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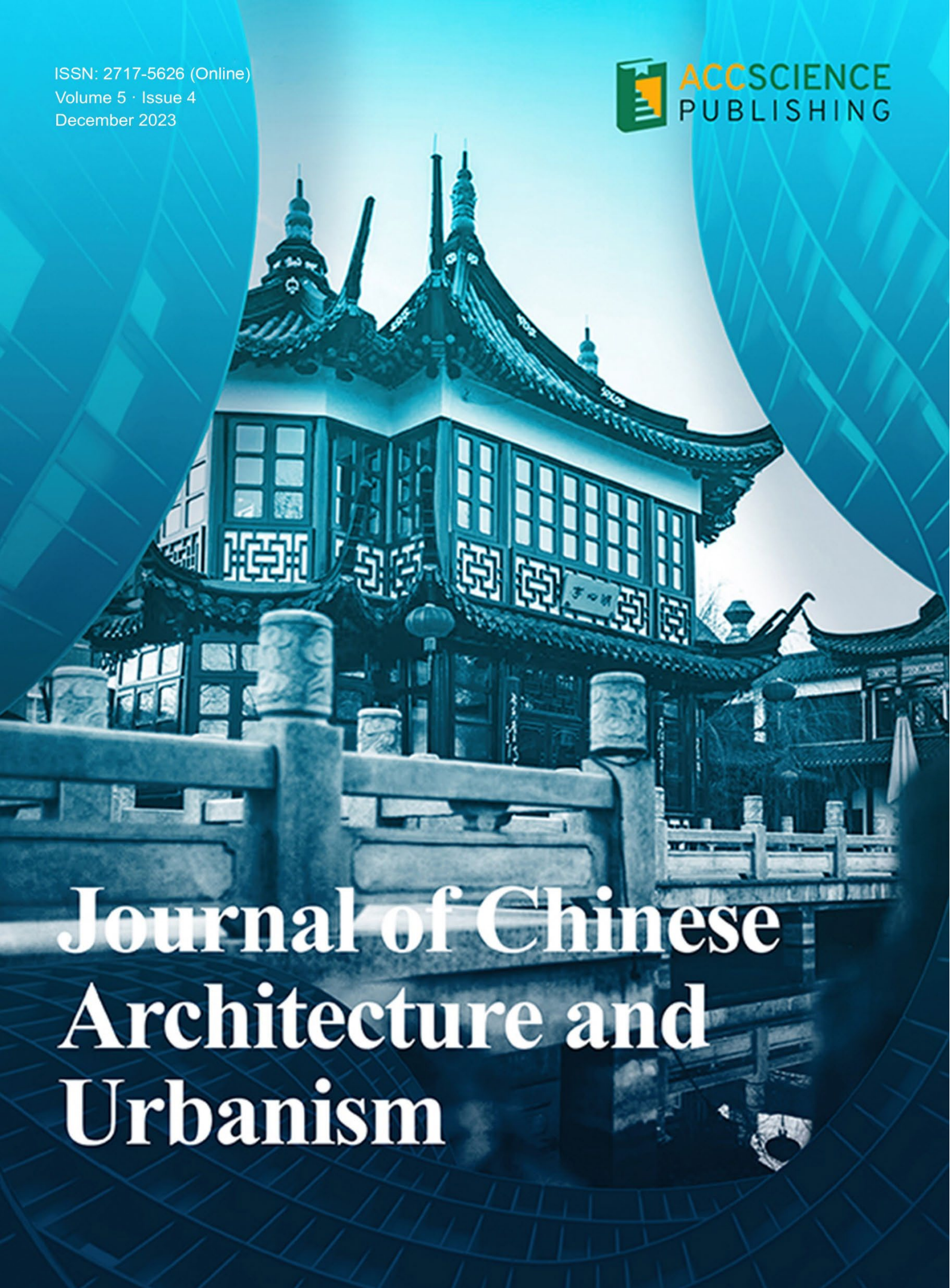

Journal of Chinese Architecture and Urbanism

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Journal of Chinese Architecture and Urbanism

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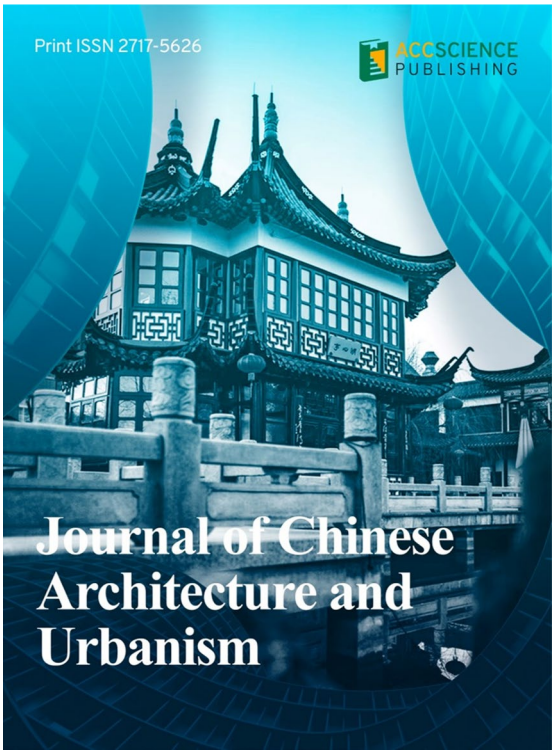

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A typical Chinese-styled building

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VIEWPOINT

Energy manifesto: Principles for regenerative architecture, arts, and design

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(This article belongs to the *Special Issue: Regenerative Architecture*)

Abstract

This viewpoint outlines the environmentally toxic view of energy that frames industrial modernism, which is fundamentally anti-life. An alternative, regenerative worldview is proposed, offering new ideals that are supposed to redesign the world by working in concert with the energies of the living world in ways that are fundamentally life-promoting. Centered on microbial metabolisms that form the living base of the biosphere, referred to as the microbial commons, the manifesto takes a decentralized approach to our engagement with energy so that diversity, resilience, and interdependence are valued through the commons of energies, which is powered by microbial metabolisms forming a substrate for regenerative design to enable the establishment of a vitalizing interspecies relationship with the earth, nature, and each other.

Keywords: Energy; Regenerative; Industrial; Commons of energies; Metabolism; Electrons

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1. Introduction

Regenerative design exceeds the performance of sustainable buildings that strive to be energetically neutral with respect to their context, by creating built environments that enrich local ecosystems (Fahmy *et al.*, 2019). The concept of energy is a key to the formation of these regenerative living spaces and habitats, which requires interrogation within a much broader context for a practice of the built environment that is compatible with an enlivened natural realm.

The word "energy" originates from the Greek word "energhéia," a concept that Aristotle associated with the state of being active or alive. This association with the life flow that sustains living things is also embodied in the Chinese concept of "qi" and Prana in Hinduism and Buddhism. Energy became an abstraction, a calculable force that was dissociated from the living world through the modern scientific understanding of the term.

The modern concept of energy is based on a reductionist and mechanistic view of the world, which regards energy as a quantifiable and transferable commodity that can be extracted, harnessed, and controlled for human purposes (Sorrell, 2015). This view of energy is closely linked to the dominant economic system, which values the marketplace, growth, efficiency, and profit over social and environmental well-being. Construction

processes established during the Industrial Revolution[1] prioritize economic productivity by carefully planning every element of a building to maximize its energetic and resource efficiency. However, this approach often overlooks the complexities and nuances of human experience and the natural environment (Edgerton *et al.*, 2014). Energy is deeply embedded in the living world and is largely accessed according to the essential need for the maintenance of life. Organisms obtain their energy through a variety of biological processes called "metabolism" that transform substrates (or food) into various metabolites, some of which are used immediately by the organism, while other products are stored or shared through ecological processes in nutrient streams and food webs. The ecological impacts of this command-and-control system have, therefore, led to a loss of diversity and adaptability, which makes buildings, spaces, and communities more vulnerable to changing environmental conditions and social needs, and are fundamentally anti-life (Holling and Meffe, 1996).

While "smart" technologies improve material efficiencies and enable more complexity within the practice of the built environment (Sassen, 2011); their associated infrastructures require significant amounts of energy and are expected to grow exponentially (Anderson, 2004). Although advances in renewable energy sources such as solar, wind, and hydropower reduce dependency on oil and gas, they do not change the underlying consumptive, exploitative paradigm underpinning their production, or use. A different conception of energy that enriches the natural realm is needed for human development to benefit our ecosystems (Armstrong, 2022).

Regenerative architecture supports fundamental life exchanges – from cooking to providing comfort and performing various kinds of housework – by orchestrating the metabolic transactions that form the living world (Armstrong, 2023a). Forming the base of the biosphere, microbes comprise most of these exchanges that take place within the microbial commons, which enables biochemical sharing, swapping, and lending – even between different species and *is open to all agentized actors.* Providing access to a coconstituted resource circularity in design the link between creating the site for the fundamental daily acts of living that provide the basis for all social transactions (Katz, 1983) and collectively, through their multitudinous types of metabolism are interlinked to form a much broader realm of metabolic exchange that comprises the *commons of energies*. These energies can be directly accessed and engaged as an energy source through the advent of microbial technologies that offer low-power electrical forms of energy capable of supporting a 12V power system (Armstrong, 2023b). When considering the human-infrastructure situated within a natural ecosystem, the work performed within regenerative architectures is, therefore, not exclusively directed inward and toward the organization of habitat, but through the actions of living microbes that comprise a vital force that animates and sustains all living beings.

The *commons of energies* are critical for the advancement of good regenerative design, which enables their just distribution to all the participating agents that make up a living space to bring about a local condition of enlivening (Händler-Schuster *et al.*, 2016).

This article offers a theory, materiality, and approach underpinning the concepts, design, and deployment of regenerative architecture culminating in a manifesto (Breton, 1972). This is a call to action for working with a living world in a state of constant flow, by engaging the metabolic exchanges of microbes through an emerging range of microbial technologies. By gaining access to the distributed *commons of energies* landscape, where consumption is constrained by the laws of nature, we can alter the impact of human development and become an enlivening force within the living realm.

2. The challenge of designing with flow

The strategic conceptualization and deployment of the flow of energy as a critical component of regenerative design can be linked through the principle of "qi" and physicality of microbial metabolisms. Naturally produced metabolic energy operates within the limits of biological exchange and can be creatively used in many ways – beyond power generation. For example, microbial metabolisms can be deployed to perform housework by turning organic matter into nutrients, cleaning wastewater, and generating bioelectricity, which can be strategically accessed through a technical system to reduce the overall environmental impact of how we inhabit specific spaces, while also reducing the operating costs of a building (Armstrong, 2023b) (Figure 1). Embracing a decentralized approach to energy that values diversity, resilience, and interdependence, regenerative design engages the *commons of energies* in ways that are compatible with an enlivening design process, to consolidate life-promoting relationships between people and the places they inhabit (Teubner, 2006; Gellers, 2021).A challenge arises when describing a modern scientific view of life as its irreducibly

[1] The Industrial Revolution refers to a period of major technological, economic, and social change that took place in Europe and North America between the 18th and 19th centuries. It was characterized by the widespread adoption of new manufacturing technologies, the growth of urbanization, and a shift from agrarian to industrial economies.

atomistic nature requires a mathematics of life to link the flowing logic of the living world to the dynamics of nonlinear computation (Chatelin, 2012) and with the fundamental materiality of the living realm through appropriate material platforms like dissipative structures (Prigogine, 1997). Collectively comprising a continuous, "Gaian" entity, this unevenly distributed flow of electrons is the fundamental characteristic of a lively world (Latour, 2017; 2018). Consequently, scientific theories of life and its origins remain incomplete. Working with living systems in an architectural context as a design substrate, therefore, requires perspectival adjustments so that it becomes possible to conceive and access the transactions at the base of the biosphere in new ways that lend access to its materiality without diminishing its vitality (Armstrong, 2019).

3. Electron flow as life's natural medium

The search for an alternative material perspective on the nature of the living world that reconciles ancient notions of flow, with science's fundamentally materialist perspective invokes some of the debates concerning the nature of life force around the turn of the 19th century. Equating "life" with electricity, Galvani's (1737 – 1798) "animal electric fluid" experiments demonstrated the principle of bioelectricity, when connecting fresh frog dissections to copper and iron wires that were inserted into different parts of their legs (Figure 2). When the wires touched, they produced movement, without requiring inputs from other external sources. Galvani concluded these observations meant that "animal electricity" – a fundamental life force that flowed through the body of a creature – had been demonstrated and seemed to be especially concentrated in the nerves and muscles.Volta (1745 – 1827), however, supposed the metal electrodes in Galvani's experiments, rather than the animal tissues, were the primary cause of the observed electrical activity. To demonstrate this, he used alternating discs of zinc and copper, separated by cardboard soaked in saltwater or an acidic solution to produce a small electrical current, which flowed through the wire when the top and bottom discs were connected by a wire (Figure 3). Initially, the voltaic pile was not strong enough to cause harm to a biological organism but nonetheless, established a significant milestone in the development of electrical power generation. Paving the way for more powerful, complex, and supranatural batteries (i.e., ones that could

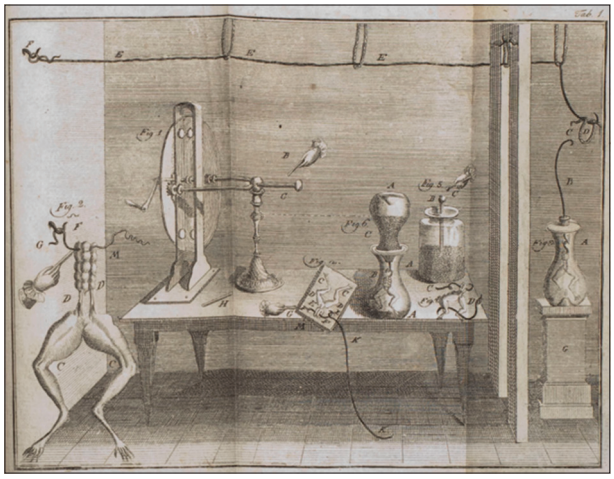

***Figure* 2.** Experiment De viribus electricitatis in motu musculari, Ex Typographia Instituti Scientiarium, Bononiae, Galvani, 1791, p58. Source: Drawing based on the original manuscript (Galvani, 1791; out of copyright); image available in the public domain

Figure 1. Provision of electricity based on the microbial metabolism of microbial fuel cells demonstrated by the *Active Living Infrastructure: Controlled Environment* installation, Dunkirk Triennale, June 2023. Source: Photo by Rachel Armstrong

Figure 3. Illustration depicting a voltaic pile, the first electric battery invented by Alessandro Volta in 1800. Source: Courtesy of Science History Institute, Reproduced from Volta, 1870 to 1900, p36, image available in the public domain: https://digital.sciencehistory.org/works/vkmmztt

generate far more power than living organisms, to the point where they could even cause them harm), his invention set the benchmarks for much higher power expectations and establishing a productive relationship between power and machines. By coupling electrons to the movement of metal, Volta separated the notion of energy from "life," and valorized increasingly more powerful sources to drive those machines capable of bringing about the Industrial Revolution.

The quality of electron flow produced by natural systems such as Galvani's organic electricity or "bioelectricity" is very different in its quality than the industrial energy produced by Volta's process. It is slower, more agile, less forceful, and can be used to alter the charge and configuration of molecules. Consequently, electrogenic activities that take place within physiological limits have the potential to perform metabolic work. Privileging power over all other outputs within these systems, this philosophical framework shaped the concept of energy for the modern industrial era, specifically through our relationship with electricity, which provided the most flexible mode of delivery.

Both observers proved to be correct about the nature of electricity, but in different ways. Generated from the flow of electrons, which are fundamental particles, electricity can be produced in many ways. It is both fundamental to nature, being a kind of transactional (bio) chemical currency that allows molecules to interact and transform their characteristics, and is also one of the most widely used forms of energy in modern society, which can reach supranatural levels when it is channeled through metal wires.

