy of demolishing houses caused by the redevelopment of the city, the displacement experienced by people of different statuses and families is multi-level and socially complex [30]. Thus, for policy evaluation and recommendations, it is necessary to conduct multi-angle measurements and an analysis of the displacement.

Displacement can be measured through data changes from various aspects [29]. In the development of the city, displacement is divided into three main aspects. One is policy-oriented, where houses are forcibly demolished, another is market-oriented, because investors or homeowners increasing housing prices, which people with low incomes cannot afford, and another is social resource-oriented, concerning community infrastructure or the adequacy of public resources [31].

In detail, measuring displacement can be judged from the following aspects: the number of houses being rebuilt, the rate of migration in and out of low-income groups, the investment in infrastructure construction, the changes in housing prices, and the investment of investors. As Garton and Lack discovered when analysing the post-colonial characteristics of Footscray [32], the ownership of houses and the status of immigrants are significant in the process of gentrification and suburban migration. Similarly, factors such as the housing crisis, rising housing prices, and the increase in the number of investors are also referenced indicators for displacement, which has a more obvious impact on the displacement of residents with low incomes [33]. The above-mentioned influencing factors all have branches that can be used for reference to the displacement problem.

The impact of urban TOD construction on displacement and gentrification is controversial because TOD does reduce transportation costs on the one hand [34], but on the other hand it does result in higher land prices due to the concentration of more businesses, infrastructure, etc. in TOD centres [35]. Various studies have shown that the impact of TOD varies across geographic settings and community characteristics [34], and even has conflicting results [36]. To determine the potential negative impacts of TOD policies, prior studies were compared and generalised. In low-income neighbourhoods, TOD has been effective in easing the stress of living for private car-dependent households, but some cities have indicated that the reduced costs have not been able to offset the rising house prices. At the same time, TOD's attraction to the middle class in the city has led to the crowding out of people with lower incomes. And it promotes market-oriented housing development. In Switzerland, for example, the redevelopment of the Rosengard district exemplifies multiple contradictions, and the authors suggest that its redevelopment is a process of recapitalisation, with the risk of privatising housing. And, because people in the area do not have a high demand for travel, its improvement in transport costs is not significant, nor is there significant displacement [34]. In Los Angeles, for example, research has linked rail development to gentrification and the displacement of public transit's core ridership. A significant finding was that 76% of zoning changes and general plan amendments approved between 2013 and 2016 increased residential density, primarily in TOD areas. These areas were also more likely to experience gentrification, as indicated by changes in educational attainment, occupational level, race, median rent, median income, and tenure. The study suggests implementing affordable housing TOD policies that include value capture to increase the supply of affordable housing around transit, highlighting the necessity of a community-driven planning process [37,38]. Meanwhile, there are also relevant studies

from India, which prove that there is indeed a positive impact on the burden of living for human beings. This also suggests that TOD may be more effective where high-density development is required.

2.3. Gentrification and Displacement in Melbourne

There are various reasons for the current displacements in Melbourne, but they are all directly or indirectly related to the policy. Displacement is the result of gentrification, and it is also the result of policies that do not fully consider the unconscious negative effects of the crowd [33].

For instance, uncontrolled taxation and lending policies have promoted investors' enthusiasm for housing and created an 'irrational exuberance' in the real-estate market [33]. When studying displacement in western Melbourne, it was found that the housing crisis is a major cause of displacement, especially for people with low incomes. Meanwhile, the distribution of social infrastructure can also lead to forced displacement. For example, there is a shortage of schools in the centre of Melbourne, which cannot meet the needs of the family, so they moved to the outer suburb [39].

However, Nethercote [39] also states that the reason for strengthening the construction of infrastructure is to unconsciously invest in the collective consumption budget in capital and upgrade the land by depriving the city of space and building infrastructure as a commodity value. Footscray also has this debate about displacement caused by the Transport City policy, which is a policy that includes infrastructure- and housing-construction incentives [40].

2.4. Research Goals

The increasing focus on transit-oriented development (TOD) in Melbourne, driven by rapid population growth, emphasizes the need for compact, high-density mixed land use centred around public transportation. This approach, while offering numerous benefits, also presents challenges, particularly in its impact on resident displacement and addressing issues of poverty and inequality in urban planning. The study conducted in Footscray, Melbourne, employs spatial analysis based on a hedonic price model and Ordinary Least Squares to investigate how TOD influences housing prices and what factors contribute to this effect. The use of observational spatial analysis, including Google Street View (GSV), to select indices like housing development types, traffic signs, sanitation facilities, and house beautification, aids in exploring the extent of redevelopment in TOD streets. This system (Figure 1) is then used to construct an evaluation system, combine the two perspectives together, and assess TOD's impact on gentrification and displacement from spatial and temporal perspectives [41,42].

The main research objectives include evaluating TOD's impact on urban sustainability and equity, focusing on changes in housing and the rebuilt environment around public-transport stations. Also, another goal is to build an assessment framework for the TOD policy practice in order to know the extent gentrification in the specific area and be considerate of the minority. Despite the success of TOD internationally, its adoption in Australia, particularly in understudied areas like Footscray, is limited.

Since the concept of gentrification was clarified, there has been a great deal of extensive research into the phenomenon in the context of the United States. There is considerable evidence that gentrification has been experienced across the globe, except for in the United States [43].

The research gap identified is the need for a comprehensive understanding of TOD's benefits and drawbacks, including how it affects property values and people in daily life [41]. Australia is no exception, but the extent to which gentrification has occurred may not be as dramatic as in the United States [44]. Different country contexts are analysed differently, and thus gentrification in Australia needs to be studied as well. And, based on the existing research in the LR section, we make the following hypothesis: the development

of urban TOD construction, although it is a positive government policy and development model, can also due to bring unconscious negative impacts.

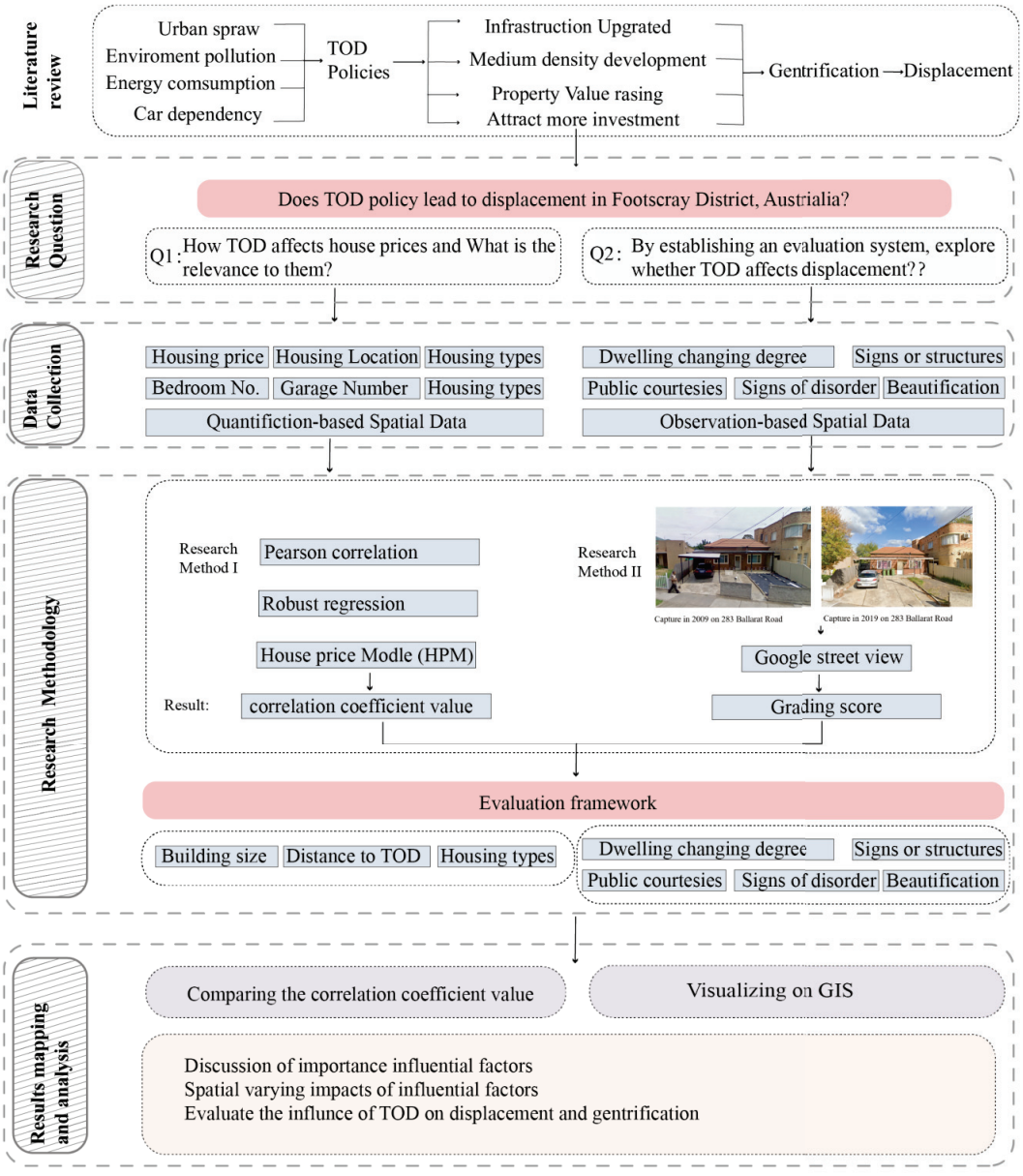


Figure 1. The research flow diagram.

However, the causes of gentrification are too complex to include displacement as one of the corollaries of gentrification [27,45]. Also, as Chapple [46] pointed out, while gentrification may be related to investment in transit-oriented development, little of the specific research has quantified their relationship. Therefore, this research will examine

displacement as a quantifiable factor to identify appropriate methods and indicators to show how TOD affects displacement [46].

Much of the existing research on displacement has been conducted through quantitative methods to demonstrate that the quantified indicator has an impact on displacement, or to demonstrate the existence of displacement through the aspects represented by the indicator [47]. Others have used a qualitative approach to critique policy shortcomings that have an impact on displacement [48]. However, due to regional social variability, different regions have different social problems and causes of displacement. Most research has been conducted in countries such as the United States and the United Kingdom, with less research conducted in Australia. There is also a lack of literature on the quantitative relationship between policies on infrastructure other than housing policy and dispossession.

The significance of this research lies in adapting existing knowledge and developing novel tools to assess the fairness in the implementation of TOD plans. This assessment aims to guide decisions in TOD planning, reducing potential adverse impacts, and providing insights into balancing economic development and social equity in urban planning.

3. Materials and Methods

3.1. Study Area

Footscray is a vibrant inner-city suburb in Melbourne, Victoria, Australia (Figure 2). Located 5 km west of Melbourne's central business district is the city of Maribyrnong's Local Government Area and its council seat, rendering it a crucial part of the city's urban fabric. Geographically, Footscray's coordinates are approximately 37°47′–37°48′ S latitude and 144°53′–144°54′ E longitude. The Maribyrnong River significantly shapes the southern boundary, contributing to the distinctive character of the suburb. The site comprises residential, commercial, industrial, and mixed-use areas and is characterized by a very diverse and multicultural central shopping district. It is strategically positioned, acting as a bridge between the inner and outer suburbs of Melbourne. According to the local mayor, the area 'would soon have the second-highest skyline outside the Melbourne CBD' [49].

Figure 2. Location of the study area (left panel) and the spatial distribution of the five streets and transit station in Footscray with the net dwelling changing score.

Demographically, Footscray has experienced successive waves of immigration, reflecting the cultural diversity Melbourne prides itself on. Over the years, the area has undergone a demographic shift, with a significant mix of long-time residents and newcomers adding to the suburb's socio-economic vibrancy. It covers an area of about 5 square kilometres and has a population of 17,131 as of 2021 [50]. Due to urban-development plans and the growing demand for housing and commercial space, the suburb has undergone a transformation. These changes affect the availability and allocation of resources and affect the socio-economic conditions of communities. In addition, Footscray's transport infrastructure plays a key role in its connectivity. It is well served by public transport, including trains, buses, and trams, facilitating activities in the suburbs and connecting it to the wider Melbourne metropolitan area [51]. Accessibility is further improved by the presence of major roads and highways. The significance of this study lies in the unique characteristics of Footscray. As a historical industrial centre, the suburbs have witnessed urban renewal and gentrification, leading to a shift in land-use patterns [52]. In addition, since large infrastructure is more evenly distributed across the region, the impact of market externalities on house prices from other pre-existing infrastructure can be avoided to ensure more accurate experimental results.

In 2001, the Victorian Government launched the Transport Cities and Places Management Plan. Based on TOD's development principles, the proposal aims to redevelop and cluster higher density mixed-use developments around the 13 designated transport hubs, revitalizing the development through better connectivity of transport and land use. Footscray Railway Station is one of the 13 public-transport hubs.

The Footscray Transit City project falls within a broader strategic planning context. Located close to the CBD and west of Melbourne, Footscray is also at the junction of three rail lines, served by one tram line and 13 bus lines with an extensive public transport infrastructure. Its unique location has made Footscray one of the 25 major activity centres in Melbourne 2030 [21] and a unique position-holder in a major transit network. In addition, the status of the Melbourne @ 5 Million strategy has been upgraded to "Central Activities District" (CAD). Footscray has a key strategic position, and the Footscray Station precinct has multiple targets based on previous strategic work. Some of them are the following: to enhance the environment, to celebrate identity, to develop an intermodal transportation hub, to encourage economic growth, to reinforce connectivity, to increase safety, consolidating retail space, etc. These goals contributed to Footscray becoming a TOD open project.

The Transport-Oriented Development (TOD) strategy implemented in Footscray aims to leverage its strategic location and transport infrastructure to promote sustainable and integrated urban living. As Footscray undergoes urban transformation, it is critical to assess the potential impact of TOD on the community's internal displacement. This study aims to analyse the interplay between TOD initiatives, socio-economic factors, and displacement dynamics to provide valuable insights into Melbourne's urban planning and development strategies.

3.2. Date Sources

In order to analyse whether Footscray's TOD construction has an impact on displacement from temporal and spatial perspectives, in this study, a mixed-methods approach was used to collect and analyse the data. The data sources are displayed on Table 1. Firstly, in the time dimension, the housing spatial data and price data before and after the transit-oriented development in Footscray will be collected. These data will then be analysed using the hedonic price model and Ordinary Least Squares to determine whether distance from the TOD becomes one of the key characteristics that affect the price of different types of housing by comparing data from two periods, before and after the construction of the TOD, and how this happens. Secondly, in the spatial dimension, the Google Street View-based spatial analysis will be used to determine the difference in the amount of housing redevelopment and infrastructure development within and outside of the walkable distance of the TOD. Finally, based on these two analyses, it is inferred whether the construction of TOD is

related to residential displacement in Footscray and how these residential displacement indicators are influenced by TOD construction.

Table 1. Data sources.

Data	Source	Reference Year	Spatial Resolution	Data Availability
Administrative boundary data	Data.gov.au	2021	vector data	Freely available
Transport sites and railway-plan policy	VIC plan	2021	PNG	Freely available
Housing rates Information	Aurin	2021	shapefile	Available with application
Housing locations, Types, and Price	Real-estate company	2012–2021	CSV	Available by using crawler extraction
Building surroundings	Google street view	2012–2021	JPG	Freely available

3.3. Methodology

The purpose of this study is to analyse whether TOD construction affects residential migration in Footscray, and if so, how it affects residential-migration indicators. As pointed out in the literature review, changes in housing prices, the number of houses rebuilt, and investments in infrastructure development can be used as three indicators to determine whether an area is experiencing residential displacement [53]. Therefore, in the temporal dimension, the changes in different types of houses' prices before and after the completion of TOD are compared, and in the spatial dimension, the differences in indicators such as the number of housing redevelopments and infrastructure investments within and outside of walking distance from the TOD are compared, and through these comparisons, it is possible to observe whether the construction of a TOD has an impact on these displacement indicators.

3.3.1. Spatial Analysis Based on Hedonic Price Model

In the time dimension, to evaluate the impact of TOD construction on housing prices, a spatial analysis based on the hedonic price model would be a suitable model for housing's spatial data and price data analysis. The hedonic price model (which is also called the HPM) is a mathematical model, which has been applied by a range of scholars, that can express the relationship between the land parcel's attributes and its market value [54]. It is particularly suitable for analysing the relationship between the house price and distance in the economic aspect. One of the cases is Sim. et al. [55], who has used the hedonic price model as an analysis method to measure the impact of Box Hill's TOD on residential property prices. Analogously, Chen et al. [56] have also used the HPM to analyse the impact of Sydney Northwest Metro development on neighbourhood residential property valuations [56].

The HPM is a mathematical model that expresses the relationship between a land parcel's attributes and its market value [54]. First, it includes collecting the property data as well as price data and spatial data of houses. These data are then substituted into hedonic price models. There are three main forms of the hedonic price model. This research will use the Linear model of the HPM as the analysis model. The equation is shown below. In Equation (1), P represents the housing price, a_0 is the constant, ε is the error term, Z_i represents the housing attribute variable, and a_i represents the coefficients that need to be estimated.

$$P = a_0 + \sum a_i Z_i + \varepsilon \ (i = 1, 2, 3, \ldots, n) \quad (1)$$

In house-price research, the data are often affected by outliers, leverage points, or heteroscedasticity, which can negatively affect the accuracy and reliability of HPM estimates. To address these issues, robust regression analysis is introduced in this study as a complementary method aimed at improving the robustness of the estimated results and ensuring good resistance to outliers or atypical observations. Robust regression requires

the use of iterative methods to solve model parameters, such as iteratively weighted least squares. LeSage and Pace [57] discussed in detail the application of spatial econometric models in their work, including how to deal with outliers and leverage points in spatial data, and also provided in-depth guidance for the application of robustness and spatial regression analysis in the study of real-estate economics.

Finally, in order to verify the results of the previous analysis and further explore the correlation between variables, we used Person correlation analysis. Pearson correlation analysis measures the strength and direction of the linear relationship between two continuous variables [58]. The Pearson correlation analysis is expressed by Equation (2), where r is the correlation coefficient, X is the seven independent variables, i is the sample data, and Y is the dependent variable, the house price before 2012 and the house price after 12 years:

$$r = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \overline{X})^2} \sqrt{\sum_{i=1}^{n} (Y_i - \overline{Y})^2}} \quad (2)$$

They ensure the logic and systematisms of the whole research and make the research results more comprehensive and reliable.

This research collected spatial data and housing-attribute data for three types of housing in two time periods, before (2004–2011) and after (2013–2020) TOD construction. For each type of house, 40 house property data points and spatial data points will be collected as a sample. The locations are shown in Figure 3. After collecting data, the HPM will be used as a mathematical model to analyse the relationship between housing attributes (e.g., the distance of the house from the TOD and the size of the house) and market value. To analyse whether there is a relationship between TOD construction and different types of housing prices and how TOD affects the prices of different types of housing in Footscray, housing attributes for both time periods will be used as variables and then regression coefficients and p-values (importance parameters) for these attributes will be calculated using the hedonic price model and robust regression analysis.

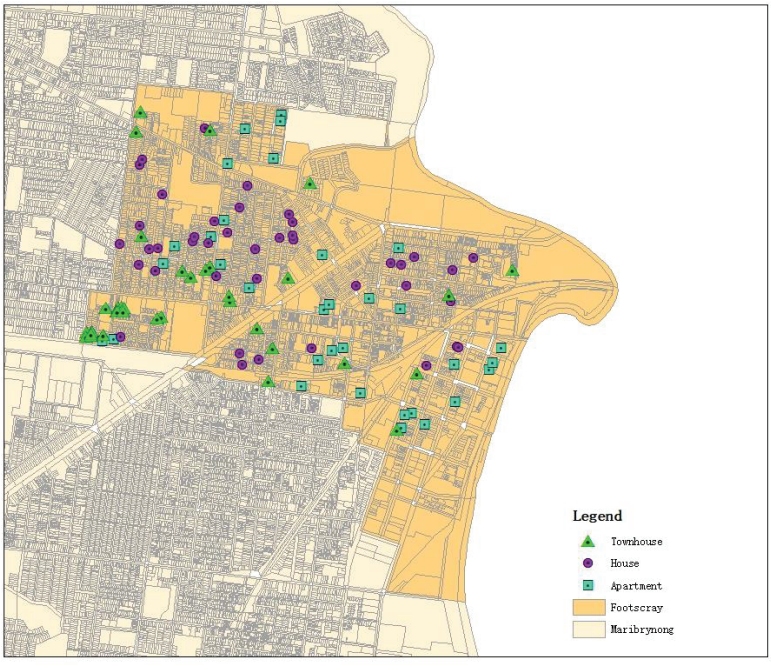


Figure 3. The locations and building types of samples in Footscray.

3.3.2. Observation-Based Spatial Analysis Using Google Street View (GSV)

In the spatial dimension, observation-based (Google Street View or field observations) spatial analysis would be an appropriate method to analyse the amount of housing redevelopment and infrastructure investment in the Footscray area. A considerable number of scholars have used the method of Google Street View to investigate the gentrification level around the world. For instance, Hwang and Sampson addressed the gap between uneven evolution across times and spaces of gentrification by introducing a method of systematic social observation using Google Street View to detect visible cues of neighbourhood change [59] and combining this with integrating census data, police records, prior street-level observations, community surveys, proximity to amenities, and city budget data on capital investments for the case study of Chicago between 1995 and 2009. Afterwards, Ilic et al. [60] applied Google Street View, which detects gentrification-like visual changes to illustrate where the spatial concentration of visual property improvements was highest within the study area at different times from 2007 to 2016 in Ottawa, Canada [60]. Similarly, Sanchez virtually visited Talca and Santiago [61], Chile, using Google Street View and followed this with an in situ observation to identify and investigate the effects of green gentrification in the Global South. It can be shown that Google Street View used for investigating gentrification is a convincing and credible method.

The spatial analysis is one of the suitable research methods to analyse how transit-oriented development influences house prices in Footscray. Spatial analysis is a geographical analysis that seeks to interpret the patterns of human behaviour and their spatial expression in terms of mathematics and geometry [62]. Spatial analysis is widely used based on microeconomics to predict the spatial patterns that should occur, for example, the growth of networks and urban systems [63]. Also, as Joe pointed out in the third-week lecture, it is possible to show how things exist or change across space by analysing spatial data [64]. The change in street infrastructure, the increase in housing and the difference in built forms are the external manifestations of urban development.

This method in our research combines street-view observations with data analysis to present an accurate and convincing discovery of gentrification. We started with looking at the Housing Development dataset in Geographic Information System (GIS) that was provided by the state of Victoria's Department of Environment, Land, Water, and Planning [65], and created Figure 2 according to the data. Figure 1 is based on the indicator of total net dwelling, which reveals the net change in dwelling stock over the year, to see how the varying degrees of dwelling changes in number on the map between 2005 and 2016. Then, we discovered there are specific streets that change the most. In order to investigate the gentrification degree of this area before and after the construction of TOD, we selected five specific streets to conduct the street-view observation. We chose three streets within the 400 m range deeply affected by TOD and two streets outside the 800 m range that would not be strongly affected by TOD, which are all the most greatly changed streets within this range shown on the map (Figure 2). We intended for Australians to select the five streets with the greatest changes, so that the comparison could be made to discuss this further at the same level, such as whether the street view near TOD changes greatly and updates more, while the area further away from TOD changes less, or whether there are different discoveries in different streets.

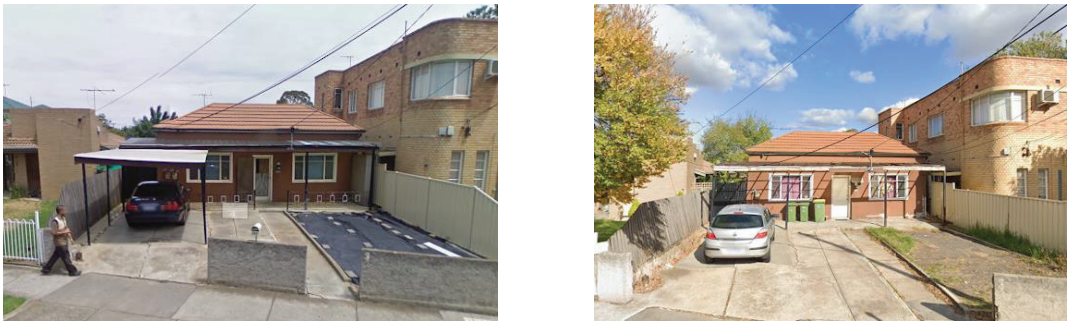
The detailed operation of this method was as follows: after the site selection, a quantitative coding model that helped to code each dwelling according to corresponding GSV and the Housing Development data [66] had been built. This model used a transformed model from Hwang and Sampson, which can be more appropriate in an Australian context [59]. The brief structure of this model is below:

- Analysing the Housing Development data
    1. For assessing the changing degree of dwellings, use the following variables: According to the dataset, if the dwelling on the selected street with the indicator "total net dwellings" is higher than 3, mark the lot as '2'; if it is between 1 and 3, mark it as '1'; if it is 0, mark it as '0', and mark it as '−1' when the total net

dwelling is less than 0. For indicator "area", if the area increases, mark it as '1', or otherwise '0';

- Grading and Recording from the Street View
  2. Signs or structures controlling traffic (e.g., speed, pedestrian crossing, bike lanes, or parking): we coded 0 for not having the traffic signs and structures and 0.5 for having them;
  3. Public courtesies (e.g., bus stop or subway entrance, street furniture, bike racks, public trash cans, or streetlamps): we coded 0 for not having the public courtesies and 0.5 for having them;
  4. Signs discouraging disorder (e.g., neighbourhood watch, anti-littering/loitering/drug use/vandalism/graffiti [including if painted over or covered by murals]): we coded 0 for not having the signs and 0.5 for having them;
  5. Beautification in personal and vacant areas and public street frontage: we coded 0 for not having any beautification, and 0.5 for having it.

Next, we looked at the dwellings in the year in which we could find the oldest and the latest in the GSV website and captured them for further access, e.g. Figure 4. The reason we chose these years is that we wanted to make sure that every change that may have been impacted by the construction of TOD was stable given these long periods. The TOD was completed in 2012, almost in the middle of the year that we chose (ranging between 2007 and 2021).



(**a**) (**b**)

Figure 4. One of the samples collected at Ballarat Road: (**a**) captured in 2009 on 283 Ballarat Road; (**b**) capture in 2019 on 283 Ballarat Road.

This study utilizes the Delphi method in scoring to explore the impact of TOD on housing. Through multiple rounds of expert panel discussions, we have sought to bring together the judgment of professionals to objectively reveal the key factors through which TOD may impact on housing. In modern times, the Delphi method has evolved into a statistical method that not only collates individual opinions, but also aggregates them into a statistically generated consensus through collective intelligence [67]. Hwang et al. also studied gentrification in Chicago neighbourhoods using Google Street View gentrification observation (GGO) as a means of data collection [59]. In this method, they used two raters to score and then they used the average from each indicator. We integrated housing data and scoring criteria (Table 2) and obtained housing scores through multiple rounds of Delphi, which strives to eliminate bias and subjective gaps in scoring.

Table 2. Scoring standard based on coding guide (Hwang and Sampson, 2014) [59].

Observation Instrument Item	Situation		Mark
Changing degree of housing	Total net dwellings	>3	2
		1, 2, 3	1
		0	−1
	Area	increase	1
		decrease	0
Signs or structures controlling traffic	Have		0.5
	Do not have		0
Public courtesies	Have		0.5
	Do not have		0
Sign discouraging disorder	Have		0.5
	Do not have		0
Beautification	Have		0.5
	Do not have		0

Finally, after all the collection procedures, we have concluded and labelled all dwellings in terms of the score that we acquired from the quantitative model. We set a_n for the new building and b_n for housing data from before. First, Formula (3) is used to show how a house indicator is calculated, and then the change score for each house needs to be calculated (Formula (4)). Then, the total value of the five elements and the change score for each of the five streets is calculated (Formulas (5) and (6)). Finally, divide the total street score by the number of homes on that street to the average (Formula (7)). After various data from different streets are obtained, they are compared to find the degree of change for the TOD. we added them up according to the total score of each street and then divided them by the number of dwellings on this street to obtain an average score, as well as each indicator in different streets, to make a comparison.

$$I_i = a_n - b_n (i = 2, 3, 4, 5)(n = dwelling\ NO.) \tag{3}$$

$$S_d = I_1 + I_2 + \cdots + I_5 \tag{4}$$

$$S_S = \sum S_{d^n} (n = dwelling\ NO.) \tag{5}$$

$$S_{I_i} = \sum I_{i^n} (n = dwelling\ NO.) \tag{6}$$

$$\mu = \frac{S_s}{N_s} (N_s = Sample\ number\ of\ dwelling\ on\ a\ street) \tag{7}$$

4. Results

4.1. Findings from the Spatial Analysis Based on the Hedonic Price Model

House attributes including lot size, build size, number of bedrooms, number of bathrooms, number of parking spaces, distance from CBD, and distance from Footscray TOD, were selected as independent variables to calculate their impact on the different type of house prices (descriptive statistics of the property data are shown in Tables 3–5).

Table 3. Dwellings' change types.

Category	Description
No big changes (score less than 0).	The exterior of the building and the surroundings remain the same.
Slight changes (score between 0 and 1).	The exterior of the building has a slight change on one or two of the following four indicators: signs or structures to do with traffic, public courtesies, signs discouraging disorder, or beautification.
Big changes (score more than 1).	The exterior of the building has a change in the following four indicators: signs or structures to do with traffic, public courtesies, signs discouraging disorder, or beautification; or, there are rebuilt buildings.

Table 4. Descriptive statistics of the apartment property data.

	Apartment				
	No.	**Mean**	**Min.**	**Max.**	**S.D.**
No. bed	40	1.8	1	3	0.54
No. bathroom	40	1.17	1	2	0.38
No. garage	40	1	0	2	0.33
DisToCBD	40	6120	5000	7500	686.42
DisToTOD	40	592	354	1500	303
Land Size	40	2177	62	8694	1983.6
Build size	40	69	44	140	18.37
Apartment Price After 2012	40	469,708	100,000	1,135,000	160,827.5
Apartment Price Before 2012	40	359,706	132,000	705,000	112,741.7

Table 5. Descriptive statistics of the townhouse property data.