4. Electron transfer and chemical change

While industrialization remained the focus for the development narratives about electricity as an energy source, the *commons of energies* can be understood by advances in physiology and cell biology in the mid-20th century, where electrical phenomena were demonstrated to be pervasive in all biological systems – from the flow of ions across cell membranes, to the transfer of electrons in metabolic pathways (Hodgkin & Huxley, 1952). While these flows could never match the sheer force that was generated by chemical energy in batteries and subsequently, even more concentrated sources of energy through their coupling with machines, the energies of life proved to be more materially performative. Through the process of electron transfer, electrochemical processes produce physical effects based on change in atomic state that are distributed through time and space. This creative and versatile platform is capable of material change and essential to understanding the dynamic nature of living systems. The coupling of material properties to electron flow can be clearly seen in chemical systems like the Belousov Zhabotinsky reaction (Figures 4 and 5), where brightly colored fractal-like patterns are generated by electrons being passed between different atoms, which are reminiscent of dynamic computer-generated fractal images (Belousov, 1959; Zhabotinsky, 1964; van Roekel *et al.*, 2015).The diverse outcomes of electron transfer can clearly be captured at the human scale by establishing time-based self-organizing chemical systems (Figure 6) that can spatialize this transfer, which can be demonstrated by a range of dynamic chemistries from protocells (Armstrong, 2015; Armstrong, 2019) to Liesegang Rings (Armstrong, 2015) and osmotic structures (Leduc, 1911), and can account for how a physical system can alter over time.

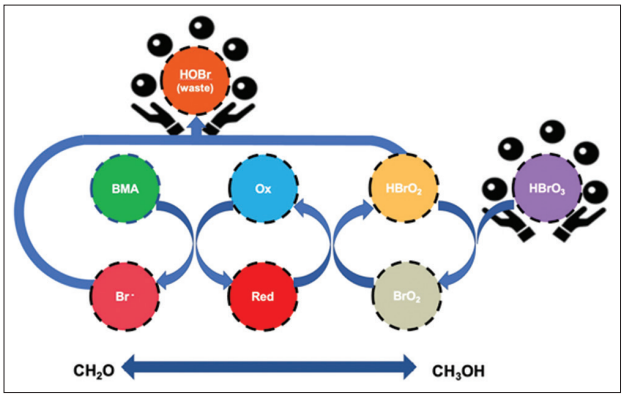

Figure 4. Diagram of the electron transfer system that provides the basis for the changing, emergent patterns that typify the Belousov Zhabotinsky reaction. Source: Diagram courtesy of Rachel Armstrong, Belgium, 2023

Figure 5. Electron transfer in chemistry can be seen in action when ions that receive and lose electrons change color, which is demonstrated here by the dynamic patterns of the Belousov Zhabotinsky reaction. Source: Stephen Morris, via Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Belousov_Zhabotinsky_reaction_(4297013382).jpg), licensed under the Creative Commons Attribution 2.0 Generic license (https://creativecommons.org/licenses/by/2.0/deed.en), cropped image.

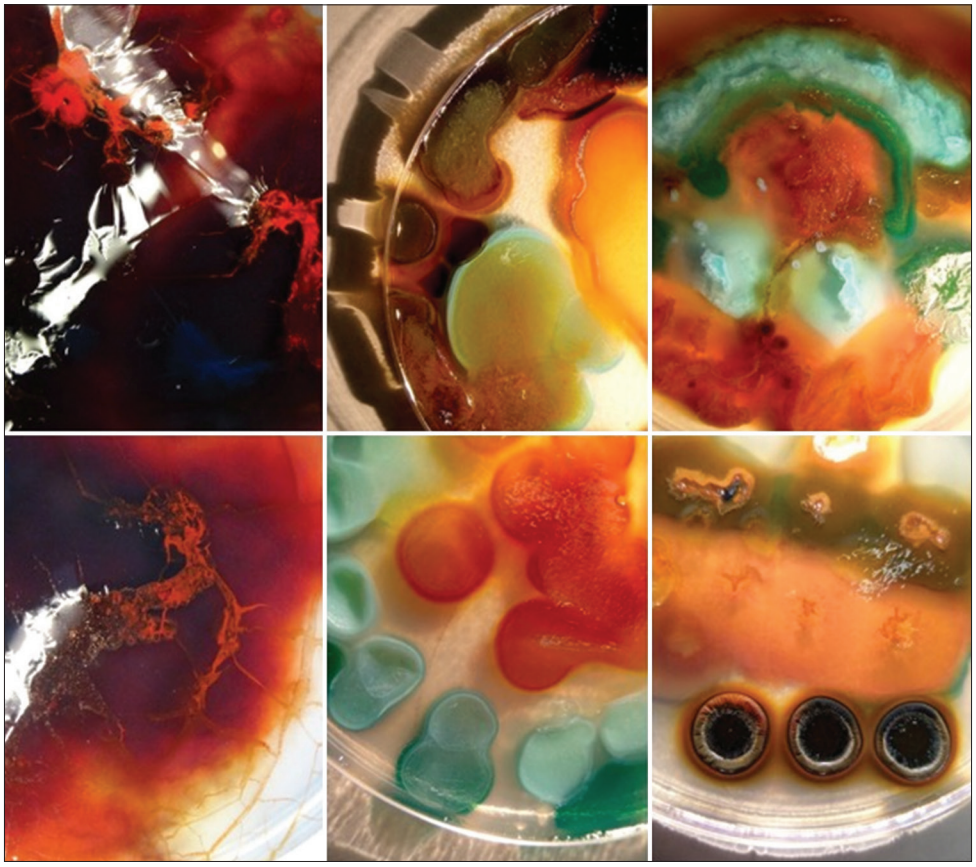

Figure 6. Spatialized chemical field produced by electron transfer systems require a different approach to design that move away from objects and geometries and invite the designer to consider designing with fields, reagents, interfaces that enable electron transfer at the basis of dynamic, metabolic exchange. Source: Photo courtesy of Rachel Armstrong, Newcastle University, 2015

5. Redox gradients as electron coordinators

The third millennium has brought insights into the role of redox gradients, which occur frequently in natural surroundings, exhibiting spatial and temporal variations, primarily observed in soils and aquatic ecosystems. These gradients arise from diverse physiochemical factors, such as oxygen availability, soil hydrology, chemical species composition, and microbial activities. In addition, chemical gradients also exist within cells, which are called the intracellular redox potential (McFarland, 2016). These gradients are maintained by highly regulated processes and compartmentalized within cells, being essential for normal cell processes (Mallikarjun *et al.*, 2012). These gradients enable the transfer of electrons between molecules in a series of reactions that generate energy through electron transport systems, which plays a key role in the production of adenosine triphosphate, the energy currency of cells. Electrical phenomena are widely recognized as essential to many biological processes, such as the transport of nutrients and waste products, the movement of muscles, and the transmission of nerve impulses, but all exist within the limits of molecular expression that are fundamentally creative and life-promoting.

The production of electrons provides a testable medium that can discuss the materiality of life because it provides a way of describing the flow of electrons and matter that is central to the behavior of living systems. At the macroscale, electron flow appears essentially classical in its overall behavior but at the molecular scale, it also exhibits fundamentally quantum characteristics (Al-Khalili & McFadden, 2014). Previously thought to be too hot, wet, and noisy to make use of quantum weirdness, quantum phenomena play a non-trivial role in biology where biomolecules tunnel through energetic barriers to carry out incredible chemical transformations; photosynthesis captures and stores the energy carried by photons from the sun and optically induced chemical reactions enable us to visualize the world (Fleming *et al.*, 2011). By understanding the flow of electricity and matter, we can gain insight into the workings of biological systems at the molecular level and potentially develop new technologies and treatments that harness the power of electrochemical processes to promote and support vital processes.

Scientific advances, in combination with advanced computing, have also enabled the dynamics of electrons in organic materials to be visualized through simulations that show how charge flows through molecular structures in real space and real time (Pelzer *et al.*, 2017). While scientific advances can now demonstrate electron transfer in organic systems, the principles do not transfer to work with design at the human scale. If we are to strategically manipulate "living" energy (i.e., electron flow in biochemical processes) within the metabolic flow of the living world as a design process, we must collaborate with the master engineers of this realm – the microbes.

Microbes are microscopic organisms that are around a micrometer (μm) to one millionth of a meter in size, and cannot be seen with the naked eye. Microbes do not simply act alone as individuals but use a range of sophisticated signaling systems to coordinate their interactions within their natural environment to form complex structures, their equivalent of our cities. To organize this process, they form a surface-adherent biofilm – an ancient mode of bacterial growth documented in the fossil record – which is produced by and contains bacteria as well as other microorganisms (Vega *et al.*, 2013).

When produced metabolically, the natural bioavailability of electrons establishes limits for performing work, so that matter and energy are coupled (not cleaved) and exchanged within a circular, yet evolving, context. Each material ecology can, therefore, be strategically metabolized using bioelectrical systems to perform all kinds of useful, creative work, without "borrowing" unlimited resources from next-generations, or elsewhere. The passage of electrons between atoms configures matter, produces physical space, and, as such, generates the basis for a changing environmental experience as a material phenomenon. The potency of this transformational capacity cannot be overstated. Bioelectricity can cross the mechanical and organic divide, providing energy and data for electronic systems and additional molecular transformation for organic systems, while working at much lower power thresholds than energy generated by fossil fuels or renewables. Whatever bioelectricity lacks in power; however, it makes up for through the quality of its operations, creating the potential for an era of low power (bio) electronics that is powered and informed by metabolic transactions occurring at room temperature.

A "living" technological platform that can bridge this organic-technological divide was developed in 1911 by Potter. Using the metabolic power of electrogenic anaerobic biofilms that produce electrons as they metabolize waste, he brought the worlds of electricity and biology together to create a "living" battery, or microbial fuel cell (MFC) (Greenman *et al.*, 2021). Potter's apparatus produced several hundred millivolts of energy through a technical choreography that engaged the vital electrogenic processes of *Saccharomyces* bacteria. Acting as biocatalysts, the microbes converted the chemical energy of organic matter from waste streams into electrons that flowed into an external circuit to provide electrical power for as long as they continued to be fed. This highly mediated relationship established a power-sharing relationship across mechanical and natural bodies that are neither entirely biological, nor exclusively mechanical. The resultant cyborg "being" – part microbial biofilm, part electromechanical system – thrives on different types of organic fuel to perform a range of metabolic tasks at room temperature, such as cleaning wastewater, generating bioelectricity, and detoxifying pollutants. While bioelectrochemical systems (BES) like the MFC produce much less power than renewables, and fossil-fuels, they uniquely set natural limits to its production, creating essential natural limits to electrical consumption.

The MFC is one example of a larger group of "living" BES[2] that represents different electrogenic biofilm-based bioreactors[3] that also includes microbial electrolysis cells[4]

[2] The effectiveness of bioelectrochemical systems (BESs) in urban spaces is being explored by the PHOENIX Cost Action Network. While the development, validation and cost-efficiency improvement of energy-aware and limited-complexity solutions are becoming increasingly time-consuming, microorganisms represent one realistic hope. For millennia, microbes have tirelessly been shaping the Earth's ecosystems and with the right approach, they can help re-introduce environmental equilibrium. PHOENIX demonstrates that BESs are low environmental impact systems that exploit the biological activity of live organisms for pollutant reduction, recycling of useful elements, synthesis of new products and production of electricity, in the case of microbial fuel cells (MFC). Recent advances in the field of low power electronics enable the exploitation of these sustainable and environmentally friendly technologies. The activities of PHOENIX will be related to the characterization of BESs technologies and their implementation as bio-remediator, biosensors, and bio-reactors connected to sustainable urban planning, educational and socio-economic aspects. The integration of biotechnologies in the urban context is a key priority for appropriate rational urban planning and minimum environmental impact. (www. https://www.cost.eu/actions/CA19123/)

[3] Bioreactors are vessels or tanks in which whole cells or cell-free enzymes transform raw materials into biochemical products and/or less undesirable by-products. The microbial cell itself is a miniature bioreactor; other examples include shake flasks, Petri dishes, and industrial fermenters.

[4] The microbial electrolysis cell (MEC) is one of the most efficient technologies for waste-to-product conversion that uses electrochemically active bacteria to convert organic matter into hydrogen or a variety of by-products without polluting the environment.

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and microbial desalination cells.[5] The importance of the MFC is that it is the only type of BES that produces harvestable amounts of electricity that is in the goldilocks region for household use – not too much, not too little, but (in an emerging era of low power electronics) it is *just right*. Potentially, then, MFC arrays can process household waste to create a currency of energy through ion and electron flow that is capable of supporting aspects of modern lifestyles based on mechanistic low-power energy systems, in ways that can incorporate the life-promoting impacts of microbial systems.

The types of apparatus that enable technologies that work within biological limits are exemplified by projects and installations that I have coordinated, namely, the *Living Architecture* project, the installation *999 years (the future belongs to ghosts)* and the *Active Living Infrastructure: Controlled Environment* prototype (Figure 7). All these demonstrators are discussed in this issue and will not be further detailed here (Armstrong, 2023b).

6. Strategically accessing the commons of energies through microbial electronics

The discovery of cable bacteria in marine sediments is a revolutionary finding, as they are centimeters long and can be seen with the naked eye. Cable bacteria mediate an electron current and can induce geochemical changes in the sediment, as well as attract other bacterial groups, which appear to benefit from the electrical connection to oxygen (Risgaard-Petersen *et al.*, 2015). The electroactive microbes that gather around cable bacteria form larger communities that generate specialized structures (nanowires, cables, and membranes), which electronically interact and modulate complex metabolic networks at cellular and multicellular levels. Being so large, cable bacteria offer a workable structural system that can be designed and engineered to strategically channel the flows of microbial electricity with more precision than is currently possible using biofilms (Bjerg *et al.*, 2023). Essentially, these microbes can be thought of as "living wires" that are compatible with traditional electronics, but also provide ways of accessing the *commons of energies* in a more directed way than can currently be achieved with electrogenic biofilms.

Although microbes are not biological equivalents of electronic circuits, their functions will likely be compared to and compatible with low power versions of classical electronics, for example, transistor, resistor, and conductor. However, their biology also involves multiple, concurrent (metabolic) activities, for instance, electron transfer systems, and coupled redox reactions that generate material and informatic changes, such as metabolism, growth (nanowires and cables), color change, and so on (Atkinson *et al.*, 2023), with the potential to offer additional features and functions to components that are not possible in conventional electronics (e.g., self-repair, secreting insulation to prevent loss of signal) (Figure 8). These metabolic networks (redox potentials) and electronic components (resistors, capacitors, and transistors) are also likely to be embedded and responsive to their environment, rendering their properties plastic, situated, dynamic, unstable, and robust. With the potential to work synergistically with the environment, microbial electronics will recognize their surroundings and work with them as a processing adjunct, rather than an extraction site, establishing a fundamental change in the relationship between metabolism (matter in a state of flow), materials production and energy performance. The advent of a new field of electroactive materials that secures access to the *commons of energies*, with concurrent capabilities in information processing, material transformation, and the use and distribution of energy, also lends to the possibility to be further optimized through additive manufacturing and control engineering, in the quest to establish a biodegradable platform for sustainable electronics with complex functions.

7. A new thermoeconomics for the home

To create the conditions for a regenerative society, the *commons of energies* must be managed through a new *thermoeconomics* so that decisions can be made through a different framework for considering the dynamics and

[5] A microbial desalination cell (MDC) is a biological electrochemical system that implements the use of electro-active bacteria to power desalination of water in situ, resourcing the natural anode and cathode gradient of the electro-active bacteria and thus creating an internal supercapacitor.

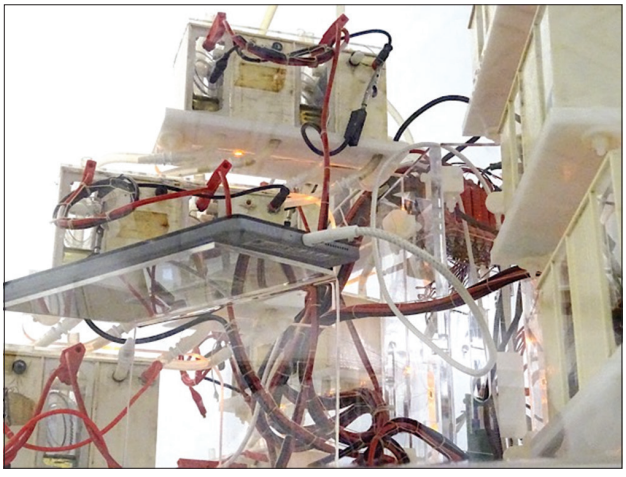

Figure 7. *Active Living Infrastructure: Controlled Environment* installation, a network of LEDs and iPads powered by 15 MFCs, as an autonomous self-powering system. Source: Photo courtesy of Rachel Armstrong, Dunkirk Triennale, June 2023

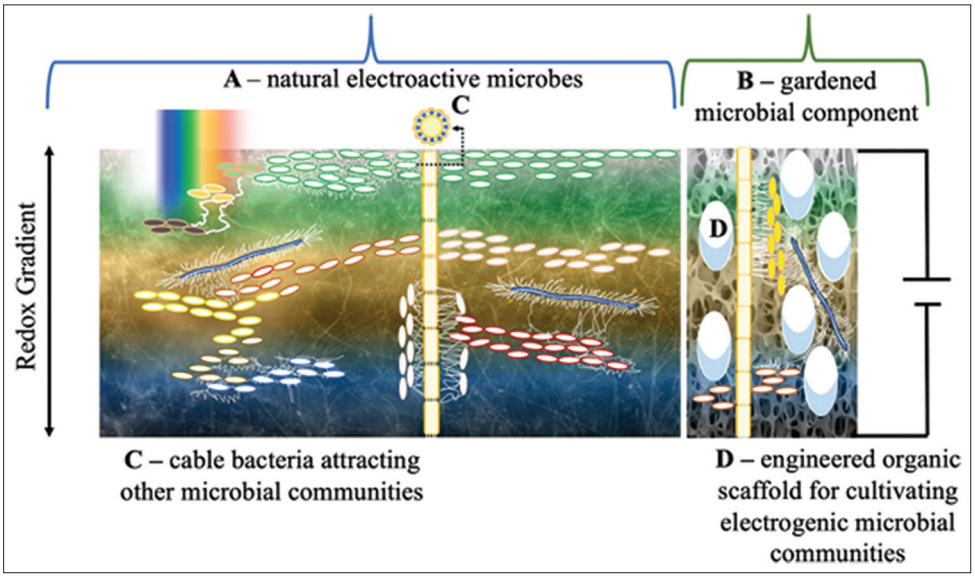

Figure 8. Microbial electronics providing access to the *commons of energies* is shown as an ecosystem of potential configurations in (A) natural electroactive microbial communities in "electric mud" that (B) are "gardened" on bioscaffolding as an electroactive component actuated by interdependent electroactive microbial communities. Fine white lines represent microbial electron paths as nanowires, cables and shuttles. A transection through cable bacteria is shown center-top (C) and semiconductive organic scaffoldings designed to channel the growth of microbes and transfer the electrons they generate are connected to a conventional electronics circuit (D). Source: Diagram drawn by and courtesy of Rachel Armstrong

concepts of energy use through microbial electronics (Garrett *et al.*, 2020). Existing electrogenic "living" technologies like MFCs can produce sufficient bioelectricity to become a material and epistemic agent for a circular economy of exchange within the household (an oikonomy). With the advent of microbial electronics, such "living" systems could ultimately replace modern utilities systems by transforming the kinds of housework performed within a living space. While enabling direct real-time exchanges with microbes, "living" technologies can represent data in appealing and direct ways, whereby it is possible to become aware of the important contribution that electrogenic organisms like microbes make to our life world through their active metabolisms. Setting such natural limits to our daily routines through how much waste we generate and the amount that can be metabolized by microbes is not about reducing our quality of engagement with the world but establishes creative limits on our usage, which catalyzes new rituals of care. For example, more creative use of materials may be used in heating (insulation) and cooling (materials with high thermal mass like stone) specific spaces in our home, embracing microclimates rather than maintaining a uniformly constant milieu. In this way, we do not just consume our surroundings but, through design, can ensure that every action can give something priceless back to our incredible, vibrant world through the *commons of energies* that is founded on the regenerative energies of life. Forged by the community of life's metabolisms, the *commons of energies* enable the creation and flow of living energy through various metabolic processes. Forged by the whole community of life's metabolisms, the *commons of energies* are, thus, a shared resource that is essential to the survival and flourishing of all living beings, which can potentially be designed, engineered, and even negotiated, by living communities of electrogenic microbes working in concert with human-readable information systems like artificial intelligence. The sustainable management of this resource requires a holistic approach that recognizes the interdependence of all living organisms and the need to maintain the health and integrity of ecosystems. Since bioelectricity is a critical and tangible system of transactions generated by living systems, which is manifested as life in flow, a specific ethics and appropriate value systems are also needed to ensure the appropriate responses and rituals of (mutual) care in their handling are upheld through the relationships forged within their ecosystemic contexts. Ultimately, being able to experience the energy flows through our living spaces through our daily rituals and interactions has the potential to bring about a transition in our environmental impacts through collective actions, and shared ecological responsibilities where a new kind of electronics communicates with human-design and machines to establish mutual exchanges that are in conversation with the living world, rather than consuming its resources (Figure 9). In this way, a *new thermoeconomics*, based on access to the *commons of energies*, which is enabled and regulated through microbial electronics, has the potential to transform the impacts of

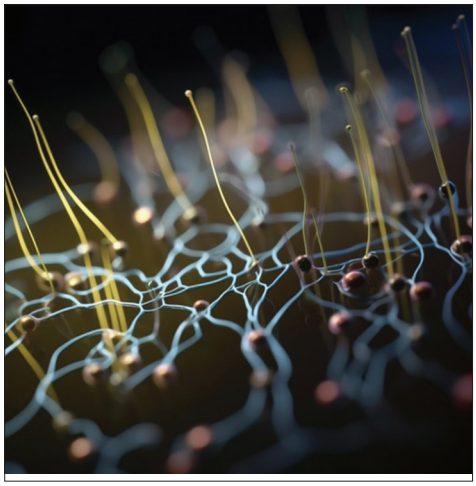

Figure 9. Future microbial electronics energy network "imagined" by artificial intelligence and co-designed by electrogenic microbes at the microscale. Source: Image courtesy of Rolf Hughes, created with Midjourney, 2023

human development so they promote enlivening of local ecosystems through the healthy, equitable, and sustainable flow of electrons through many different bodies.

Subverting the modern expectations of what a "good" home may be the design of metabolic electron flow is, therefore, valued through its contributions to the living realm by increasing the liveliness of its communities and transforming our behavior into invisible acts of environmental care, which is fundamental for sustaining the world. No matter how living architectures are deployed, we are accountable for them through the mutuality of everyday relationships, and to behave in convivial ways, they will require our socialized engagement with them (Latour, 2012). Through the maintenance of day-to-day interfaces, metabolic choreographies, and myriad acts of care, our homes may even acquire a unique character and inner "life" – perhaps, even a unique vitality, or spiritual dimension that (re)confers the concept of energy with sacred qualities that are a precondition for life itself.

8. A manifesto against the modern industrial energy: For a new thermodynamics

1. Energy should be considered a fundamental human right, and access to it should be guaranteed to all, regardless of their social or economic status.
2. Access to energy resources should be based on principles of sustainability, equity, environmental, and social justice, establishing a new thermoeconomics. This means that the extraction, distribution, and consumption of energy should be guided by ethical and ecological considerations, and not by profit-driven motives.
3. We believe that the commons of energies represent a transformative vision for the future of the relationship between humanity and nature, one that is based on cooperation, solidarity, and respect for the planet and its people. The commons of energies represent the shared heritage of humanity, a legacy of knowledge and creativity that transcends national borders and individual interests. The commons of energies encompass all forms of energy, from the sun and wind to geothermal and hydroelectric power, and beyond. These energies are abundant, renewable, and accessible to all, and their benefits can be shared by everyone. By embracing this vision based on a new thermoeconomics, we can build a more sustainable, equitable, and just society, one that honors the legacy of our different pasts, the complexity of our many presents, and the promise of our many futures.
4. We reject the consumptive, toxic paradigms of industrial modernism that has led to a sense of alienation and disconnection from nature and from our own inner selves, to embrace a more holistic and life-affirming approach through the regenerative energies of life that can help us to reclaim our sense of purpose and meaning in relationship with the natural realm.
5. We condemn how modern industrial energy paradigms have colonized technology, people and nature, and have burned hydrocarbons in the pursuit of a god-like project to acquire unprecedented power for the few. We abhor the environmental degradation, social inequality, and other forms of harm and exploitation of the many that such practices engender, and instead seek to distribute the natural energies of life through our everyday activities to empower, and establish a more just and sustainable society of distributed, constantly flowing energies.
6. We invite beings from all other species and walks of life to participate in the commons of energies that operates within the natural carrying capacities of bodies and local habitats, without robbing resources from other locales, beings, or generations.
7. We invite such kith and kin to embrace their inner creativity, intuition, and spiritual connection, and to make mutually beneficial exchanges through a currency of electrons to create a more just, sustainable, and life-affirming world.
8. We, the multitudes of beings entangled in the web of life, find ourselves at an energetic crossroads. The planet we call home is facing unprecedented ecological and social crises, driven by a voracious extractive economy and exploitative modern industrial energy systems that value transient profit over sustained investments in people, the living realm, and the planet.

9. We declare that energy is at the heart of these crises. The way we produce, distribute, and consume energy is profoundly unjust and unsustainable. It perpetuates social and environmental inequalities, destroys ecosystems, and fuels the climate emergency.
10. We reject the dominant energy paradigm that relies on finite, polluting, and centralized sources of energy, such as fossil fuels and nuclear power. We refuse to accept the false promises of technofixes that perpetuate the logic of domination and control.
11. Instead, we embrace the commons of energies that value diversity, resilience, and regeneration. We recognize that energy is not a commodity to be owned and traded, but a fabric of transformational potentiality to be shared and cared for. We demand that this transition be led by frontline communities, workers, peoples, creatures, and all affected beings, who have been historically excluded from decision-making processes. We honor the knowledge and wisdom of indigenous and traditional peoples who have shared the commons of energies through distributed and just means to live in harmony with the living realm and have done so for millennia.
12. We envision a world where energy is generated and consumed locally, where communities have control over their energy systems, and where energy is used for the common good rather than private profit. We recognize that this requires a radical transformation of our social and economic systems, based on principles of equity, solidarity, and mutual aid.
13. We commit to building alliances and networks of resistance and solidarity, across borders and differences, to challenge the power structures that perpetuate the energy injustices we face. We invite all those who share our vision to join us in the struggle for a world of energies that sustain life, enhance diversity, and foster creativity.
14. The commons of energies should be managed collectively as a shared project and economic system embraced by the community of life, through metabolic processes that ensure that decisions about energy production and distribution uphold the liveliness of the natural realm.
15. The development of living technologies, which sustain the commons of energies through distributed and just systems, should be prioritized over all other forms of energy. Research and development of innovative "living" technologies like BES should be encouraged to promote energy efficiency and establish circular principles of exchange through negotiations through microbial electronics that eliminate the very concept of waste.
16. The commons of energies should be protected from privatization, corporate control, and state domination, and defended as a common heritage of humanity. This means that governments and corporations should not be allowed to exploit energy resources for their own profit, but rather distribute the flow of energies equitably to serve the common good.
17. We are not alone. We are many. We are entangled. We are energized.

9. Conclusion

The concept of regenerative design offers a profound departure from traditional approaches to sustainable buildings and energy usage. It goes beyond striving for mere neutrality and sets out to create built environments that actively enrich and contribute to local ecosystems. By engaging with the ancient notions of energy as a life force and rethinking the reductionist and mechanistic view of energy, regenerative design seeks to establish a harmonious relationship between the built environment and the natural realm.

Drawing parallels with the concepts of "qi" in Chinese culture and "Prana" in Hinduism and Buddhism, energy is a vital force that sustains all living things. The modern scientific understanding, however, has often divorced it from the living world, leading to an exploitative paradigm focused on economic productivity. This approach has had negative ecological impacts, resulting in a loss of diversity and adaptability.

Regenerative architecture proposes to heal this rift created by modernity by considering how microbial technologies can harness the power of electrogenic biofilms to bring about a novel way of working with the electricity of life via integrating microbial electronics into the fabric of our daily lives. These living technologies offer a unique potential to access the commons of energies in a way that respects natural limits and fosters mutual exchanges with the living world. The use of microbial electronics can transform the way we inhabit spaces, enabling creative and sustainable solutions for energy generation, waste treatment, and even information processing.

Such advances cannot exist alone and a new thermoeconomics is needed to establish a holistic and ethical approach for managing the commons of energies as a kind of marketplace where natural and engineered forms of energy can be exchanged. Such an approach recognizes the interconnectedness of all living organisms and the importance of maintaining ecosystem health. By embracing regenerative design and working with the natural flows of energy, we can move toward a more enlivening and mutually beneficial relationship with our environment.

A paradigm shift in how we approach the design and utilization of energy is possible by embracing regenerative design principles and integrating microbial technologies to

create living spaces that not only sustain but also enhance the natural world. This transformation can lead to a profound impact on our environmental footprint and bring about a future where human development is harmoniously embedded within the living realm. The journey toward regenerative living spaces is not just a technical or architectural challenge; it is a deeply philosophical and ethical endeavor that calls for a reevaluation of our place within the broader ecosystem of life.

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Conflict of interest

The author declares that there are no competing interests.

Author contributions

This is a single-authored paper.

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Not applicable.

Consent for publication

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ACCSCIENCE PUBLISHING

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ORIGINAL ARTICLE

An analysis of the spatial morphology of cohesive village in Leizhou Peninsula of western Guangdong Province

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(This article belongs to the *Special Issue: Vernacular Architecture: Typology and Regionalism*)

Abstract

There is a cohesive village with a highly geometric spatial form in the Leizhou Peninsula of western Guangdong province. Due to the lack of historical records, scholars generally believe that the spatial form of this village is a variation of the local comb-type village, influenced by the typical village form of the main migration areas and provincial administrative regions. However, the evolution of this village form in the area did not exist. The existing studies are unable to explain the development of cohesive villages. Through field research combined with spatial observation techniques, this work explored the spatial form generation mechanism of the cohesive village from two aspects, natural environment adaptation, and social environment adaptation and found that there is a spatial form isomorphism among this village and the cross-administrative comb-type village, and the "nine dragons toward a pearl" village. The established clues are based on isomorphism that can provide a reference for the exploration of the cohesive village and offer new perspectives and methods for the study of the culture of similar dwellings where historical data are lacking.

Keywords: Leizhou Peninsula; Cohesive village; Spatial morphology; Isomorphism

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1. Introduction

The previous studies on traditional villages have focused on typical cases, with weak cognition of cultural commonalities and differences at the regional level, much focus on the core range, and insufficient recognition of village culture in the peripheral areas. However, culture is transmitted at the regional level, and spatial form is an element of planning and design, as well as a material carrier of political, economic, and cultural change. Taking the isomorphism of spatial forms as an entry point, studying atypical traditional villages in marginal areas can help recognize the generational mechanism and evolutional law of traditional villages in a more profound and systematic way and in a broader scope. Research in this aspect also provides clues regarding the village culture with missing historical data and provides the basis for unified protection and utilization of traditional villages to assist in rural revitalization.

The Leizhou Peninsula is in the southwestern part of Guangdong province, the southernmost point of mainland China. The research found that there is a special kind of cohesive village in the Leizhou Peninsula. The standard spatial form of a cohesive village

is characterized by the vertical arrangement of courtyard residences, with the ancestral hall or a pond located at the entrance of the village that provides access to all directions, generally in the shape of a fan. It is laid out in a more centripetal manner than other villages, with a highly geometric characteristic (Figures 1 and 2). Due to the lack of historical records, no scholars have yet conducted research on cohesive villages. The same village form has not been found elsewhere in Guangdong, indicating that it is unique to the Leizhou area (Tao *et al.*, 2021). The author believes that exploring the generational mechanism of the spatial form of this village will help generate a more comprehensive and profound understanding of the traditional village culture in the Leizhou Peninsula.