	Townhouse				
	No.	**Mean**	**Min.**	**Max.**	**S.D.**
No. bedroom	40	2.7	5	3	0.67
No. bathroom	40	1.72	3	2	0.64
No. garage	40	1.4	2	2	0.55
DisToCBD	40	6991	5100	7600	730
DisToTOD	40	544	86	1250	291
Land Size	40	129	73	272	42.2
Build size	40	145	54	276	52.02
Apartment Price After 2012	40	819,175	328,000	1,411,000	180,770
Apartment Price Before 2012	40	472,071	241,000	627,150	99,098

4.1.1. Different Categories of the Relationship

- Impact of Housing Configuration

Firstly, data provided in Table 6 shows the correlation between housing configurations (such as the number of bedrooms, bathrooms, and garages) and house prices. By analysing the *p*-values for correlation using both the HPM and robust methods, we find that the number of bedrooms has a significant impact on house prices, followed by the number of bathrooms, while the impact of the number of garages is relatively smaller. This indicates that internal housing configurations are important considerations in valuations, especially the number of bedrooms and bathrooms, which may reflect the market's high demand for living comfort.

Table 6. Results: impacts of house features on seven factors of properties.

House Features					
Models			**HPM**	**Robust**	**Pearson**
Before 2012	Apartment	No. bedroom	0.92	0.847	0.414 **
		No. bathroom	0.035 *	0.040 *	0.513 **
		No. garage	0.382	0.388	0.148
	Housing	No. bedroom	0.251	0.312	0.279
		No. bathroom	0.162	0.159	0.416 **
		No. garage	0.033 *	0.069	0.503 **
	Town housing	No. bedroom	0.701	0.489	0.128
		No. bathroom	0.242	0.227	0.29
		No. garage	0.357	0.246	0.330 *
After 2012	Apartment	No. bedroom	0.14	0.049 *	0.671 **
		No. bathroom	0.956	0.971	0.272
		No. garage	0.871	0.474	0.169
	Housing	No. bedroom	0.064	0.039 *	0.520 **
		No. bathroom	0.425	0.347	0.358 *
		No. garage	0.247	0.155	0.508 **
	Town housing	No. bedroom	0.186	0.06	0.560 **
		No. bathroom	0.393	0.49	0.142
		No. garage	0.056	0.033 *	0.510 **

Note: (*) signifies a *p*-value less than or equal to 0.05, (**) indicates a *p*-value less than or equal to 0.01.

- Impact of Housing Distance

In Table 7, we focus on housing-distance features, such as the distance to the CBD (Central Business District) and the distance to the TOD. The data shows that the correlation *p*-values for the distance to the CBD and TOD undergo significant changes before and after the construction of the TOD. Notably, properties closer to the TOD increase in value correlation significantly after the TOD is built, suggesting the potential role of TOD in enhancing the value of nearby properties. This finding emphasizes the positive impact of public transportation convenience on property values, especially in areas surrounding TOD.

Additionally, based on the data from all three tables, it is observed that the *p*-values for apartments and townhouses, after the construction of a TOD (after 2012), show significant characteristics with *p*-values less than 0.01. From the perspective of housing types, apartments demonstrate a greater correlation with the construction of TODs and proximity to the TOD centre. This also suggests that apartments tend to appreciate more in value and witness faster price growth with the increase in TOD infrastructure and the decrease in distance to available services.

The correlation between distance and CBD did not change much across models, while the correlation between distance and TOD was negative in Pearson's model (e.g., −0.29), which may indicate that properties closer to TODs have higher values, reflecting the positive impact of public-transport accessibility on property values.

Table 7. Results: impacts of availability on seven factors of properties.

Availability					
Models			**HPM**	**Robust**	**Pearson**
Before 2012	Apartment	Distance To CBD	0.993	0.957	−0.267
		Distance To TOD	0.203	0.13	−0.29
	Housing	Distance To CBD	0.605	0.764	−0.021
		Distance To TOD	0.758	0.676	−0.236
	Town housing	Distance To CBD	0.561	0.445	0.122
		Distance To TOD	0.014 *	0.003 **	−0.388 *
After 2012	Apartment	Distance To CBD	0.783	0.679	−0.268
		Distance To TOD	0.002 **	0.000 **	−0.276
	Housing	Distance To CBD	0.416	0.464	−0.165
		Distance To TOD	0.191	0.101	−0.332 *
	Town housing	Distance To CBD	0.007 **	0.000 **	−0.155
		Distance To TOD	0.103	0.023 *	−0.538 **

Note: (*) signifies a *p*-value less than or equal to 0.05, (**) indicates a *p*-value less than or equal to 0.01.

- Impact of Construction Scale

Lastly, Table 8 explores the correlation between the size of the construction (including land size and building size) and house prices. The results indicate that both land and building sizes have their correlation with house prices strengthened after the construction of TODs. This may reflect that larger spaces can provide more possibilities for use and comfort, thereby increasing the market value of the property. Especially after the construction of TOD, these areas might become more popular, further amplifying the positive impact of size on value.

Table 8. Results: impacts of construction scales on seven factors of properties.

Construction Scales					
Models			**HPM**	**Robust**	**Pearson**
Before 2012	Apartment	Land Size	0.010 **	0.007 *	0.383 **
		Building Size	0.000 **	0.000 *	0.662 **
	Housing	Land Size	0.825	0.769	−0.085
		Building Size	0.533	0.597	0.350 *
	Town housing	Land Size	0.861	0.831	−0.082
		Building Size	0.164	0.1	0.159
After 2012	Apartment	Land Size	0.866	0.845	0.037
		Building Size	0.000 ***	0.000 **	0.838 **
	Housing	Land Size	0.744	0.675	−0.161
		Building Size	0.521	0.725	0.447 **
	Town housing	Land Size	0.008 ***	0.000 **	−0.276
		Building Size	0.115	0.009 **	0.548 **

Note: (*) signifies a *p*-value less than or equal to 0.05, (**) indicates a *p*-value less than or equal to 0.01, and (***) signifies a *p*-value less than or equal to 0.001.

4.1.2. GSV Score of Each Street

The above Figure 2 and tables show the overall and average scores that we obtained from the data collection and analysis. Figure 5 explicitly shows the values of the five indi-

cators corresponding to each street. Figure 6 is obtained by dividing the total score of each street by the number of dwellings in that street to obtain the average score of each street that would be compared with the change equitably happening in each street. According to Figure 5, we can find that although Ballarat Road has the highest overall score, in Figure 6, its average score is lower than Hocking Street. It reveals that Ballarat Road has a higher quantity of updated dwellings or improved environment, while Hocking Street has a higher quality of the improved environment or greater transformation efforts for dwellings. In terms of the characteristics of each street, the findings are as below:

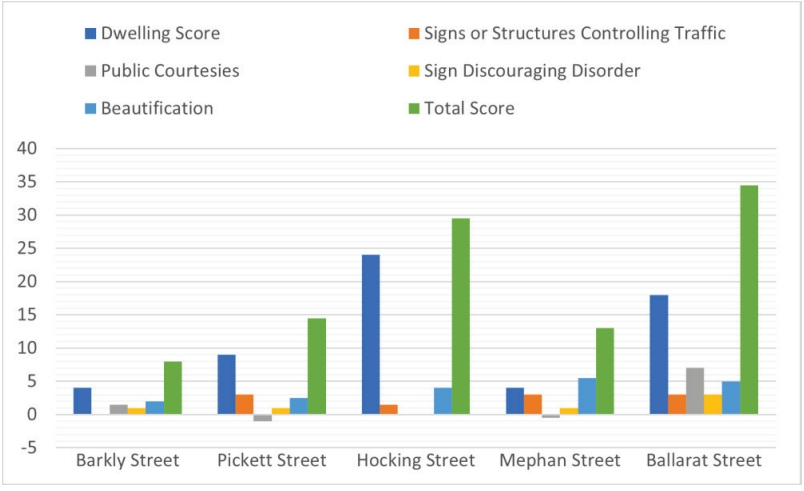


Figure 5. Five indicators and total score of each street.

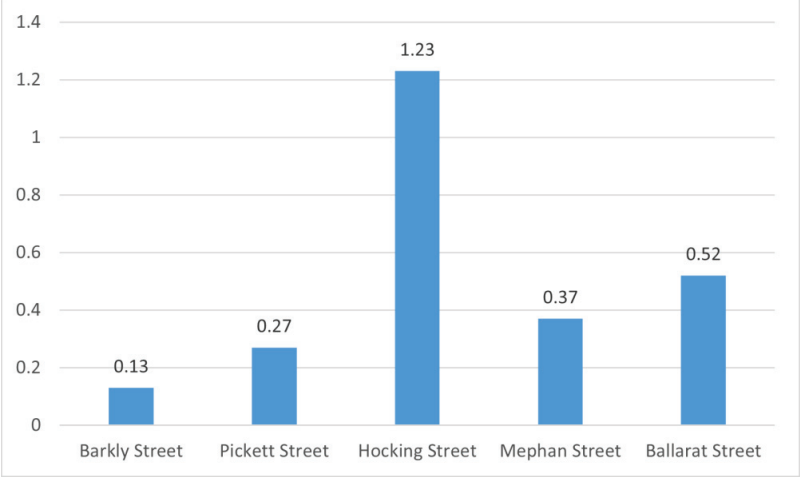


Figure 6. Average dwelling-change score of each street.

Barkly Street: It has the lowest overall and average scores, with the lowest five indicators among the five streets. The main dwelling type on this street is commercial, and only two buildings have been rebuilt during the year we investigated.

Pickett Street: It is mainly a residential area with three redevelopment dwellings, two lots rebuilt from one-storey dwellings to apartments, and the others from single

dwellings to townhouses. The upgraded buildings are accompanied by beautifications, and other environmental improvements have also taken place to some extent.

Hocking Street: With the top beautification and dwelling scores, Hocking Street has the second-highest overall score and the highest average score. The main type of dwelling on this street is residential. Due to nine built townhouses on vacant lots and one rebuilt townhouse, the net dwelling number increases dramatically, as well as the increasing beautification score—in which the land used to be vacant.

Mephan Street: The street has three new developments, with one developed on the vacant lot and two redevelopment dwellings. The amenity environment goes along with the new development.

Ballarat Road: the redevelopment combined rebuilt and newly built dwellings on vacant lots, but the significantly developed building is a four-story apartment building near the intersection of the arterial road: Ballarat Street and Gordon Street.

5. Discussion

5.1. The Effect of TOD on House Price

The finding of the hedonic price model shows that the construction of TOD has an impact on the prices of different types of housing and may unconsciously influence the surrounding affordable house price (residential displacement indicators). In most of the current academic studies, it is stated that the closer the house is to the TOD, the higher the economic value will be. As pointed out by Yuer Chen. et al.'s [56] and Sim. et al.'s [55] studies, the distance from the TOD is negatively correlated with the price of the house. In the finding of the hedonic price model of this study, a similar conclusion was obtained that distance from the TOD is one of the important factors affecting the prices of apartments and houses in Footscray after the completion of the TOD. Distance from a TOD is also negatively related to different types of house prices in Footscray.

However, by comparing the results of the hedonic price model for the three types of houses, it was found that apartments are the housing type most likely to be affected by TOD construction. More importantly, the apartment is one of the affordable types of housing.

Although the authors [66,68] set different policies to support medium-density development and apartment development, the prices of apartments close to the TOD are still much higher than the prices of apartments away from the TOD currently. According to Alfred Marshal [69], the principle of the supply and demand theory of Economics, the higher prices of apartments close to the TOD may be due to the low supply of apartments close to the TOD or the higher demand for apartments near the TOD. However, in general, the distance to the TOD does become an attribute that affects apartment prices. This attribute, in concert with the improvement of public services around apartments, the rise in the number of people settling in Footscray, and other factors, indirectly leads to a decrease in the affordability level of apartments near the TOD and an increase in rents, thus affecting displacement indicators [53] and potentially leading to residential displacement.

TOD does have the potential to be one of the factors driving the redevelopment of the surrounding houses and the improvement of the surrounding infrastructure. Combining the findings of the two approaches representing two different dimensions(Figure 7), they both demonstrate that TOD has the potential to drive the redevelopment of surrounding housing. As the finding of the spatial analysis based on the hedonic price model shows that the closer the house is to the TOD, the higher the price, at the economic level, it would be more profitable to redevelop the low-density houses that are close to the TOD into high-density ones. Furthermore, the findings of the observation-based spatial analysis indicate that a significant amount of townhouse redevelopment is located on Hocking Street, one of the streets close to the TOD. However, the type of housing that the developer chose to redevelop in Hocking Street is not apartments but townhouses, which indicates that it is possible that the developer's redevelopment near the TOD is aimed at the middle- and high-income groups. However, this also elaborates on the potential for generating

residential displacement. Due to the high economic returns of redevelopment around TOD, developers do not redevelop affordable housing types, choosing instead to build townhouses for middle- and high-income groups, in which case there is a significant risk of residential displacement despite the increased housing density around the TOD.

Figure 7. Separated indicators of each street and the total score of change options for people with low incomes [70], who are more likely to experience residential displacement.

5.2. The Effect of TOD on Displacement

During the street-view research, we wanted to use the indicators related to displacement for judging whether displacement would happen in the circle of the TOD's effective services. In former research, generally, the infrastructure and environment improvement should have occurred in the inner circle due to the TOD bringing benefits for these areas [71].

It can be easily seen that the highest average score is in Hocking Street, and the second one is in Ballarat Street. These indicators do not reflect that of the general or regular areas. As the indicator relevant to the displacement phenomenon, we still need the price data to combine this with, in order to check that these increasing indicators are able to represent displacement within the TOD range. Choosing 36–40 Hocking Street as an example, the housing price increased and there was an obvious redevelopment and submission in 2004, but meanwhile, a redeveloped site with increasing indicators also can be found at

Ballarat Road, which is far away from the TOD station. Thus, from our findings, these increasing indicators could present and describe the displacement to some extent and describe the displacement level but cannot highlight the clear relationship between TOD and displacement from spatial distribution.

Comparing the main indicators of improvement of the environment, then, we found that the group which is outside of the TOD service circle receives a higher average score than the inside of the TOD in beautification, public courtesies, and signs.

Moreover, we found more details using Google Maps; the indicator of total net dwellings shows higher scores in the large site in almost all streets, which mainly contain four types of development: commercial development, housing, public services, and apartments. Following [68] and the transit city plan, the TOD policy started to be operated, encouraging medium-density development close to transport stations. However, it can be seen from data that most developments of apartments are on Ballarat Road rather than the streets within the TOD-radiation distance. Although this reflects the low income of consumers who have immigrated from near the TOD to far away from TOD circles due to the supply of the affordable product, implicating the socioeconomic segregation to some extent [72], it still cannot be shown using a simple TOD-theory model.

The complicated factors existing in a real TOD city cannot abstract the TOD station as the single affected factor. Ballarat Road has a higher score, though it is far away from the TOD station and its policy, mainly because of the well-equipped infrastructure. Musterd, Marcińczak, van Ham, and Tammaru [73] state that social welfare and infrastructure can also have an impact on social justice and reflect on spatial distribution. Also, the Hospital and education source in Mephan and Ballarat, and the commercial complexes, can be regarded as a positive exterior, which also increases the land value and pushes the land development [74]. These indicators are influenced by diverse dimension overlays; thus, they are not reflecting the general regularity of the TOD theory.

Although the construction of a TOD has a driving effect on the redevelopment of the surrounding houses, there are many other external factors that will drive the redevelopment of the houses in the area. Combining the findings of the two methods representing two different dimensions, a new phenomenon was found in Footscray. As the finding of the spatial analysis based on the hedonic price model shows, apartment prices are most likely to be influenced by the distance between the apartment and the TOD. However, the finding of the observation-based spatial analysis shows that although Ballarat Street is far from the TOD, there are still a large number of apartment redevelopment projects on this street. In terms of economic benefits, the proximity of Ballarat Streets to the TOD is not a positive motivation for developers to redevelop apartments in Ballarat. However, the Footscray phenomenon demonstrates that, in addition to the external factor of TOD construction, there are many factors that may influence the amount of housing redevelopments (residential-displacement indicators), such as the improvement of public infrastructure around Ballarat Street and the existing well-developed transportation within this area, which are factors that may drive investors to redevelop. So, while TOD is likely to drive the redevelopment of surrounding houses, there are a number of factors that can drive the amount of housing redevelopment in an area in reality. However, in the reality of Footscray, apartment redevelopment is concentrated on in streets far from the TOD, which creates a lack of affordable housing within the TOD area, and may indirectly drive the occurrence of residential displacement in Footscray.

6. Conclusions

The case study of Footscray demonstrates that displacement is a temporal and spatial phenomenon influenced by TOD. The HPM model reveals that house prices increase as TOD distance decreases, with apartments being the most affected. However, our methods cannot separately measure the unconscious negative impact of TOD on displacement. Google Street View analysis shows that displacement factors are complex, making TOD one of the compounded influences. This research supports future housing and transport

policies to counteract TOD's unintended effects and reduce displacement, achieving social justice while promoting high-density residential development near TOD areas, ensuring affordable housing provision, which is crucial for social equity [28].

Additionally, measures should be taken to mitigate land-value appreciation's adverse effects, especially for vulnerable communities. Our research highlights the importance of urban-development policies that prioritize social equity and inclusivity. TOD offers opportunities for sustainable growth, but addressing its unintended consequences requires nuanced policy interventions. Despite limitations like the subjectivity of manual scoring and the incomplete consideration of factors influencing house prices in the HPM formula, our study provides valuable insights into urban planning and policy debates. Further research is needed to clarify the relationship between TOD and displacement more clearly.

Author Contributions: Conceptualization, X.W. and Y.X.; methodology, B.L., L.X. and J.H.; software, Y.X. and J.H.; validation, X.W., Y.X., L.X. and J.H.; formal analysis, Y.X.; investigation, X.W., Y.X. and L.X.; resources, J.H.; data curation, X.W., Y.X. and L.X.; writing—original draft preparation, X.W., Y.X., L.X. and J.H.; writing—review and editing, X.W., B.L. and Y.X.; visualization, X.W.; supervision, Y.X.; project administration, Y.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by University of Oklahoma Libraries' Open Access Fund.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

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Promoting Social Equity and Building Resilience through Value-Inclusive Design

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Abstract: Urban design and architecture have inadvertently contributed to the bifurcation of societies divided into haves and have-nots, thus undermining social equity, restricting opportunity, and resulting in poverty next to overabundance and waste. Global population growth and urban migration pressures compound the problem. The call for social equity and justice is, therefore, urgent from a social perspective and an environmental one. This study explores a concept we call 'value-inclusive design' and its potential for transformation toward 'judicial equity'. Our value-inclusive design method proposes neighborhood interactions and co-design as a way to create welcoming spaces that preserve natural resources, support economic sustainability, and improve architectural design to foster health and wellbeing for people and the environment. This article discusses the potential of our value-inclusive design model in contributing to judicial equity by applying it to an international student competition called the 'Global Greenhouse Challenge #3', launched by Wageningen University and Research. By viewing the results of the Global Greenhouse challenge through the lens of value-inclusive design, we find that the model has merit and provides a useful theoretical framework for promoting social equity in urban planning and design. We conclude that by applying the model, its constructs can enhance design approaches that seek to improve the quality of life of residents while building resilience and shifting agency through co-design. The model can, thus, be a means for driving continuous improvement in architectural design and applying it in an educational setting such as the Global Greenhouse Challenge student competition.

Keywords: social equity; urban resilience; value-inclusive design

Citation: Harris, E.; Franz, A.; O'Hara, S. Promoting Social Equity and Building Resilience through Value-Inclusive Design. *Buildings* **2023**, *13*, 2081. https://doi.org/10.3390/buildings13082081

Academic Editors: Steffen Lehmann and Monika Szopinska-Mularz

Received: 28 May 2023
Revised: 21 June 2023
Accepted: 23 June 2023
Published: 16 August 2023

1. Background

Urban design and architecture have inadvertently contributed to the bifurcation of societies into haves that invest in designing, developing, and building their environment and have-nots that must accept the outcomes ushered in by others, which contributes to social inequity. Standard design approaches, thus, restrict opportunities for some, while others indulge in overabundance and waste. Global population growth and urban migration pressures compound the problem. Therefore, the call for social equity and justice is urgent from both a social perspective and an environmental one. Design can foster equity and justice, build resilience, and ameliorate the current bifurcation. Yet, in order to do so successfully, architects, planners, designers, scientists, and other stakeholders must promote a green urbanism to create sustainable and resilient spaces that improve community health and wellbeing [1]. Integral to this kind of green urbanism is the integration of food production into the urban-scape. Communities and neighborhoods within growing cities can create sustainable food systems, mitigate poverty, and increase resilience [2]. To develop a comprehensive model for social equity and justice, this study proposes a new urban planning and architecture model using value-inclusive design (VID). In this approach, community interaction is solicited to co-create inclusive environments that seek to conserve natural

resources, strengthen sustainable economic development, and enhance green architecture. This approach incorporates food production with the goals of promoting health and well-being. VID builds on the urban design and planning framework of Meerow et al. [2] which incorporates recognitional, procedural, and distributional equity, whereby healthy urbanism is described as 'inclusive, equitable, and sustainable'. VID also builds on the values of empathy, placement, accessibility, and identity developed by Stuiver et al. [3,4]. It aims to outline equitable approaches for promoting social equity and building urban resilience by engaging local stakeholders. This article suggests that, in doing so, value-inclusive design also improves educational outcomes, which is a prerequisite for improving more equitable design outcomes in the future. The current literature discusses parallels to value-based education for inclusion. The VID concept builds on these value-based concepts as it applies to architectural education and community resilience.

To test its suitability for improved educational outcomes that advance goals of 'social equity' and 'resilience', we apply our model of value-inclusive design to an international student competition. This competition was launched by Wageningen University and Research's (WUR), a university with a focus on agriculture and sustainability in the Netherlands called the Global Greenhouse Challenge. It engaged international teams of students in designing an urban greenhouse for a low-income, disinvested neighborhood in Washington DC. The neighborhood houses one of four urban food hub locations of the College of Agriculture, Urban Sustainability, and Environmental Sciences (CAUSES) of the University of the District of Columbia called the East Capitol Urban Farm [5]. Student teams were asked to design an urban greenhouse that meaningfully improves the quality of life of residents while meeting financial and environmental sustainability objectives. At the outset of the Urban Greenhouse Challenge, an instructive online lecture on inclusive design through co-creation was presented to the competing student teams. This introductory lecture was important in clarifying for the student teams how design can be used for transformation. Proposals with designs representing design indicators for the value of 'transformation' and considering 'judicial equity' as a social equity dimension were judged superior to other submissions. In analyzing the designs submitted by 20 teams, we found that VID criteria were clearly observable in guiding the development of socially equitable and sustainable designs that advance human health and dignity, as well as form the basis for improved quality of life outcomes. The next section briefly discusses frameworks that influenced the concept of value-inclusive design before turning to the application of the concept to the designs submitted by the student teams who competed in the 2022–23 Urban Greenhouse Challenge.

1.1. Definitions for Wellbeing in Urban Architecture and the Dimensions of Inclusive Design

Goals of green design and social inclusion are values underpinning any planning and design process that can be considered inclusive design [1–6]. The model depicted in Figure 1 shows how the three facets of social equity intersect. The case study process underlying our assessment of the effectiveness of value-inclusive design consists of a two-step process for examining the model and its constructs: step one consists of the construct validation similar to hypothesis-testing in research; step two consists of an in-depth limited-scope study [7–9]. Applying the case study material from the Global Greenhouse Challenge to Meerow's model for social equity in the context of urban resilience planning yielded four emerging values—Identity, Placement, Accessibility, and Empathy [10]. These four core values were presented in a workshop offered to student teams competing in the Global Greenhouse Challenge [11]. From this framework and resulting values, an inclusive design canvas with design principles was prepared that planners, designers, and architects can adopt as their own design approaches in order to qualify as inclusive green design practices.

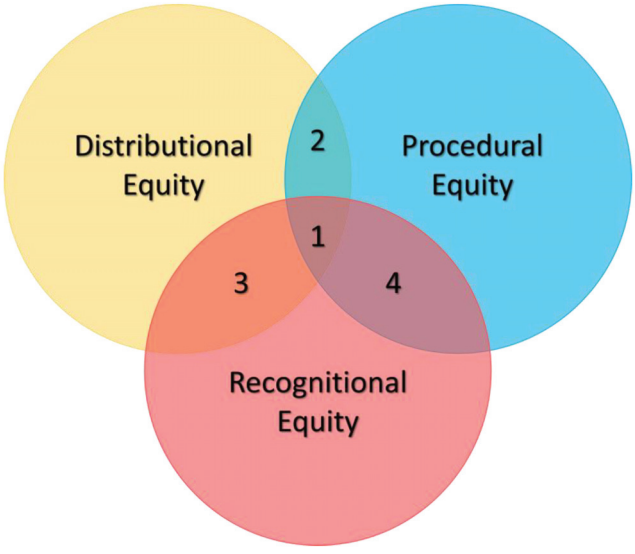

Figure 1. Model for inclusive green design. Four values that intersect with Meerow's model for social equity (2019): 1 = empathy; 2 = placement; 3 = accessibility; 4 = identity. This figure was developed by M. Stuiver, S. Sarabi, M. Takken, L. Rondard, R. Valkenburg, and T. Yuksel for "https://ewuu.nl (accessed online 22 January 2023)" [10].

(1) Identity. An individual's identity is determined by the values of human necessities and dignity, and by their acceptance of different lifestyles. It involves understanding human histories, skills, and physical, mental, social, and spiritual health needs. Identity allows people to express themselves without fear of judgment. Habermas advanced a similar definition with his term "Lebenswelt", the life world of individuals [12].

(2) Placement. This value is associated with overcoming distrust and anonymity in the public and private spheres of buildings and private and public areas as the basis of healthy living. Placement looks at the magnitude of relationships and explores solutions by applying building blocks for improved health outcomes and quality of life.

(3) Accessibility. For cities to be accessible, humans and nonhumans must have access. As a result, it reflects the scale of the urban environment. The availability of accessible architectural, landscape, and interior design resources promotes equitable distribution of resources.

(4) Empathy. Figure 1 highlights empathy as the central value of wellbeing in urban architecture. Embracing the needs of both human and nonhuman actors (Latour) [13] is the basis of the design. Empathy acknowledges the need for co-existence for all creatures in the city as the basis for truly co-creating public environments [1].

The systematic bibliometric analysis and literature review presented in The International Journal of Sustainable Development and World Ecology presented further details of this high-level framework for inclusion [14]. The framework suggests mapping the critical dimensions of an inclusive approach, which incorporates economic, social, political, spatial, and environmental aspects. When these dimensions are combined, they create equitable and inclusive spaces, enhancing wellness and quality of life. As the social scientists Ora and Isaac Prilletensky stated, 'those who live in more egalitarian countries live longer and achieve better outcomes' [15]. Designs are based on assumptions about human behavior and the space requirements of groups, families, and individuals [16]. These theories, taught in architecture schools, were created through actual research into how people utilize buildings and public spaces, as well as historical studies of different building types and layouts. Additionally, architects create hypotheses on the basis of their observations of the world

and how people interact [16]. These notions result from design thinking, user-centered design, and co-creation methodologies. All of these support good health, happiness, and a sense of community to raise living standards in neighborhoods, cities, and nations.

This paper proposes two concepts of the VID that enhance the framework summarized in Figure 1, namely, 'transformation' and 'judicial equity'. Both are generated by social capital.

1.2. Social Capital Link to Wellbeing and Social Impact

Social networks within a community give rise to social capital [15]. It appears because our networks enable us to complete tasks we cannot complete on our own, such as seeking employment, providing care for a loved one with an ailment, or simply quickly disseminating knowledge. They provide us with materials that we might not have access to on our own. Social networks have advantages for the community and each of us individually. They 'foster trust and reciprocity, facilitate the flow of generosity and altruism, contribute to lower crime rates, advance better public health, and support reduced political corruption', as noted by Nicholas Christakis [17]. Infrastructure can have an essential impact on the growth of social networks and the ensuing values of civic engagement and community involvement. For instance, public gathering places such as libraries, parks, and community centers might support the growth of social networks [14]. Strongly individualist designs, in contrast, would obstruct the development of social capital. John Helliwell and Robert Putnam, authors of The Social Context of Wellbeing, examined social capital's direct relationship to what they refer to as 'subjective wellbeing' through a variety of avenues [18,19]:

> "New research supports the notion that social capital influences subjective wellbeing through a variety of independent pathways and manifestations. Marriage and family bonds, ties to friends and neighbors, workplace ties, civic participation (both personally and collectively), trustworthiness, and confidence all appear independently and robustly connected to happiness and life satisfaction, both directly and through their effects on health."

As a result, active social networks are essential to both communal wellbeing and personal wellbeing. Furthermore, it is crucial that everyone in the neighborhood has access to those networks. Infrastructure, physical places, and services that cater to the community's requirements are additional crucial components of the community that influence individual wellbeing [15]. The VID framework takes into consideration the value of community space, how the term 'commons' is used, and how value is or can be promoted utilizing public vs. private space for the advancement of economic and social development in communities. Because of social capital, wellbeing is regarded as a measure of the worth of 'transformation'. The more people perceive their social environment as hostile, the more unequal the nation is [15]. This prevents the development of larger social networks and public confidence. People in unequal societies not only profit less from social networks, but they also have less access to essential resources such as decent housing, quality healthcare, and quality education. They have less or no opportunities to find fulfilling work. They are more prone to be victims of crime and to reside in places with pollution or other health dangers. Additionally, kids are constantly exposed to the elevated stress caused by a hostile environment in both big and minor ways [15]. Social capital produces equality, viewed as a sign of 'judicial equity'. According to O'Hara's analysis of these disparities, specific individuals of society bear heavier sink capacity than others and are disproportionately exposed to the adverse effects of tiredness, stress, and pollution [20]. Following 25 years of research, British scientist Michael Marmot concluded that 'the chances you have for full social involvement and participation are vital for health, wellbeing, and lifespan' [15]:

> "Responding to the needs of the neighborhood community to encourage an equitable division of rewards and responsibilities, encouraging underprivileged groups to engage in fair commerce, respect for human rights, and other equity-

related behaviors. Community wellbeing is the collection of social, economic, environmental, cultural, and political factors that people and their communities believe are necessary for them to thrive and reach their full potential. Research shows that individual empowerment is linked to overall community wellbeing, especially when people have a say in how policies are implemented. Individual participation fosters teamwork and a sense of ownership, which raises community satisfaction levels and improves both individual and group wellbeing."