2. Natural environmental adaptability of village spatial form

During the field research, it was found that the terrain of this type of cohesive village is low in the front and high at the back. According to the "Genealogy of Luling Zhou Gong in Western Guangdong" of Zhou Family Village in Suixi County, the seventh-generation grandson of Zhou Fu, Zhou Liang, and Zhou Ze moved to Zhou Family Village in the 1st year of Hongxi of the Ming dynasty (1425) and chose a low-lying place to build the village. According to local people, this construction method has the *feng shui* symbolism of "each new generation will be better than the previous one." Analyzing the natural environment of this spatial layout, the topography of the Leizhou Peninsula can be divided into three categories: Basalt platform (43.3%), marine terraces (12%), and marine plains (17.4%), but the cohesive villages are mainly located in the marine terraces with gentle terrain below 25 m above sea level (Table 1) and are often located on the many flat slopes, low-lying land, and depressions interspersed between them (Figures 1 and 2), resulting in backdrop characterized by low terrain in the front and high terrain at the back.

The Leizhou Peninsula is located in the subtropical coastal region. Despite the frequent typhoon occurrences in this region, the uneven rainfall, efficient evaporation,

Figure 1. Typical cases of the cohesive village form. Source: Google Earth

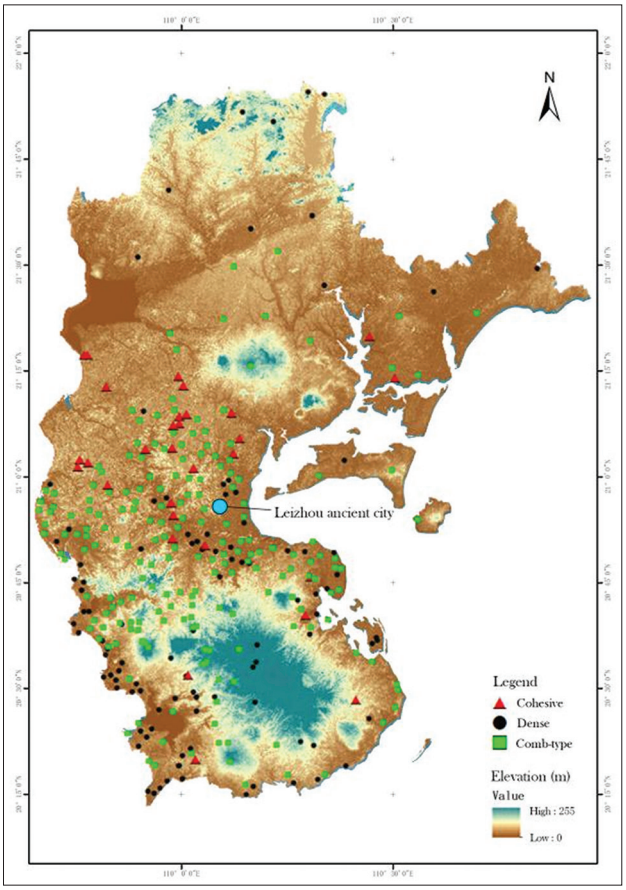

Figure 2. Elevation distribution map of the cohesive village

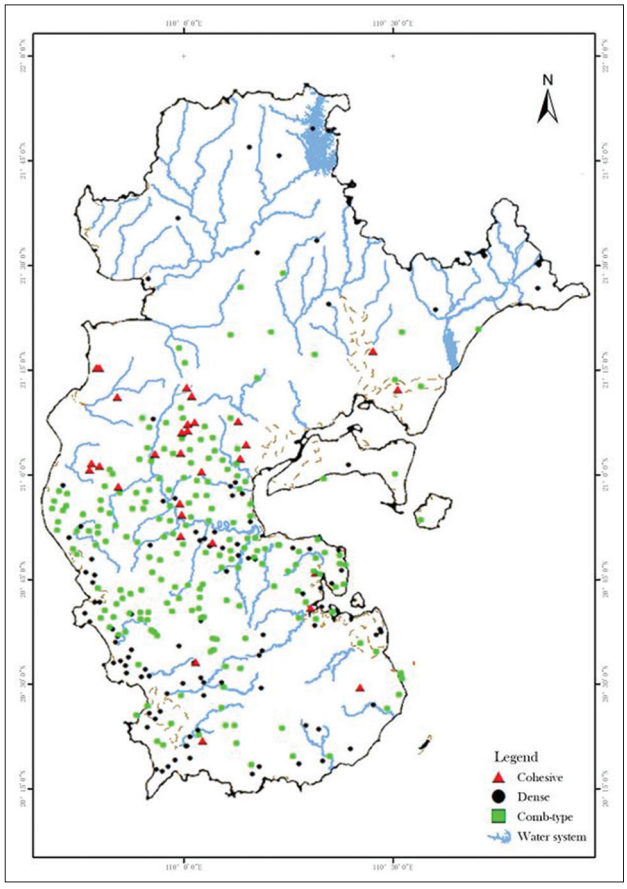

Figure 3. Water system distribution map of the cohesive village

Table 1. Number of traditional villages classified by topographical distribution in Leizhou Peninsula (PCS)

Village type / Terrain topography	Cohesive	Dense	Comb-type
Basalt platform	0	9 (3%)	19 (2%)
Marine terraces	72 (92%)	10 (4%)	385 (51%)
Marine plains	4 (5%)	197 (71%)	260 (34%)
Waterfront	2 (2%)	60 (22%)	98 (13%)

and long hours of sunshine contribute to a climatic condition characterized by high temperature and drought. Most of the cohesive villages are far from surface water systems (Figure 3). Because the terrain is low in the front and high at the back, the village adapted the difference in elevation for water storage in the direction of cohesion. There are water storage ditches perpendicular to the main lane along the front and back of the longitudinal houses, and the water stored by each household is first collected into the storage ditch through their own ditches, and then through the storage ditch of the main lane straight to the reservoir in front of the village for water storage. When typhoons arrive between July and October, rainfall on the Leizhou Peninsula can reach more than 400 mm (Huang & Zhou, 2001). In this case, the water storage system of the cohesive village is transformed into a drainage system, which can effectively prevent waterlogging in the rainy season (Figure 4). In addition, the low-lying topographic site, cohesive roadway planning, and regular building layout are also very effective in resisting typhoons.

The village is surrounded by greenery, and the trees are planted in a cohesive shape. Water-tolerant and light-loving banyan trees dominate these areas. These plants can withstand strong sunlight radiation and regulate microclimate on the one hand, and play a defensive role on the other. Some cohesive villages even plant a small forest between the dwellings and the pond, which not only protects the dwellings from the wind and holds the sand but also conserves water. The exterior of the building is closed but the interior is open, except for the general residences of a few well-off official families. These residences are relatively small in area, with a building height of about 2.5 m, and the buildings are located at low terrains, hidden in the woods, to defend against bandits, and repercussions of strong wind.

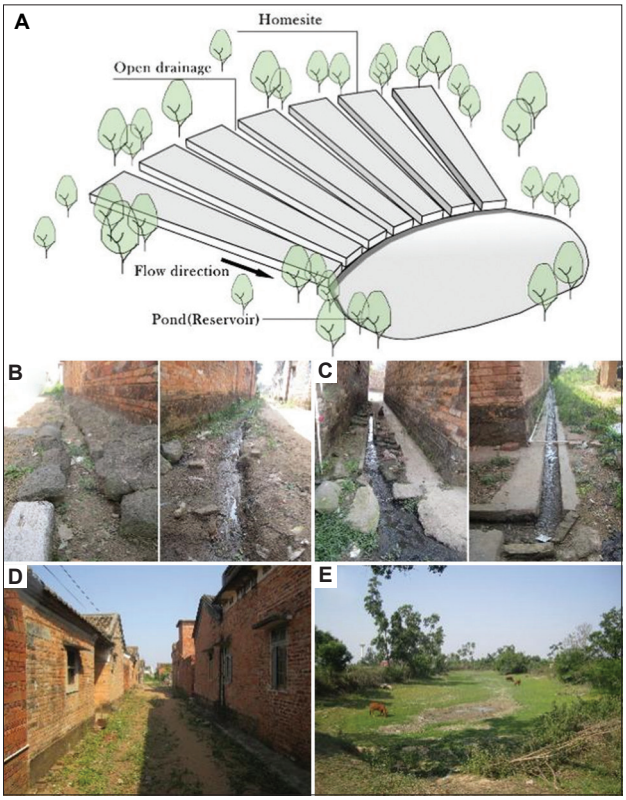

Figure 4. Storage–drainage system in the cohesive village (Xinpozai Village, Kelu Town). (A) Schematic diagram of storage and drainage system in cohesive village. (B) Water storage ditch of the main lane. (C) Residential water storage ditch. (D) Main lane. (E) Water pond in front of the village during the dry season. Source: Drawing and photos by the author

3. Social environmental adaptability of village spatial form

The Leizhou Peninsula was used to be the land of Luo Yue, which is vast and sparsely populated. The existing traditional villages were built in between the Tang (618 – 907) and Song (960 – 1279) dynasties, and the Ming (1368 – 1644) and Qing (1616 – 1911) dynasties, the periods in which the migration of immigrants caused significant changes in the demographic composition of the Leizhou Peninsula. The reasons for immigration can be summarized into four aspects: (i) The migration caused by war, such as the end of the Southern Song dynasty (1127 – 1279), the invasion of Yuan (1206 – 1368) soldiers, the southbound movement of Song family, and the movement of a large number of Min people into the Leizhou Peninsula along the sea route; (ii) the government's policy of migration, such as the Tang (618–907) dynasty's policy of "migrating Min people to Hezhou" to consolidate border defense (former Hezhou is today's Leizhou); (iii) the migration of a large number of Min people to the Leizhou Peninsula as a result of maritime trade, especially after the opening of Xuwen Port by Han Dynasty government to establish the Maritime Silk Road, and the relocation of Silk Road city from Guangzhou during the Tang and Song dynasties to Quanzhou during the Ming and Qing dynasties (Liu, 2002); and (iv) the banishment or suspension of aristocratic officials (Jin, 2009). During this period, the Putian people from Fujian province gradually became the main population of the Leizhou Peninsula. In addition, Zhejiang people adjacent to Fujian, Chaoshan people, Guangfu people, Hakka people in Guangdong, and Central Plains people in Henan, Jiangxi, and other areas moved in with them (Cai, 1988; He, 1986; He, 2018; Liu, 2015; Zhang, 1974). At this time, government control over the Leizhou Peninsula gradually increased, and the clan culture in the villages flourished exceptionally.

3.1. Spatial form of the village in line with the ideal model of the clan

The spatial form of the cohesive village can meet the needs of both single- and multiple-surname clans. For single-surname clans, some of their villages are developed as fan-shaped cohesion; some are divided into branches as the clan population grows, reflected in the spatial form of the village; some relatively independent "fans" will be formed that are similar to the original texture but have a certain deviation; and the ancestral hall of the branch is organized around the large ancestral hall. This spatial relationship of villages derived from consanguinity takes ancestral halls or temples as the core. Some place them in the center of the village; others place them at road traffic hubs. The cohesive villages perfectly embody the strong cohesion of the clan, and the highly geometric spatial form delineates a clear center and boundary range for the life of the clan. The hierarchical expansion of the morphological structure also reflects the strong ritual order of the single-surname clan, and the spatial hierarchy highlights the distinct hierarchical order.

For multiple-surname villages, multiple clans restrict each other and coordinate their development. Resource sharing is its basic feature. The spatial form of the cohesive village highlights the sharing of resources to the utmost and satisfies the coexistence of people with different surnames in the "neighborhood" living pattern. First of all, the spatial pattern of the village is zoned clearly, generally with the clan of the same surname in a zone. As a result, multiple similar fan-shaped spatial sequences have emerged, with a spatial form similar to that of single-surname cohesive villages of clans and branches, but with relatively weaker cohesion and less obvious primary and secondary relationships. Second, the spatial layout of the village is weakly centered or polycentric. The ancestral hall of each surname clan becomes the clan's center, or other public buildings and spaces such as squares and temples serve to form their own cohesive spatial forms.

3.2. Spatial form matches requirements of management and production of the village

In ancient China, under the patriarchal clan system and absolute monarchy, the self-sufficient agricultural economy became the root of economic development, but handicrafts failed to become the pillar industry to support urban development. Therefore, cities were economically reliant on and could not survive independently of the countryside, forming a symbiosis with the "city ring gathering area," which was village clusters. Cities of different levels needed villages of the corresponding scale to provide them with the means of subsistence. The distribution map shows that the clustered villages gathered around the Leizhou historic city at the time (Figure 2), and the "management and supply" relationship between the two is obvious. At the same time, the spatial pattern of the village was recovered through historical traces, and the population size of the village was about 50 – 60 people, which was in line with the "Tuntian system (storing the farming system)" and "Lijia system (system for tax payment)," as large as a military hamlet and as small as a migrant hamlet (Wang, 1959). The composition of the population also corresponded to the policy immigrants (migrant hamlet), military people (military hamlet), commercial people (commercial hamlet), and sinful people (relegated hamlet). The above is sufficient to prove that the spatial form of cohesive village matches the requirements of management and production (Anderson, 2020).

4. Isomorphism with comb-type villages

There are many comb-type villages around the cohesive villages, and the spatial forms of both are almost the same, except for the "cohesiveness." Therefore, scholars believe that the cohesive villages evolved from the local comb-type villages. One view is that it was a form of village planning carried over by immigrants from Putian, Fujian province; another view is that it was influenced by the comb-type villages of Guangfu during the Ming dynasty (1368–1644) when the Leizhou Peninsula ended up under the jurisdiction of Guangxi or Huguang province, instead of Guangdong, strengthening the connection with Guangzhou, the central city of Guangdong, and the coastal ports.

From the visual comparison of the spatial forms of the four, the local cohesive villages and comb-type villages in Leizhou do not fit in well with the spatial forms of villages in Putian, Fujian, but there is isomorphism with the forms of comb-type villages in Guangfu (Table 2).

Isomorphism is the use of a basic form while keeping its important characteristics unchanged, and assimilating or adapting to new elements to complete the re-creation. It is both a process and an outcome. Thus, an understanding of the evolutionary process of a known village could provide insights into Leizhou's cohesive villages, considering the relationship established by the isomorphism (Skowronek *et al.*, 2005; Tao *et al.*, 2023; Tao *et al.*, 2018).

The isomorphism between the Guangfu comb-style village and the Leizhou cohesive village stems from two main causes:

First, the ancient Chinese used the unit of field, *mu*, as the basis for measuring the spatial scale of land, residences, palaces, and gardens. It is widely believed that the spatial form of the Guangfu comb-style village was born out of the Jingtian system (the square-fields system) and matured in the Lijia system (system for tax payment). It is evident that the spatial form of cohesive village, which is compatible with management and production, is inevitably inseparable from the field division and land system at that time.

Second, the cohesive village has a "core" and "cohesiveness" compared to the comb-type village. Ancestral halls in general are the main characters that act as the "core." In a typical Guangfu comb-style village in the present situation, ancestral halls are more often lined up at the front of the village. It is found that the comb-type villages in Guangdong have undergone a development process from the "core" to the "front row." In the initial period of comb villages in Guangdong, the clans were not strong, and several small clans would live together in a village. They formed architectural groups around ancestral halls, adopting the core form of ancestral halls. After a long period of development, especially after the legalization of the common people's ancestral halls[1], the number of clan ancestral halls also increased correspondingly, gradually forming a comb-type layout

[1] The *de facto* legitimization of the common people's ancestral halls began during the Jiajing period (1522–1566) with the "Great Rites Proposal" and the subsequent "Benevolence Order." Such as the 15th year of Jiajing (1536), the Minister of Rites Xia Yan suggested on the "order of the subjects can sacrifice ancestors to establish the family temple" that "the emperor promotes filial piety and tells all the people in the world that, as Cheng Zi said, sacrifices to the ancestors of the first born people on the winter solstice and to the ancestors above the high ancestors below the first ancestors in the beginning of spring. All worship two ancestors, but cannot build a temple beyond their duty... The emperor widely promoted filial piety, the ministers did not suspect the state sacrificial rites, the folk can sincerely trace back to the ancestors, at the same time they can make the family harmony, relatives and friends honest and sincere, educate the people, so as to nurture good moral, therefore bringing in certain benefits."–The Memorial of Guizhou Xia Wenmin Gong, vol. 21.