1.3. Framework for Inclusive Design and Economic Development

The research's proposed framework for inclusive design strengthens the three social justice pillars listed in Meerow's tripartite framework for social justice [2]. It became apparent that the prevalent conceptions of equity are often linked to a distributional orientation, with less emphasis on the recognitional and procedural aspects, when this framework was initially employed to analyze how much cities focus on equity. Here, the distinction between equity and equality is significant [21,22]. While equity refers to a fair conclusion that need not be equal, equality refers to equal measures regardless of the outcome. For instance, using health as an example, an equity approach would encourage measures such as green spaces, healthcare, and social work in underprivileged rather than privileged neighborhoods. In contrast, an equality approach would offer all neighborhoods the same number of measures [23]. An approach that includes equity and equality fosters wellbeing and builds social capital. This regenerates underserved communities and increases proprietary engagement within communities to improve the quality of life. Economic development promotes opportunities for fair distribution of capital, labor, and resources.

1.4. The Commons

The infrastructure (physical places and services which serve the community's requirements) is another essential aspect of the community influencing individual wellbeing [15]. All members of an equal community share the entire advantages of society. Everyone is given fair and reasonable treatment in such a community and can actively engage in social, cultural, and economic life. Infrastructure that may enhance personal wellness in several ways, such as through addressing fundamental human needs, fostering social capital, and facilitating good lifestyle decisions. Lack of equal access to the same number and quality of community resources and services is one of the traits of systemic racism [15]. Everyone in the community needs access to these resources, and there is a conscious commitment to guarantee equality for all marginalized groups. More people now perceive their social environment as a secure place to live and work. This encourages the development of more extensive social networks and community trust. Social networks provide advantages such as access to essential resources including decent housing, healthcare, and education. Additionally, this creates new chances for employment and business, which lowers crime, lowers health hazards, and boosts long-term returns on investment. Public spaces (the commons) boost social networks and social capital through urban resilience and sustainability.

According to a Chicago study, residents in public housing who lived near trees and greenery said they knew more people, felt closer to their neighbors, cared more about supporting and helping one another, and felt more a part of their community than those who lived in buildings without trees [24]. Public space may significantly influence the growth of social networks and subsequent values of community involvement and civic engagement. For instance, public gathering places such as libraries, parks, and community centers can support the growth of social networks. Infrastructure contributes to creating social networks that enable community members to exchange opportunities and information and offer crucial resources. The wellbeing of individuals and the community can be improved by a community that works to guarantee fair access to these resources. It can also take away obstacles to good behavior. People will, for instance, walk more in a community if it seems secure for them to do so, whether through the installation of sidewalks on

busy streets, improved lighting, or a neighborhood watch program. With lovely green landscapes, walking could also be more enticing [14]. Per O'Hara's five pillars of economic development, the 'commons' build participatory environments for healthy communal living and quality of life [25,26]. The 'base theory' of economic growth used to be the main concept in past economic discussions. It made the case that a region's economy will expand if its foundation sector prospers. Therefore, economic policy should concentrate on establishing a robust base sector and ensuring its success. According to the five pillars approach, successful economic development strategies today should instead concentrate on the three primary objectives:

1. Enhancing a region's capacity for economic development.
2. Enhancing a region's quality of life.
3. Fostering a diverse regional economy to avoid reliance on a single industry or business [25] (see Figure 2).

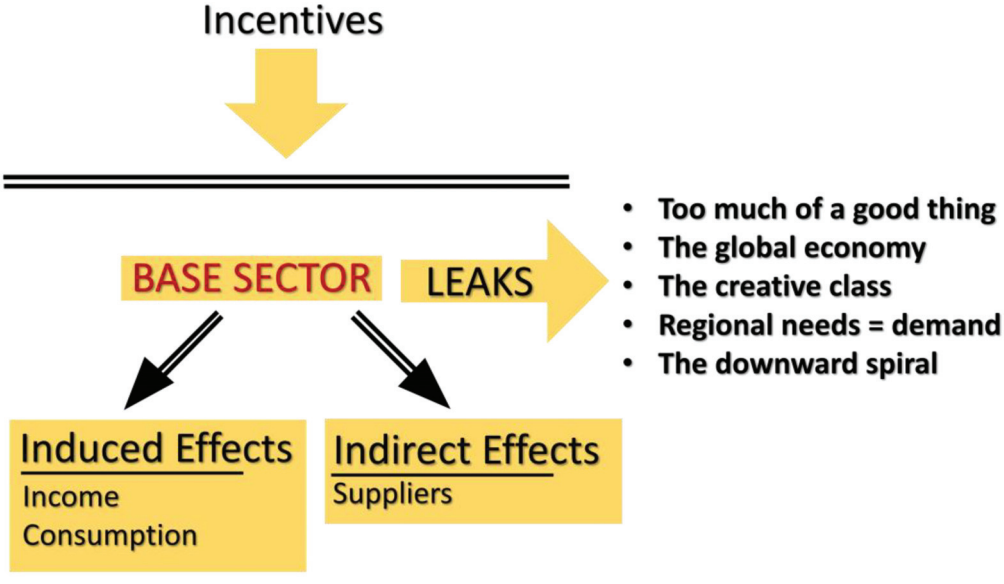

Figure 2. Base theory of economic development [25].

Five indicator categories can gauge a community's likelihood of long-term economic success using the five pillars model as a baseline: (1) health, (2) education, (3) environmental quality and recreation, (4) social and cultural amenities, and (5) information and transportation access [25,26]. These categories cover a variety of pertinent elements in which local stakeholders and governmental, corporate, and nonprofit organizations are interested. Therefore, the 'five pillars' categories can help these organizations work together and coordinate their development activities more effectively. By monitoring important indicators of local needs and resources, the 'five pillars of economic development' idea offers a useful, consistent, yet flexible method for assessing a region's quality of life and determining its ability to fix gaps [26]. Indicators that are considered leads, as opposed to lags, are the emphasis of the five pillars approach. In other words, it looks at markers that offer a future trajectory [25]. Figure 3 depicts this future in which social capital will increase through acceptable behaviors and equal access to resources.

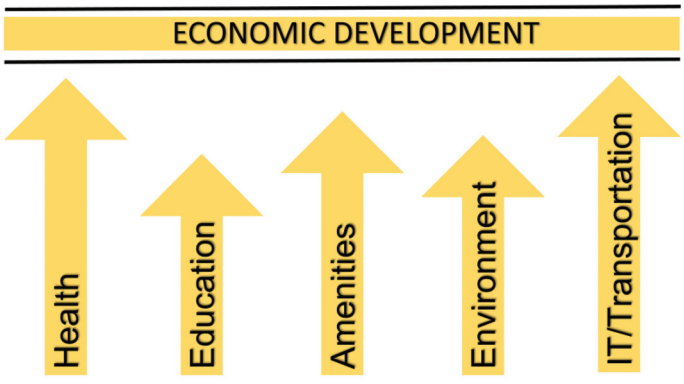

Figure 3. The five pillars of economic development [25].

1.5. Design Values: Review of the Literature

This literature review provides a broad overview as it relates to 'values' and their impact on design, the built environment, and its agency to build resilience. This includes social equity and inclusive frameworks that lack 'transformation' as a social value for economic development. To start, several 'ethics-first' methodologies have been demonstrated in academic writing and design practice [27]. These methods frequently concentrate on detailing methods for openly infusing values into design or explaining the normative aspects of design. Although this body of literature has grown significantly over the past 20 years, two key themes—(a) designer agency, and (b) the strength of normative claims informing the design process—have not yet been systematically discussed concerning one another. In order to address this gap, the literature looked at a methodical evaluation of the most influential ethics and values in design (E + VID) methods and criticisms [26–36]. In the literature, 13 critiques and 18 various approaches were found to satisfy the review's inclusion criteria [27–37]. A variety of opinions on normative strength were represented among the included articles, and it was found that neither the methodology nor any of the critiques pointed to a position characteristic of 'low' designer agency, which impacts socioeconomic factors and builds resilience in communities.

According to the research, the lack of methods with 'low' designer agency led to designers failing to consider essential impacts on design as potential targets for their interventions [28]. The study concluded with recommendations for future research that could shed light on methods to achieve an ethical design in information-mature societies. It makes the case that 'meaningful' ethical design would continue to face difficulties if the tensions caused by balancing normatively 'strong' future visions with restrictions placed on designer agency in corporate-driven design settings are not addressed [27]. The literature argues that moral principles and ethical issues are no longer separate from society [28]. Human values, particularly those with an ethical significance—such as the right to privacy and property, physical wellbeing, informed consent, trust, and responsibility, to mention a few—are crucial, but that does not make them any less contentious. What qualities matter? Who makes the decisions? Are values relative? Do universal ideals have varying cultural and contextual expressions? If not, how do values enter the design process? It also is evident that values might clash. Innovations in technology affect human values. However, how precisely can moral principles enter into technical conceptions? This debate over 'who evaluates' and 'whose values are applied' is similar to the lively debate about community development and the function of involvement in decision making [29].

The literature offers three categories: embodied, exogenous, and interactional stances. The embodied approach contends that designers imbue technology with their own objectives and ideals, and that this imbuing results in a system that, once developed and put to use, prescribes specific patterns of human behavior. According to the exogenous approach, sociocultural elements that have to do with the economics, politics, racism, class,

and religion have a significant impact on how a design is used. Lastly, the interactional approach asserts that, although people have a tendency to build characteristics or qualities into their communities which more easily encourages some values and hinders others, the purposeful use of such features or qualities depends on the goals of the people using them. Communities have made great strides in incorporating moral principles and ethical behavior into the design profession during the past 10 years [27,28]. The task of designing intelligently and morally to establish the necessary circumstances for humans to exist and prosper persists as the subject develops [27]. An inclusive design strategy must expand the principles of ethics and values in design for effectiveness.

Inclusive design, an ethical design technique incorporating the human ideal of inclusion, may generate economic value [28]. However, considerable research on the connection between economic value and human values in inclusive design still needs to be completed. The topic of value and values in the investigation of inclusive design is the main subject of this literature survey. The research shows how evolving views on inclusive design affect how people perceive value and values. The benefits of inclusive design for human values at the individual and social levels have been discussed, along with the economic benefits of inclusive design. In the literature, these contradictory talks are categorized into 'value creation' and 'value distribution', and chances for an integrated strategy that would link conversations on economic value and human values in future studies have been suggested [30].

To build inclusive designs, several layers of thought are required [31]. The relationships between layers of this framework are vital to address in accordance with a systems-based approach. Many methods for inclusive design are presented in this section, and the concerns presented here are relevant regardless of the methodological approach. Building interdisciplinary teams, involving members of a community or individuals with extensive understanding of the target community, and continuing to practice iterative design are all recommended practices for inclusive design, regardless of technique [31]. The more designers and design students can experience the world and their ideas through the eyes and skin of individuals who are older or less capable than them, the more likely they are to sympathize with and want to problem-solve for those who are less capable than themselves [32]. Inclusive design is a well-established, although yet relatively new, subject. Early pioneers laid out the subject's enormous region, and we now have strong examples of best practice, for both design and industry, as well as tools and methodologies to assist practitioners. However, there is still much work needed, as well as a great opportunity for a new generation of young and committed designers to complete the transition from the margins to the mainstream and deliver a truly inclusive and considerate environment for the predominantly urban society of the 21st century. Extending that user-centered and accessible design approach to bring comparable advantages to rural people, particularly in developing countries, is another difficulty that has yet to be addressed. It will be in the less advantaged and resourced areas that we will witness dramatic new breakthroughs in the more mature period of inclusive design that we are now approaching. Moreover, it is in these sectors that we may have the most possibilities to create inclusive and sustainable products and services [32].

According to studies, the architectural design community's acceptance of inclusive design is still fairly restricted [33]. Inclusive design integrates accessibility principles, and its expanded definition takes into account essential social and behavioral components such as physical, sensory, and cognitive demands [33]. Inclusive design has just recently begun to be considered in architectural design practice [34]. With the progression of design for disability into accessible design, as well as the increased awareness of inclusive design among architects and design professionals, governments have lately begun to enact guidelines and rules to foster the creation of more inclusive spaces [35]. However, the research shows that complete acceptance of inclusive design with an expanded idea of inclusion, diversity, equality, and accessibility in architectural design is currently restricted. This appears to be prompted by various problems, including a misunderstanding of inclusive design owing

to professional mentality, unconscious prejudice, unsubstantiated regulatory constraints, and time/cost-efficiency considerations during the building development process.

Inclusive design trails physical accessibility, yet research has found that complete acceptance of inclusive design in architectural design practice was restricted during the previous two decades, and that inclusive design is often misunderstood by architectural design professionals [34,36,37]. As a result, inequities, exclusion, and prejudice still can be seen at various levels and in various settings. Moreover, these difficulties have the ability to influence people's behavior and perceptions of society [35]. Rather than starting with relative moral norms, it is feasible to talk with people from other cultures about their values and create a 'bottom-up' or participatory framework influenced by worldwide partnerships in the field [38]. To establish a successful conservation process in our historic and vernacular built environment, cultural values must be grasped on a broader scale [39]. This observation is to propose a system that enables a mindful reflection of the cultural traits and values of the community and surroundings in one's creations. This problem is mostly related to the architecture of vernacular surroundings [40]. The proposed value-inclusive design model aims to address these issues by testing the social value of 'transformation' and construct of 'judicial equity' and its impact on community resilience. This is achieved by promoting human and moral values to increase social equity.

Similarly, Manders-Huits and Zimmer [41] first coined the term value-conscious design (VCD) to refer to a group of initiatives that promote human and moral values as an essential component of the conception, design, and development of technological artifacts and systems. The word is given additional weight in this essay, including the other projects, and introducing an ethical element. Various VCDs actively impact the design of technologies that take moral and ethical principles into account throughout conceptualization and design process. Recently, design frameworks have been created which incorporate moral and ethical intelligence into commercial and technology design environments. Two efforts incorporate ethical intelligence for technical design communities, influencing how technology is designed ethically and by values, with mixed results [41]. The paper highlights three significant obstacles to pragmatic engagement with technical design groups taking into account these failed attempts: (1) addressing conflicting values; (2) determining the role of the values advocate; (3) providing evidence to support a value framework. If one wants to be successful in pragmatically interacting with real-world business and design settings to bring moral and ethical intelligence to bear on the design of developing information and communication technologies, addressing these issues must take priority. The VID framework is a proposed catalyst for future change in design.

Value-sensitive design (VSD), a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner, has drawn the most attention for this objective in ethics and technology. More focus has been recently placed on integrating moral concepts into emergent design's conception, creation, and evolution [42–44]. According to this research, VSD is an excellent option for incorporating prescriptive considerations into the design. These approaches are assessed from conceptual, analytical, and preceptive angles. Here, the attention is on whether VSD may be used to incorporate moral ideas into technical design in a way that supports an analytical perspective on technology ethics. Although promising, VSD falls short in several ways: (1) it needs a transparent methodology for identifying stakeholders, (2) it needs to be clarified how empirical methods and conceptual research integrate within the VSD methodology, (3) it runs the risk of making a naturalistic fallacy when using empirical knowledge to implement values in design, (4) the concept of values, as well as their realization, is left undetermined, and (5) it does not include a framework for evaluating the effectiveness of the approach [43,44]. For the prescriptive evaluation of technology, a justified ethical guiding principle is required. The value-inclusive design model surpasses prescriptive principles of VSD for more equitable and inclusive approaches that foster co-creation and co-design.

Additionally, the examination of VSD as the top contender for implementing moral principles in design [42–44] leads to the requirements for an adequate strategy or methodology. Value-inclusive design has nothing to do with these claims. Values may be ingrained in technical systems and objects (artifacts), according to a number of academic approaches to the study of technology, society, and humanity [45,46]. Designers and producers are compelled by pragmatic pressure to consciously include values into the criteria according to which the perfection of technology assesses this descriptive stance. This is possible by changing the emphasis from description to design. The design of systems must take into account both the first and the second values if the ideal world is one in which technologies support the fundamental social, moral, and political values that societies and their citizens uphold, as well as the instrumental values of functional efficiency, safety, reliability, and ease of use. These values may include autonomy, nourishment, privacy, security, companionship, comfort, justice, and enlightenment in technologically sophisticated liberal democracies. Generally, supporting and committing to these ideas is one thing, but putting them into reality through the design of technological systems, which may be viewed as political or moral activism, is not straightforward [45,46]. Companies, users, and society all benefit from design [47]. Value statements indicate whether a particular product or situation is excellent or valuable in a particular way. When items or situations are unpleasant, they frequently lack worth and could have a negative value. Value statements should be separate from preference statements or declarations of personal preferences. Probing something's value or asserting its existence entails saying it is essential and that it is or ought to be helpful to others. Evaluative statements evaluate something or a state of affairs in terms of value [47]. These statements discuss the value of things or states of affairs. Figure 4 summarizes the links among inclusive design features.

Figure 4. Inclusive design dimensions that promote social equity and inclusivity [48].

1.6. Social Values and Their Impact on Design

In his 1977 book 'A pattern language on urban planning', Christopher Alexander stated that 'towns and buildings will not be able to come alive unless all members of society create them and create these structures within a common pattern language' [49]. 'Society struggles to comprehend the value of culture because it cannot measure in terms of a number; rather, its worth is determined by the significance that individuals and

communities place on it', according to John Young [50]. The culture in development choices is crucial for social sustainability, particularly in inner cities susceptible to gentrification. On the basis of architectural choices that are socially fair, cities and urban areas either separate or unite their inhabitants. According to E. Harris in personal correspondence, 'we must appreciate the importance of the opportunity to transform our local communities into the green cities of today through co-creation and value-inclusive design approaches with an empathic lens and perspective for wellbeing' [1]. It might be challenging to select the proper measurements [51]. The objective is to establish key performance indicators (KPIs) that properly and meaningfully assess progress toward the anticipated project outcomes. KPIs also must be directly tied to the main objectives [51]. It might be challenging to determine whether a social innovation is practical without a measurement method [52].

1.7. Value-Inclusive Design for Socially Equitable Communities: A New Model for Promoting Opportunity through Recognition, Health, and Wellbeing, and Equitable Distribution of Resources

In recent years, there have been conversations about mental health and wellbeing that have spread throughout the field of architecture. As a response, architects have conducted evidence-based research to support their ideas. This includes research in environmental psychology that demonstrates the behavioral effects of nature-based design and offers essential and well-documented contributions to architecture [53]. In order to comprehend learning settings and to support the best solutions for complicated problems, the programmatic design underwent a thorough examination. This field of knowledge enables architects to make well-informed choices on the materials, colors, lighting, and several other components that go into the design of a place. It is possible to produce a human-centered design by fusing social science knowledge with architecture [53]. Architecture contributes to health and wellbeing, enriches life artistically and spiritually, creates economic possibilities, and leaves behind a legacy embodying and reflecting culture and customs. It promotes all forms of human activity and gives a feeling of location [54]. It is a mutually beneficial process. Infrastructure not only provides necessary resources but also aids in developing social networks enabling community members to exchange knowledge and opportunities. The wellbeing of individuals and the community as a whole promotes a community that works to guarantee equal access to these resources [14].

1.8. Food Systems

Conflicts, pandemics, and natural disasters have all shown how urgently we need more equitable, sustainable, and resilient food systems with food produced close to where it will be consumed [55,56]. Urban farms are potential game changers in countering these challenges. If designed with multiple purposes in mind, urban farming can improve the livelihood and health of urban dwellers, reduce the ecological footprint of food production, and improve the living environment in our cities. Research into new ways of food production is essential, and systems such as indoor farming, urban greenhouses, and urban food hubs can help counter the many issues cities face in feeding their urban dwellers. Simultaneously, ensuring equitable access to food and creating a convincing business model supporting underserved communities' livelihoods is not easy. However, it is a prerequisite to contributing to an equitable, healthy, and sustainable future. Exploring the potential of new food systems and concepts, such as urban food hubs, will result in long-term solutions that embrace the inclusive-design ideology [56–58]. These are the backdrops for the Global Greenhouse Challenge held in 2021–2022. As an extension of the previously launched competition by Wageningen University and Research, this third competition brought an explicit focus on social equity into the competition.

1.9. Applying Inclusive Design Values: The Intersection of Design (Translating Theory to Practice)

The VID framework expounds value principles that translate theory into practice. These principles, illustrated in a design canvas in Section 1.13, address a broad range of research-based knowledge fields and call for the capacity to apply theory to practice. In

collaborative design processes, this study evaluates the adoption of values influencing social equity and how these values translate to socially equitable communities that promote opportunity. VID fosters socially equitable communities by intersecting design principles through the value of 'transformation' and the dimension of 'judicial equity'. The East Capitol Urban Farm at the University of the District of Columbia is the VID model's testing ground for problem-based projects. This urban farm utilizes The University of the District of Columbia (UDC') Urban Food Hubs Models and its College of Agriculture, Urban Sustainability, and Environmental Sciences (CAUSES) programs of multidisciplinary studies dedicated to serving the needs of the community in Washington, DC. It became the location for participants in the Urban Greenhouse Challenge #3, the Social Edition. The intention in choosing this location was to offer a specific site to teach socially equitable values and develop co-created solutions within a community. In order to plan the urban extensions around such areas, architects, planners, urban designers, politicians, and administrative authorities must agree. Rather than just considering metropolitan nodal development, inclusive development is necessary because these areas will eventually join metropolises, making cohesive development desirable [58]. Thus, in this challenge, VID meets today's urgent call for social equity and the need for urban vibrancy and health.

Cities evolve and grow due to economic, social, and political forces. However, the most significant impact of these factors is on the growth and development of the country's residents and communities, which have seen significant reductions in money, labor, and resources to promote socially equal communities. The inclusive design framework tackles these socioeconomic gaps. It encourages student-designed responses to architectural issues that are socially just and enhances people's health and the general wellbeing of communities. VID fosters economic opportunity, social fairness, and sustainable ecosystems. Section 1.13 shows a framework for inclusion with 'judicial equity'. Integrating food production with the development of the built environment is readily envisioned as a step toward positive and socially fair urbanization and poverty alleviation through economic opportunity. Given that rural communities may have more access to land and other resources due to the availability and affordability of land, the development of cities is more difficult.

1.10. Social Equity and Inclusion

The value-inclusive design model fosters transactions that translate into social equity. The VID model takes an 'inter-transformational' position; design, context, and interaction result in equal distribution of social equity in inclusive design thinking and practices. All members of an equal community share the full advantages of society. Everyone is given fair and reasonable treatment in such a community, and everyone can actively engage in social, cultural, and economic life. Figure 5 proposes five values, identity, placement, accessibility, empathy, and 'transformation', as well as the fourth dimension of social equity, 'judicial equity'; these values underscore social equity and inclusion as defined by the research:

1. Identity recognizes individual human value and worth.
2. Placement considers the quality of apparent relations.
3. Equal distribution is made possible through accessibility.
4. Empathy recognizes the presence of all beings in harmony.
5. Both the micro and macro levels of 'transformation' within a community are present.

1.11. Transformation as a Missing Value

Transformation is the central value in the figure as the NEXUS for innovative solutions in urban architecture for wellbeing that informs how we live in society. The design looks at the scale of the community by embracing heritage, social values, and transformational qualities to promote economic investment, facilitate the preservation of infrastructure, regeneration of communities, and job acquisition and advancement. This includes fair distribution of capital, labor, and resources that impact policy, laws, and codes in the public environment to support local populations and restore and sustain ecosystems. These conditions, combined with social equity and inclusion, result in 'transformation', as shown

in Figure 6. The next section provides a summarized description of 'judicial equity' and its application to inclusive design values.

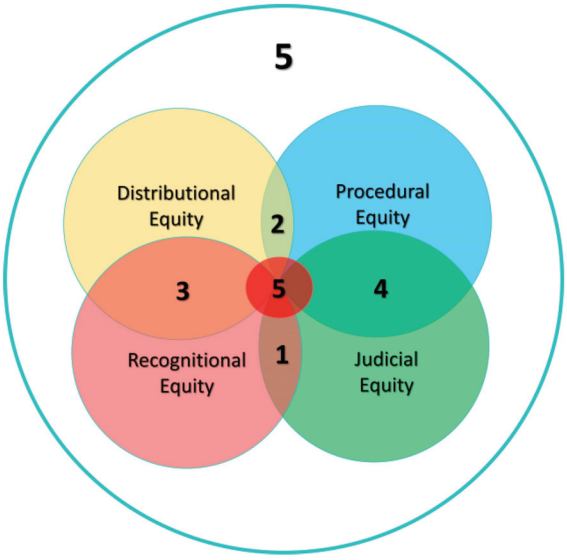

Figure 5. Value-inclusive design model. This model expands the four values that intersect with Meerow's 2019 model for social equity, 1: Identity, 2: Placement, 3: Accessibility for all, 4: Empathy, and introduces, 5: Transformation as a new social value construct.

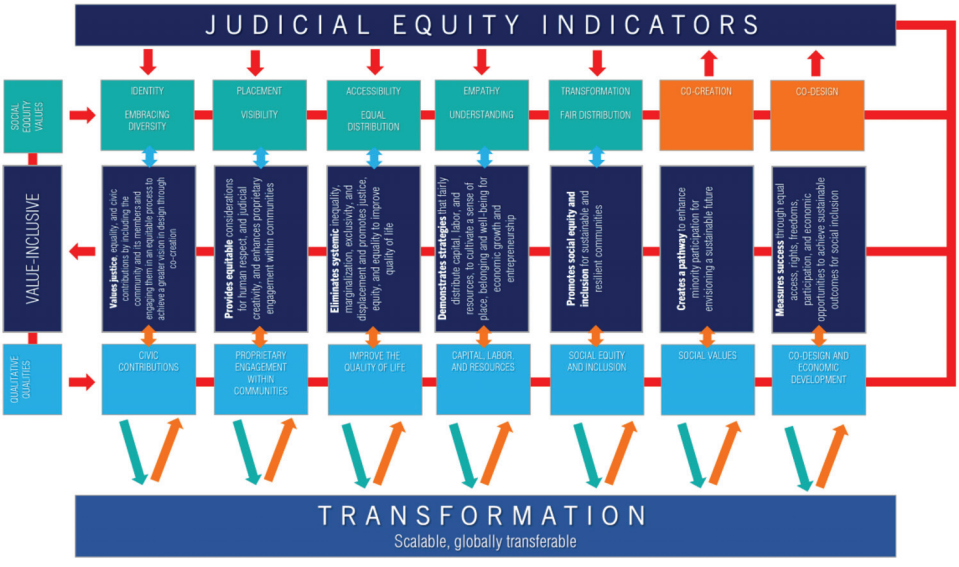

Figure 6. Value-inclusive design model: judicial equity indicators and transformation value.

1.12. Judicial Equity as a Fourth Dimension of Social Equity

Judicial Equity is a symbiotic component of Meerow et al.'s [2] recognitional, procedural, and distributional social equity model and design canvas that forges a new holistic link among theory, research, teaching, and application in architecture and urban sustainability

for co-creation and co-design. Figure 6 highlights policy and governance and the importance of 'the commons'. This dimension of social equity includes the following values:

- Values justice, equality, and civic contributions by including the community and its members and engaging them in an equitable process to achieve a greater vision in design through co-creation.
- Provides equitable considerations for human respect, and judicial creativity, and enhances proprietary engagement within communities.
- Eliminates systemic inequality, marginalization, exclusivity, and displacement and promotes justice, equity, and equality to improve quality of life.
- Demonstrates strategies that fairly distribute capital, labor, and resources, to cultivate a sense of place, belonging, and wellbeing for economic growth and entrepreneurship.
- Creates a pathway to enhance minority participation for envisioning a sustainable future.
- Measures success through equal access, rights, freedoms, participation, and economic opportunities to achieve sustainable outcomes for social inclusion.

1.13. Design Objectives

Values are connected to design objectives. A design canvas was prepared to map planning, design, and policy construct complexities and show how theory translates to practice as a primary design objective. Figure 7 represents a dynamic set of processes that connect human health and dignity, interactive settings for the quality of life, and inclusive green cities.

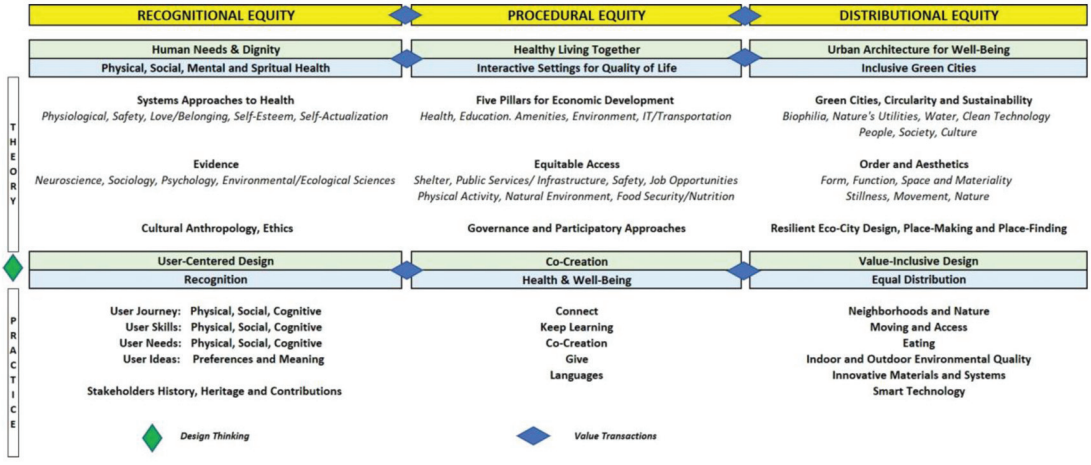

Figure 7. Inclusive design: design canvas for inclusion [3,11].

Judicial equity is added to Figure 3, outlining the necessity for equitable policy and governance, as shown in Figure 8. In Figure 8, symbiotic cities better represent urban architecture for wellbeing and sustainable place-making, and place-finding further defines inclusive green cities. Appropriately, value-inclusive design was moved under judicial equity for socially equitable communities resulting in regeneration and equal access through co-creation and co-design. The design canvas is supported by the earlier work of Zallio and Clarkson [33,35], fostering an inclusive mentality. The second objective was to capture a comprehensive picture of community resilience.