Table 2. Comparison of spatial morphological characteristics of villages in Leizhou, Guangfu, and Fujian

Village	Leizhou Peninsula Village		Cantonese Village	Putian Village, Fujian Province
Typical type	Cohesive	Comb-type	Comb-type	Dense
Satellite map	 Hunan Village, Kelu Town	 Titang Village, Yang Family Town	 Fengyuan Village, Conghua, Gangzhou	 Yangwei Village, Putian, Fujian
Residential type	Courtyard style; large and small	Courtyard style; large and small	Courtyard style; consistent size	Courtyard style, row-houses style; large and small
Residential layout	Longitudinal and regular; strong cohesion	Longitudinal and regular; cohesion	Longitudinal and strong regularity; no cohesion	Longitudinal and irregular; cohesion
Alleyways planning	Main lane: village entrance, surrounding village, longitudinal and horizontal	Main lane: village entrance, surrounding village, longitudinal and horizontal	Main lane: village entrance, surrounding village	Main lane: village entrance, surrounding village
	Branch lane: longitudinal and horizontal, consistent width	Branch lane: longitudinal and horizontal, consistent width	Branch lane: longitudinal (main), consistent width	Branch lane: longitudinal and horizontal, wide and narrow
	Obvious and regular structure	Obvious and regular structure	Obvious and regular structure	Inconspicuous and irregular structure
Fengshui pond	Village front, other parts	Village front, other parts	Village front	Village front, other parts
	Different shapes, protective ditches	Different shapes, protective ditches	Half-moon shape, oval shape	Different shapes
	There are often trees behind the pond	There are often trees behind the pond	There are no trees behind the pond	There are no trees behind the pond
Ancestral hall Layout	Few; front end, core	More; front end, core	Front end, core	Core

led by many ancestral halls in the front row, that is, a large number of ancestral halls were built as the premise for the appearance of comb-type, and the "front row" of a large number of ancestral halls evolved from the "core" of a single ancestral hall (Figure 5).

In addition, we also found that there is a spatial morphological isomorphism between the cohesive village and a radial village in central Guangdong (Figures 6 and 7). The radial villages radiate around the "core" to the periphery. The core comes from the ancient "choice of the center," according to the ideology and political system of the ancients that building the capital laid in choosing the appropriate center, because they believed that the chosen center favorably maximized the timing, geographical, and human conditions. The concept of choosing the center spread to the folk and it has become "centripetal." The common people of that time

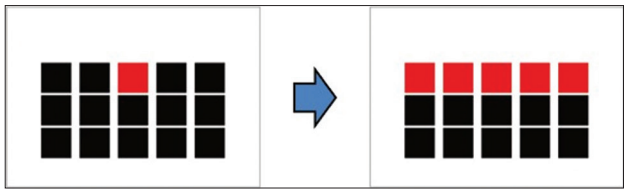

Figure 5. The change of spatial form from "core" to "front row" in Guangfu comb-type villages. Source: Drawings by the author.

could not and did not want to be self-centered. This mentality was then reflected in the form of traditional villages, which, in contrast to the "centering" of the imperial family, gave rise to the phenomenon of centering on something and developing around while depending on it (Ding, 1997). This center was not necessarily a geographic or geometric center, but a starting point for building attachment construction, a factor that dominated the development of the settlement, so

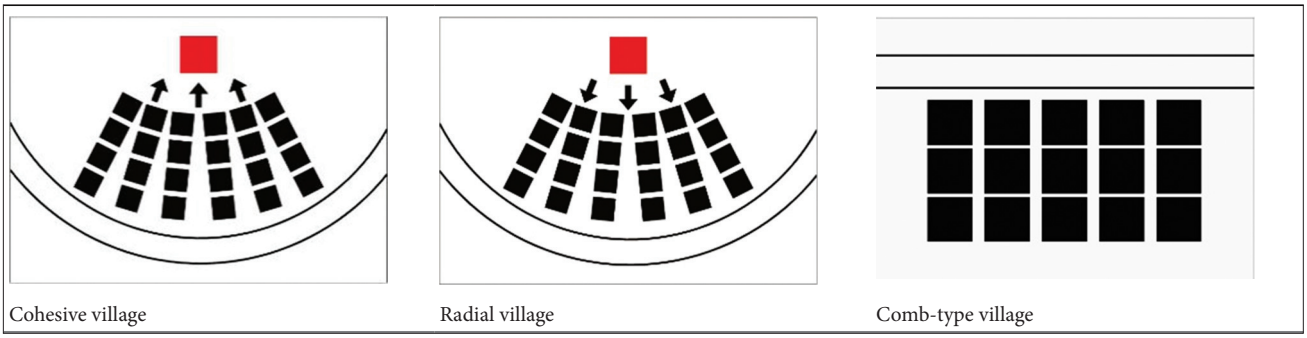

Figure 6. Schematic diagrams of typical spatial forms of cohesive, radial, and comb-type villages. Source: Drawings by the author

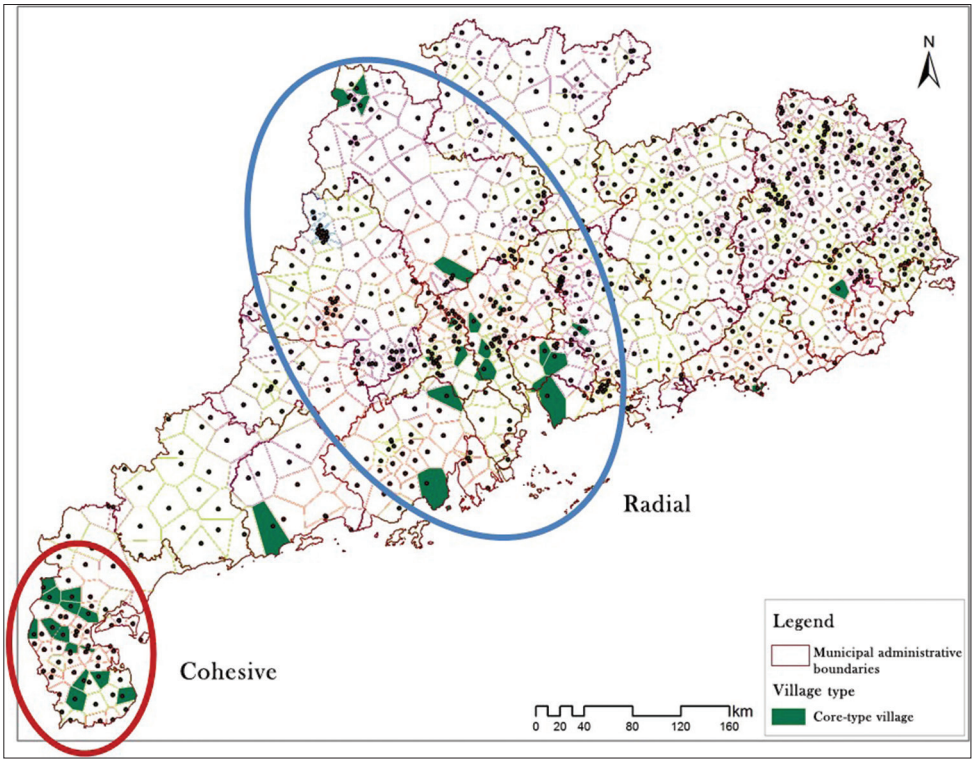

Figure 7. Distribution map of Guangdong's cohesive and radial core-type villages. Source: Map by the author

it seemed more appropriate to call it a "core." In addition, according to the research on the migration of Guangdong immigrants and the date of village establishment, such radial villages emerged much earlier, as early as the Sui (581–618) and Tang (618–907) dynasties (Table 3).

This map shows that the "core" village, such as the Leizhou's cohesive village, should have been formed before the comb-type village, rather than evolving from the comb-type village.

5. Isomorphism with the "nine dragons toward a pearl" village

We found the same cohesive villages called "nine dragons toward a pearl" (九龙攒珠, Jiulong Zanzhu is a special name for the morphology of the local immigrant village on the north shore of Chao Lake in the early Ming dynasty) in the area of Zhongmiao Town and Huanglu Town on the north shore of Chao Lake in Hefei in the similar period (Table 4), which are literally "nine lanes and one pond," featured by the pond as the center and the dwellings connected to each other in the front and at the back, with a vertical layout in ten columns, and nine lanes built with open ditches for drainage and connected to the dark ditches in the courtyard of the dwellings. The residential dwellings drain into the pond through the alleyway ditches. It is named after the nine lanes that drain like nine dragons playing with water during heavy rains. Both villages are located in the natural environment

Table 3. Distribution characteristics of core-type villages

Village type Distribution characteristics	Cohesive village	Radial village
Quantity (PCS)	76	107
Proportion (Guangdong)	2.5%	3.7%
Location	West Guangdong (Leizhou Peninsula)	North and central Guangdong (Qingyuan, Guangzhou, etc.)
Era	From Tang and Song dynasties to Ming and Qing dynasties	Sui and Tang dynasties to Ming and Qing dynasties

Table 4. Comparison of spatial morphological characteristics between the cohesive village of Leizhou and the "nine dragons toward a pearl" village of Chao Lake

Village	Leizhou Peninsula cohesive village	Chao Lake "nine dragons toward a pearl" village
Satellite map	 Potouqiao Village, Leizhou	 Chao Lake, Longqiao Village
Topography	Hills, plains (depressions, flat slopes), and lack of surface runoff	Hills, plains (depressions, flat slopes), and lack of surface runoff
Village morphology	Fan-shaped, scissors-shaped, nest-shaped, etc., with comb-type-shaped edges	Fan-shaped, scissors-shaped, nest-shaped, etc., with comb-type-shaped edges
Morphological function	Storage and drainage	Storage and drainage
Residential Type	Courtyard style, large and small	Courtyard style, large and small
Residential layout	Longitudinal arrangement, strong cohesion, spacing, and regularity	Longitudinal arrangement, strong cohesion, tight, and irregularity
Alleyway planning	Main lane: village entrance, surrounding village, longitudinal and horizontal	Main lane: village entrance, surrounding village, longitudinal and horizontal
	Branch lane: longitudinal and horizontal, wide and narrow	Branch lane: longitudinal and horizontal, wide and narrow
	Structural cohesion and regularity	Structural cohesion and regularity
Fengshui pond	Village front end and other parts	Village front end and other parts
	Different shapes, the main form near the residential end is curved	Different shapes, the main form near the residential end is curved
	There are often trees behind the pond	There are no trees behind the pond
Ancestral hall layout	Central node	Central node
Fortification	Outer layer: trees; middle layer: walls, defense ditches; inner layer: sluice gate, watchtower	Outer layer: walls, defense ditches; middle layer: sluice gate; inner layer: roof "Cuanjiao" (roof connection), no watchtower
Population nature	Policy immigration, Jiangxi people	Policy immigration, Jiangxi people
Social environment	Military and civilian hamlets, construction of large-scale water conservancy projects	Military and civilian hamlets, construction of large-scale water conservancy projects

of dips and flat slopes in hilly or plain areas, commonly known as "swallow's nest" and "phoenix's back" in Chao Lake. Both places receive uneven rainfall and lack surface runoff, and the villages use spatial forms to plan water storage, reflecting their adaptability to the natural environment. Among them, most of the *fengshui* ponds

Changyuan Village, Chao Lake, Anhui province | Hou Family Village, Jiangxi province | Zhou Family Village, Leizhou Peninsula

Figure 8. The cohesive village spatial form of isomorphism in three places. Source: Google Earth

in the front of the cohesive and "nine dragons toward a pearl" villages have a curved shape near the residential side, which is very different from the common half-moon shape of *fengshui* ponds in general migrant villages, where the part near the residential side is straight (Zhang *et al.*,2019).

In terms of social environment, the "nine dragons toward a pearl" villages were built by Jiangxi people mainly in the Chao Lake area during the Ming dynasty (1368–1644) government-led immigration reclamation movement. The villages' size is consistent with those of the military hamlet and migrant hamlet which were for storing the farming tools at the time, with intermediate distributions. The "nine dragons toward a pearl" type is an ancient and widely adopted village planning model, spread by Jiangxi immigrants to the northern shore of Chao Lake. Although the northern part of Chao Lake lacks surface runoff, the West Huang Mountain, 8 km from the shoreline, is subject to annual flash floods, so the immigrants built the large water conservancy reservoir Xujiaba to hold the water for irrigation. It is evident that Jiangxi immigrants have a wealth of technical experience in the modification and utilization of water resources (Zhang, 2010).

The study found that the immigrant population and garrison soldiers on the Leizhou Peninsula were organized by the government to carry out large water conservation projects, such as dike reclamation from the Tang (618 – 907) and Song (960 – 1279) dynasties. Especially in the Ming dynasty (1368 – 1644), on the basis of the Song-Yuan Dai Gong Dike and He Gong Dike that had been built, the Telv ponds, Xihu Canal, and other water conservancy facilities were continuously improved, and the North-South Dike and its matching sluice gates were built to resist typhoons, salty tides, and irrigate fields (Zhang, 2010). The cohesive villages are evenly distributed, and their size is consistent with those of military hamlet and migrant hamlet. The two villages share many coincidences in terms of their genesis, which are more like artificially created. The research found that immigrant ancestors of Jiangxi origin do appear in the typical cohesive villages. For example, the ancestor of the Zhou Family Village in Suixi County, Zhou Fu, a native of Ji'an, Jiangxi, is a descendant of the Song's Prime Minister called Zhou Bida, who came to Leizhou in 1275 during the Southern Song dynasty (1127 – 1279) as a governor of the local army. There are also cases where the ancestors of Jiangxi immigrants were mistakenly recorded as immigrants from Putian, Fujian province[2]. At the same time, historical texts confirm the existence of temples unique to Jiangxi in the history of the Leizhou

[2] "Xuwen County Local History" recorded that Jiayang Gao family originated in Putian, Fujian, but according to the "surname" and "Gao's genealogy," the Gao family in the present Leizhou Peninsula area was mainly divided into two branches: north and south. The ancestor of the South Branch, Gao Liandeng, was originally from Yeru Village, Qingjiang County, Linjiang Prefecture, Jiangxi Province, and came to Leizhou to serve in the Ming dynasty, and then stayed in Gao Shan Village, Leizhou. Gao Han, the distant ancestor of the North Branch was Governor Pingzhang (vice Prime minister) in the Song dynasty, originally from Yeru Village, Qingjiang County, Jiangxi Province, and later settled in Anhai, Jinjiang, Fujian Province. His descendant, Gao Shiyi, participated in Zhu Yuanzhang's Volunteer Army at the end of the Yuan dynasty or in the early Ming dynasty (1388) in the 21st year of Hongwu in Leiyang serving for the thousand-household bureau. His son, Gao Yu, was transferred to Stone City (now Lianjiang) in the 5th year of the Ming dynasty (1440) and became the founding father of the Lianjiang Gao clan (Jiang & Fang, 2008).

Peninsula[3]. The same spatial forms of villages were found in the corresponding emigration areas of Jiangxi as in the cohesive villages and the "nine dragons toward a pearl" villages (Figure 8). The above is enough to infer that the influence of Jiangxi traditional residential culture on the cohesive villages is greater than that of Fujian's Putian culture.

6. Discussion and conclusion

In conventional understanding, we would assume that the spatial form of a particular village in a region evolves from the common practices of the village. However, it is found that special village's spatial forms may precede the formation of common villages. We, generally, believe that the spatial form of a village in the regions is generally influenced by the residential culture of the main immigrant places. However, the study found that the major immigrant cultures may have assimilated the early ones and that some characteristics of the early cultures were retained during their adaptations to the new natural and social environments (Ngwato, 2012).

The research establishes a connection between two or more spatial forms through "isomorphism," and the numerous connections form a "network" that can fill the knowledge gap of residential culture due to the loss of built environment or the lack of historical records. Although this exploration of the origin of Leizhou's cohesive villages tends to be more inferential, we can be sure that the cohesive villages did not exist in isolation, and that the isomorphic spatial form is an ancient planning model adapted to the arid environment and also suitable for production and management, and has been adopted in various places in China. To a larger extent, this spatial form has a long history and is well-known among and mastered by the immigrants.