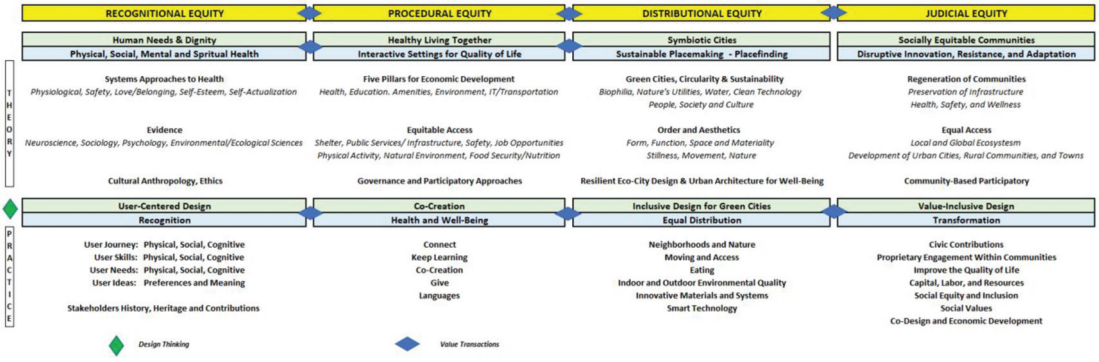

Figure 8. Inclusive design: design canvas for inclusion and judicial equity.

2. Materials and Methods

2.1. Methodology: Qualitative Case Study Method

A case study approach was chosen to examine value-inclusive design constructs, as well as construct validation akin to hypothesis-testing research. This allowed to an in-depth limited-scope study [7–9] of the design cases collected and analyzed as a part of the Urban Greenhouse Challenge (Figure 9). The first part of the study examines the Urban Greenhouse Challenge #3 competition methodology leading to the top three winning teams. The second part examined the constructs of 'transformation' as a leadership value and 'judicial equity' as a fourth dimension to social equity based on a case study examination of the designs submitted to the Challenge.

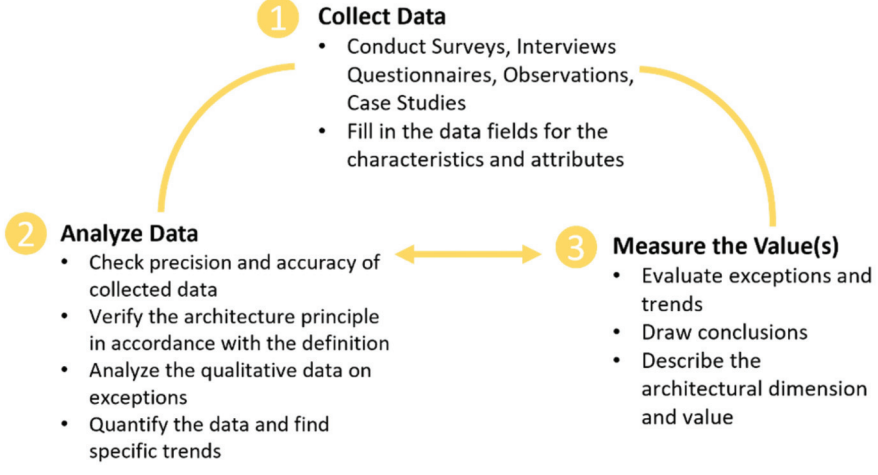

Figure 9. Measurement methods [7,8].

2.2. Part One: Case Study Method—Urban Greenhouse Challenge #3, the Social Edition

Inclusive design promotes social impact through urban farming in rural and urban environments. The Wageningen University and Research (WUR) launched the Urban Greenhouse Challenge in 2018, intending to foster innovation in urban farming. This competition was open to students from all disciplines and from around the world. Students were tasked with creating an urban farming site that significantly enhances the quality of life and nutritional needs of residents in one of the most diverse lower-income neighborhoods of Washington, DC, as part of the Urban Greenhouse Challenge. This meant that students

had to address the social context of Ward 7, an underserved area in Washington DC where residents struggle to access healthy food in what experts define as 'food apartheid' areas. 30 teams of 260 students from 74 colleges across 19 countries set out on a mission to solve these problems by the end of 2021. Twenty of the 30 teams advanced in the design competition. The challenge inspired many young minds to rethink how they would produce food in their home cities. Several also reported that the competition influenced their future career choice. Apart from interaction with each other and with residents from the Ward 7 location, students were also able to connect with leading companies in the horticultural sector. The challenge aimed to foster creativity among the participating students as well as cross-disciplinary innovation. Teams of participating students collaborated with coaches from the corporate, public, and nonprofit sectors to create their concepts (see Figure 10). After two successful competitions, the third Urban Greenhouse Challenge added a fresh twist with its deliberate focus on improving the quality of life for residents in a food apartheid neighborhood. Through the collaboration between Wageningen University and Research and the University of the District of Columbia (UDC), the competition was able to establish connections to community members to help the competing student teams better understand existing challenges and needed improvements. The competition also engaged UDC architecture student as resident advisors to the competing student teams from around the world.

Figure 10. Competing teams in the Urban Greenhouse Challenge #3: the social impact edition [59].

2.3. East Capitol Urban Farm—Site for the WUR Challenge

The East Capitol Urban Farm (Figure 11) is located on a three-acre site in Washington DC's Ward 7. UDC leased the site from the DC Housing Authority for 3 years to build a communal urban farm. From its inception, ECUF was designed and built with input from local residents and partners. Its goals include promoting urban agriculture, enhancing food access and nutritional health, providing nutrition education, encouraging community gardening, fostering entrepreneurship, enhancing green infrastructure, and offering education and demonstration opportunities on the above topics. Despite being situated in an urban area, ECUF is the consequence of peri-urbanization. Peri-urbanization is the process of turning rural regions into urban areas. This transition affects the area's physical, economic, and social characteristics and results in a place that is only partially rural and increasingly urban. Peri-urban zones are always open to change. Change results from the development process but may be controlled by sustainable development strategies [58]. Using co-creation and co-design, the Urban Greenhouse Challenge sought to fundamentally reshape not only the ECUF site but also its surrounding neighborhood. This involved using more robust, sustainable, and inclusive design principles. The ECUF is a model for future development that addresses food insecurity and other socioeconomic issues locally with urban agriculture serving as a catalyst for workable solutions.

Figure 11. Different views of East Capitol Urban Farm, UDC CAUSES [60].

2.4. Data Collection—Three Competition Elimination Phases

The challenge included webinars on sustainability, business model approaches, and inclusive design practices. Each of the three elimination phases (milestones) had design criteria for jurors to identify the teams that contributed to (1) social impact that results in social equity and inclusion, (2) food production for healthy consumption, (3) business modeling, which promotes economic development, (4) food distribution that is scalable, (5) urban design for underserved communities, and (6) sustainability to lessen waste, increase health, wellbeing, and quality of life [59]. The challenge criteria during each phase included four categories for the jurors, as shown in Table 1.

Table 1. Team scorecard: challenge criteria.

Total Concept	Spatial Concept	Design Detail	Context Analysis
Co-creation	Functional	Cultivation (food) system	Socioeconomic factors
Co-design	Attractive	Environmental impacts	Site and users
Local context	Scalable/adaptive	Business model	Social impact

The total concept criteria have the potential to create social impact through a convincing and coherent design that is relevant to the local context and surrounding communities for co-design and co-creation. The spatial concept, including an artist impression developed a functional and attractive design solution that was adaptive and scalable locally, regionally, and globally. A design criterion defined the correct selection of cultivation techniques and crops for food production, as well as the use of solutions that minimize negative and increase positive environmental factors, which were clearly developed through a comprehensive business model that suited the overall objective. Lastly, the context analysis category of the challenge criteria analyzed socioeconomic aspects and the impact of environmental influences that would benefit its location and users (community) that would create social impact through equality and inclusive design approaches. As the competition progressed, the scorecard criteria became more stringent to identify qualifying teams meeting the above comprehensive plan and design requirements.

2.5. Part Two: Case Study Method—Transformation as a Leadership Value and Judicial Equity as Fourth Dimension to Social Equity

The second part of the qualitative study explored whether architectural solutions promote social impact through the VID model, which recognizes people, co-creates the built environment in collaboration with the community, and provides access to resources and opportunities [61]. In a first step, indicators for transformation and judicial equity were established to assess the VID model on the basis of the literature and contextual factors. Construct validity for social equality was confirmed during the three elimination rounds of the WUR competition, and the indicator judgments contributed to dependability. The themes and indicators behind 'transformation' and judicial equity were examined in the data and reflected in the top three proposals. Using the four categories (Table 1) as a baseline, the data were reviewed without bias or presumptions using the scores and feedback from the jurors to determine which teams successfully exercised traits from each

dimension of equity (recognitional, procedural, and distributional). The three elimination phases used the same criteria; however, more emphasis was placed on the development of each category and how well each team incorporated them into their final design. The case study examined the population of competing teams and the three elimination phases resulting in the top three made by different sets of jurors. The community added reliability to the study.

2.6. Assessment Tool—Planning and Design Development Proposal

On the basis of the VID model, an assessment tool was developed to judge WUR design proposals and their potential social impact on the communities of Ward 7. Table 2 provides a crosswalk of jury judgments and the proposal for evaluating 'transformation' and 'judicial equity'.

Table 2. Planning and development for proposal.

	WUR Competition—Planning and Design Development			**Proposal**
Social equity constructs	Recognitional equity recognizing people	Procedural equity Co-create the built environment with communities	Distributional equity access to resources and opportunities	Judicial equity Scalable, globally transferable
Social equity values	(1) Identity embracing diversity)	(2) Placement (visibility)	(3) Accessibility (equal distribution) (4) Empathy (understanding)	(5) Transformation—novel, innovative, changing meaning
Jury judgments (milestones) One Two Three	Social impact	Business model Urban food production	Design Sustainability Food distribution	Value-inclusive design observations (case study) based on value-inclusive design framework

As noted in Table 3, 20 competitive international team proposals were generated as participants in the Wageningen University and Research's (WUR) Urban Greenhouse Challenge #3, the social impact edition, were compared to the VID model to determine if the value of transformation and fourth social equity dimension (judicial equity) were integral to the framework. From November 2021 until June 2022, teams, through three competition phases (milestones), explored innovative ideas for urban farming with an indoor production facility aimed at creating social impact and inclusion, equity, and resilience. The scorecards represent the most comprehensive designs.

During the grand finals, it was discovered that the three equity themes and four leadership values were present in many of the teams. Final deliberations to determine the top three design proposals included meeting with the final jury, 1 min video pitches, presentation boards, and models to display each team's concept. The teams that moved forward in the competition identified the community's needs but, more importantly, demonstrated the constructs of social equity (recognitional, procedural, and distributional) and the proposed judicial equity in their proposals. The teams displaying the social value of transformation rose to become one of the top three winners of the challenge. However, the teams who failed to advance or continue in the competition needed help grasping the social, economic, and geographical context of the communities in Ward 7, particularly the region closest to the location of the East Capitol Urban Farm. In addition, many teams still needed to provide a comprehensive business model for food production, distribution, and economic development, and promote social impact.

Table 3. UGC elimination phases (milestones) and team scorecards.

	Milestones 1 and 2 (x = 1), (X = 2)															
		Total Concept			**Spatial Concept**			**Design Detail**			**Context Analysis**			**Jury Assessment**		
	Teams	**Co-Creation**	**Co-Design**	**Local Context**	**Functional**	**Attractive**	**Scalable Adaptive**	**Cultivation (Food)**	**Environmental Impacts**	**Business Model**	**Socio-Economic Factors**	**Site and Users**	**Social Impact**	**Score**	**Results**	**Elimination**
1	Team A	0	1	1	0	0	0	0	2	0	1	1	0	6	Least	
2	Team B	2	2	2	2	2	1	1	2	2	3	2	1	22	Good	
3	Team C	4	4	2	4	4	2	2	3	3	2	3	2	35	Best	
4	Team D	0	0	2	0	0	0	0	2	0	0	0	0	4	Least	x
5	Team E	2	2	3	2	2	1	1	2	1	1	2	1	20	Good	
6	Team F	1	1	3	2	3	3	1	1	3	2	1	1	22	Good	
7	Team G	3	3	3	4	4	2	2	2	4	3	2	2	34	Best	X
8	Team H	1	1	3	3	2	2	1	1	3	1	2	1	21	Good	X
9	Team I	2	2	4	5	4	2	2	2	4	2	3	2	34	Best	
10	Team J	3	3	3	4	5	2	3	3	3	3	2	2	36	Best	
11	Team K	3	3	2	4	5	2	3	3	3	3	2	2	35	Best	X
12	Team L	1	1	1	2	2	0	0	1	0	1	1	0	10	Least	X
13	Team M	1	2	2	2	1	1	2	1	1	1	2	1	17	Good	X
14	Team N	0	0	0	0	0	0	0	0	0	0	0	0	0	Least	x
15	Team O	1	1	1	1	2	0	1	1	1	1	0	0	10	Least	
16	Team P	0	0	2	1	1	1	0	1	1	1	2	0	10	Least	X
17	Team Q	0	0	2	3	3	1	2	2	3	1	2	1	20	Good	
18	Team R	1	1	1	1	1	1	1	1	1	0	0	0	9	Least	X
19	Team S	1	1	1	1	2	0	0	1	0	1	2	0	10	Least	X
20	Team T	2	2	2	3	3	1	1	3	1	1	2	1	22	Good	X
21	Team U	1	1	1	2	3	1	1	2	2	1	2	1	18	Good	X
22	Team V	2	2	4	4	4	1	2	2	4	3	2	1	31	Good	
Scorecard breakdown: total concept (10 points max), spatial concept (10 points max), design detail (10 points max), contextual analysis (5 points max); total score value = 35 points [35–25 best; 25–15 good; 15–0 least]; limitations include limited access to data and time constraints.																
	Grand Finals															
1	Team A	3	3	3.25	3	3	1	6	7	7	4	4	1	45.25	Least	X
2	Team B	3	2	2.75	4	5	1	4	6.5	5	3	4	1	41.25	Least	X
3	Team C	3	3	4.75	5	4	3	8	8.5	6.5	4.5	5.5	3	58.75	Best/Top	
4	Team E	4	4	3.75	5	4	1	8	8	5	4	4	1	51.75	Least	X
5	Team F	3	3	4.25	4	3	1	6.5	6.5	8	4	4	1	48.25	Least	X
6	Team I	3	3	4.75	5	4	1	8	8.5	6	4	5	1	53.25	Least	X
7	Team J	4.5	4.5	4	4	5	3	9	7.75	8	7	7.5	3	67.25	Best/Top	
8	Team O	3	3	3.75	4	4	1	6	6.5	6	3	3	1	44.25	Least	X
9	Team Q	3	3	2.75	3	3	1	7	4.5	8	4	4	1	44.25	Least	X
10	Team V	3	3	3.75	4	5	3	8	8.5	8	6	7	3	62.25	Best/Top	
Scorecard breakdown: total concept (15 points max), spatial concept (15 points max), design detail (25 points max), contextual analysis (20 points max); total score value = 75 points [75–55 best; 55–0 least]; limitations include limited access to data and time constraints.																

It became evident that the winning teams' perceived value met local, regional, or global scalability and adaptation for co-creation and co-design, resulting in resilient communities transformed by socially equitable design solutions, as shown in Table 4. The calculations result in the teams that demonstrated the social value of 'transformation' and construct of 'judicial equity'. The names and results of the team proposals have been assigned a letter to protect their identity. However, the scores of all designs indicate that the teams succeeded in taking the social and sustainability criteria of the competition into account in their submissions.

Table 4. Assessment of the dimensions of social equity, constructs, and values.

Top 10 Teams	Recognitional Equity	Procedural Equity	Distributional Equity	Judicial Equity
1. Team A	No	Yes	No	No
2. Team B	Yes	No	Yes	No
3. Team C	Yes	Yes	Yes	Yes
4. Team E	No	Yes	No	No
5. Team F	Yes	No	Yes	No
6. Team I	Yes	No	No	No
7. Team J	Yes	Yes	Yes	Yes
8. Team O	Yes	Yes	No	No
9. Team Q	No	Yes	Yes	No
10. Team V	Yes	Yes	Yes	Yes
Judicial Equity				
Regeneration of communities	2,3,5,6,7,8,10	1,3,4,7,8,9,10	2,3,5,7,9,10	3,7,10
Community-based participatory	3,5,7,9,10	1,2,5,7,8,10	2,3,4,6,7,10	3,7,10
Open public space (equal access)	2,3,5,6,7,8,10	1,3,4,7,8,9,10	2,3,5,7,9,10	3,7,10
Economic development (model)	3,5,7,9,10	1,2,5,7,8,10	2,3,4,6,7,10	3,7,10
Resilience (preservation/adaptation)	2,3,5,6,7,8,10	1,3,4,7,8,9,10	2,3,5,7,9,10	3,7,10
Impact (local and global ecosystem)	3,5,7,9,10	1,2,5,7,8,10	2,3,4,6,7,10	3,7,10
Inclusive Leadership Values				
Identity	3,5,6,7,8,10	1,3,4,7,8,9,10	2,3,5,7,9,10	3,7,10
Placement	1,2,4,5,6,7,9,10	1,2,5,7,8,10	2,3,4,6,7,10	3,7,10
Accessibility for all	3,5,6,7,8,10	1,3,4,7,8,9,10	2,3,5,7,9,10	3,7,10
Empathy	1,2,4,5,6,7,9,10	1,2,5,7,8,10	2,3,4,6,7,10	3,7,10
Transformation				
Civic contributions for human-centered design (co-creation)	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10
Proprietary engagement within communities	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10
Opportunity (capital, labor, and resources)	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10
Aesthetic factor (co-design)	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10
Improve the quality of life	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10
Innovation for social values and social impact	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10
Perceived value	3,6,7,8,10	2,3,5,6,7,8,10	2,3,5,7,9,10	3,7,10

3. Results

3.1. Observations of the Top Qualifying Teams

The competition results from three different juries were reviewed to confirm that the indicators used in the review process were properly recognized, understood, and communicated. The Urban Greenhouse Challenge comprised three phases (milestones), resulting in impressive conceptual design solutions that promote and foster social impact in an underserved community. The teams' first concepts were inspired by specific cultivation techniques or interests in specific technologies [62] that could improve the quality of life for Ward 7 residents. After 8 months, three final teams were selected. All three teams had to demonstrate their understanding of a business model and how to implement sustainable solutions and strategies to combat food insecurity that would reduce food apartheid in Ward 7 and the surrounding community. Team C, won third place as well as the 'local resident's award' with their living lab greenhouse and communal area, while Team V, came in second with a fresh food production and mobile distribution market. Team J's 'block-by-block' modular mosaic proposal won first place [62]. The organizers and the jury were amazed to see the students' commitment and investment in learning, expanding their knowledge base, and creativity in seeking the best solution for the Urban Greenhouse Challenge #3. Participating in such competitions allowed the students to unlock professional opportunities for their future. The developed concepts and innovations will potentially serve as prototypes and inspiration for affordable, sustainable, and urban-resilient design. East Capitol Urban Farm would be a catalyst for the inclusive design model. After assessing each team using the VID model to measure the values of judicial equity and transformation, the data validate architectural solutions promote social impact through value-inclusive design.

Three of the 20 potential designs from the third iteration advanced to the finals [62]. Each team presented a concept that transformed meaning (two types of innovation in architecture—changed meaning or technological epiphanies): sustainable, affordable, and inclusive. Findings indicated that all three equity themes and four leadership values were inherent to the top three proposals. It was observed that the top proposals were unique in that they addressed 'judicial equity' as an additional dimensional construct and 'transformation' as another essential value to the value-inclusive design model. The top

proposals outlined innovative urban prototypes that were scalable for local communities and could be implemented across the globe, having the potential to change meaning for society. The top three scoring teams incorporated the following elements into their holistic designs:

- Global/community impact, flexible, straightforward solution.
- New business concept, mobile systems approach for outreach.
- Community impact, sustainable food production, and site design that defined the community.

3.2. Value-Inclusive Design Instrument and Method

The Urban Greenhouse Challenge developed value-inclusive design-oriented transactions that translated into social equity, confirming that VID takes an inter-transformational position on human-centric design, context, and interaction, resulting in equal distribution of social equity in inclusive design thinking and practices. The VID model used indicators (Table 5) as a checklist to evaluate qualitative themes and characteristics for each team proposal.

A Elimination phase one—twenty teams were selected to move forward; two teams were eliminated according to criteria.
B Elimination phase two—ten teams were selected to move forward; ten teams were eliminated according to criteria.
C Elimination phase three—three top teams were selected as winners; seven teams were eliminated according to criteria.

Table 5. Evaluation: value-inclusive design indicators.

Indicators	Team Proposal 1	Team Proposal 2	Team Proposal 3
Milestone/phase 1	Top	Middle	Top
Milestone/phase 2	Top	Middle	Top
Grand finals/phase 3	Top	Top	Top
Judicial equity			
Regeneration of communities	Yes	Yes	Yes
Community-based participatory	Yes	Yes	No
Open public space (equal access)	Some	Some	Yes
Economic development (model)	Yes	Yes	Some
Resilience (preservation/adaptation)	Yes	Some	No
Impact (local and global ecosystem)	Global	Regional	Local
Transformation			
Civic contributions for human-centered design (co-creation)	Yes	Yes	Yes
Proprietary engagement within communities	Yes	Yes	Yes
Opportunity (capital, labor, and resources)	Scalable to the community	Retail/commercial	Education/restaurants
Aesthetic factor (co-design)	Transformative	Equitable access	High sense of place
Improve the quality of life	Yes	Yes	Yes
Innovation for social values, social equity, and social impact	Scalability: scale up-scale down site based on communities needs	Mobility: mobile market to access the community	Flexibility: living lab operable 24/7—365 days for the community
Perceived value	Global	Regional	Local

As summarized in Table 5, the three top winning teams captured critical indicators for the proposed fourth dimension of 'judicial equity', and the design and business models presented the social value construct of transformation. The next section depicts the intersection of design with value-design values, confirming the construct validity of the model, as well as its application to create social impact to address food insecurity and food production in underserved communities.

3.3. Application of Value-Inclusive Design Values—Intersection of Design/Top Three Teams

Unlike other editions of the Urban Greenhouse Challenge, the social impact edition was marked by the participation of members in Ward 7 in the selection process. From the beginning, Advisory Neighborhood Commissioner and the Deanwood Citizens' Association President were part of the local selection committee, one of two committees designed to judge student submissions on several criteria [62]. For them, this meant evaluating the potential for social impact in their community and awarding the 'local residents' prize' to

a qualified team. 'What I most look for in a proposal is a strong city symbol that shows the transformation in Ward 7 and simultaneously brings job opportunities, benefits local entrepreneurship, and generates economic development', said Commissioner Holmes [62]. When asked what she expected from her involvement in this Challenge, the Deanwood President mentioned, 'We do the best to give them (the students) local context, and it is amazing to see what they can come up with'. When justifying the choice to award the first place to Team J, the final jury acknowledged this proposal as the most holistic and comprehensive design to encapsulate inclusivity. Team J believed that 'communities are the real architects' because the proposed modular urban farming concept can be tailored to their needs. More importantly, the winning concept derived a globally scalable design solution that could be replicated in other communities within the most diverse socio-economic contexts, empowering communities block by block (Figure 12) [62].

Figure 12. First place winning design concept in the Urban Greenhouse Challenge #3 [62,63].

3.3.1. Team J—The Mosaic Garden, First Place

To tackle Ward 7's challenges as a neighborhood with poor access to food, education, and economic opportunities, Team J (Figure 13) proposed a mosaic urban farming concept that is scalable to the necessities of the community [62].

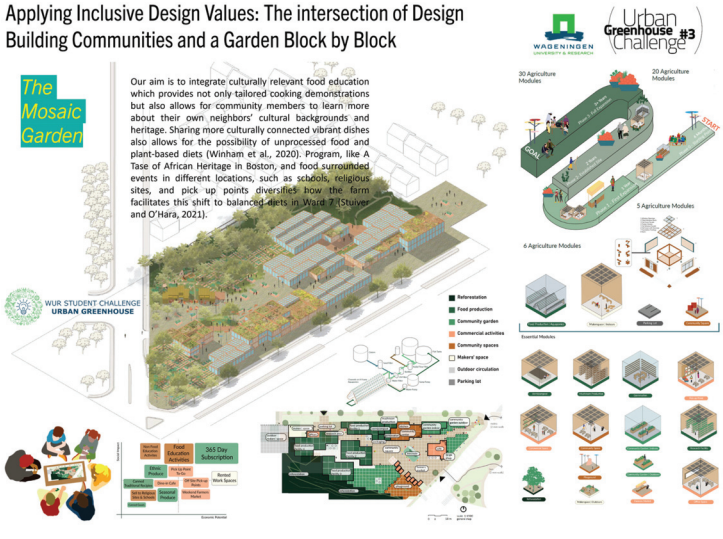

Figure 13. First place winning design team of the Urban Greenhouse Challenge #3 [63–65].

The strategy used by winner Team J allowed for local involvement during conception, creation, modification, and expansion [62], which was achievable via configurable modules for the site's functions: food production, community engagement, education, and employment. In their concept, functions were proposed to be incorporated at various stages of community development as they grew financially to achieve long-term objectives for urban farming. Their design included a symbiotic, dependable, year-round aquaponic food production system that is adaptive to the required scale of operations and different crops. Mushrooms and fish provided year-round healthy protein to supplement leafy greens and tomatoes. Culturally connected produce can be grown in the indoor community garden and hydroponic research facility. The food production system was supported by a business model that serves and employs community members through strategies including a year-round subscription service, small stalls, and partnering with local organizations for distribution. Modularity enabled the community to finance the first few modules entirely from government funds and incentives. Circularity on site was realized by recycling all primary waste that flows into the food production chain. Rainwater harvesting and solar energy generation will further increase the site's self-sufficiency. At the same time, the site, as a biodiverse green space, served as a buffer against floods and heat, thus contributing to its resilience and surroundings. Educating for the future, members will be engaged through the community garden, square, playground, and market. The site also facilitates education for all age groups. On-site agricultural and sustainability techniques were highlighted in an interactive learning path that is available to anyone. The site comprised an extended UDC workforce development and lifelong learning division campus, focusing on employment upskilling and personal development workshops. As a team, they acknowledged the current local governance efforts to address the challenges of Ward 7 and the efforts of local community members. Their design aims to create programs that safeguard the current and future vibrant character of Ward 7 by empowering communities block by block [62]. Importantly, this proposal was transformational and globally transferrable, and it offered changed meaning for communities to make decisions on farming, education, and greening their environment.

3.3.2. Team V—Stack Smart Farming, Second Place

In addressing food insecurity and promoting wellness in Ward 7 and beyond (Figure 14), the issue is about "something other than building more grocery stores and growing produce". Instead, it is about "building a more innovative network for food distribution and positively redefining the relationship consumers maintain with their food suppliers", according to Team V [62].

Team V's concept 'Stack Smart Farming' established numerous jobs and long-term career prospects, which focused on food production, agritech operations, green energy generation, and a large-scale mobile grocery store company, which included automation and machine learning agents, combining intelligent farming and a market and supply chain ecosystem. Team V's stack smart farming ensured the development of first-layer distributional infrastructure in Ward 7 and a platform to develop a healthier food supply chain while maximizing opportunities for community engagement, empowerment, and long-term growth [62], which was achieved by utilizing the proven scalability of our product delivery business models and leveraging their triple-bottom-line approach. Due to inadequate transit infrastructure, buying fresh and healthful produce in specific communities is disproportionately more expensive and complex than in other areas [62]. This is especially true in areas with limited access to food. Thus, their approach focused on food production, distribution, and education to address the core problem effectively. It must promote active participation and investment from the community and its stakeholders. Team V's stack smart farming was created with the three following verticals in mind: (1) the total distribution capacity of our products, (2) the creation of empowering employment opportunities, and (3) capturing high-value produce markets. In order to do this, Team V proposed a 'mobile market model'—a novel paradigm for scalable food delivery

and community participation. As a result of not having to construct expensive, inefficient physical storefronts, stack smart farming can provide the community with improved accessibility and a far more pleasurable shopping experience. They described their concept as a "grocery store on wheels", although it was designed to fit far more land than the three-acres they were given. Since much more local land would be set aside for plant cultivation, the farm's output and profitability as a standalone enterprise would rise. This proposal was crucial because it offered strategies for eradicating food apartheid and ensuring everyone had access to food while illuminating local challenges.

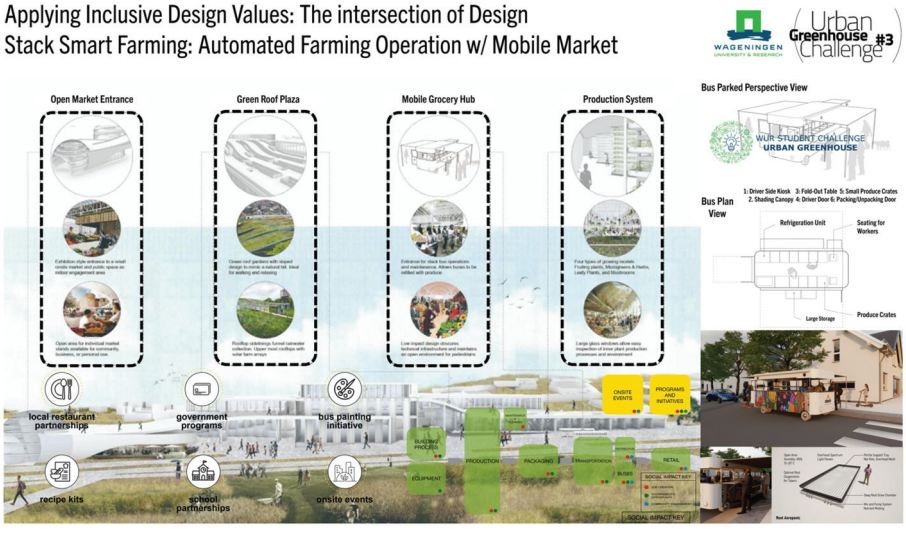

Figure 14. Second place winning design team of the Urban Greenhouse Challenge #3 [63].

3.3.3. Team C—Chrysalis, Third Place

This design was proposed to develop a sense of community through an adaptable, self-sufficient urban farm that provides local food security and economic sustainability, infrastructure durability, and meaningful public space (Figure 15) [62].

Taking third place in the Urban Greenhouse Challenge was Team C, whose design focused on creating social impact in communities experiencing food apartheid. They proposed a convincing and coherent design that offered innovative solutions to people's everyday needs. The team presented an attractive, functional design promoting a sense of belonging. Due to its unique design, the butterfly structure would constitute a landmark, earning Team C the 'local residents' prize' for their creative qualification. This resulted in a holistic concept design incorporating agricultural, economic, social, spatial, and organizational elements necessary to create an innovative, self-sustaining urban farm facility that increases food accessibility and social equity in Ward 7 of Washington, District of Columbia. Their overall concept embodies the metamorphosis of a caterpillar to a butterfly, and the core of their mission is to preserve and support community spirit. Their community-centered design draws from Team C's 'Living Lab' approach, bringing research into society-wide implementation by incorporating co-creation by different disciplines and stakeholders. Team C considered five topics to be their unique differentiators, integrating community needs and challenging outcomes with the UN Sustainable Development Goals (SDG) [62], as a universal call to action to illuminate food apartheid, sustain the planet, and improve the quality of life for all people by 2030. Through an internal integrated design framework (IIDF), an interdisciplinary strategy used to design exterior experience, Team C paired their living lab approach with year-round food production, circularity and sustainable design, organizational structure, and economic planning. Lastly, they

drew inspiration from urban farms in the US and state-of-the-art innovations developed in Amsterdam. Their proposed combination of SDG alignment, interdisciplinary high-tech proposals, and global inspirations increases access to fresh produce, meaningful public space, and economic opportunity, thus improving the quality of life [62]. Importantly, this team demonstrated the importance of civic contributions to provide food in the local community and create a nature-based environment. The proposed concept design successfully applied inclusive design values and intersections through a community-centered based ecosystem that is sustainable and resilient for DC residents.

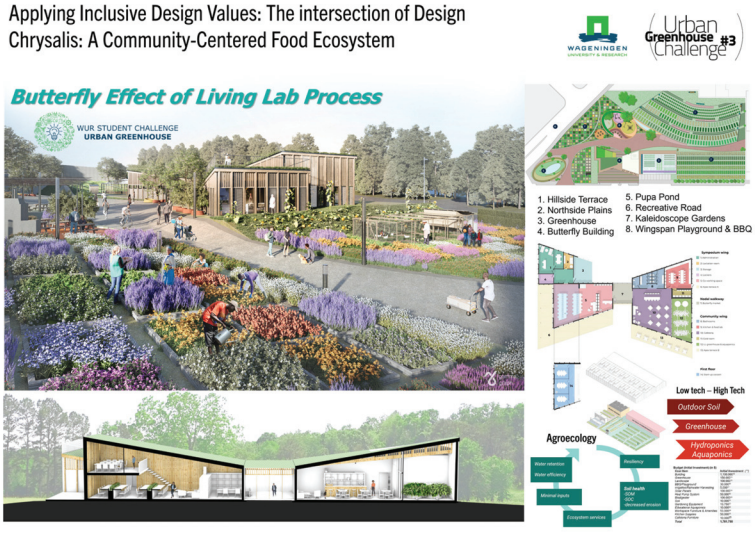

Figure 15. Third place winning design team of the Urban Greenhouse Challenge #3 [63].

4. Discussion

Limitations of the study included access to the site and residents of the community, impacting the effectiveness of the participating teams' design solutions. Other limitations include access to data and time constraints to meet the competition's deadline for completion. The teams received indirect input from the community by posting questions and receiving answers; the population was $\leq$20 people. Without first-hand knowledge, the difficulty of designing for a targeted demographic due to cultural, societal, and political differences was noted by the competitors. Understanding transformative events impacts translating qualitative themes into design concepts, despite cultural, socioeconomic, and political barriers. Interdisciplinary training encourages not just excellent design but also practical design solutions. According to the competition results, a close relationship was observed between equitable and equal approaches to inclusive design values. These values recognize and respond to the community's needs, explicitly addressing food insecurity, economic disparities, and the adverse effects of gentrification. The VID framework investigated and analyzed these concerns to create and propose architectural solutions that improve social impact. Concepts and innovations created are prototypes and sources of inspiration for inexpensive, sustainable, rural, peri-urban, and urban resilient design. The WUR Challenge encouraged social and inclusive design while challenging social equity theory. On this premise, the study advocated 'transformation' and 'judicial equity' as essential concepts for VID. The outcomes of the Urban Greenhouse Challenge 3, social edition, contribute to the social value of 'transformation' and construct of 'judicial equity' by enhancing resilience locally or regionally and globally.

An international jury was tasked with determining the challenge's three winners. After hearing the proposals during the competition's final, the Founder and CEO of Vertical

Harvest, the Program Director of Sustainable Urban Delta, an International Society of Horticultural Science (ISHS) Board member, and a Wageningen Ambassador selected proposals from three excellent teams [62]. The Urban Greenhouse Challenge presented straightforward design solutions for complex social issues. Each winning concept inclusively demonstrated how to improve access to affordable and nutritious food which included robust and resilient year-round sustainable food production in an urban context and were stunning initiatives supported by a robust business model that may turn East Capitol Urban Farm into a notable landmark location. The winning design proposals contributed to social impact in Ward 7 of Washington, DC, which included (1) fostering social equity through a new type of food economy, (2) eliminating food apartheid, (3) promoting education and food preparation, (4) creating employment and generating income for economic development, and (5) serving as a prototype for affordable, sustainable, and urban resilient design. With the exception of Meerow et al. [2] and Zallio and Clarkson [33,35], few studies have attempted a holistic approach to expanding education which promotes social equity and building community resilience, theoretically, and practically. There is a lack of definitive standards or guidelines in research that must be addressed, and the results of the design competition correlated with need for the social value of 'transformation' and construct of 'judicial equity', confirming that there is a gap in the literature, and that the proposed model would further develop many of the theoretical frameworks of 'value' in the built environment and architectural education and foster social impact.

Expanding architectural education and practice through value-inclusive design creates a gateway between old philosophies, theories, and procedures through transformational occurrences. Those occurrences promote innovation and social change to the status quo by building a more inclusive and equitable society. The new VID model is a change in thinking to promote opportunity through recognition, health, wellbeing, and the equitable distribution of resources. Knott suggests that architects 'focus on metrics that demonstrate the creation of capability by measuring progress in four dimensions: team (leadership and development), domain coverage (guidance), change coverage (delivery method), and governance (decision-making and communications)' [66]. Social science information may be a great asset to architecture since it can confirm or refute intuitions and reveal previously unnoticed details. The basis for a design based on knowledge rather than personal conviction is, thus, provided by the social sciences, resulting in an architecture that is more adapted to the demands of its users [43]. A new social atmosphere must be created to achieve social fairness and inclusion. The ongoing process of developing solutions that consider the perspectives, experiences, and circumstances of individuals not previously considered is known as inclusive design [67]. In collaborative design processes, this study evaluated the adoption of values influencing social equity and how these values translate to designing socially equitable communities that promote opportunity. Applying the VID model to architectural education and practice was proposed to achieve social equity and inclusion. The effectiveness of the new model and how well the new dimension satisfies the anticipated value received in terms of needs met and experiences satisfied by the values of (1) identity, (2) placement, (3) accessibility, (4) empathy, and (5) 'transformation' are anticipated to be measurable.

It was discovered that the Urban Greenhouse Challenge Case Study supports the value-inclusive design framework and its impact on social equity and community resilience. There is ongoing discussion among Ward 7 residents, shareholders, and community leaders to revitalize East Capitol Urban Farm in Washington, DC as a means of social impact. Sustainably feeding the future's growing population will require a global transition of our food systems, especially in urban areas. In order to make these metropolitan regions' food robust in the face of present demand and supply-chain volatility, food must be produced close to where people live. Urban farming is one of many promising solutions to the urban food challenge [67], guaranteeing the sustainability of society, culture, economy, and feeling of community. As a result, anyone attempting inclusive green design would face difficulties brought on by antiquated designs built on exclusion from outmoded ideas and ideologies.

A key aspect of inclusive design is getting rid of these discriminatory areas. These might be temporary, long-term, short-term, physical, or emotional. Race, gender, mobility, and age are examples of physical, permanent, and non-situational factors. Inclusive design cannot create a sole product for everyone to respond to individual and communal needs. The model develops various methods for everyone to engage in an experience and feel a part of it. Therefore, the inclusive design addresses all circumstances [67], rethinking and reworking the current built environment to go beyond its exclusionary features. More study is planned to prove the extended model's usefulness as a fresh paradigm for advancing social fairness via design practice. This includes analyzing the University of the District of Columbia's Master of Architecture Graduate Thesis projects to assess the project's impact on social equity and determine if 'transformation' and 'judicial equity' result in proposals that promote socially equitable communities through regeneration, equal access, and community-based participatory design solutions for sustainability and resilience. Anticipated outcomes of the assessment aim to provide a baseline of current education and practices and propose revisions to the UDC curriculum to meet the social equity and inclusion criterion. The study suggests VID as a new architectural education and practice paradigm to meet new accreditation requirements for social equity and inclusion, as well as expand the breadth of knowledge that exists in the literature, research, and practice.

5. Conclusions

A fundamental shift is necessary for how healthy urbanism must address environmental deterioration's widely dispersed health effects and growing demographic disparities, including decisions about designing neighborhoods and buildings. From the design and planning phases to occupancy, the built environment tends to disadvantage or exclude women, children, seniors, people with disabilities, people experiencing poverty, and other groups, which has preventable social, health, and other implications. Although these ideas are not new, they are quickly becoming research and practice priorities for the built environment without a clear grasp of the related objectives of healthy environments that are sustainable, egalitarian, and inclusive [68]. Combining theory, practice, and education, this article suggested a new paradigm of architectural education and practice based on value-inclusive design, demanding practice roles that actively participate in the co-creation process and co-design for social impact. In addition, co-creation must value 'transformation' and take into account judicial equality as another social equality factor. Our communities' regeneration enhances residents' quality of life by fostering health, safety, and wellbeing. The social construct of judicial equity through the value of transformation can increase social capital for economic development and provide access to local and global ecosystems. This approach also investigates design options to support social impact for resilience. As part of that exploration, other architects, designers, planners, shareholders, stakeholders, and members of the community are invited to assess this framework to see if the value of 'transformation' and construct of 'judicial equity' mobilize a community's quality of living, serve as a model for community planning, promote inclusive green cities and towns, and revive underserved urban areas. This entails expanding architectural education and practice in line with VID principles and fostering ideas in planning that incorporate wellness, equitable resource distribution, social equality, and inclusivity. A fundamental goal for achieving social fairness and inclusion and urban resilience is envisioning a sustainable future. The architecture industry and others can contribute significantly to the body of knowledge with further research on this topic of 'transformation' and social construct of 'values', as well as engage in policy implementation to increase socioeconomic development.

The VID model proposed in this study makes several important contributions such as promoting social equity in urban planning and design and introducing the social value of 'transformation' and construct of 'judicial equity' for resilience. It points to the opportunity for improving architectural education/curriculum and practice as the VID framework can examine the outcomes of design work and its impact on community resilience. Future research is needed to examine these concepts facilitated through co-creation and co-design

and develop definitive design standards with indicators based on theoretical aspects for value-inclusive design as highlighted in the design canvas. With additional study to substantiate our VID approach, future research proposes to develop a certification process for meeting inclusive design standards in communities, thus promoting social equity and building resilience.

Author Contributions: Conceptualization, E.H. and A.F.; methodology, E.H. and A.F.; analysis, E.H.; original draft preparation, E.H.; review and editing, E.H., A.F. and S.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: The authors gratefully acknowledge the inspirations so generously offered by their colleagues and friends, Rio Pals, Marta Eggers, and Marian Stuiver from Wageningen University and Research (WUR), Netherlands. Your partnership in the Urban Greenhouse Challenge has been an enrichening experience for UDC, the communities of Ward 7, students, and the design teams. Furthermore, the authors specially thank Antawan Holmes, Jimell Sanders of Washington, DC, and Marianne Vaes for their amazing contributions to promote the success of the UGC #3. Lastly, our congratulations to all the participating teams in the UGC#3 competition. The culminating award ceremony was a fitting event to acknowledge the hard work of all the teams, it can be viewed here: Urban Greenhouse Challenge Awards.

Conflicts of Interest: The authors declare no conflict of interest and have no known competing financial interests or personal relationships that could have influenced the work reported here.

Abbreviations

CAUSES	College of Agriculture, Urban Sustainability, and Environmental Science—Multidisciplinary Studies
IIDF	Internal integrated design framework—an interdisciplinary strategy that can be used to design experience inside interiors/exterior
ISHS	International Society of Horticultural Science—leading independent organization of horticultural scientists that study the growth and development of plants and crops, including vegetables and fruit
SDG	Sustainable development goals, also known as the global goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030
UDC	University of the District of Columbia—embracing its essence as a public historically black urban-focused land- grant university in the nation's capital, UDC is dedicated to serving the needs of the community in Washington, DC, and producing lifelong learners who are transformative leaders in the workforce, government, nonprofit sectors and beyond
UGC	Urban Greenhouse Challenge—students from all over the world join forces to work on projects that make a difference to the quality of life: a global design competition.
US	United States—Country in North America
VID	Value-inclusive design—proposed model for social value and construct of 'transformation' and 'judicial equity' as a fourth dimension of social equity (Meerow et al., 2022)
VCD	Value-conscious design refers to a group of initiatives that promote human and moral values as an essential component of the conception, design, and development of technological artifacts and systems
VSD	Value-sensitive design—value-sensitive design is a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner
WUR	Wageningen University and Research—university located in the Wageningen, Netherlands with a focus on Agriculture and Sustainability: creators of the Urban Greenhouse Challenge

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Temporary Urbanism as a Catalyst for Social Resilience: Insights from an Urban Living Lab Practice-Based Research

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Abstract: This research paper investigates the impact of Urban Living Labs (ULLs) on social resilience within urban communities, with a specific focus on the Multicultural City ChatterBox project in Portsmouth, the UK. Drawing on a rich body of literature and empirical data collected through ethnographic research methods, including interviews, focus groups, and participant observations, this study explores how participatory placemaking and co-creation activities foster community resilience. The ChatterBox project, a collaborative effort between the local community and researchers, led to the construction of a temporary timber pavilion in an underutilized urban space, serving as a vibrant hub for social interaction and engagement among diverse community groups. Our findings reveal that ULLs significantly contribute to enhancing social resilience by empowering communities, fostering a sense of belonging, and facilitating the development of social networks. Through the process of co-design and co-creation, participants not only gained a deeper understanding and ownership of their urban environment but also developed valuable skills and knowledge, thus strengthening their capacity to adapt to societal challenges. Furthermore, this study highlights the role of ULLs in bridging gaps between different community groups, thereby promoting inclusivity and social cohesion. The Multicultural City ChatterBox project exemplifies how ULL interventions can serve as catalysts for social innovation, offering flexible and adaptive solutions to urban challenges while simultaneously enriching the social fabric of cities. This paper contributes to the growing discourse on urban resilience, placemaking, and community-led urban development, providing valuable insights for policymakers, urban planners, and community organizers seeking to foster resilient and vibrant urban communities.

Keywords: temporary urbanism; urban living lab; placemaking; social resilience; co-creation; public space

Citation: Robazza, G.; Priego-Hernández, J.; Caputo, S.; Melis, A. Temporary Urbanism as a Catalyst for Social Resilience: Insights from an Urban Living Lab Practice-Based Research. *Buildings* **2024**, *14*, 1513. https://doi.org/10.3390/buildings14061513

Academic Editor: Haifeng Liao

Received: 20 November 2023
Revised: 28 April 2024
Accepted: 1 May 2024
Published: 23 May 2024

1. Introduction

In urban environments, disadvantaged residents are increasingly subject to systemic exclusion, poverty, and hardship [1]. Chronic stresses are increasingly common in contemporary societies [2]. These include social isolation, cultural ethnic segregation, political exclusion, economic struggle, uncertainty, and multiple deprivation (e.g., high unemployment, limited safety nets, and tlack of education). In the current context, augmenting resilience in society has become a primary aim for policy makers and urban communities.

The Resilient Cities Network [3] defines urban resilience as 'the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience'.

At the community level, resilience enables local groups to withstand adversities and preserve their social infrastructure [4]. Community resilience is not merely a passive

attribute; it is an active social dynamic emerging from interactions and cohesion within a community. This dynamic requires positive, regular reinforcement of social interactions to effectively prepare for shocks, changes, or chronic inequities [5].

Public spaces can play a pivotal role in facilitating these interactions. Often, however, the use of public spaces is controlled and enforced by restrictive local or city rules or influential private sector entities, leading to a disconnection between citizens and their urban surroundings. Contrary to this, the literature suggests that empowering local communities to take ownership of public spaces can revitalize the public realm [6]. This empowerment can transform citizens into active agents of urban change [7–9], fostering new forms of civic participation, alternative methods of urban regeneration, and social innovation [10]. Moreover, it strengthens social capacity and community cohesion, enabling communities to respond more effectively to the evolving challenges of global crises [11].

This article explores the extent to which Urban Living Labs (ULLs) and the engagement of local disadvantaged groups in co-created placemaking public art activities can become a socially innovative process and contribute to building community resilience. The paper investigates the hypothesis that temporary urbanism can contribute to social resilience by empowering communities and amplifying the voices of citizens, encouraging public participation, and building social cohesion and a sense of belonging. Furthermore, the research aims to enhance city governance by elaborating on the discourse of urban resilience and exploring the potential incorporation of Urban Living Labs (ULLs) within the planning and development framework for sustainable and resilient urban futures.

A substantial body of literature, as highlighted by Lara Hernandez and Melis [12], demonstrates that temporary appropriation activities in public spaces are effective in fostering resilience, defined here as the community's ability to adapt to changes during global crises. While the fields of temporary urbanism and social resilience are often studied separately, there is limited research exploring their intersection. Venable-Thomas [13] establishes a direct causal link between placemaking and resilience but also notes the limitations of using placemaking as a resilience strategy. These limitations include the influential role of intermediaries, the necessity to incorporate cultural placemaking, and the need for interdisciplinarity, participation, and disruptive approaches for more significant outcomes. Baibarac et al. [7] implemented and examined various case studies to understand how agency and empowerment in the governance of urban commons can act as a mechanism for urban resilience. Recent studies by scholars like Afacan [14] and Naumann et al. [15] have established a correlation between Urban Living Labs and urban resilience, demonstrating their broader impact on social innovation. Furthermore, it is posited that Urban Living Labs (ULLs) can be instrumental in developing capabilities that not only enable a community to recover but also energize the social dynamics central to community resilience [16,17]. ULLs are inherently place-based activities, deeply embedded within a specific context and linked to particular groups of people. These practices actively engage individuals in public art activities centred around place, thereby contributing to the transformation and creation of spaces. Consequently, an exploration of ULLs necessitates a thorough examination of placemaking processes.

1.1. Placemaking

'Placemaking is the way all of us as human beings transform the places in which we find ourselves into places in which we live' [18]. Placemaking includes any physical transformations of the built environment. It not only alters the physical environment but also the connections and relationships we build with others in our community [18]. It is the act of transforming a space into a meaningful place, building community, and designing a place for everyone to create meaningful relationships. This process happens through actions that build memories and relationships with others and with place. As it is a community-driven practice it relies on effective community participation [19,20]. Placemaking is transformative only insofar as power is devolved to communities, allowing them to direct all parts of the process [21]. For this reason, co-design and co-creation,

considered the most effective methods to delegate control, are fundamental ways by which meaningful placemaking may co-produce community resilience.

1.2. Co-Creation, Co-Design, and Co-Production

The concepts of co-creation and co-design emerged from the concept of participatory design, a concept used in various disciplines since the 1970s. Although originating in northern Europe to improve industrial production [22–24], participatory practices were suddenly diffused around the world, became an important part of design practices worldwide and, by 1980, also had become part of the process of designing places. Co-creation protocols put users at the centre of the design process, making them the designers. Non-experts co-design with expert designers using design innovation tools to convert the design and shift responsibilities [25]. Co-design is a specific instance of co-creation; the latter includes any act of creativity that is shared by two or more people [26], while the former entails collective creativity across the whole design process. In co-design, users play a central role in informing, ideating, and conceptualizing the design product up-front in the early design phases. Although Arnstein [21] does not mention co-creation in the ladder of citizens' participation, other scholars include it at the top of the scale [27]. Following this claim, the strongest approach to co-creation is attained when practitioners are facilitators and participants become designers and own the ideas generated within a design process.

It is relevant to mention that the value of placemaking lies not only in the final outputs of the process but in the process of collective production itself. Placemaking transforms the community in more ways than by granting immediate liveability benefits [28]; it produces social capital throughout the engagement of those directly involved [29]. Placemaking can be recognized not so much by the art produced but more significantly by the skills acquired and connections made throughout the process [30]. As Guinard [31] remarks, public art is not just an aesthetic tool, but a method for generating knowledge based on life in the local community. A recent study that connects placemaking, community, and art practices suggests that 'collaboration, connectivity, creating space and altruism can be potential mechanisms leading to a stronger sense of belonging, social cohesion and inclusion' [32]. If artistic activities are conducted in a group environment, they can facilitate new social interactions [33], especially in groups that are diverse, as artistic activities often involve non-verbal communication [34]. Co-production involves a range of issues regarding belonging, citizenship, and ownership [35], and the 'citizen is the co-implementer' of change [36]. Some scholars and practitioners in the field of urban innovation directly relate co-production to this production of social values, where resilience is the main outcome, rather than to the physical artefact or practices that result [37]. In line with this view, we interpret community-engaged temporary urbanism ultimately as a practice that aims at creating social value as the most important outcome. To effectively investigate the relationship between Urban Living Labs (ULLs) and resilience, it is crucial to delve deeper into the conceptual framing and understanding of resilience itself.

1.3. Community Resilience

In recent decades, scholars have focused on the concepts of resilience in fields such as social-ecological systems, developmental psychology and mental health [38], disaster risk reduction, climate change adaptation, and community development [39], as well as in architecture and urban studies. A resilient city is one that is able to assess, prepare for, and respond to hazards [40] and organize following 'inclusive decision-making processes in the realm of planning, open dialogue, accountability, and collaboration' [41]. Social learning, participatory decision-making, and processes of collective transformation are central aspects of social resilience. The key component of community resilience is reinforced when individuals are well connected to each other and are part of supportive social networks [42]. Community resilience is not a static property but is constituted by the interlinking synergies of different resilience-promoting capacities operating simultaneously [43]. Although it is

relatively easy to define social resilience, understanding the intricate complexities of how it works and how it can be fostered is both complex and demanding.

Our starting point is the understanding that urban resilience is a complex phenomenon that has many causes and is dynamic in structure and uncertain in nature [41]. From the literature, it is clear how social resilience is closely related to the idea of social capacities [44]. These capacities are identified by different scholars as interdependent factors. Berkes and Ross [45] integrate the social–ecological and psychology and mental health bodies of literature in the diagram below (Figure 1) and identify how community resilience is dependent on a range of characteristics that lead to agency and self-organization. These are 'people–place connections; values and beliefs; knowledge, skills and learning; social networks; engaged governance (involving collaborative institutions); a diverse and innovative economy; community infrastructure; leadership; and a positive outlook'.

Figure 1. Community resilience as a function of the strengths or characteristics that have been identified as important, leading to agency and self-organization. Source: Berkes and Ross, 2018 [45].

Similarly, Faulkner et al. [43] characterize the capacity for social resilience as dependent on attachment to place, leadership, community networks, community cohesion and efficacy, knowledge, and learning. They argue that attachment to place is 'instrumental in mobilizing community resilience by providing [the] foundation upon which other capacities for [it] depend' [43]. If local people care about the place where they live and each other, community strength emerges as the capacity for them to unite and act together [46].

There is a shared understanding that 'resilience building can be accomplished by actively developing and engaging the capacity to thrive in an environment characterized by change' [4,47]. It is interesting to observe also that community resilience can be reinforced by the presence of disruption more than by its absence. Khanlou and Wray [48] suggest that adversity itself may have a positive outcome in strengthening and building resilience, triggering purposefulness, connectedness, or even joy. Some aspects of well-being, such as a stronger sense of community, could be positively affected by the collective experience of hardship [43]. Pelling [49] holds that social resilience is 'a product of the degree of planned preparation undertaken in the light of a potential hazard'. Social actors need to develop their anticipatory capacities and pre-hazard preparedness to learn from adverse events. Glavovic et al. [50] push preparedness further, writing that social resilience is 'influenced by [. . .] institutions [. . .] and networks that enable people to access resources, learn from experiences and develop constructive ways of dealing with common problems'.

Placemaking and ULLs may be tools that equip community groups to become resilient by placing them in challenging situations, where they must make decisions that impact others, solve problems, confront unfamiliar issues, and meet unknown people and collabo-

rate closely with them. While not entirely adverse, these conditions can present significant challenges to community members unaccustomed to such scenarios, effectively creating a simulated stress experience. Consequently, capacities such as the ability to network, foster connections between place and people, and build new knowledge can be stimulated and enhanced by placemaking activities and collective creative endeavours in public spaces.

The aim of this research is to implement a ULL practice in the city and study its efficacy in fostering a range of capacities related to social resilience. It further aims to explore the extent to which social resilience can be considered a direct outcome of these practices.

2. Materials and Methods

2.1. Research Context

To evaluate the effectiveness of ULLs in enhancing community resilience, a study was conducted in collaboration with Chat over Chai (CoC), a local Black, Asian, and Minority Ethnic (BAME) community group. This effort led to the construction of a temporary timber pavilion named ChatterBox, located in an underutilized space in the heart of Somerstown, Portsmouth.

In the UK, and particularly in cities like Portsmouth, migrants, refugees, and asylum seekers encounter a range of socio-cultural and political challenges. These challenges are multifaceted, often rooted in socio-economic deprivation, social invisibility, cultural barriers, and stereotyping. Many migrants in the UK are found in low-wage, low-skill sectors, facing employment discrimination and exploitation. In 2014, approximately 16% of all those in low-skilled work were migrants, a figure which underscores their vulnerability in the job market [51]. Politically, the national discourse on immigration and integration policies has often been divisive, affecting public perception and the social integration of these communities. In Portsmouth, a city with a growing diversity owing to its status as a hub for international trade and education, these challenges are amplified. In the city, 'the percentage of people who did not identify with at least one UK national identity increased from 7.45% in 2011 to 10.43% in 2021' [52].

Furthermore, according to a report from the Equality and Human Rights Commission [51], the broader societal perception of migrants in the UK has been tainted by stigma and misconceptions. For instance, widespread beliefs about immigrants 'stealing jobs' or negatively impacting the country have been reported, even among children. Such stigmatization is compounded by sensational and often unbalanced media coverage, which frequently depicts immigrants and ethnic minorities in a prejudicial manner.

CoC consists of approximately 25 people in their fifties, with diverse religious backgrounds and nationalities, including Bangladeshi, Pakistani, and first-generation British, and a majority of women (80%). CoC members' life catalyse around a specific neighbourhood in Portsmouth: Somerstown. Despite several past regeneration initiatives, Somerstown remains within the 10% top deprived areas in England [53], with a high unemployment rate and a large share of residents with low skills and low income. It is a high-density neighbourhood with a general lack of open spaces, which, in the opinion of residents, is detrimental to liveability [54].

The selection of participants was influenced by the existence of a naturally occurring group within the community, which has been supported by the Portsmouth City Council. This group, emerging at the community level, has a history and initial demographic targets—adults over 50 and BAME communities—aiming to be inclusive of 'everyone' who wishes to join. Rather than concentrating on the individual characteristics of the participants, we focused on engaging a group characterized by high 'information power' [55] through convenience sampling. This approach was chosen to capitalize on their experiences as socially active citizens of Portsmouth, facilitating their participation in this project. Participation in the project largely depended on self-selection and consistent attendance at the naturally occurring group and the sessions held specifically for this project. Inclusion was based on convenience, sampling from a naturally occurring group according to availability. The relatively high percentage of women in the group likely reflects ongoing challenges to

gender mainstreaming in policy and implementation at the community level. Despite these efforts, there is still significant work required to incorporate a diversity of voices, especially those of the most oppressed (e.g., socially excluded groups identifying within the same gender), as highlighted by the literature on participation and global development.

The CoC group aims to address loneliness and social isolation and improve access to support services for BAME residents. It organizes events to raise awareness about adult social care services and support individuals actively seeking employment and those who have experienced abuse, have mental health problems, or who are carers. From initial conversations with the group, it was immediately clear that CoC has frequently had a positive impact on group members, giving them access to information about the city, fostering new relationships, and reducing isolation.

2.2. The Methodology

To test the capability of ULLs to strengthen community resilience, the pilot study collected qualitative observational data and subsequently analysed and interpreted it using social science tools. The temporary timber pavilion (ChatterBox) was collaboratively designed and built by Chat over Chai (CoC), a BAME community group, and a team of architectural, social science, and performative arts researchers. The participatory design approach aimed to foster key social capacities that could develop from the integration of CoC members in the city through their involvement in a complex production activity.

The intervention was designed around the consolidated methodology of Urban Living Labs, defined as 'user-centred, open innovation ecosystems based on a systematic user co-creation approach in public–private–people partnerships, integrating research and innovation processes in real life communities and settings' [56–59]. The development of the co-creational pilot follows the Double Diamond innovation framework [60–62], which is structured around four key non-linear phases, discover, define, develop, and deliver, encouraging people to understand the problems and define the challenges (first diamond) and develop answers and test solutions (second diamond). This framework was followed in our pilot, which was highly participatory and iterative and used design tools to visualize ideas. This design framework also suggests a set of design methods, or tools, that are partially derived from the service design processes. As Manzini [25] notes, design tools are fundamental in coordinating the relationship between expert designers and non-expert designers. The social innovation process should establish a conversation between the interested expert and non-expert actors, which has to be supported by various design tools at different stages and with different aims. This approach is grounded in theories of design [63–65] and design-enabled innovation [66] and how these practices are transferred to the urban realm. To explore community urban practice, we used three main design toolkits, a human-centred design by IDEO.org [67], the DIY (development, impact, and you) kit by NESTA [68], and Recipes for Systemic Change by the Helsinki Design Lab [69], which provided frameworks to help people think differently such as the 'Fast Idea Generator' that facilitated the conversation, disrupting existing conventional rules and generating new possibilities in an inclusive manner.