This dynamic and cross-regional study of village forms can explain cultural diffusions that were previously difficult to explain by static, descriptive studies that focused only on typical cases and specific scopes. The isomorphism of spatial forms is a clue for studying the connection between regional cultures, thereby providing an innovative way of thinking for the study of residential houses and contributing to the diversity and holistic protection of regional cultural heritage.

[3] In the "Leizhou Prefecture History- Establishment-Wanshou Palace Records," it is mentioned that there is a Jiangxi-nationality Wanshou Palace, which was built in the Kangxi period of the Qing dynasty. The Qing dynasty Leizhou governor Zhang Gengyun wrote "Lei Prefecture White Horse Temple Records" stating that "White Horse God surnamed Dong, Weijin, the Eastern Jin dynasty.....… live in a place called Jiangxi Fenning for generations; Fenning is now the Wuning County."

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Conflict of interest

The author declares no competing interests.

Author contributions

This is a single-authored paper.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Data will be made available from the corresponding author on reasonable request.

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ORIGINAL ARTICLE

The seductive choreography of space: Learning regenerative design strategies from (cyborg) flowers

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(This article belongs to the *Special Issue: Regenerative Architecture*)

Abstract

Unlike traditional net-zero emissions approaches, regenerative methods not only manage resources efficiently but also invigorate the environment. Architects focusing on regenerative design can draw inspiration from flowering plants, whose exceptional spatial strategies exemplify the choreography of ecosystem interactions that sustain fertility. The paper introduces the concept of "XENO," an artistic installation comprising a robotic carnivorous plant, a mosquito, and a microbially-powered fuel cell, exhibited at CIVA, Brussels in 2023. This installation serves as an epistemic object, exploring complex energy system diversity, ethics, and interactions. XENO's cyborgian elements encapsulate the intricate relationships and energy flows present in ecological architecture, highlighting the ethical concerns that exceed conventional eco-friendly practices, to explore life and death cycles, microbial decomposition, and material transformation within ecosystems — all of which form the basis for new life. In this way, flower structures provide a creative lens for ecological architects to integrate scientific knowledge, societal values, and experience design in ways that foster diverse and ethically resonant energy exchanges that contribute to a more balanced and environmentally conscious future.

Keywords: Flowering plants; Design-led research; Complex ecosystems; Epistemic artifact

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1. Introduction

Sustainable design is currently framed around the concept of net-zero emissions (Zhao, 2022), where a system produces as much energy as it uses. Regenerative methods build on good resource management by also contributing in diverse ways to environmental liveliness just like natural systems. This paper argues that architects concerned with regenerative design can learn next-generation sustainable approaches and practices for spatial protocols from the capacity of flowering plants (angiosperms) to generate extraordinary design strategies through what we are terming "the seductive choreography of space." Flowers are culturally symbolic, valued for their diversity, scent, geometries, patterns, and contribution to cuisine (citrus blossom, clover, daisies, dandelions, hibiscus, honeysuckle, lavender, lilac, mums, nasturtium, pansies, roses, sunflowers, and violets) as well as medicine (chamomile, lotus, rose, chrysanthemum, marigold,

and poppy). As such, flowers offer a combined biological and conceptual frame by which we can investigate core regenerative design principles. Unfurling spatial and experiential invitations for their pollinators, flowers are exemplary in maintaining a choreography of ecosystem exchanges between diverse agents to sustain the fertility of spaces. They demonstrate an exquisite complexity that regenerative design practices have much to learn from – not least, in highlighting the often-hidden ethical considerations when designing the choreography of space. Using a design-led research approach, this paper outlines the challenge of designing flowers beyond nature, illustrated by the authors' installation of a model ecosystem (titled *XENO*), comprising a carnivorous robot plant, a mosquito, and a benthic fuel cell for a major exhibition on Energy at CIVA, Brussels, Autumn 2023. Regenerative flower design raises important themes such as alternative (non-human) sensory apparatuses, challenges for regenerative human development, regenerative choreographies for ecosystems, the evolution of flowers and pollinators, and biological strategies that can be adapted by the regenerative architect. The artistic artifact *XENO* provides a thought experiment that explores the diversity, complexity, and ethics of energy systems.

1.1. Challenges for regenerative human development

The impacts of human development have reached the dimensions of a geological scale force heralding an era called the Anthropocene (Crutzen & Stoermer, 2000). Typified by a toxic ecological condition produced by more than a century of worldwide industrialization, contaminated environmental spaces have led to biodiversity loss with rapidly declining pollinator populations and a subsequent collapse in the range of native ecosystems to sustain communities. The rise of urbanization and megacities have destroyed prime farming land, where agricultural monocultures grown on massive scales in hinterlands are causing soil degradation and loss, resulting in less space for people and nature to rebuild intrinsic relationships. With the accumulation of greenhouse gases in the atmosphere, the ensuing climate emergency is causing dramatic swings in temperature, rainfall, and severe weather events that are changing the conditions for survival faster than natural adaptation can respond.

A better understanding and design of how we interact with angiosperms can play a critical role in mitigating and adapting to this cascading negative situation being vital to many ecosystems and supporting a diverse range of other species. Conserving, restoring, and even increasing the biodiversity of angiosperms is critical for maintaining healthy ecosystems, ensuring food security, providing renewable building materials such as biomass and even providing important compounds for treating diseases. Moreover, flowering plants sequester carbon dioxide from the atmosphere through photosynthesis and store it in their tissues as biomass, reducing the levels of greenhouse gases in the atmosphere while also providing ecosystem services such as erosion control, water regulation, and carbon storage. However, many plant species are threatened with extinction, and there is an urgent need to better understand and conserve plant diversity to ensure that these resources are available for future generations. While science is playing a significant role in this challenge, and massive seed banks to conserve crop genetic diversity such as the Svalbard Global Seed Vault, or "Doomsday Vault," have been constructed, design can also make important contributions, particularly when it comes to the design of our living spaces by investigating the critical role that flowers play in this complex choreography of environmental relationships.

2. Methods

2.1. Researching regenerative choreographies for ecosystems

The blossoming of flowers each Spring is more than a symbolic event, their regenerative capacity is based on myriad exquisite, sustained choreographies forged by interspecies codesign. These complex structures are composed of several different parts, each with a specific function. The female part of the flower is called the pistil, which is composed of three parts: The stigma, the style, and the ovary. The stigma is the sticky surface that receives the pollen, which is then transported down the style to the ovary. The ovary contains one or more ovules, which eventually become seeds after fertilization. The male organ of the flower is called the stamen and comprises two parts: the anther and the filament. The anther is where the pollen is produced, while the filament is a long, slender structure that supports the anther. Petals are the colorful, leaf-like structures that surround the reproductive parts of the flower, while the sepals are the small, leaf-like structures that protect the developing flower bud. Together, these parts enable the flower to produce seeds so that the plant can reproduce (Figure 1).

Without the devoted attention of pollinators, many angiosperms would not be able to produce seeds or fruits, which would have a significant impact on the ecosystems they inhabit. Flowers therefore invent a range of strategies that appeal to creatures, which are very different from themselves including visible cues (color, form), invisible codes (scent, ultraviolet markings), and food (nectar, pollen). Depending on their needs and preferences,

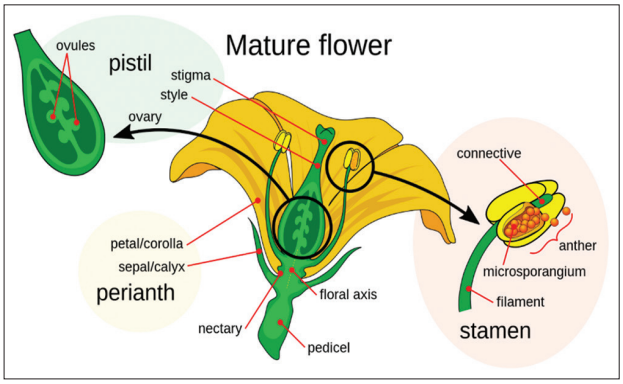

Figure 1. Diagram of key flower structures by Mariana Ruiz. Source: https://commons.wikimedia.org/wiki/File: Mature_flower_diagram.svg (Accessed August 08, 2023)

Figure 2. Echinacea (an inspiration for *XENO*). Source: Photo by Anna Vershinina

pollinators find themselves ensnared in exquisitely designed environments full of sensory delights. By spreading another organism's sperm, pollinators are therefore engaged in a vegetal tryst, which can be so precisely orchestrated that only a particular type of creature and its associated behavior is invited. Thus, a compelling choreography of body and space begins (Figure 2).

Charles Darwin first noted the exquisite relationship between orchids and their pollinators, with more than 28,000 species of these plants worldwide (Darwin, 2015). One of the most common tactics that orchids use to lure insects toward their pollen is by producing fragrant oils or nectar. For example, the vanilla orchid produces a sweet fragrance that attracts bees and butterflies. Some orchids also mimic the appearance and scent of female insects to attract male pollinators. The *Ophrys* orchid produces a flower that resembles a female bee, complete with a scent that mimics its pheromones, which attracts male bees who attempt to mate with it, becoming showered in pollen during the process. Other orchids have evolved to attract specific species of pollinators through a range of highly unique features (Figure 3). The bucket orchid, for example, has a deep, conical shape that forces its bee pollinators to crawl deep inside the flower to reach the nectar. As they do so, the bee is coated in pollen and must exit the flower by a specific path, thus ensuring pollination of other flowers of the same species.

Orchids also use visual cues to attract pollinators. The Dracula orchid, for instance, produces dark, reddish-black flowers with long, dangly petals that resemble a bat, which draws the attention of fruit flies, its primary pollinators. Such relationships are so specific that Darwin even predicted the existence of moths with extremely long mouthparts to reach the nectar at the long tubular base of the Madagascar star orchid (*Angraecum sesquipedale*). This pollinator, the Wallace's sphinx moth (*Xanthopan*

Figure 3. Insect mimicry by orchids. Source: Photo by Rolf Hughes, 2023

morganii praedicta) was finally discovered in 1903 by the entomologist Frederick William Edwards who recognized it from Darwin's predictions, which was instantly recognizable by possessing an exceptionally long tongue in a later collaboration between entomologists at the Muséum National d'Histoire Naturelle (France) and the Natural History Museum (United Kingdom), which was led by Professor Joël Minet, where the average tongue length for the Wallace's sphinx moth was shown to be 21.97 cm (8.6 in) in females and 20.65 cm (8.1 in) in males (Figure 4; Minet *et al.*, 2021).

2.2. Investigating alternative ways of experiencing the world

Pollinating insects have different sensory apparatuses than we do and their encounters with flowers is likely far different experience than our own. Angiosperms use a variety of strategies to compel and overwhelm pollinators

Figure 4. The Wallace's sphinx moth, a Madagascan hawkmoth whose existence was predicted by Darwin and Wallace and has now been recognized as a new species. Source: Adapted from Minet *et al.*, 2021 (photo by Anna Vershinina, 2023)

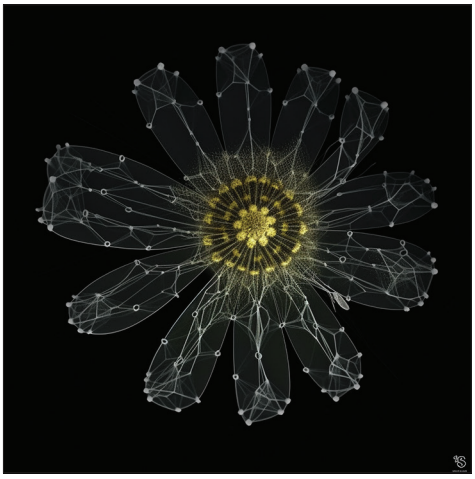

Figure 5. Flower under ultraviolet (UV), highlighting how structures become visible to insects that can see in the UV part of the electromagnetic spectrum. Source: Photo by Rolf Hughes, 2023

to the full. While the human eye can detect around 10 million different shades, our vision is limited to the red, orange, yellow, green, cyan, blue, and purple wavelengths of the electromagnetic spectrum that lie between about 400 and 780 nanometers (nm) in length. Pollinators like bees can perceive ultraviolet light at wavelengths between 300 and 560 nm in length on the electromagnetic but cannot appreciate red light. For a bee (and most other insects), red flowers appear black, while we perceive ultraviolet markings as black. Many flowers also have ultraviolet nectar guides that humans cannot see but act like runway lighting directing insect pollinators toward the center of the flower (Moye, 2017). Pollinators can also perceive polarized light, another stimulus that is beyond the sensory repertoire of humans (Figure 5). Polarization patterns are created when sunlight moves through atmospheric air molecules to produce effects that bees can identify and use as navigational cues that can be shared with other workers in the hive.

2.3. Drawing inspiration from the corpse flower

The corpse flower also known as *Titan arum* or *Amorphophallus titanium* is a rare plant that is native to the rainforests of Sumatra, Indonesia, that is infamous for being "the worst smelling flower in the world" as it smells just like a rotting corpse (Figure 6). The population has declined more than 50% over the past 150 years owing to logging and planting out the native forest habitat to make oil palm plantations. The plant's colossal inflorescence, or flower structure, can reach three meters tall and 1 meter wide, and emits a powerful odor, from the spadix, a tall, central column that is surrounded by a frilly, skirt-like structure called the spathe, whose wrinkled, veiny deep maroon

Figure 6. Corpse flower. Source: Photo by Anna Vershinina, 2023

looks like rotting flesh, and heats up to a temperature of 37.8°C (the same as human body temperatures) dispersing the volatile scent molecules into the air. Attracting carrion beetles and other scavenging insects that normally feed on dead animals, pollinators are drawn into the flower by the promise of a meal. On arrival, they encounter a waxy surface on the inside of the spathe that makes it difficult for them to climb back out. As they struggle to escape, the insects become covered in pollen from the male flowers located near the base of the spadix. Should they manage to escape, then these insects carry the pollen with them transferring it to other nearby corpse flowers.

2.4. Interdependency: Flowers as companion species

From an evolutionary perspective, flowering plants are more than a vital resource, or a compelling place of experiences but owing to the two-way interdependency

at the heart of their relationships, are companion species for humans and other creatures (Haraway, 2003). As we navigate the complexities of choosing a companion species, we must acknowledge the entanglements that exist between all beings. We must consider the webs of interdependence and mutual shaping that connect us to our potential companions. To select a companion species is to engage in a process of becoming-with, to form a relationship that transcends individuality and embraces the hybridity of all beings. We must ask ourselves: What are the ethical implications of bringing a new being into our world? How do our subjectivities and positionalities shape our desired relationships and how can the design process enable us to fully coexist with other beings that are not like us? How can we create conditions of flourishing for all beings involved through design? By engaging in a reflexive and relational process of decision-making, we can navigate the complexities of choosing a companion species in a way that acknowledges our mutual interdependence and creates a more just and equitable world for all. Recognizing the status of flowering plants as companion species in design promotes an ethical approach by actively engaging them through designed encounters that are more sensitive to their needs and that ultimately, promote their flourishing to catalyze more sustainable and ethical relationships between humans and the natural world. Elevating the status of angiosperms from resource, or object — to co-constitutive agents, enables designers to develop a deeper connection with and responsibility toward the natural world through the cultivation of values and associated actions that foster a sense of responsibility towards actively promoting life on Earth.

3. Findings

Our investigations into the complex forms of flowers and the choreographies of space they devise and coordinate led the authors to design a robotically operated artificial flower mechanism for the *Energy* group exhibition at CIVA[1], Brussels (October 2023 – January 2024). *XENO*, the cyborg flower, was also inspired by Charles Baudelaire's poetry collection "Les Fleurs du Mal" for reasons stated below (Baudelaire, 1989).

[1] C I.II.III.IV. A Culture—Architecture (CIVA) is a museum, library, archive and publisher that emphasizes Belgian architecture from the mid-19th to the 21st century. Created in 2016 at the initiative of the Brussels-Capital Region, CIVA brings together within a single structure the resources, knowledge and know-how of several cultural associations active in Brussels in the fields of architecture, town planning, landscape, and the study of ecosystems: the Archives d'Architecture Moderne, the René Pechère Library, the Fonds pour l'architecture, the Paul Duvigneaud Centre and CIVA asbl (now dissolved).

3.1. Les Fleurs du Mal

By associating flowers with the concept of evil, Charles Baudelaire's poetry collection "Les Fleurs du Mal" (The Flowers of Evil) challenges conventional expectations about aesthetics and moral boundaries, contrasting unconventional expressions of human passions with normative notions of love, thereby exposing the complex and often contradictory nature of human desires. Throughout the collection, Baudelaire's vision of beauty is intertwined with elements of decay, corruption, and sensuality. Flowers, often used as symbols of purity and innocence, are here transformed into embodiments of desire and eroticism, highlighting the disconnection between societal expectations and taboo or transgressive individual impulses. The appeal of the transgressive for Baudelaire emerges from the intersection of opposites, such as light and darkness, good and evil, pleasure and pain, allowing him to explore the allure of forbidden desires, the sensuality found within the realm of decay and corruption, and ultimately to present beauty in the embrace of decadence. Beauty, for Baudelaire, arises from intense and individual experiences. Aesthetic appreciation is thus subjective. A sense of awe and sublime beauty can be invoked by juxtaposing elements of beauty and horror. Paris of the 19th century with its bustling streets, crowded markets, social inequalities, and elegant architecture under threat of modernization is the ideal laboratory for Baudelaire to examine the impact of industrialization, urbanization, and capitalism on human experience. His focus on the transitional nature of beauty and mortality locates his poetic project in the pursuit of transient experiences and fleeting moments. Baudelaire's flowers metaphorically subvert conventions of beauty and morality, celebrating in their stead more unconventional aspects of attraction and desire, and challenging readers to question their own morality and understanding of the boundaries of human emotions.

3.2. Designing flowers beyond nature

All experience of flowers is based on experimental relationships with time. Some of these have evolved spontaneously long before the arrival of humans while others are detailed acts of cultivation. Our late arrival to address the biodiversity crisis that typifies the unfolding sixth great extinction provides a powerful motivation to design new kinds of flowers to draw together multiple, complex ecosystems through an exquisite choreography of exchange. By developing systems that both embody and are inspired by the biodiversity-promoting tactics of angiosperms, we may find new ways to build ecosystem relationships that can resist extreme weather challenges of weather, polluted environments, and carry out bioremediation (McCarty,

2023). Moreover, designing flower structures and systems that facilitate interspecies relationships enables the exploration of diverse environmental conditions through the specifics of geometry, choreography, and interaction that can be applied more generally to provide diverse habitats for different species. Specifically designing flowers can help us better understand and design for cooperation and coevolution between species through a range of interactions with pollinators and their communities, which are the foundations for developing diverse and resilient ecosystems that can better withstand environmental changes.

Flowers have been cultivated and bred by humans for thousands of years, having been selected for their colors, shapes, sizes, and fragrances, to develop many different varieties of flowers that are not found in nature. Hybrid species have also been created by crossbreeding, resulting in new and unique varieties of flowers that would not exist in nature. These hybrid flowers can be seen as artificial, as they are the result of human intervention and manipulation so the design of flowers within an unnatural or manufactured context is in keeping with the nature of flowers themselves.

There is no obligation to design a flower that is only limited to already established natural capabilities. Using technology, new materials, and other artificial means, flower systems can be created that can perform functions beyond what they can do in nature. This could include enhancing their beauty or color, increasing their lifespan, making them resistant to environmental stressors, or even imbuing them with new functions, such as emitting light or producing fragrances in response to specific stimuli. Artificial flowers could be designed to perform a variety of functions depending on their intended purpose. For example, they could be designed to clean the air by removing pollutants or to provide a sustainable source of energy by converting sunlight into electricity. They could also be designed to respond to human touch, trap biting insects like mosquitoes, or change color in response to environmental pollution. Artificial flowers could be used in a variety of settings, such as indoor and outdoor decor, as well as in smart clothing. Ultimately, the possibilities for designing artificial flowers are limited only by our imagination and the technology available to us.

For example, the modern trend for Artificial Lighting at Night is a significant threat to biodiversity in general and nocturnally active insects in particular and may be contributing to a decline in insect populations (Davies *et al.*, 2012). Many pollinators, such as moths and bats, are active at night and rely on their ability to see flowers to find food; however, artificial street lighting can disrupt their natural behavior and make it difficult for them to find flowers, leading to a decline in their populations.

By developing flowers that are specifically adapted to bloom at night, we can help to address this problem and provide a food source for nocturnal pollinators. These flowers could be designed to be more visible in low-light conditions, with colors that are easily distinguishable from the surrounding environment, and keep track of pollinator populations using infrared cameras. In addition, these flowers could be designed to emit fragrances that are attractive to nocturnal pollinators.

The development of night-blooming flowers could also have other benefits, such as reducing the impact of artificial lighting on the environment and improving the esthetics of urban areas at night. By providing a food source for nocturnal pollinators, we can help to support the health and diversity of ecosystems, while also promoting sustainable practices and reducing our impact on the environment.

Overall, the idea of a flower for night-time can help to address the pollinator crisis caused by artificial street lighting, while also providing a range of other benefits for the environment and society.

3.3. *XENO:* A robotically operated artificial metabolism

XENO captures its prey and main energy source — mosquitoes — when they activate motion sensors that are situated within its sweet, scented petals. Performing useful work that is drawn from metabolic exchanges that operate within natural systems and processes, the petals are made of bioplastics, which are produced from spoiled food such as blueberries. This deep purple material emits a powerful scent that attracts mosquitoes, which primarily obtain their energy from sugar-rich plant nectar and are generally drawn to flowers that have a broad surface area, which makes it easier for them to land and access the nectar. A scent hotspot located at the tip of the artificial anther is heated by a current from a benthic fuel cell at the flower base, which releases fruity volatiles (Figure 7).

Benthic fuel cells are also known as sediment microbial fuel cells (SMFCs), or sediment fuel cells (SFCs), which harness the power of microbial activity in sediments or aquatic environments to generate electricity. They consist of two electrodes — an anode and a cathode — which are placed in the sediment. Typically, the anode is buried in the sediment, while the cathode is exposed to the surrounding water. Microorganisms, such as bacteria, naturally inhabit sediments where they oxidize organic matter present in the sediment as part of their metabolic processes. On breaking down organic matter, they release electrons as a byproduct, which are transferred to the anode electrode and then to

Figure 7. *XENO*, robotic flower mechanism with blue light LED, potent scent, and zapper for mosquito prey, which falls into the benthic fuel cell at the base of the system, which in turn powers the robot. Source: Design sketch by Rolf Hughes and concept by Armstrong, 2023

the cathode, to generate an electric current. The electrons at the cathode combine with a suitable electron acceptor, such as oxygen from the surrounding water, completing the circuit and generating electricity, which can be harvested and utilized for various applications, such as powering remote sensors, environmental monitoring devices, or low-power electronics.

The efficiency and power output of benthic fuel cells vary depending on factors such as the type and abundance of microorganisms present in the sediment, the availability of organic matter, and the design and configuration of the fuel cell system, with the potential for practical applications in renewable energy generation and environmental monitoring (Figure 8).

While male mosquitoes obtain their energy solely from plant nectar, which provides them with all the necessary carbohydrates throughout their lifespan (Nature, 2010), females must have human or animal blood meals for a healthy reproductive cycle and egg development and are also attracted away from the flower by the scent of carbon dioxide and other chemicals emitted by gallery visitors. The need for blood only occurs when females are ready to mate and they emit specific pheromones that act as chemical signals to attract males who use highly specialized antennae to detect these scent trails. Typically flying in a zigzag pattern in search of the pheromone plume, male mosquitoes adjust their flight path based on the changing concentration of the pheromones in the air to locate a female mosquito. The mating ritual involves specific behaviors such as wing beating and other courtship displays, and once successful, the female mosquito will seek a blood meal to support her egg development.

Figure 8. *XENO*. Source: Design sketch by Anna Vershinina, 2023

Caught between eating, mating, and the robot flower's potent scent, the mosquitoes in the gallery select their energy pathway. Those that choose to consume the bioplastic polymers ingest an energy-rich meal, those females that mature their eggs seek out carbon dioxide from the breath of gallery visitors, while the robot lures all towards its lethal tip with a blue light to electrocute approaching mosquitoes on a metal grid (Figure 9). When a mosquito comes into contact with the electric grid of a zapper, it completes an electrical circuit and receives a lethal electric shock. Falling to the base of the petals, and down through pores into the benthic sediments, the insect cadavers provide nourishment for the microbes in the "living" fuel cell and through their electrogenic metabolism, provide a source of electrical energy capable of stunning the next insect prey.

Interrogating the possibility of establishing multiple codependencies between different species — human, mosquito, flower, microbes — *XENO* generates an overall benefit to the local ecosystem by catalyzing the different exchanges between the participants and highlighting the exchange between them while establishing ethically challenging inflection points of energy transfer. Spotlighting these ethical dilemmas implicit within all natural energy systems, *XENO* operates through cycles of life (feeding, breeding) and death (decomposition) to ensure continuous electron flow through all bodies as a basic currency of life (Armstrong, 2023). Designed to consume mosquitoes, on the one hand, *XENO* represents a mechanism for pest control, while on the other hand, it is a means of capturing energy from within a living system. Mosquitoes, in turn, prey on humans, subjecting gallery visitors to a sense of ill-ease as they share the space with hungry female mosquitoes. On receiving a lethal current delivered through the metal grid located on the anther, the mosquitoes fall through pores into the benthic fuel cell. Here they are consumed by microbes and turned into electricity generation and compost, which returned

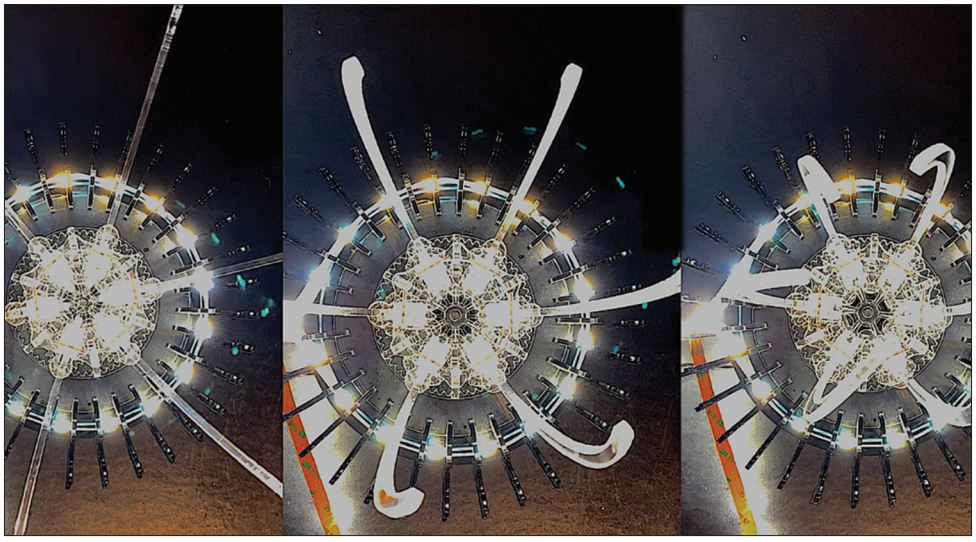

Figure 9. *XENO* placeholder. Source: Composite image by Anna Vershinina, 2023

to the robot system, showcasing the potential for resource recycling and renewable energy production. The benthic fuel cell represents a way to harness energy from organic matter (dead mosquitoes) through microbial activity. This concept reflects the principles behind SMFCs, where microorganisms generate electricity through their metabolic processes. It highlights the potential of utilizing renewable energy sources and sustainable practices within energy systems.

Gallery visitors are implicit in these exchanges becoming part of the energy transfer through the appetites of the female mosquitoes. The electric shock delivered at the anther tip can cause immediate death or immobilize the insect, and it is likely to induce discomfort and pain during the process. While insects have a different nervous system and sensory perception than mammals, they possess nociceptive receptors that can sense harmful stimuli and trigger pain-like responses. However, since insects' nervous systems differ significantly from mammals,' it is difficult to determine the exact nature and intensity of pain experienced by mosquitoes.

This scenario raises ethical considerations on various levels. From a human perspective, the carnivorous robot plant could be seen as an innovative solution for mosquito control, potentially reducing the spread of diseases. However, ethical concerns may arise regarding the treatment of animals (in this case, mosquitoes) and the potential unintended consequences on ecosystems. Balancing human interests, ecological well-being, and ethical considerations is a complex and irreducible challenge that is implicit in the transfer of energy and resources within all lifeworlds. Ethical permission for the installation was sought and obtained since insects, along with other invertebrates, are currently not explicitly covered by animal welfare legislation in the European Union[2], and are not afforded the same level of legal protection as vertebrates.

The current rationale behind the exclusion of insects from animal welfare legislation is to protect animals that are considered sentient, with the capacity to experience positive or negative states of consciousness. While it is now widely acknowledged that many invertebrates, including insects, exhibit complex behaviors and sensory perception, there is ongoing scientific debate about their level of sentience and subjective experiences. Animal welfare legislation is often influenced by societal values, available resources, and practical considerations, so as insects are highly diverse and abundant, it is challenging to develop specific regulations and enforce them effectively. Moreover, cultural attitudes position insects differently from vertebrates and have historically been subjected to various forms of exploitation and control without the same ethical considerations.

Discussions around the ethical treatment of insects and other invertebrates are evolving as the understanding of invertebrate sentience and cognitive abilities advances. Implicit in *XENO* is the provocation for increased consideration and potential changes to animal welfare legislation to include a wider range of animals — some of which are culturally unpopular — like mosquitoes. In all cases, the need for pest control must be balanced with

[2] The legal frameworks for animal welfare in the EU, such as the Treaty on the Functioning of the European Union and the European Convention for the Protection of Animals Kept for Farming Purposes, generally focus on vertebrate animals.

ethical considerations related to the treatment of creatures and with respect to the potential unintended consequences on ecosystems such as the loss of pollinators.

4. Conclusions

Natural flowers encapsulate complex, biodiversity-promoting systems that act as sites of negotiation between different actors in ecosystems. Each approaches the space with the intention of deriving a range of experiences from food to sex, rapture (scent, pheromones), wonder, and beauty. Beyond functionality and material exchange, the experience of the flower structure is complex invoking contradictory paradigms that may be lethal to a visitor (corpse flower) or may create selective pressures that transform the nature of the pollinator (orchids and their pollinators).

XENO interrogated some of these complex principles to consider spatial engagement and simple choreography through a model ecosystem. It comprised a carnivorous robot plant, a mosquito, and a benthic fuel cell. The artistic work is here positioned as an epistemic object, aiming to explore the diversity, complexity, and ethics of energy systems. While this scenario has poetic elements, being positioned as a performative work within CIVA's gallery space, each component represents a distinct entity with its own characteristics, needs, and interactions. This diversity highlights the complexity and interconnectedness of ecological systems while demonstrating the intricate relationships and flows of energy and matter, that are orchestrated by carnivorous robot plants and spotlights the mixed motivations and transactions that take place within other types of flowers. Like the work's performative presence in CIVA's gallery space, ecological architecture embraces a holistic approach where each component of a building represents a distinct entity with its own characteristics, needs, and interactions. This recognition of diversity within architectural systems underscores the understanding that ecological systems are intricate and interconnected. By highlighting the intricate relationships and flows of energy and matter through the presence of a carnivorous robot plant, and the mixed motivations and transactions occurring within other types of flowers, the work emphasizes the orchestration of sustainable energy systems, where renewable energy sources and efficient technologies work in harmony to minimize environmental impact. The ethical questions raised by *XENO* do not simply regurgitate ecological architecture's emphasis on responsible design practices such as minimizing resource consumption, using eco-friendly materials, and prioritizing the well-being of occupants and the broader environment. Its complex exchanges are intrinsic to the cycles of life and death within the natural world where ultimately, at the end of an organic agent's life, it is actively broken down by microbes at the base of the biosphere, and its components transformed into substrates that can re-enter the webs of life. For regenerative architectures to promote additional benefits to local surroundings in ways that exceed the routine promises of resource circularity and energy conservation through net-zero targets which are sought by sustainable systems, they must go beyond a rhetoric of market transactions that involve matter and energy exchange; they must ethically engage with more complex exchanges that traverse the cycles of life and death through composting microbes and managed material transformation to bring regenerative benefits for ecosystems.