The process brought together many different agents in the city, encouraging the emergence of a dynamic system of relationships based on the common interests between key public organizations, such as academic institutions, city authorities, and the third sector. It is worth noting that the ChatterBox project is the sixth in a series of interventions part of the Co-Creation of Temporary Interventions in Public Space as a Tactic to Build Community Resilience project, aimed at developing a long-term strategy on several sites across the city [70].

2.3. Project Data Generation and Analysis Methods

The objective of the data collection was to assess the project's success in relation to its stated goals and to gauge the significance and perception of the experience within the community. The research strategy encompassed continuous field observation. Data

were collated through field notes, focus groups, structured interviews (filmed), and casual conversations, as detailed in Table 1.

Table 1. Types of research tools used for ethnographic research.

Date	Type	Name	Participants
2 August 2018	Field Notes	Approaching meeting and brief definition	18
11 September 2018	Field Notes	Concept idea development	18
24 January 2019	Field Notes, Focus Group	Jury meeting and design feedback session	18
March 2019	Field Notes, Focus Group	Co-design meetings (3×)	18
16 May 2019	Field Notes, Casual Conversations	Co-creation workshop—making tiles	10
20 September 2019	Field Notes, Casual Conversations	Construction residency week	10
30 September 2019	Focus Group	Debriefing meeting	10
17 October 2019	Structured Interview	Interviews with participants	4

The research was underpinned by a trans-disciplinary collaboration involving academics from social sciences, arts and performance, architecture, and engineering and a team of research assistants.

Approaching conversations explored group engagement and willingness to participate. The co-design meetings were planned as focus groups with around 18 participants as they were a natural environment for creative discussion [71,72]. Field notes and casual conversations aided the data gathering during the co-design meetings and the practical activities. We placed special importance on casual conversations [73] because we realized during the research that the simple but meaningful things said during the time spent together reflected what people felt and thought of the process. Towards the end of the project, focus groups and structured interviews represented opportunities for the researchers to investigate the achievements of the project aims and the impact on the community, exploring the level of community engagement and enjoyment of the process.

All the data were recorded and transcribed. A thematic analysis was conducted for a detailed examination of the materials, following the key procedures suggested by Braun and Clarke [74] and identifying various key codes. The researchers followed a deductive analysis process, which involved a methodical approach establishing categories prior to the analysis. Following this, the analysis focused on determining how the data connected to these specific categories. The researchers analysed together their notes, the transcripts of the focus groups, and casual conversations, identifying the recurring codes that were related to the key research questions. The authors then discussed the coding with collaborators and the codes were re-adjusted and agreed. Ambiguous and difficult codes were examined and thoroughly analysed to avoid confirmation bias [75]. The approach followed a critical realist perspective [76] and aimed to identify, through the language used by participants, the fundamental concepts and perspectives that emerged from the conversations.

In the results and discussion, the method involved synthesizing key codes derived from the interviews, focus groups, and casual conversations transcripts—meticulously processed using NVivo 20 software—by strategically aligning them with the resilience capacities identified in the existing literature and then critically reflecting on these alignments through a combination of field observations and the researchers' subjective interpretations, which attempted to remain unbiased, ensuring a comprehensive and methodologically sound analysis.

2.4. The Process

The co-production project, spanning a year, exemplified a collaborative effort integrating community members, researchers, and architecture students (as researchers). It was structured into four distinct phases, strategic definition, design development, fabrication, and wrap-up, adhering to more conventional architectural design processes. The project's meetings took place at community gatherings, and construction utilized university and out-

door spaces, with around 18 participants consistently involved, though numbers dropped during the construction phase.

In the initial phase, the project was introduced to the community, laying out the aims, roles, and timeline, with a strong emphasis on transparency. The community's input on public space and urban perceptions was gathered, encouraging them to frame the design challenge and envision themselves as decision makers. Inspired by Dorothy Heathcote's [77] concept of role playing, participants were invited to assume the role of the expert so they gained confidence in design and problem solving [78]. Architecture students provided technical guidance, transforming community ideas into practical design proposals. Several brainstorming conversations took place to define a collective brief.

With a full brief from the community, architecture students were invited to prepare a set of design concepts. The community participants, in a jury decision meeting, decided which one would be taken forward to the design development stage to be built. This was a key moment that transferred the decision-making power to the group. The prospect of a range of concept designs prepared by the students and presented visually steered the participants' initial ideas into feasible design outputs. This constituted the basis for a more in-depth and creative co-design conversation.

During the design development phase, several co-design and hands-on co-creation workshops [79] were conducted to refine the pavilion's detailed design, incorporating feedback through an iterative process.

A 1:10 scale model was used to visualize the structure, enhancing the participatory design process. The model was essential to deepen the participants' understanding and make their contribution to the design more meaningful. Manzini [25] defines these tools as 'experience enablers' because they describe 'what the world could be like if. . .' and are tools that enable a more fluid conversation between expert and non-expert designers. This phase focused on the pavilion's spatial layout and the integration of visual elements, facilitating a deeper engagement with the project's aesthetic and functional aspects.

A workshop introduced community members to the fabrication phase of the project, involving them in the creation of graphic artwork for the pavilion. This session, held at the Eldon Production Centre, allowed participants to contribute personally and collectively to the pavilion's visual identity, symbolized by a teapot motif representative of the group's identity. The artwork, including images of local landmarks and teapots, was destined for inclusion in the final structure.

A 5-day construction residency workshop engaged the students and CoC members in a week of intense co-construction. This phase was meticulously planned to accommodate diverse activities and mixed teams, fostering a collaborative atmosphere among the participants. The construction process was designed to be inclusive, with multiple types of activities, ensuring that each participant could contribute meaningfully.

The culmination of the project was marked by an unveiling event, celebrated with refreshments, musical performances, and speeches. This event, attended by approximately 120 people, including community members, university representatives, and local officials, celebrated the collective achievement and the pavilion's contribution to the community's public space.

Throughout the project, the emphasis was on co-creation, participatory design, and community empowerment. From the initial concept discussions to the final unveiling, the process exemplified a model of collaborative urban development, with the pavilion serving as a tangible outcome of the community's active engagement and creativity (Figure 2). This approach not only resulted in a physical structure but also fostered a sense of ownership and pride among the participants, highlighting the potential of collaborative design to enhance community resilience and cohesion.

Figure 2. Co-design meetings, co-creation workshops, residency week, and unveiling event that show participants preparing their artwork, engaging with tools at the university workshop spaces, getting on site to assemble the pavilion, and celebrating their achievements.

3. Results and Discussion

We identified two major significant findings of our research. These findings can be summarized as follows:

The ChatterBox Pavilion has proven to be effective in enhancing community resilience capacities, which was the primary objective of our research. We have substantiated this claim with qualitative responses, gathered through focus groups, interviews, and field observations. These findings align with indicators of community resilience that have been previously identified in the existing literature.

It is important to note that there is a lack of prior research on the use of qualitative research methods in public spaces, particularly in the context of practice-based research and Urban Living Labs, especially in a setting similar to Portsmouth and involving participatory approaches with disadvantaged communities. One of the significant outcomes of our research, as discussed in 'Architectural Research Methods' by Linda Groat and David Wang [80], is that the ChatterBox Pavilion emerges as an exemplary case study suitable for further investigation. By comparing multiple case studies and examining emblematic instances, scholars can identify common patterns, shared characteristics, and unique aspects within the field of architectural adaptation. This involves selecting works that share common features like collaborative and multi-dimensional design approaches, co-creation, the consideration of ecological factors, and fabrication processes.

This section discusses in detail the finding related to social resilience and to what degree any of the resilience-promoting capacities identified in our literature review have emerged in conversations with the participants and as a result of the ULL undertaken. The conversations from the focus groups and interviews have been transcribed and coded. These codes were also compared to the key considerations from field observations and ultimately associated with key social resilience capacities in discussions with the team of researchers. The most significant quotes have been extracted and used to support the reflections discussed below. The key codes that emerged through the thematic analysis are shown in Figure 3.

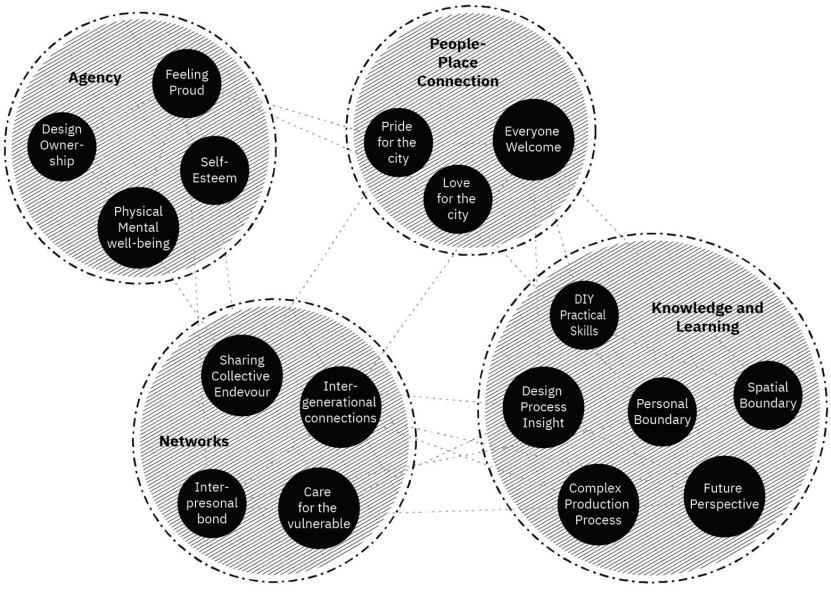

Figure 3. Diagrammatic representation of the codes (black circles) emerged as part of the analysis of the focus groups, casual conversations, and structured interviews, grouped by resilience related capacities (grey circles).

3.1. Agency

According to an extensive and robust body of literature, which is foundational for the present article, community resilience can be assessed through agency indicators associated with the utilization of public spaces across various categories such as leisure, sports, rituals, religious practices, commerce, and social interactions [12,81,82]. In the following section, we elucidate the methodology we devised to facilitate the emergence of these forms of agency. Moreover, we substantiate how these agency indicators have contributed to the sense of ownership over both public spaces and creative endeavours. Our argument is supported by excerpts from focus groups, interviews, and field observations, providing empirical evidence for the development of indicators indicative of community resilience, as expounded upon earlier in the methodology section. This analysis underscores the significance of community resilience through insights gleaned from interview extracts.

The endeavour in question sought to endow the Chat over Chai (CoC) with agency, as defined by its ability to pursue whatever goals one wishes to [83] or the capacity of individuals to act independently [84]. Its overarching objective lay in conferring upon a specific group the authority to make determinations concerning the public domain. As previously expounded upon, the attainment of this objective, if realized, would serve as compelling evidence and a demonstrative parameter of community resilience. To achieve this aim, an equilibrium had to be found during the design process among the various groups of actors involved. The researchers embraced the role of initiators and supervisors, and the students engaged in design support and were technical advisors, helping the community participants to express their ideas through the novel medium of design. The participants were the designers, and it was they who held the power to decide what would be created.

This entire design process was a collective one. The participants appreciated the ability of the researchers to listen and act on their views. This helped to establish the direction of the project and participants to feel that their voice was heard. One participant said:

> *You have taken into account the things that we said. One of the reasons we chose you [a students' team] in the first place was because you adapted your original design.*

The participants saw their idea fully materialized in the finished pavilion, including the idea that it must be open and represent the city and that they had made something for the city. They believed that the final output was the result of their input, their ideas, their reflections, and their constructions and craftwork. This was very significant for the co-creation process and for improving their degree of empowerment, agency, and ownership of the design.

The co-creation methodologies employed played an important role in empowering the CoC members and deepening their appropriation and ownership of the final product, which several referred to as 'their own design'. The participants fully engaged in the role of being designers, aiming for a design that was open, low maintenance, interactive, informative, and useful for chatting, and they found all these features in the final output. Negotiation over some of the ideas was unavoidable but this was conducted and moderated transparently. Overall, in a focus group, the participants explicitly praised the researchers for listening to their brief and translating into physical designs their ideas:

> *You listened. You listened to what we were wanting, and you came back and forwards till you got a bit more from us and a bit more. I think that was really positive [. . .]. You didn't just go 'Oh we've decided now, we're doing it'. You came back to us to make sure we were happy.*

Successful listening determines the quality of the participation and its meaningfulness. Effective civic participation can happen only when participants' voices are truly heard [18]. The feeling of ownership was mainly connected to the degree to which participants contributed. The workshops and the residency activities contributed to building this sense of ownership of the process and its outcomes through involvement in the constructing and craft activities, allowing participants to make an artistic contribution to the process and to build a meaningful personal connection with the outcome. Participants expressed clear ownership regarding the artwork, specifically regarding the tiles, the benches, and the final overall installation produced. Some of them said

> *This belong to us, literally, this is mine. Not that is just for me, but this is the best project we made.*

> *This bench is mine. I will come back tomorrow to sand it. No one should ruin it.*

Although the construction part of it was daunting and worrying because it required time, engagement, and the use of unfamiliar skills, ultimately, participants were proud of the result. Although some people were not interested in the hand-on creative activities, others thoroughly embraced them and enjoyed their 'therapeutic' effect:

> *It helps your well-being also, you know. You focus on the picture and you forget about your worries and whatever you're going through. And it helps mental health. I think that's important.*

> *Everyone finds working with your hands very therapeutic.*

From the analysis, a distinct sense of ownership among participants emerged, primarily fostered by (a) their structural inclusion in the decision-making process and (b) the creative efforts undertaken during the workshops. Nevertheless, it remains uncertain whether this has led to any long-term impact on community agency beyond the scope of the process itself.

In conclusion, the study of agency has effectively demonstrated that the employed methodology successfully facilitated the development of a sense of ownership over co-creation processes and engendered participatory authorship, both of which serve as self-evident indicators of community resilience. According to insights gleaned from interviews, participants not only expressed a profound sense of involvement but also articulated a heightened sense of self-actualization. While the latter aspect falls beyond the immediate

scope of this research, it suggests the potential for expanding our investigation beyond the domains of urban design and social sciences into the realm of urban psychology. This extension opens avenues for future research strands.

Regarding the alignment with the community resilience categories initially outlined, it is essential to acknowledge a certain level of uncertainty. Specifically, the manifestation of agency as a form of community resilience in this context primarily pertains to collective acts of creativity as a means of appropriating public spaces. However, it remains a limitation of our study that a comprehensive literature review does not definitively establish whether the domain of arts, particularly performative arts, can be neatly categorized within the realms of leisure or sports. Alternatively, it raises the possibility that our discourse on the ChatterBox Pavilion may serve as an opportunity to expand the taxonomies of community resilience, introducing a more nuanced understanding of agency that extends beyond the simplified categories of sport, leisure, and commerce.

3.2. Knowledge and Learning

In the realm of the social sciences, it is a well-established practice to acknowledge the potent influence of serendipity alongside deterministic methodologies in research endeavours [85]. Our current investigation is no exception to this tradition. While our primary inquiry revolves around the concept of community resilience, it is noteworthy that the outcomes of this study may yield supplementary revelations concerning the efficacy of the methodologies employed. These serendipitous discoveries have the potential to enhance the utility and encourage further exploration of these methodologies within the domain of practice-based research, particularly within the dynamic context of the Urban Living Lab.

This pertains notably to the learning process, which was initially conceived as a means to cultivate a heightened sense of belonging and community involvement and subsequently evolved into an opportunity for leveraging creative work as an educational instrument. Esteemed works such as 'Research by design: A research strategy' by Hauberg [86], along with *Practice-Based Design Research* authored by Vaughan [87], corroborate that instances akin to ChatterBox proffer valuable insights encompassing diverse approaches, methodologies, and case studies. These contributions occur within the overarching framework regarding the built environment as a crucible for both experimentation and pedagogical enrichment.

The participants were exposed to the process of designing an architectural installation, learning about the design process, and reflecting on the political and sociological implications of the role of public realms in the city. By reflecting on these issues, they learned new facts about the place they live in and how to navigate complex management processes. This knowledge may be useful in future situations in which they will have to balance different options and their feasibility, and take executive decisions.

For example, it was very interesting to note how some conversations during the co-design phase centred on what kind of sociability the new public space should accommodate. It was discussed how the structure had to be interactive and inspiring and generate useful interactions, such as when charging a phone, and also that it should have a 'no-Wi-Fi zone' to encourage users to 'sit and communicate with each other' and possibly learn something new about the city. The information displayed was intended to serve as a conversation starter, coupled with considerable reflection on the idea that the more interactive the structure was, the more engagement it would generate from the public. It was also hoped that this would make the structure more accepted by the wider community, which could deter possible acts of vandalism. The group playing with the model engaged in deep thought about the openness and porosity of the space as they wanted to balance privacy with providing space to gather people together, without making it too enclosed. The 1:10 scale model was very useful for the participants to understand and visualize the space and to discuss its qualities for gathering people together. Using the model, the participants suggested increasing the space in the centre. They discussed the entrance and the way the space could be used and went on to discuss its accessibility and child-friendliness.

The issue of disability and the need to be mindful of people who lack mobility or have a disability emerged frequently in these conversations. All these reflections around the design enhanced participant knowledge on the design process and the skills involved.

In this learning process, two polar attitudes were expressed: a strongly idealistic projection towards the future versus a pragmatic and practical attitude. Some participants started dreaming about possibilities, how they could be helping others and how they could represent the city of Portsmouth. There was a general level of enjoyment and excitement when discussing design options, particularly the design of the tiles, and brainstorming ideas. At other times, participants remained very pragmatic, carefully analysing the practicalities of the design and their ideas. When the conversation moved to making a specific piece of art, members started considering how to realize the artwork, what materials to use, whether it could be waterproof, what colours to use, and how to produce it. Furthermore, concerns about health and safety, security, vandalism, accessibility, cost, and maintenance were all part of the decisions. One area where the weaknesses in their original thinking was exposed was when they considered looking after and maintaining the structure. Although, for example, they wanted to have green elements like plants, this idea was discarded because the group did not feel committed to watering them. In some cases, the researchers had to moderate the participants' ideas because they were either unpractical or technically unfeasible.

CoC participants valued learning the 'how it is done' and said that observing how the design process worked had alerted them to new perspectives. In the same way, understanding the process of collaboration in a design process helped to enlarge their knowledge of collaboration, management, and production. Two participants during the interviews observed the following:

> *The positive thing was the start and the finish, so we saw the project right through and you [do] not always have the opportunity to see something from the beginning, you know, and the end result [. . .] was really exciting.*

> *And all of it, I think, from the beginning, from the planning, from using the ideas and scrapping the ideas and changing the ideas. I love changing. Lovely to be creative. The story, I think, is fascinating. How it's changed.*

This process may have stimulated in participants various ideas, intentions, desires, and aspirations for the future. Two people expressed the aspiration to promote further urban actions in the surrounding areas, such as painting a big mural in a massive adjacent wall or promoting a similar placemaking activity in another derelict urban area. Another had a more personal potential response. Perhaps a simple sentence like '*I want to be a student! Can I just come in a lecture next week?*' could be interpreted as an emerging desire, a push to the horizons that the process had opened up to individuals.

Learning DIY skills was also valued. Debriefing on the construction process and the 'making' aspect generated euphoric reactions. The members of the group were excited about learning new hands-on craftsmanship skills. Actively using large machinery and drills and the advanced equipment available in the Architecture School workshop made them feel more confident about their manual skills. They considered the activity of drilling, sawing, and assembling timber elements in the university workshop particularly useful and important. One of them said the following:

> *I love to see a lot of the other women using them [who] had never used drills before. I did actually [get] on with some drilling and I got [on] with some of the assembly . . . but it was great to see women [who] have never drilled before [doing it]. And now they know [about] drilling. . . . I think everybody should know how to drill something.*

It is worthwhile to consider the aspect of learning in this discussion. Learning often involves expanding our own boundaries, whether personal (mental or physical) or relational. A recurring theme in the conversations was that the project initially instilled some anxiety in participants regarding the challenges and situations it presented. However, it was also noted that these anxieties diminished towards the project's conclusion. Participation in

the project, in some manner, contributed to expanding the usual life boundaries of the participants and mitigating their initial fears.

Exploring new territories such as the university spaces and environment and workshops was also valuable. This pushed the CoC participants into visiting new places, gaining a relationship with hitherto unknown experiences, and vaulting some of the socioeconomic boundaries that had existed prior to this experience:

> *I [went] down every single day and I've enjoyed working with the students [and going into] the university [and] the workshop. [I enjoyed] the drills the equipment and I think . . . [that] some people [in our group who went to] the university [had] never set foot into a [university workshop before].*

On one hand, a participant remarked on the visible socio-geographical barrier between the local community and the university in Portsmouth, while on the other hand, another praised the project dynamics because this barrier was fading as a result:

> *So, I think the more you can bring the community into the university, like this project does, [the better].*

Some members of the group also had to deal with personal self-esteem and sociability issues or their anxieties in engaging with the project or being accepted by students. One clearly remarked:

> *I was soo nervous before I met [the students]. 'Oh [how] are they going to react to me?' And all of that—oooh. And then I came in and I was . . . 'Oh yeah, they're fine'. They were really lovely—and I got on really well with a couple of them.*

The participants boundaries were also enlarged by the engagement with various activities outside their comfort zone. The challenge of creating artwork as well as using the drills and technical machineries had a significant impact, clearly evidenced by this statement:

> *I was [. . .] terrified when I saw all [that] big machinery there, but [. . .] I said to myself 'No, I've just got to get on and get into it'. And once I started working with a group of students, I mean, my fears [. . .] went away and I was [. . .] excited to do something.*

Undoubtfully, the production of new knowledge and learning of new skills by the participants has taken place during the process. This concluding statement stands as one of the most serendipitous discoveries arising from our research. The transition from an initial state of preoccupation to a gradual emergence of understanding and appropriation is particularly enlightening within the framework of teaching threshold theories [88]. This transitional space highlights the realization that genuine discoveries can only be achieved through a profound comprehension of the broader implications of teaching and learning, extending beyond the mere transmission of knowledge.

In a broader context, this alignment resonates with the observations made by Cousin [88] regarding the prevalent academic tendency to impart copious amounts of knowledge, often with the expectation that students will passively absorb and reproduce it. However, the notion of expanding teaching thresholds, as exemplified by the ChatterBox project, introduces a transformative and ontological realm where knowledge becomes intrinsic to one's identity. In this light, it envisions a series of dynamic and stimulating workshops reminiscent of the collaborative Renaissance workshops, fostering a teacher–student relationship (where everyone, including stakeholders and participants, becomes both students and teachers) that embraces unconventional educational experiences. This approach draws inspiration from individuals and groups who adopted a personal and less structured approach to the observation of reality.

By creating an immersive and experiential educational environment, the pavilion successfully strikes a harmonious balance between nurturing creativity and imparting knowledge, a fact attested to by the participants. This reaffirms Cousin's assertion that challenging intuitive understandings, while potentially uncomfortable, is essential for the acquisition of knowledge that transcends conventional approaches. Such approaches may

no longer be adequate to meet the evolving needs of future generations, particularly in the context of environmental challenges. Consequently, it becomes increasingly pertinent within the realms of arts and architecture to embrace a more radical and exploratory pedagogical approach that fosters associative thinking and creativity.

In contrast to the puritan and top–down model of public interventions [89], ChatterBox has demonstrated a critical stance toward a prevailing tendency in architectural practice. This tendency prioritizes maintaining established positions over exploring ecologically sustainable architectural forms. Pedagogically, the primary aim of a traditional design workflow is often to transmit knowledge while equating it with upholding the authority and prestige of the designer at any cost. This mindset has been reinforced by outdated practices that fail to provide effective tools to address current global challenges. The ChatterBox Pavilion attempted to explore a more innovative and radical pedagogical model by involving several stakeholders as active members of the design team, unleashing their creative energy in diverse forms.

3.3. People–Place Connection

In the preceding section, we addressed how an installation, exemplified by ChatterBox, aligns with the objectives of practice-based research as an educational tool. Extant literature consistently associates the learning process with a profound sense of belonging, a fact that, as previously discussed in relation to agency, signifies growth in community resilience. Notably, the concept of belonging is inherently intertwined with creative arts within the public domain. For instance, research in the global south [90] has also offered evidence that the intrinsic capability to engender awareness and facilitate valuable learning experiences, as exemplified by the ChatterBox case, concurrently nurtures a profound sense of belonging. However, the thematic analysis of the conversations did not reveal clear evidence of attachment to place. The CoC group was already strongly rooted in the city and attached to it.

Nevertheless, it is important to observe that during the design process, several ideas emerged, such as that the pavilion should send a clear message welcoming others and promoting multicultural integration. The participants decided that the structure should provide information about the city of Portsmouth and celebrate the diversity and the beauty of the city.

Welcoming others, intended as greeting them, is a key concept embodied in the entire design process. CoC participants continually expressed pride in their city and said that welcoming other people in the city and creating something useful towards integration and inclusiveness was their most important goal. They considered this intervention as instrumental in that goal. This sentence by a participant embodies the group's views:

> *Our community hope is for the city in Portsmouth, we want to invite people want to make it a space where people can be happy to come in.*

Although this genuine love of Portsmouth was the starting point, the process of actively creating something for the city has without doubt tightened the bond between the community and the place itself. Their pride and sense of purpose and caring for others emerged from the idea that they had created something for all city residents, projecting the explicit inclusive message that 'everyone is welcome'. Their pride reinforced their sense of place, belonging, and attachment because it was related to the place where they live. It is sensible to argue that the more that people care for their surroundings, the more they become attached to it. The care for the space contributed to reinforce the group's love for the city.

In summary, the notion of belonging manifests within the ChatterBox project as a collective sense, or an extended form of agency, pertaining to the appropriation of public space through creative endeavours. This creative activity mirrors the multifaceted community engagement akin to activities observed in historic centres, thereby affirming the positive impact of a certain level of participant diversity. This finding resonates with contemporary researchers in the field and aligns with seminal works in this area.

3.4. Networks

Resilience-promoting capacities entail building networks, via placemaking activities, as well described by Schneekloth et al.: 'Placemaking is not just about the relationship of people to their places; it also creates relationships among people in places' [18].

Group art practices can provide opportunities for bonding among members of the same community and may also lead to collaborations between different communities and networks. Gilchrist [42] argues that community development's role is to facilitate interaction between different networks, called 'meta-networking' or 'networking the networks'.

The ChatterBox intervention connected CoC members with other communities. Researchers observed genuine altruism and care for others throughout the process. This caring attitude manifested through discussions about more vulnerable residents, such as people with disabilities, those experiencing homelessness and children, and also in deciding on a design aiming to welcome and share knowledge with others. Sharing knowledge was a central feature of this altruism.

During the design process, the participants demonstrated their willingness to collaborate with others and involve other local groups, demonstrating a desire to embed themselves in the socioeconomic context of the city to work out ways to improve their experience and tapping into local resources. They considered approaching local companies to donate materials and engaging other community groups who could have benefited from the project.

Most participants were positively affected by the intergenerational collaboration process. They found working with students to be an enriching experience, developing teamwork and dialogues with some of them. This helped establish a network of personal social connections, bonding, and meaningful exchanges. During the interviews, participants observed the following:

> *I thought that was really good, because I could listen to his [student] perspective and he could listen to mine, you know. I thought that that whole relationship is really, really good.*

> *It's really nice—she's in her twenties and it was just nice to have the different age groups working together.*

The researchers are not aware if any of these relationships actually continued after the intervention ended. Indeed, if they had, this would be a strong basis for arguing that our method of work contributed to building long-term community interactions. Future research should address this key aspect and monitor it in the long term, and its concomitant ethical dimensions.

Certainly, during the project, the sharing of a complex and, at times, difficult task during the construction week was particularly effective in creating intense bonds between students, researchers, and participants, thanks to the collaborative environment and sharing of tasks, goals, and sense of achievement at overcoming the barriers and challenges presented to them. Collaborating with a common goal and sharing a purpose enabled people to get closer faster and more intensively, giving a sense and meaning to their working and being together in a task that could be competed only with collaboration and teamwork. This interview sentence encapsulate this perspective:

> *We've had something in common. I think that's the whole point is having something that you're sharing. You've a shared interest of some sort.*

The project also created a few opportunities to connect with other local action groups and public representatives in the city, such as the Makers' Guild, as well as meeting the local MPs, national politicians, and City Council officers, to whom they could explain their project and personal efforts. The unveiling event provided a great opportunity for the group to be at the centre of the celebration and fostered connections with other people and groups, allowing the group members meet each other, meet other groups, and celebrate with the students.

3.5. Limitation of the Study

As delineated in Section 3, our study has delimited its inquiry to capacities that were more prominently discernible through thematic analysis, encompassing agency, knowledge and learning, people-place connections, and community networks. It is important to acknowledge that certain resilience-promoting capacities beyond this scope did not prominently surface in this project. This can be attributed to the specific design of the co-creation activity, which did not anticipate their emergence during conversations with the participants. Consequently, more systematic research is requisite to comprehensively investigate the impact of temporary urbanism on capacities such as leadership, community infrastructure, and values and beliefs. These elements, in part, eluded examination due to the absence of suitable measurement mechanisms. Additionally, it is pertinent to note that the assessment of a diverse and innovative economy lay entirely beyond the purview of this intervention.

Another notable limitation of this study pertains to the inherent trade-offs in the process of inclusion and exclusion: the inclusion of certain individuals or groups often implies the inadvertent exclusion of others [18]. In the context of Urban Living Labs (ULLs), there exists an inherent constraint wherein only a limited number of local individuals can actively participate. On occasion, these participants may already constitute a cohesive group, thereby inadvertently excluding other local citizens who do not partake in the project.

Furthermore, during the phases of co-design and creative activities, variations in participation levels among individuals became evident. Some individuals naturally assumed more active roles, while others gradually distanced themselves from the process. This divergence may have occurred either because they did not feel adequately included or because they simply chose not to participate actively. In a few instances, participants exhibited a gradual disengagement, eventually ceasing their involvement in the project altogether.

This dynamic also gave rise to a discernible sense of ownership over both the public space and the installation itself. While there was indeed a palpable sense of ownership, primarily attributed to (a) their active participation in decision making and (b) the creative endeavours undertaken during the workshops, the question arises as to whether this newfound sense of ownership has translated into any enduring influence on community agency beyond the immediate scope of the process.

In this regard, it remains challenging to ascertain how this newly acquired knowledge can be subsequently applied in real-world situations. Furthermore, the extent to which this knowledge has effectively contributed to enhancing long-term resilience within the community remains uncertain.

4. Conclusions

The findings have shown that co-creation made a strong contribution to place-making and also that ULL interventions such as Multicultural City ChatterBox offer adaptive and flexible responses to evolving social and environmental conditions. Even when the social conditions change and pose threats to individuals and groups in terms of cultural segregation and economic or social deprivation, ULLs such as the ChatterBox project continue to provide support to the community and help to adapt to these transformations.

Collaborative and creative placemaking stimulates a range of community capacities, including the capacity to build networks, to enlarge and set new boundaries, to learn new skills and knowledge, to foster a sense of belonging, and to generate new aspirations. The CoC community group had the opportunity to discover new places (the university), meet new people in their city (the researchers and students), share a purpose with this new community, and build a bond with its members. Their public outlook was also publicly presented as caring for their city and playing a new social role in the community, bringing them visibility. Throughout the process, the group was exposed to unfamiliar activities and spaces that became familiar, and by fighting and overcoming fears, they pushed some of their personal and psychological boundaries. They learned from witnessing the full process of creating and constructing a pavilion in a public space, ranging from

legal impediments to their gratification upon achieving their goal. They learned from co-designing an architectural installation and how great ideas need to find practical solutions. They were surprised and excited at using drills and big lab machinery. The process of caring for and acting on a public space nurtured their love and knowledge of the city and fostered a connection between people and place, consolidating the socio-geographical territory of this group. Enlarging boundaries by exploring new activities and spaces and meeting younger people seeded new aspirations and opened new and different perspectives to them.

The achievement of these outcomes is highly dependent on the methodology used in the process. The participatory design, via co-creation and co-design, must effectively transfer full decision-making powers and responsibilities to the participants, making the environment safe and playful. The early transfer of power and authorship to the participants, is paramount in creating a sense of ownership of the process. Engaging the participants in making art and crafts is a key dimension for exploring new skills, learning new things, enlarging one's personal boundaries, and building relationships. Potentially, if they are sustained over time, and are not seen as the means to achieving another goal, collective art practices can also have a therapeutic impact on participants' mental and physical well-being. Every participant needs to feel included and offered a range of activities that allow each one to find their own place in the creative activity. Finally, the process should involve other groups, aiming to create a network of networks and help the community to become well connected [42].

There is clear evidence that the temporary activation of public spaces through community-led placemaking possesses transformative potential and can effect positive change within local communities for the duration of these activities. Throughout the intervention, a range of social capacities were stimulated and developed. ULLs help to increase the capacities of the social system, reduce fragilities, and decrease isolation and therefore fosters, nurtures, and supports vulnerable members of a community (and therefore the urban system). This demonstrates the significant value of ULLs in their role within cities as safe, experimental, and transitory training grounds for enhancing social capacities closely linked to resilience. However, further research is necessary to evaluate the production of resilience engendered by ULLs in the long term.

According to the analysis section, an additional aspect that enhances the research's transferability is the distinctive and original value of ChatterBox as a case study that can be originally linked to the extensive body of literature on practice-based research (PBR) and Urban Living Labs (ULL). According to principles describes in 'Urban living laboratories: Conducting the experimental city?' by Bulkeley et al. [56] and 'The role of urban living labs in a smart city' by Baccarne et al. [91], ChatterBox has been described as a ULL paradigm, delineating its principles, methodologies, and applications in the realms of urban research and design.

It underscores, as the intervention design workflow has shown, the active engagement of architects and designers in the generation of novel knowledge and insights through their design practice. This knowledge can subsequently be shared with the broader community. As ChatterBox demonstrated, through their involvement in practice-based research, architects effectively bridge the gap between theoretical concepts and practical implementation, thus facilitating the creation of innovative design solutions.

This approach has been supported within the context of ChatterBox also through the active involvement of stakeholders, encompassing residents, users, and community members. These participants have played a pivotal role in understanding and enhancing the architectural and urban environments. The ULL framework, concurrently, has fostered a culture of collaboration, co-creation, and participatory design methods. These elements have proven invaluable in addressing real-world challenges and cultivating knowledge tailored to the specific context. ChatterBox's methodology offers potential for transferability, as per qualitative research scholarship [92,93].

Furthermore, our examination of the methodological rigour of the best practices and comparative case studies has not only underscored the alignment of ChatterBox's methods

and outcomes with the existing literature but has also accentuated the project's unique multidisciplinary approach. This affirmation further solidifies its status as an exemplary best practice. These findings underscore the vital role of practice-based research and the ground-breaking differentiation between architectural cases and Urban Living Labs (ULLs) within the realm of architectural studies. According to the definition of ULLs, ChatterBox has emerged as a valuable contributor to the field of architectural studies, effectively bridging the divide between theory and practice while promoting innovation and knowledge generation, as attested to by the experiences of its participants.

Author Contributions: Conceptualization, G.R., S.C. and A.M.; methodology, G.R. and J.P.-H.; investigation, G.R. and J.P.-H.; data curation and analysis, G.R.; writing—original draft preparation, G.R.; writing—review and editing, G.R., S.C. and A.M.; visualization, G.R.; supervision, G.R., A.M. and J.P.-H.; project administration, G.R.; funding acquisition, G.R. Some of the text of this manuscript is a further development of G.R. PhD Thesis. All authors have read and agreed to the published version of the manuscript.

Funding: Chatterbox has been seed-funded by the University of Portsmouth (CCI Research, Innovation & Impact Accelerator Fund 2018-19) and the Portsmouth City Council, with match funding, and in-kind contributions from both institutions.

Data Availability Statement: All the data in this study were routinely collected and contained no information about specific people. Our data are available upon request to the corresponding author.

Acknowledgments: The authors gratefully acknowledge the support and contributions so generously offered by their colleagues and friends. Rowshonara Reza, who generously opened the doors of CoC to us, and saw the project through. Sharilyn Woodman, who participated in several community meetings, took field notes, and transcribed the community conversations, preparing them for thematic analysis. The Erasmus students Pepe Sánchez-Molero and Helena Kranjc, who very patiently contributed as research assistants in developing the architectural ideas in collaboration with the community and orchestrating some of the co-creative workshops.

Conflicts of Interest: The authors declare no conflicts of interest.

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Systematic Review

Advancing Urban Life: A Systematic Review of Emerging Technologies and Artificial Intelligence in Urban Design and Planning

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Abstract: The advancement of cutting-edge technologies significantly transforms urban lifestyles and is indispensable in sustainable urban design and planning. This systematic review focuses on the critical role of innovative technologies and digitalization, particularly artificial intelligence (AI), in urban planning through geo-design, aiming to enhance urban life. It begins with exploring the importance of AI and digital tools in revolutionizing contemporary urban planning practices. Through the methodology based on the Systematic Reviews and Meta-Analyses (PRISMA) protocol, this review sifts through relevant literature over the past two decades by categorizing artificial intelligence technologies based on their functionalities. These technologies are examined for their utility in urban planning, environmental modeling, and infrastructure development, highlighting how they contribute to creating smarter and more livable cities. For instance, machine learning techniques like supervised learning excel in forecasting urban trends, whereas artificial neural networks and deep learning are superior in pattern recognition and vital for environmental modeling. This analysis, which refers to the comprehensive evaluation conducted in this Systematic Review, encompasses studies based on diverse data inputs and domains of application, revealing a trend toward leveraging AI for predictive analytics, decision-making improvements, and the automation of complex geospatial tasks in urban areas. The paper also addresses the challenges encountered, including data privacy, ethical issues, and the demand for cross-disciplinary knowledge. The concluding remarks emphasize the transformative potential of innovative technologies and digitalization in urban planning, advocating for their role in fostering better urban life. It also identifies future research avenues and development opportunities. In light of our review findings, this study concludes that AI technologies indeed hold transformative promise for the field of geo-design and urban planning. They have proven instrumental in advancing predictive analytics, refining decision-making, and streamlining complex geospatial tasks. The AI's capacity to process expansive datasets and improve urban planning accuracy has facilitated more sustainable urban development and enhanced the resilience of urban environments.

Keywords: artificial intelligence; urban planning and environmental modeling; machine learning applications; sustainable urban development

Citation: He, W.; Chen, M. Advancing Urban Life: A Systematic Review of Emerging Technologies and Artificial Intelligence in Urban Design and Planning. *Buildings* **2024**, *14*, 835. https://doi.org/10.3390/buildings14030835

Academic Editor: Haifeng Liao

Received: 29 February 2024
Revised: 17 March 2024
Accepted: 18 March 2024
Published: 20 March 2024

1. Introduction

Artificial intelligence (AI), which offers unprecedented opportunities to enhance urban environments, has fundamentally altered urban life and impacted sustainable urban design and planning irreplaceably. This systematic review aims to underscore AI and digital tools' significant role in transforming contemporary urban planning practices through geo-design, delve into the intricacies of AI's application within the realm of urban planning and help understand the historical context and the evolution of this field.

1.1. Research Background

Governments worldwide are beginning to tackle the problems caused by urbanization in the 21st century [1]. The sustainable development of cities and nature increasingly depends on the successful planning of urban growth and the geographical planning and design of regions [2]. In the past thirty years since the influential Brundtland Commission Report, humanity still faces the pressing task of altering its behavior to secure a sustainable future [3]. Despite the intricate nature of these challenges, they demand our full technological prowess to devise solutions for both the immediate and distant future. Artificial intelligence (AI) stands out as a significant opportunity in this endeavor, with its capability for machines to "learn from experience, adapt to new information, and carry out tasks similar to those performed by humans" [3].

AI technology presents three primary advantages. Firstly, it automates crucial yet monotonous and time-intensive tasks, freeing up human capacity for more sophisticated endeavors. Secondly, it unlocks insights buried within vast quantities of unstructured data, including video, photo, textual reports, business documents, social media content, and emails, which previously required manual oversight and analysis. Thirdly, AI has the power to harness the capabilities of thousands of computers and additional resources to tackle highly complex challenges. Hence, utilizing AI to explore solutions for the climate crisis is vital. To accomplish this effectively, comprehensive research is required to understand how AI can seamlessly integrate with human emotions, thought processes, social norms, and behaviors.

In this paper, the authors present the case that AI can aid in creating organizational processes and individual practices that are culturally sensitive and reduce the demand for natural resources and energy in human activities. The real significance of AI lies not just in its capacity to help individuals and society lower their consumption of energy, water, and land beyond.

1.2. The Wide Application of Artificial Intelligence Technologies

The progress in AI and data science today holds the potential to fundamentally alter business operations. It achieves this by aiding knowledge workers in conveying their analytical findings, backing up evidence, and making informed decisions [4]. Almost every organization is now focused on understanding their business and transforming data into actionable insights. For example, to detect and quantify a water pollution problem, a water quality monitoring network is designed and established through artificial intelligence technology [5]. Large-scale soil regulation and agricultural sustainability can be addressed with geographic information systems [6]. In landscape architecture planning and design, using scientific analysis methods to quantitatively study the law of site change and provide a scientific decision basis for planning has always been an important topic. The emergence of new technologies, such as big data, has rapidly grown the data related to landscape architecture, providing strong support for the quantitative analysis of site laws.

1.3. Advances in Artificial Intelligence Technologies and the Interrelation of Urban Planning

In the past, planners would display their data on large, physical maps and employ tracing paper overlays to incorporate stakeholder information. However, the advent of Geographical Information Systems (GIS) revolutionized this approach by substituting the need for transparent maps with digital map layers, which are presented and manipulated within a GIS on a computer screen [7]. The numerical analysis available in GIS is often combined in landscape architecture during the generation of planning and design schemes. The application of artificial intelligence in urban space and architecture began in the 1970s. In the past 10 years, with the great changes brought about by the Internet, artificial intelligence has been applied and explored in many research directions of geographical design and related aspects. With research depth and breadth enhancement, geographical design intelligence has gradually formed. Artificial intelligence in geographic design transforms complex qualitative descriptions in space into quantitative analysis and design

models through intelligent mechanisms. The role of artificial intelligence technology in geographical design is mainly reflected in two aspects: (1) Using artificial intelligence algorithms and thinking to calculate and analyze the relevant data in geographical design research efficiently and accurately and mining knowledge and rules from it; (2) Aiming at complex and difficult problems in geospatial research, establish a spatial intelligence model to reveal the internal mechanism behind the phenomenon. Artificial intelligence applied to geographic design mainly refers to "weak artificial intelligence": execution ability is generally better than humans and can formulate and apply digital technology to achieve goals [8]. Its core lies in applying artificial intelligence technology to replace the work handled by the human brain in the past and improve the reliability, validity, and accuracy of geographical planning and design.

Technological change is a key driver of long-term growth in regional planning, design, and management [9]. AI allows humans to devise, strategize, and implement comprehensive solutions to environmental degradation and the climate crisis, moving beyond narrow-minded and self-serving approaches of individuals and small groups [3]. GIS is one of the main tools to realize the application of artificial intelligence in geo-design and planning [10]. There are two main types of artificial intelligence in geo-design and planning applications. One is the "inference type", such as logical reasoning, theorem proving, etc., including the knowledge type and the "learning type", such as deep learning, support vector machine, and so on. The other is according to the type of artificial intelligence algorithm, divided into "symbolism", such as expert systems, knowledge engineering, etc., including "connectionism", such as neural networks; "behaviorism", such as multi-self-agents, cellular automata, and so on [11]. Symbolism is the process of simulating human-like intelligence using logical reasoning to deduce the whole theoretical system [12]. According to the attributes and functions of artificial intelligence technology and the types of geographical design problems that can be solved, the artificial intelligence methods applied in the field in recent years are divided into three categories: artificial life, intelligent random optimization, and machine learning.

1.4. The Value of Geographic Design in Regional Spatial Applications

In recent years, urban areas worldwide have frequently experienced both natural disasters, such as earthquakes, floods, and hurricanes, and man-made accidents, including terrorist attacks, chemical spillages, fires, and explosions. Due to the importance of spatial information to geographical research, the application of artificial intelligence is mainly reflected in social science research, data sorting, disaster prevention, early warning, and other aspects [13]. One of the main advantages of AI technology is that it can explore the ecological challenges that future landscapes may face. Geo-design is a planning and design approach that closely integrates the simulation of the impact of the geographic environment, system cognition, and digital technologies to create design solutions [14,15]. Geographic design provides a comprehensive framework for landscape information processing. In addition, geographic design tends to be applied across disciplines and differs from traditional landscape architecture education. Geo-design is rooted in using digital technologies that integrate information from social and natural systems as a basis for modeling, analyzing, and communicating design and planning effects. Geo-design as a strategy helps planners and designers address pressing urban and landscape issues such as climate change, sustainability, environmental quality, and justice. These problems can be represented, described, and analyzed using geographical information [16].

1.5. Research Questions

This paper aims to comprehensively review AI-related technology applications in urban design and planning. The research questions include: (1) Which AI-based technologies have been used to study this area? (2) What are the trends and research areas of the published literature? (3) What are the key data inputs and analysis themes when applying these technologies?

2. Method

In conducting the literature review, researchers adhered to the rigorous standards of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [17]. PRISMA protocol outlines a transparent and systematic methodology for database searching, selecting relevant literature, and synthesizing gathered information. By following PRISMA, researchers ensured a comprehensive and replicable search strategy, which involved clearly defined criteria for inclusion and exclusion, identifying databases and other sources of relevant studies, and a meticulous documentation process for each step taken.

2.1. Search Keywords

This study developed a list of keywords based on the above research questions. This research utilized a thorough search methodology across the Web of Science. Multiple variations of keyword strings were employed, each specifically adapted to the search functionalities of these databases, ensuring the retrieval of the most pertinent and consistent findings. The time frame for the publications included in this search spanned from January 2003 to June 2023. The search keywords included two groups: (1) Topic-related words: "geo-design", "geo", and "design", "GIS", and "design", "geographic" and "design", "geospatial", and "design"; (2) Method-related words: simulation, parametric, deep learning, big data, social media, remote sensing, neural networks, grasshopper, machine learning, virtual reality, VR, decision model, computing, AR, MR, computer vision, swarm intelligence. Combining topic-related and method-related words generated a total of 85 search terms (Figure 1).

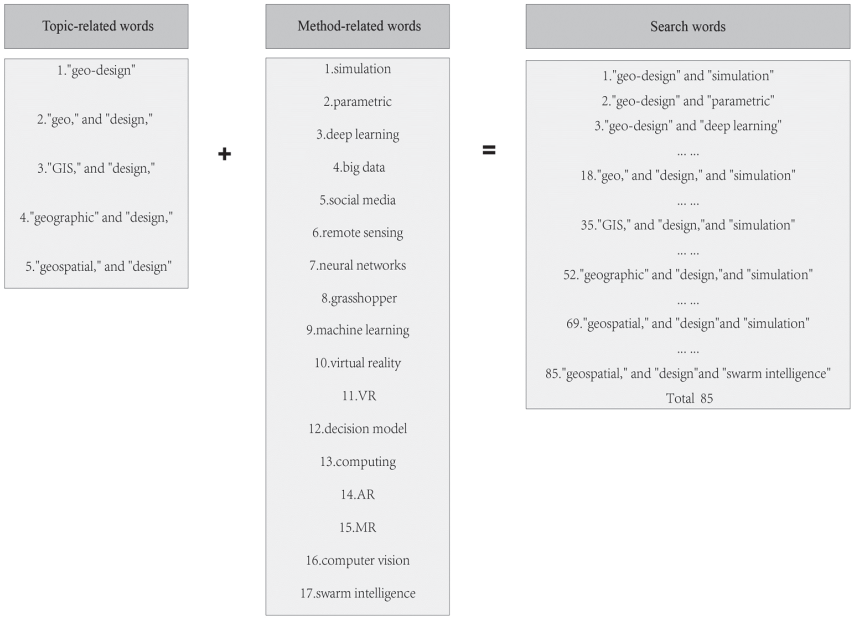

Figure 1. Search Words.

2.2. Search Strategy

Using a total of 85 search words, our initial search yielded 25,241 articles from the Web of Science, as visualized in Figure 1. Rigorous deduplication and title screening reduced this to 14,779 articles. A subsequent detailed review of titles based on our inclusion criteria further narrowed the pool to 1400 articles (Figure 2). This involved excluding off-topic articles outside the urban planning and design scope, employed outdated technologies or were not conducted in an urban, outdoor context. Studies were included if they met the following criteria:

1. The study must be conducted in an urban, outdoor context. Studies in rural areas, forests, or natural river environments are excluded.
2. The focus of the study should be on the use of geospatial information in planning and design.
3. The study must incorporate state-of-the-art technologies, with a preference for articles published within the last decade to ensure relevance to recent advancements in artificial intelligence.
4. The study should fall within the disciplinary categories of planning, landscape, geography, or forestry. Articles dedicated to computer science focusing primarily on algorithms or models are excluded.

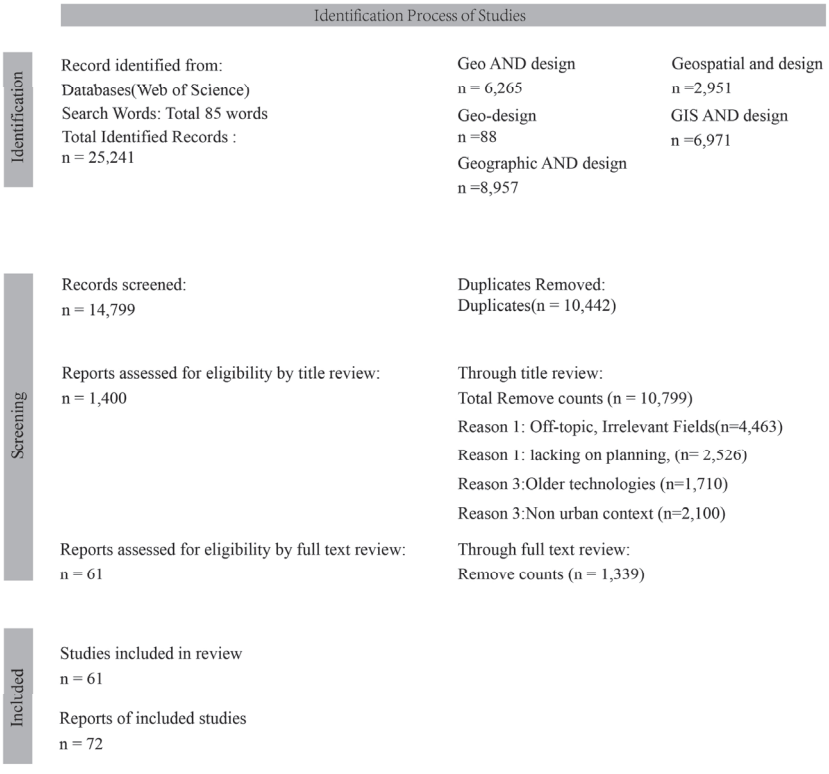

Figure 2. The procedure of the review (based on the PRISMA review protocol).

Review papers, conference proceedings, book chapters, and studies that did not meet the above criteria were excluded. Studies focusing on indoor environments or employing traditional monitoring technologies were also excluded. Any disagreements between reviewers were resolved through discussion and consensus. This additional scrutiny led to a final set of 61 articles.

2.3. Data Extraction and Synthesis

For each included article, data were extracted on the study design, vision-based and/or sensor-based technology employed, research themes and areas, and strengths, limitations, and considerations of using these technologies. A data extraction form was developed and piloted to ensure consistency in data extraction across studies. The extracted data were then synthesized using a narrative approach to provide a comprehensive overview of the current state of research in this field. Researchers developed a data extraction sheet, including the parts: basic information (titles, publication year, author, country, and keywords), topic and

method (themes, types of data, algorithms, vision/sensor/hybrid, and sample size), and findings (outcome results, strength, and limitations).

3. Results

3.1. Research Trend

In the domain of geo-design and planning, a diverse array of scholarly journals has contributed to disseminating research on artificial intelligence applications (Figure 3). The most prolific of these is the *ISPRS Journal of Photogrammetry and Remote Sensing*, which stands out with the most published articles, followed by *Urban Forestry & Urban Greening*, and *Landscape and Urban Planning*. These journals indicate a strong interdisciplinary interest in bridging the gap between technical remote sensing techniques and their practical implications in urban and environmental contexts. The presence of specialized journals such as *Computers, Environment and Urban Systems* and *Transactions in GIS* further emphasizes the technological advancement in the field, focusing on the intersection of computer science and spatial analysis within urban systems.

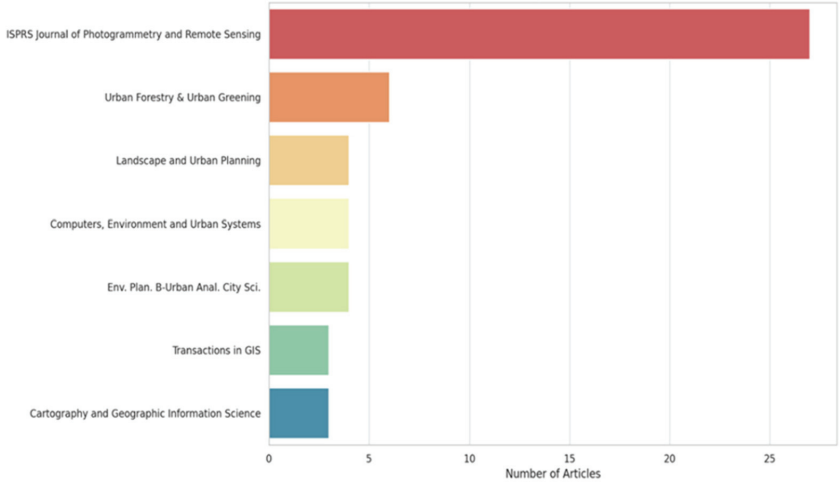

Figure 3. Frequency of journal.

Figure 4 compares the distribution of the top 10 research areas. The distribution reveals a comprehensive engagement with geo-design and planning across multiple academic disciplines. 'Physical Geography' precedes the highest volume of published articles, signaling its dominance and centrality in the field. The following closely follow 'Computer Science' and 'Remote Sensing', reflecting the integral role of technological innovation and analytical methods in understanding and managing geographical spaces.

Other key disciplines, such as 'Environmental Sciences & Ecology' and 'Urban Studies' are well-represented, denoting a concerted focus on sustainable development and the intricate dynamics of urban environments. 'Public Administration' also emerges as a crucial area, underscoring the relevance of policy and governance in shaping the landscape of geo-design and planning. The inclusion of 'Plant Sciences', 'Forestry', and 'Engineering' within the top ten research areas further illustrates the multifaceted nature of the field, where biological, ecological, and engineering insights converge to inform comprehensive geo-design strategies. Within the expansive domain of geo-design and planning, the role of 'Urban Ecology and Environmental Sciences' is particularly salient. This field acts as a critical nexus where the imperatives of urban development meet the principles of ecological sustainability. As cities expand and transform, urban ecology provides essential insights into the complex interplay between urban growth and the natural environment, informing approaches prioritizing biodiversity, ecosystem services, and resilience in urban design.

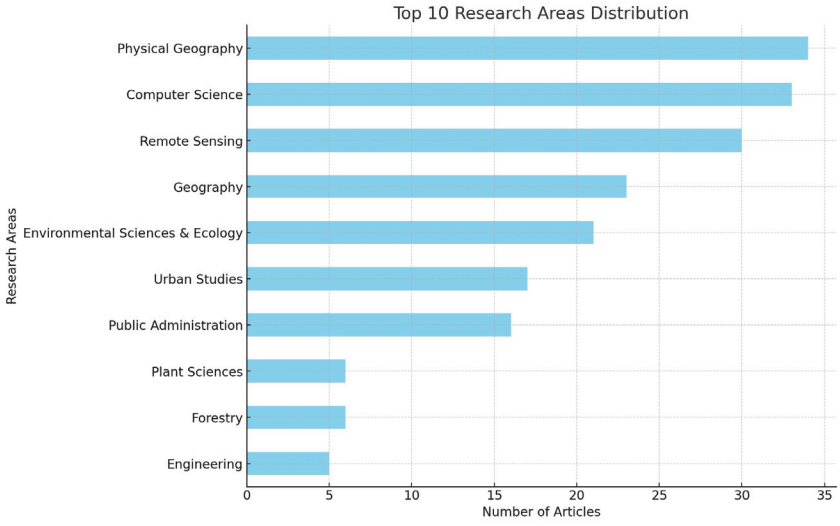

Figure 4. Top 10 research area distribution.

The trend of publications over the years reveals a growing interest and increasing research output in the field of AI in geo-design and planning (Table 1). Starting from 2016, there has been a noticeable upsurge in the number of articles, reaching a peak in 2022. This uptick reflects the accelerating integration of AI technologies in geospatial studies and the heightened recognition of their potential to address complex urban and environmental challenges. Although there is a slight decrease in 2023, the overall trajectory remains upward, suggesting a sustained and expanding engagement with AI research within the geo-design and planning disciplines. This pattern underscores the evolving nature of the field and the continual advancements in AI technologies and their applications. The observed decrease in publication rates in 2021 may be primarily due to the lagged effects of the pandemic, wherein the delayed impacts of disruptions in research activities persisted in influencing publication outputs. Additionally, the subsequent year saw a notable advancement in AI-assisted tools, such as GPT, which enhanced research efficiency. This development allowed researchers to swiftly pivot to applying AI tools within their fields, further impacting publication trends.

Table 1. Publications by years (percentage).

2016	**2017**	**2018**
2 (3.28%)	1 (1.64%)	3 (4.92%)
2019	**2020**	**2021**
7 (11.48%)	11 (18.03%)	10 (16.39%)
2022	**2023**	**total**
16 (26.23%)	11 (18.03%)	61 100%

Analyzing the interconnectivity of concepts within the literature on AI in geo-design and planning, a prominent thematic cluster can be observed around “machine learning”, a central node linking various sub-themes and technologies (Figure 5). The prominence of “machine learning” signifies its fundamental role in advancing geo-design and planning methodologies. Adjacent to this core, “street view” and “live images” are significant,

illustrating the emphasis on real-time data processing and visualization in urban studies. Another noteworthy cluster centers around "urban occupation", "phone data", and "activity space", highlighting the growing interest in human dynamics and mobile data utilization for urban planning. The intricate network of these themes showcases the multidisciplinary approach in the field, integrating advanced computational techniques with practical applications such as urban street network analysis, occupancy modeling, and real-time environmental monitoring. This complex web of interconnected terms reflects the current research landscape and underscores the synergy between AI technologies and their practical deployment in shaping the urban spaces of tomorrow (Figure 6 and Table 1).

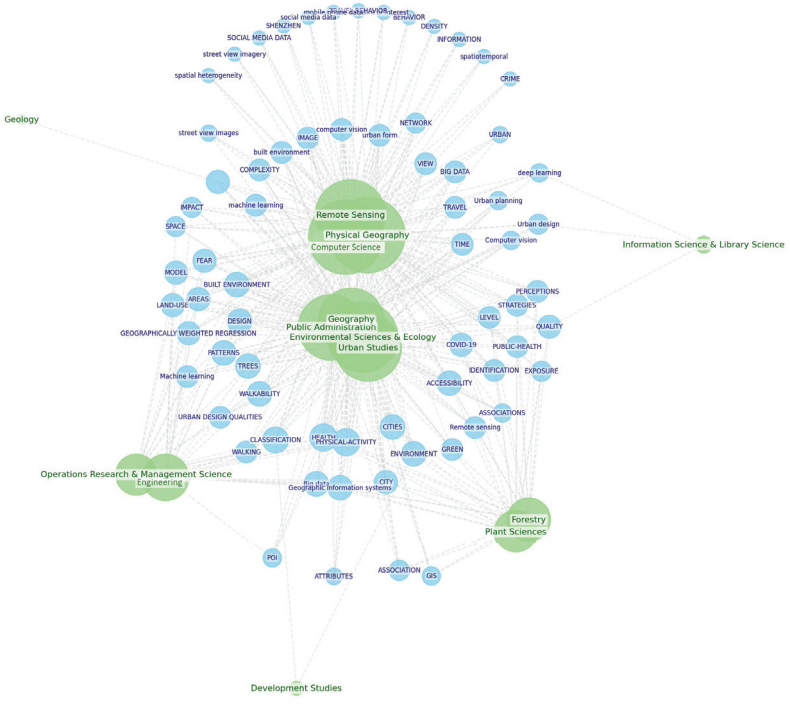

Figure 5. Research area network visualization.

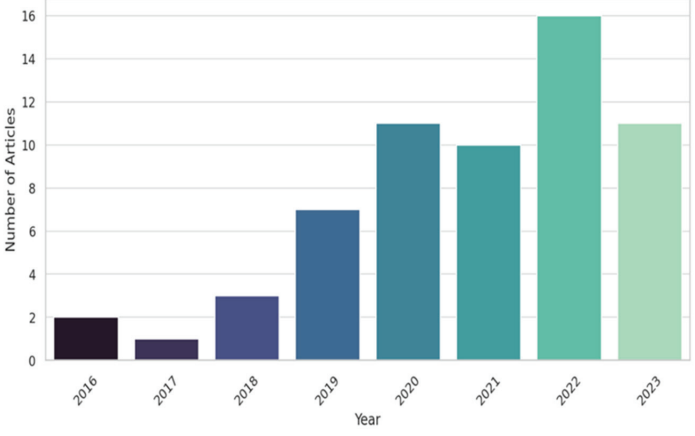

Figure 6. Publications by years.

3.2. Methodological Approaches

The systematic review comprehensively analyzed the data types utilized in geo-design technologies, identifying a multifaceted array of sources that underscore the breadth and depth of information employed in the field (Table 2). Image-based data sources, including satellite imagery, Normalized Difference Vegetation Index (NDVI), and Digital Elevation Model (DEM) data, form a critical foundation for high-resolution spatial analysis, allowing for detailed landscape assessments and vegetative indexing. Furthermore, street view images and map data provide granular details of urban fabric essential for meticulous urban planning.

Table 2. Data types of the geo-design technologies.

Data Type	Crowdsourced Data Source
Image	Satellite imagery Normalized Difference Vegetation Index (NDVI) data Street view images Map data
Spatial Distribution	Land use data Crop production data Ecosystem services Soil property data Point of Interest (POI)
Spatiotemporal	Tracks Road network data Location coordinates GPS Location data
Numeric	Socioeconomic data Population numbers Mobile Phone Data Building and housing data Data for ridership
Social media data	Crowdsourced data
Emotion and empirical data	Emotion and empirical data

In the spatial distribution category, land use, crop production, and ecosystem services data contribute to a holistic understanding of land management practices and environmental stewardship. Soil property data enhances the precision of environmental modeling, while Points of Interest (POI) and tracks offer insights into urban dynamics and mobility patterns. The integration of spatiotemporal data like road network data, location coordinates, and GPS data facilitates advanced modeling of movement and urban growth patterns, providing a temporal dimension to spatial configurations.

Numerical data types, including socioeconomic datasets, population numbers, and mobile phone data, enrich the analytic capabilities by introducing demographic and behavioral dimensions. These datasets are pivotal in understanding and predicting urban occupation patterns and infrastructure needs. Building and ridership data contribute to a more nuanced view of urban utilization and transport dynamics. Lastly, the review identified the emergence of social media data as a potent tool for gauging public sentiment and emotional landscapes, offering a new frontier in geo-design that incorporates human-centric data. Including such diverse data types enhances the accuracy and applicability of geo-design technologies and points to the potential for creating more responsive and adaptive urban environments.

3.3. Application Theme

As AI technology continues to evolve, the field of geo-design is increasingly incorporating AI to address various challenges. Based on an analysis of 61 articles, this review section explores different themes of AI applications in geo-design. This study categorized these into four main themes: Transportation and Context, Built Environment and Perception, Data-Driven Approach, and Urban Region. Under these four primary themes,

researchers have further classified the applications into 28 specific categories, offering a detailed exploration of AI's diverse roles in geo-design (Table 3).

3.3.1. Transportation and Context

The "Transportation and Context" theme primarily focuses on the interplay between human mobility and transportation systems within urban environments. This theme delves into optimizing transport, analyzing traffic patterns, and understanding the broader context of transportation operations. Based on a review of 11 papers in this field, it can be categorized into five distinct areas: TOD Planning, Traffic Flow Analysis, Transportation Management, Transportation Safety, Transportation Decision and Simulation.

Contrasts with traditional 3D TOD designs that typically rely on linear functions. Dong et al. [18] advanced TOD (Transit-Oriented Development) planning by implementing a multi-objective optimization design with a nondominated sorting genetic algorithm III with an ensemble learning method. Their approach demonstrated superiority regarding ridership objectives, achieving better optima and convergence than linear models. This signifies a notable improvement in the efficiency and effectiveness of the Math method in TOD planning methodologies.

In addition, traffic flow analysis forms a foundational pillar in urban transportation optimization. Tang et al. [19] and Semanjski et al. [20] advanced travel time and transport mode detection based on traditional GIS and mobile-sensed spatiotemporal GPS data. However, reliance on traditional ways may limit adaptability in dynamic urban environments. Following this, deep learning methods like SVM, KNN, PCA, RT, and Faster R-CNN have gained prominence in traffic flow analysis. Golej et al. [21] utilized these techniques alongside high-resolution satellite imagery for vehicle detection.

Furthermore, deep learning technology in the field of image classification can also be used to automatically identify parallel lines in images and high-visibility crosswalks in the field of traffic safety [22]. Complementarily, Chen et al. [23] used machine learning techniques, such as the LDCF algorithm, for pedestrian volume assessment via street view images. Nadarajan and Sivanraj [24] further developed traffic forecasting with the ANST model, integrating LSTM networks and attention mechanisms, significantly enhancing traffic prediction by considering spatiotemporal dynamics and environmental factors.

Finally, AI tech can address issues related to transportation decision-making and simulation in addition to the above scenarios. Advancements in urban data research have demonstrated the effectiveness of deep learning methods in evaluating active mobility potential for urban environments. Yap et al. [25] integrated street view imagery and urban networks to evaluate active mobility, using deep learning to assess traffic environment factors impacting subjective decisions. Unlike traditional GPS resources, Chen and Yang [26] combined social media signals with pedestrian simulation technologies in historic neighborhoods, addressing conflicts between tourists and locals and enhancing urban planning. These studies underscore the value of diverse data and visual elements in urban design.

The research in the "Transportation and Context" theme offers valuable insights for urban management. AI enables precise traffic flow analysis, aiding cities in implementing effective congestion reduction measures and identifying signalized intersections and crosswalks, thus enhancing pedestrian safety in urban areas in a geo-design framework. Additionally, integrating AI and geographical data supports data-driven decisions in transportation planning and urban development, promoting a more complex system.

3.3.2. Built Environment and Perception

The "Built Environment and Perception" theme in geo-design research focuses on how built environments affect human perception and activity. This theme encompasses studies that utilize AI tech and big data to analyze and improve human interactions with urban spaces. Key research areas include optimizing urban safety, understanding emotional responses to urban environments, and the impact of visual and socioeconomic elements on human perception. Additionally, this theme explores the assessment of urban space quality,

linking street view imagery, social media data, and economic factors to urban planning and design. These studies collectively highlight the critical role of AI in creating more livable, efficient, and engaging urban environments. This part is based on a review of 22 papers in this field; it can be categorized into two main distinct areas: Human Perception and Activity (12 papers) and Building Environment Assessment (10 papers).

In Human Perception and Activity, techniques such as urban network analysis and image processing have been extensively utilized. Recent studies typically integrate various sensor data and socioeconomic survey data to objectively assess perception and the physical environment, exploring their impact on human activities and emotional responses. For instance, Li et al. [27] introduced an emotion-tracking technique based on Geographic Information System (GIS), quantifying the relationship between people's emotional responses and urban spatial characteristics through spatial analysis and logistic regression. This method evaluated the impact of multiple urban features on emotional responses, including architectural shapes and textures, façade parameters, visual entropy, and visual fractals.

AI technology in geo-design is primarily employed for data analysis and mining data related to humans and their environment, aiding in establishing the relationship between urban environments and human activity perception. Liu et al. (2020) explored urban vitality, spatial patterns and driving mechanisms using multi-source big data, including mobile location data, geospatial big data, and shared internet data. Huang et al. [28] analyzed city images on social media through text mining and image annotation, introducing "Instagram ability" and "Twitter ability" as new urban image indicators. Gong et al. [29] developed an algorithm to identify patterns of human activities by analyzing mobile data and spatial analysis techniques.

Moreover, in Building Environment Assessment research, technologies such as Convolutional Neural Networks (CNN) automate the analysis of images, extracting data from Google Street View images and pictures from social media platforms like Flickr. Yang et al. [30] utilized the VGG-16 deep learning architecture, while Wang et al. [31] employed the DeepLabv3 model to learn about the physical environment, extracting semantic information from street view images to quantify the built environment.

Applying AI technologies like these is crucial in geo-design, offering diverse methods to analyze, understand, and quantify urban environments. Using social media and big data, researchers acquire valuable insights into urban dwellers' perceptions and needs, informing policy-making aligning with public interest. Automated image analysis in environmental assessments provides real-time, precise data essential for adapting to rapid urban changes.

3.3.3. Data-Driven Approach

The "Data-Driven Approach" theme of geo-design research focuses on leveraging AI and advanced data management tools for geo-design or combining multiple frames to achieve multidimensional data visualization. Based on a review of seven papers in this field, it can be categorized into two main distinct areas: Data Visualization (four papers) and Geospatial Data Management (three papers).

The data visualization field has enhanced the richness and clarity of maps through innovations in GIS systems and spatial analysis processes. Schiewe [32] optimized the accurate representation of geographic information through task-oriented data classification, integrating steps like interval selection and spatial unit aggregation, but was mainly limited to desktop GIS systems. To broaden understanding, geographic data visualization has evolved from 2D to more immersive 3D and 4D, with corresponding web interface designs. Lafrance et al. [33] enhanced public engagement and understanding of urban planning through web-based multidimensional visualization and interactive tools like timelines and animations. Deep learning technologies, such as GAN-based segmentation, effectively enhance the realism and precision of data visualization. Benita et al. [34] advanced the field with deep learning methods like SIDE and GANs, pushing forward automated and detailed reconstruction of building facades.

Furthermore, Geospatial Data Management focuses on the underlying logic and code of database construction to suit large-scale data processing. Burini et al. [35] proposed the J-CO

framework based on JSON format. At the same time, Bareche and Xia [36] developed the VeST indexing technique, and Wang et al. [37] implemented the STR method, all contributing to more precise and dynamic analysis of urban spatial data. These techniques allow for more accurate and efficient processing of larger-scale and complex urban spatial data in geo-design.

3.3.4. Urban Region

The "Urban Region" focuses on studies that contribute to our understanding of geo-design, how to use it in urban function, the health impacts of urban environments, and how urbanization affects ecosystem services, providing valuable insights for sustainable urban development and planning. Based on a review of 15 papers in this field, it can be categorized into three main distinct areas: urban function classification (7 papers), public health (3 papers), and urban ecosystem services (5 papers).

In urban function classification, prime studies like Luo et al.'s [38] leveraged POI data and kernel density analysis to identify urban functional areas based on special analysis tools with machine learning. Zhai et al. [39] introduced the Place2vec model, an advancement over conventional semantic models, for effectively identifying urban functional regions using POIs and K-means clustering. Xu et al. [40] and Zhao et al. [41] applied deep learning and graph neural networks for building function classification and pattern recognition in urban areas.

For public health, research like that of Peng et al. [42] and Benita and Tunçer [43] examined the impact of urban features on physiological stress responses, employing techniques like environmental monitoring and machine learning. Li et al. [44] explored how urban park features and psychological factors affect perceived restoration using methods like PPGIS and deep learning. Further, it underscored the transformative role of Geo AI in enhancing urban pattern recognition and building function classification.

Table 3. Analysis of themes and categories.

Analysis Theme	Category	Description	Citation
Transportation and Context	TOD Planning	Multi-objective optimization design based on nondominated sorting genetic algorithm III	[18]
	Traffic Flow Analysis	Uses machine learning, including SVM, KNN, PCA, RT, and Faster R-CNN, for vehicle detection.	[21]
		The ANST model combines LSTM and attention mechanisms for traffic forecasting.	[24]
		Using spatial context mining and a support vector machine model to identify transport modes from big data.	[20]
		Estimates urban intersection travel times using low-frequency GPS data, analyzing traffic patterns, and applying fuzzy fitting to calculate flow speed and delay.	[19]
		Using LDCF machine learning algorithm to automatically assess pedestrian volumes in urban areas.	[23]
	Transportation Management	Using a two-step method of spatiotemporal pattern extraction and Gaussian modeling for precise urban transport management.	[45]
		Combines road network analysis, street view images, and deep learning to efficiently identify signalized intersections.	[46]
	Transportation Safety	This study employs imagery and a deep learning-based model to detect marked crosswalks.	[22]
	Transportation Decision and Simulation	Enhances active mobility planning using deep learning DeepLabV3 segmentation trained on a WideResNet-38 model analyzing street imagery.	[25]
		Uses big data, pedestrian simulation, and AnyLogic to identify facility gaps and traffic issues.	[26]

Table 3. *Cont.*

Analysis Theme	Category	Description	Citation
Built Environment and Perception	Human Perception and Activity	Using multi-source big data and data mining to analyze influencing factors to optimize unsafe urban areas.	[47]
		Uses deep learning and random-forest algorithms to analyze human perceptions of urban spaces.	[48]
		Uses deep learning to explore how urban space characteristics influence people's emotional responses	[44]
		Analyses urban vitality's spatial patterns and driving factors using multi-source big data.	[49]
		Analyzes the built environment's impact on occupational diversity using GeoDetector-based indicators for in-depth analysis.	[1]
		Employs deep learning for image segmentation and NDVI to measure urban greenness.	[50]
		Utilizes a mix of text mining, image processing, clustering, kernel density estimation, and sentiment analysis to assess urban perceptions.	[28]
		Uses multiple linear regressions to analyze three types of urban residents' activity spaces at multiple geographic scales.	[29]
		Develops an analytical framework using mobile phone data to assess occupational diversity in urban areas.	[51]
		Uses machine learning to predict urban street running intensity.	[52]
		Analyses Dhaka's travel patterns using household diaries, artificial neural networks, and regression.	[53]
		Evaluating human perceptions of streetscapes using integrating PSPNET, attention mechanisms, and transfer learning.	[54]
	Building Environment Assessment	Develop a framework for assessing urban street quality using the DeepLabv3 model.	[31]
		Examines the Street commercial pedestrian block characteristics using Isovist_App software simulation and spatial analysis.	[55]
		This study employs machine learning and a Fully Convolutional Network (FCN) for image segmentation to improve street quality.	[31]
		Conducts a deep learning-based classification analysis of public space images.	[30]
		Leveraging semantic segmentation and information entropy models for assessing visual perceptual information in urban street spaces.	[56]
		Introduces a deep learning approach to comprehensively analyze the spatial ratios of streets.	[57]
		Employs GIS, deep learning DeepLab-v3 +model, and sensors to assess urban walkability.	[58]
		Examines how street greenery affects older adults' walking behavior using global (linear regression, Box–Cox) and local (geographically weighted regression) models.	[59]
		Utilizes deep convolutional neural networks to classify urban street frontages.	[60]
		Employs a multiscale analysis method and Multiscale Geographically Weighted Regression (MGWR) to explore the impact of environmental features on crime.	[61]

Table 3. *Cont.*

Analysis Theme	Category	Description	Citation
Data-Driven Approach	Data Visualization	Develops a task-oriented approach. The method enhances geo-design maps for change analysis by integrating spatial data preprocessing, local extreme value preservation, and context-aware classification techniques.	[32]
		Introduces a novel 3D-4D interface that combines GIS, geo-located data, high-resolution 3D models, and multimedia for immersive visualization of large space-time datasets in smart cities.	[34]
		Develops a deep learning method with GANs and Single image depth estimation for 3D reconstruction of building façades.	[62]
		Enhancing citizen engagement in urban planning, using dynamic, immersive tools for visualizing city evolution.	[33]
	Geospatial Data Management	Introduces VeST, a novel indexing model for efficient CKNN queries on moving objects in a distributed environment.	[36]
		Introduces STR, a multivariate hierarchical regionalization method for uncovering spatiotemporal patterns, focusing on spatial, temporal contiguity, and attribute similarity.	[37]
		Introducing the J-CO framework for analyzing JSON-formatted data sets to improve urban planning in regeneration and mobility.	[35]
Urban Region	Function Classification	Applied POI data from an online map service and kernel density analysis in various grid sizes to identify urban functional areas.	[38]
		Develop a machine learning approach with Random Forest, Support Vector Machine, and Naive Bayes algorithms to identify rural residential land.	[63]
		This study introduces and validates the Place2vec model for effectively identifying urban functional regions using Points of Interest (POIs) and K-means clustering.	[39]
		Focuses on classifying building functions in urban areas using deep learning techniques, specifically Graph Convolutional Networks (GCNs).	[40]
		The study introduces a novel deep neural network based on graph convolutions, designed to automatically identify patterns in building groups with arbitrary forms.	[41]
		This study introduces a method to identify and analyze influential urban regions using spatial interaction networks based on human movement data.	[64]
		This research proposes the Spatial Vector Deep Neural Network (SVDNN) model to measure the Multidimensional Poverty Index (MPI).	[65]
	Public Health	Examines the commercial pedestrian block characteristics using Isovist_App software simulation, big data statistics, and spatial.	[42]
		Utilizing environmental monitoring, machine learning explores the impact of urban features and environmental factors on physiological stress responses.	[43]
		Uses PPGIS, Deep Learning, and PLS methods to analyze how urban park features and psychological factors affect college students' perceived restoration.	[44]
	Urban Ecosystem Services	Investigate the relationship between urban spatial patterns and ecosystem services using spatial metrics and the Geographically Weighted Regression (GWR) model.	[66]
		Based on remote sensing and spatial analysis, the spatial and temporal changes of green space distribution and spatial and temporal patterns of green space distribution index were analyzed.	[67]
		Bivariate Moran's I and multiple regression are adopted to explore the equity of urban green space accessibility.	[68]
		This study uses land use regression to assess urban greening's impact on air pollution.	[69]
		Combines including rainfall simulation, remote sensing analysis, and semantic information analytics to identify flooded roads.	[70]

4. Discussion

4.1. Methodological Approaches

Image data types serve as a cornerstone in geo-design, enabling a wide spectrum of analyses that significantly enhance urban planning and environmental management. Tasks such as urban spatial patterns analysis and vehicle detection leverage high-resolution imagery to discern and quantify intricate urban layouts and vehicular presence, respectively. This data is pivotal in analyzing urban green space distribution, coupled with the quantification of ecosystem services, which provides a detailed understanding of environmental assets within urban settings. Studies focusing on the spatial association of urban greenness with dockless bike-sharing usage demonstrate the potential of image data to reveal correlations between environmental features and urban mobility patterns. Further, image data is instrumental in assessing street safety and evaluating the impact of built environment features on public health and crime occurrence. The Visual Perception Information Quantity of Street Space task underscores the ability to assess urban streetscapes' aesthetic and functional aspects. Beyond structural analysis, image data facilitates active mobility planning by enhancing urban walkability, contributing to healthier and more sustainable urban environments. In summary, image data underpins a diverse array of tasks within geo-design and planning and enriches the decision-making process by providing a multifaceted view of urban ecosystems and human-environment interactions.

Spatial distribution data encompasses information regarding geographical patterns and distributions. Land use data [18,63,69] aided in transit-oriented development planning, vulnerability identification, and urban green cover status assessment. Crop production data [63,65,66] contributed to quantifying ecosystem service, vulnerability, and measuring poverty. Ecosystem services, including water yield, soil conservation, carbon storage, and crop production, were evaluated using meteorological and soil property data [63,66]. Points of Interest (POI) analysis [37,39,47] facilitated diverse assessments such as street safety, urban functional region identification, and street space quality evaluation. Spatial distribution data aids urban planning, environmental conservation, and resource allocation. It enabled efficient land management and resource utilization. However, challenges may include data accuracy issues, evolving land use patterns, and the need for continuous updates to maintain relevance.

Spatiotemporal data encapsulates various information sets crucial for understanding spatial and temporal aspects of urban dynamics. Tracking data involving crowdsourced trajectory and check-in information [52] facilitated calculating road running intensity, offering insights into urban road movement patterns and utilization. Road network data analysis [31,47] aided in assessing street safety, diagnosing strategies for urban street space, and contributing significantly to urban planning and safety assessments.

Location coordinates sourced from diverse data sets such as China Mobile signaling data [59], dockless bike sharing records [50], cell phone location data [49], and travel location points (Sharmeen et al. 2020) offered insights into residents' distribution, spatial usage patterns, transport mode recognition, and understanding travel behaviors. GPS location data analysis [19,47,70] contributed to street safety assessments, estimating intersection travel times and providing valuable spatiotemporal insights crucial for urban planning, transportation management, and safety analysis. Spatiotemporal data involves information related to both space and time. GPS location data tracks positions at specific times, while road network data outlines connectivity and routes. Tracking data records movement paths aids in understanding mobility patterns.

Spatiotemporal data enables real-time tracking, navigation, and route optimization. It assists in transportation planning, disaster management, and logistics. However, challenges include data privacy concerns, accuracy issues in dense urban areas or mountainous regions, and the need for substantial storage and computational resources.

Numeric data encompasses quantitative information pivotal to demographic, economic, and infrastructure aspects. Socioeconomic data include indicators like urbanization rate, labor income per capita, and sown area per capita [63], providing insights into local

development levels. Factors like the secondary industry proportion, per capita fiscal expenditure, night light index, healthcare facilities, and phone access ratios aided in poverty measurement [65]. Population data and investigating population changes [61] elucidated the correlation between street-built environments and crime occurrence. Mobile phone data revealed patterns in population demographics, exploring urban spatial features related to COVID-19 transmission [42]. It also aided in understanding residents' activity space, occupation assessment, transport mode recognition, and modeling human movement [20,29,35,51,64]. Building and house data encompassing information on location, number of floors, house prices, and structural attributes played pivotal roles in assessing street safety, evaluating occupation mixture mechanisms, understanding street greenery's effects, urban image classification, and analyzing urban vitality [15,47–49,59,60,68]. Data for ridership, involving smart card data, residents' travel behavior, traffic flow, and environmental data, contributed to transit-oriented development, understanding street greenery's impacts on walking time, evaluating street walkability, and urban street planning [18,22,59]. Numeric data, spanning demographics to infrastructure, supports policymaking, urban planning, and resource allocation. It aids in understanding societal trends and transportation patterns. Challenges include data accuracy maintenance, ensuring representativeness in sampled populations, and privacy concerns related to demographic and ridership data.

Social media data comprises information from various online platforms, reflecting user-generated content and interactions. It includes textual, visual, or multimedia content shared by users across social networks. These data sources offer insights into various urban aspects. For instance, Huang et al. [28] leveraged Instagram and Twitter data to construct the social media image of cities. Gong et al. [29] utilized geo-tagged images and texts to identify residents' activity spaces. Peng et al. [42] and Wang et al. (2022) utilized Weibo data to explore spatial features of COVID-19 transmission and assess street space quality, respectively. Flickr data analysis aids in understanding urban public spaces [30], while WeChat data is utilized for historic neighborhood design [23]. The Baidu Search Index measures residents' mental well-being [71], and general search data is used to gauge city connectivity reflected in different languages [72]. Social media data offers real-time insights into public sentiment, trends, and user behavior. It aids in marketing strategies, trend analysis, and understanding public opinion. However, limitations involve data privacy concerns, data authenticity verification, and the dynamic nature of social media content.

Emotion data and environmental data are pivotal in understanding the emotional urban environments' practical aspects of the urban environment, encompassing physiological responses and perceptual variables, and provide insights into how urban settings influence human emotions and well-being. On the other hand, empirical data involves practical, observed, and experimental evidence, guiding evidence-based decision-making and policy formulation in urban studies. Emotion data, encompassing body skin temperature, electrodermal Activity (EDA), Health Stress Index, and the Wet Bulb Globe Temperature (WBGT), as studied by Li et al. [27] and Benita and Tuncer [43], provided insights into assessing essential qualities of urban spaces and understanding the impact of urban features and immediate environments on human physiological responses. Additionally, Li et al. [58] analyzed the perceptual variables questionnaire data, exploring the influence of urban park characteristics and psychological factors on the perceived restoration of college students, shedding light on the emotional and psychological impacts of urban environments on individuals. On the other hand, empirical data analyzed by Dong et al. [18] contributed to transit-oriented development and land use planning, providing practical, observational, and experimental evidence for urban planning strategies centered around transit-oriented development. Research such as that of Turhan et al. introduced an innovative "Mood State Correction Factor" (MSCF) for adjusting thermal environments to occupants' mood states, extending this approach to outdoor settings for pedestrian comfort [72]. Fan et al. also integrated machine learning with energy management to optimize consumption without sacrificing comfort [73]. This convergence of AI, psychology, and environmental science signifies a shift towards creating energy-efficient urban spaces attuned to the emotional

well-being of inhabitants, illustrating the potential for AI to foster more livable and responsive cities.

Emotion data and empirical data collectively offer a holistic view of urban dynamics. Emotion data provide direct insights into the emotional impact of urban settings, aiding tailored urban planning. Advantages include tangible physiological insights and evidence-based decision-making. However, interpretation complexities and subjective perceptions pose limitations. Empirical data's advantages lie in its factual basis for decisions, while limitations include biases, generalizability concerns, and the need for ongoing data collection and analysis in ever-evolving urban landscapes.

4.2. Strengths, Limitations, and Implications

Methodological approaches encompassed in urban planning and environmental management draw upon an extensive range of data types. Each data type serves a unique purpose, facilitating detailed analyses of urban layouts, green space distribution, mobility patterns, socioeconomic trends, and the emotional impact of urban environments on individuals. The strengths of these approaches lie in their ability to provide a comprehensive and nuanced understanding of urban ecosystems through the integration of sources. High-resolution imagery and spatial analyses enable precise assessments of urban features and dynamics, while socioeconomic and emotional data contribute insights into the human aspects of urban living.

However, these methodological approaches are not without their limitations. Data quality issues, privacy concerns, and the need for continuous updates pose significant challenges. The dynamic nature of urban environments, characterized by evolving land use patterns and shifting population demographics, requires adaptable and responsive research methods. Furthermore, the interpretation of emotional data and the subjective nature of some analyses highlight the complexity of understanding urban spaces through these lenses.

Despite these limitations, the implications of adopting such varied methodological approaches are profound. They enrich the decision-making process in urban planning and environmental management, facilitating the development of more livable, sustainable, and tailored urban environments. By leveraging the strengths of these diverse data sources while navigating their limitations, urban researchers and planners can enhance their strategies, ultimately contributing to healthier and more resilient urban ecosystems.

4.3. Comparative Analysis

Across these themes, AI technologies play a crucial role in enhancing the capabilities of geo-design and planning. While each theme focuses on different aspects of urban environments, they collectively demonstrate the versatility and impact of AI in addressing complex urban challenges. The transition from traditional methods to AI-based approaches signifies a paradigm shift in geo-design, offering more efficient, accurate, and comprehensive analyses of urban systems.

AI's integration into geo-design promotes a holistic understanding of urban dynamics, from transportation systems to human-environment interactions. The methodologies highlighted in these themes, including deep learning, machine learning, and data visualization techniques, illustrate the diversity of AI applications in urban planning. This systematic review underscores the transformative potential of AI in geo-design and planning, paving the way for more resilient, sustainable, and human-centric urban environments.

By comparing these themes, it is evident that while the applications of AI in geo-design are varied, the overarching goal remains the same: to leverage technology to create more efficient, sustainable, and livable urban spaces. The detailed categorization and analysis of AI applications within each theme provide a foundation for future research and development in geo-design, highlighting areas of growth and potential for further innovation.

4.4. Future Directions

Following the trends, it can be seen that data from various sources are popular data sources for a currently good AI model, or analysis requires strong data to back it, vis-a-vis good predictions and insights that can only be guaranteed by a good AI model. Keeping this fact in mind, the research highlights the use of crowdsourced data, which is prone to noise, outliers, and incomplete or unstructured data. It can also be unethical as the people reporting their data might not be consciously aware that their data will be used for studies. Considering these keys and disclaimers while collecting such data would be more ethical and ensure more clean data is collected. In the future, integrating large language models (LLMs), a state-of-the-art text-based and multimodal analysis technology, will be useful. Once again, its predictions and insights can be different every time, so a good framework for research might help structure the study.

5. Conclusions

This systematic review has elucidated the diverse and profound ways in which AI technologies are transforming the field of geo-design and planning. Researchers categorized these technologies into analysis themes and analyzed the literature trends and data inputs. Our extensive analysis of the literature from the past two decades reveals a marked trend toward integrating AI in various aspects of geo-design, including urban planning, environmental modeling, and infrastructure development. Adopting AI technologies, such as machine learning, neural networks, and spatial data analysis, has significantly enhanced predictive analysis, decision-making processes, and the automation of complex geospatial tasks.

The transformative potential of AI in geo-design and planning is evident in its ability to analyze vast and complex datasets, automate and optimize planning processes, and provide more accurate predictions and insights into urban and environmental dynamics. These advancements have enabled a more efficient and effective approach to urban planning and environmental management, leading to more sustainable and resilient urban environments.

However, the integration of AI in geo-design also presents several challenges. Concerns about data privacy, ethical considerations, and the need for interdisciplinary expertise are critical issues that must be addressed to ensure the responsible and effective use of AI in this field. The complexity and novelty of AI technologies require a comprehensive understanding of their application's technical aspects and societal implications in geo-design.

In conclusion, AI technologies hold immense promise for revolutionizing geo-design and planning. They offer new opportunities for addressing the complex challenges of urbanization, environmental management, and sustainable development. However, to fully realize this potential, addressing the accompanying challenges and fostering an interdisciplinary approach that combines technical expertise with an understanding of geo-design's social, ethical, and environmental dimensions is imperative. Future research should focus on exploring these interdisciplinary aspects, developing ethical guidelines for AI application in geo-design, and advancing AI technologies to meet the specific needs of this field. This will ensure that AI enhances geo-design and planning practices and contributes positively to creating sustainable, equitable, and resilient urban environments.

Author Contributions: Conceptualization, methodology, investigation, and visualization, M.C.; writing—original draft preparation, data curation, W.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data available in a publicly accessible repository. The data presented in this study are openly available in Web of Science.

Conflicts of Interest: The authors declare no conflicts of interest.

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Tel.: +41 61 683 77 34

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ISBN 978-3-7258-2376-5