Flower structures provide a means for creatively exploring this interconnectedness. The ethical dimensions of energy systems, and ecosystem dynamics within real-world energy systems, are core concerns in this research. Orchestrating scientific knowledge, societal values, and experience design in the development of regenerative design, an ecological architect must engage more diffuse and ethically engaged forms of energy exchange if our species is to contribute to the urgent need for re-enlivening our habitats. By embracing diversity, complexity, and ethics within energy systems, regenerative architecture can enhance the natural world and promote a more balanced and environmentally conscious future.

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Conflict of interest

The authors declare that they have no competing interests.

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Writing – original draft: Rachel Armstrong and Rolf Hughes

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ORIGINAL ARTICLE

Learning from the countryside: Designing in Chinese rural-urban areas

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Abstract

The current transformation of the countryside in the rural hinterland of Chinese city regions faces challenges in conserving an extensive architectural and landscape heritage. The villages situated in these regions represent the historical core of metropolitan areas. By examining the hinterland territories, we can readily recognize the features of the Chinese urban-rural continuum that G. W. Skinners has defined in his studies spanning from the 1940s to the 1970s on rural marketing networks, cities, and the hierarchy of the local system. These local systems present a morphology that continually adapts to geographical and cultural contexts, offering rich architectural and rural urbanism solutions that seamlessly harmonize the urban and rural functions. Today, this part of the settlement is extremely vulnerable to the pressure of urban expansion as towns evolve into cities and cities transform into metropolitan regions. The conventional top-down planning practice in these areas lacks innovative tools capable of integrating both "urban" and "rural" features simultaneously. Scholars such as M. Davis and G. Guldin have recognized the Chinese hybrid rural-urban settlement as a potentially "new form of settlement for humanity" (Guldin, 1997). In this article, we present a holistic design approach aimed at shaping this hybrid settlement into a "green city," applying the model we first used in 2010 – 2013 in Huiyang in the Pearl River Delta, a region characterized by Hakka villages territorial system, to two other cases in city regions: Pidu in the Chengdu metropolitan area and Kandun in the Ningbo metropolitan area. These regions are characterized by their respective Lin Pan and Seawalls territorial systems, which we have more recently studied. The aim of the paper is to illustrate how drawing inspiration from local countryside architecture and rural urbanism enables the development of individual planning solutions as an alternative to the current planning practice in peri-urban rural areas, which tends to homogenize countryside landscapes to urban blocks.

Keywords: Urban-rural continuum; Hybrid landscape; Holistic design approach; Hakka villages architecture; Linpan architecture; Seawalls territory architecture

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1. Introduction: The urban-rural hybrid landscape in China and its roots

The growth of city regions in China, whether classified as megacities or megalopolis such as the Pearl River Delta (PRD), has been marked by aggressive and intensive urbanization of the agricultural hinterland territories on the peripheral areas of these city agglomerations since the early 1980s (Guldin, 1992). Our observation of this phenomenon, which was initiated almost 20 years after its inception, draws from our Hakka heritage preservation research.[1] We embarked on the mentioned study by analyzing cases of inland transformation in the PRD region, focusing on various stages of development in Hong Kong, Shenzhen, and Huizhou.[2]

> "Spatial and social-economic transformation of these hinterland settlements in south China had been defined by G. E. Guldin as a hybrid landscape '(…) no longer clearly urban or rural (…) but a ...blending of the two.'" (Guldin, 2001, p. 14)

In 2010 – 2013, when examining both Shenzhen and Huizhou, traces of the distinct components defining "urban" and "rural" patterns that form the "hybrid" landscape could be identified, as observed by Guldin in the 1990s. However, within the Shenzhen Special Economic Zone (SEZ), these components were no longer spatially distinguishable due to the intensive and rapid development that transpired during the 2000s.

The original "rural settlement" in this area was characterized by monumental, enclosed residences founded by Hakka immigrants, mainly during the 16 – 19th centuries. These residences were modeled after the *weilong* houses architectural style. They functioned as a fortified citadel, bringing together groups of families who shared a common ancestor, emphasizing the key ritual of clan culture (Hayes, 2001). In the center of these settlements stood a temple known as *citang*, which enclosed a crescent-shaped water pond in front, carrying apotropaic meaning.

In SEZ territories such as Longgang, the once "rural territory" that surrounded Hakka residences has been progressively and completely overtaken by the compact and densely populated fabric of "urban villages."[3]

In the first decade of the 21st century, the process of townization became even more intensive with the growth of high-density housing blocks, some rising to 17 floors, and vast industrial parks. During this period, certain Hakka residences, such as Hehu in Longgang, underwent transformations, serving as the local museum for the Hakka people, and the nearby original marketplace expanded, eventually becoming a shopping mall.[4]

It should be noted that the landscape observed by Guldin in the 1990s in PRD still retained a significant ratio of the rural landscape. It constituted a kind of urban-rural hybrid settlement, which was defined at that time as an "urban-rural integration" (*Chéngxiāng Yitihua*). Davis (2004), in his report on Guldin's studies from the 1990s comparing rural transformations in South China with Indonesian *desakotas* (Guldin, 1997), asserted that a new form of human settlement was emerging in China, blending rural and urban elements. In the areas observed by Guldin in Dongguan and Shenzhen, the rural component of this blend has all but disappeared today. However, as one moves eastward from Longgang to Huizhou prefectural territory in Huiyang district (also part of the PRD city region but outside the SEZ), the rural and urban components of the "hybrid landscape" in 2010 were still present and distinguishable.

When investigating the case study of Hakka villages (Figure 1) and attempting to recognize the historical structure of Huizhou and Huiyang territory (Figures 2 and 3), we followed the well-known studies by G. W. Skinner about the Chinese "urban-rural continuum" and rural marketing network, which provide an articulated explanation of the roots of the "hybrid" landscape described by Guldin: this landscape originated not through a rural exodus to the city but through an "urbanization *in situ*" (Friedman, 2005) of rural hinterlands.

Skinner's works assume that the population density, the number of villages, and the distance of villagers (on foot) from the marketplace are the key factors that define the geographical structure of the urban-rural continuum. It can be schematized as a tiling of a hexagon, representing the marketing community area that collects a certain number of villages, each with its center in standard market towns.

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1 Our research began in 2010 and continued until 2015, following a program outlined by the School of Civil Architecture, Politecnico di Milano, and the Technical Office of the Municipality of Huizhou. This program wa developed within the context of a cooperation agreement signed in 2008 between the Italian Government and Guangdong Province of China.

2 A description of this comparison of cases is provided in Meriggi (2015, 2017).

3 For a detailed exploration of the specific characters of this urban type in Shenzhen and its transformation issues, please refer to Urbanus (2005).

4 A comprehensive survey of Hakka villages in eastern and north Guangdong is detailed in Meriggi (2018).

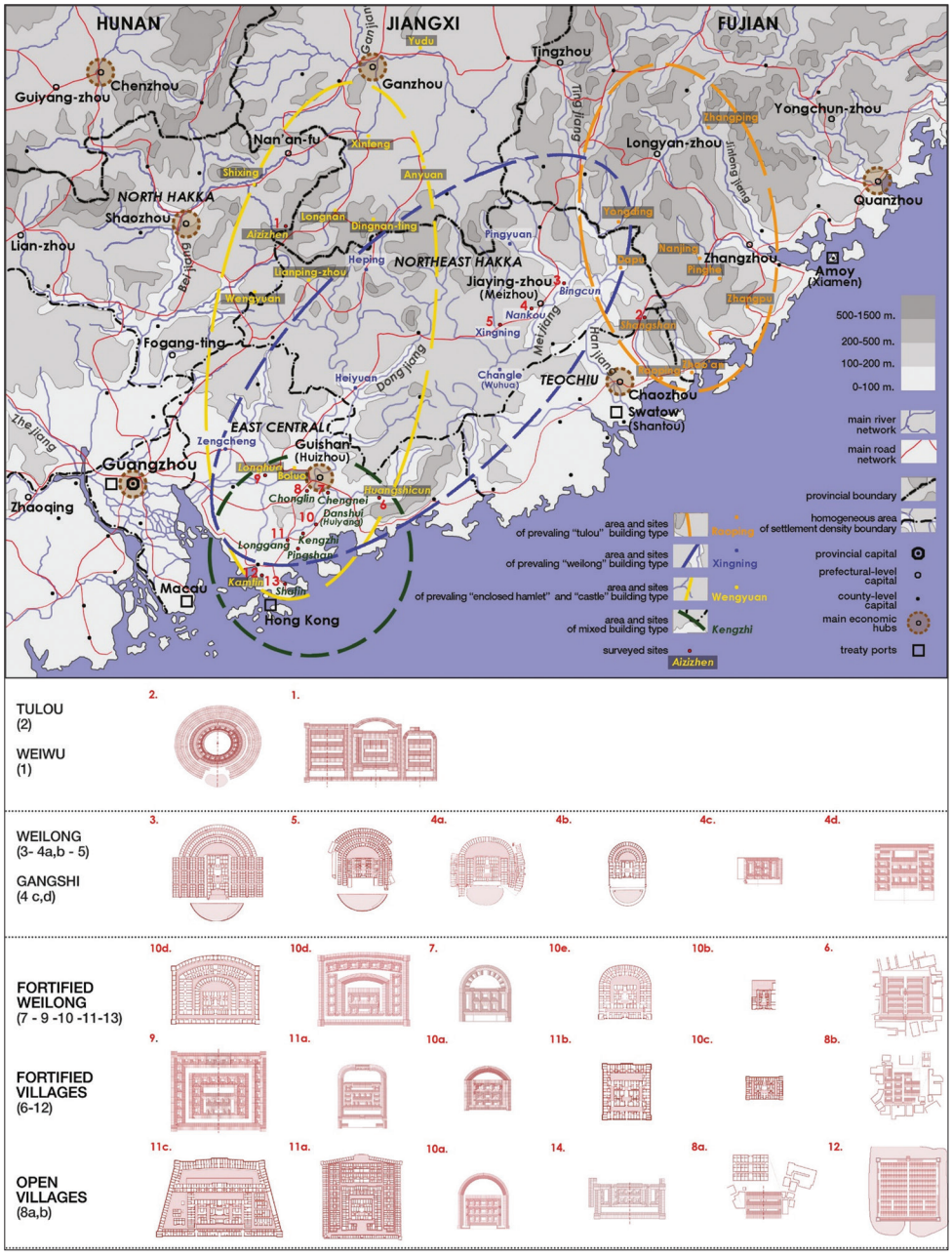

Figure 1. Geography of cultural areas of Hakka architecture in Eastern Guangdong. Orange: area of tulou buildings; yellow: area of weiwu buildings; blue: area of weilong buildings; green: area of mixed fortified building types. Source: Meriggi, 2018, p. 59

By surveying several cases in China (Skinner, 1964-1965), he determined that a marketing community for one market cannot consist of fewer than 6,000 people or exceed 12,000 people. In addition, the distance of the most disadvantaged village from the marketplace cannot exceed 8 km. He provides eight developing models based on hexagonal tiles that enable us to understand different situations depending on the density of population and number of villages – from the simplest and most homogeneous, with one standard market town, to the most developed and inhomogeneous, with a network of market towns at different hierarchical levels and specialization (Figures 2 and 3).

In addition to this simple assumption, the variation in the structure of the urban-rural continuum depends on the geographical location of the marketing community, ranging from the simplest and isolated communities in mountain areas to those gradually becoming more articulated in continuous hilly and plain areas and finally

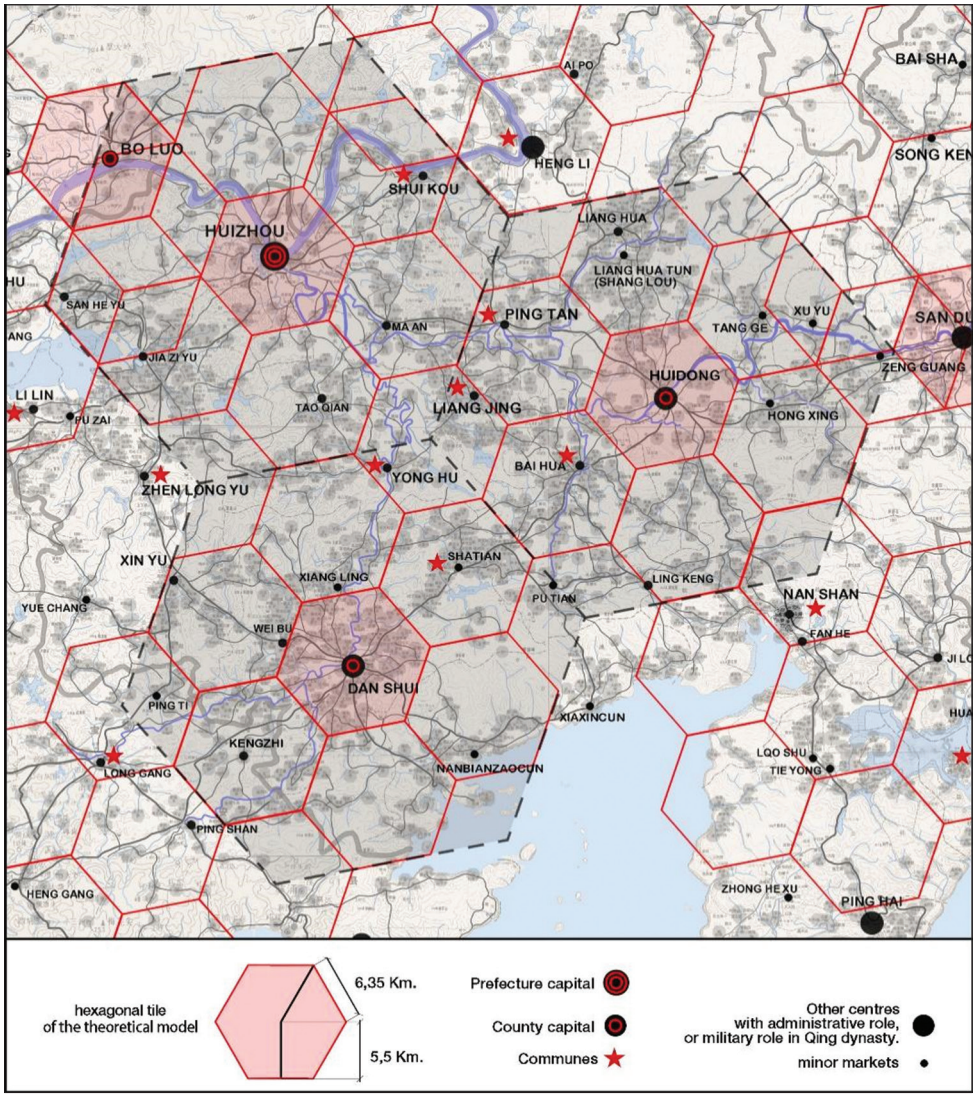

Figure 2. The theoretical model of the area of Huizhou prefecture marketing urban-rural continuum structure. The three centers of Huizhou, Huiyang, and Huidong form an equilateral triangle with sides measuring 33 km. The hexagons identifying the market areas have sides that are 1/6 of the distance between the three centers, equal to 5.5 km. Source: Meriggi, 2018, p. 38

to the most articulated and integrated ones in high-density deltaic areas.[5]

Skinner's studies showed that a form of urbanization *in situ* already existed in traditional Chinese settlements and that the urban-rural continuum should be considered as a specific form of territorial structure characterizing Chinese urbanism. This structure matches the top-down network of administrative centers in the imperial bureaucracy, composed of cities at different levels following the geographical structure of the water flow hierarchy, on the one hand, and the bottom-up organization of marketing activities that follow the distribution of villages around different levels of market towns and cities, on the other hand. These two networks intersect in what is defined as the "standard market town," a type of settlement positioned between the village and the county due to its economic and social performance. These are small towns where rural marketing is conducted alongside urban functions, such as local administration, social regulation, and traditional rituals – like the *citang* of clan culture[6] – as well as temples dedicated to local deities. In addition to these functions, there are institutions of higher education, referred to as

[5] We could find samples for almost all the variants defined by Skinner in our work (2018) about Hakka villages and marketing communities in eastern and northern Guangdong Province.

[6] More information about the clan culture and its origins, see: Faure (2006, 2007) and Hayes (2001).

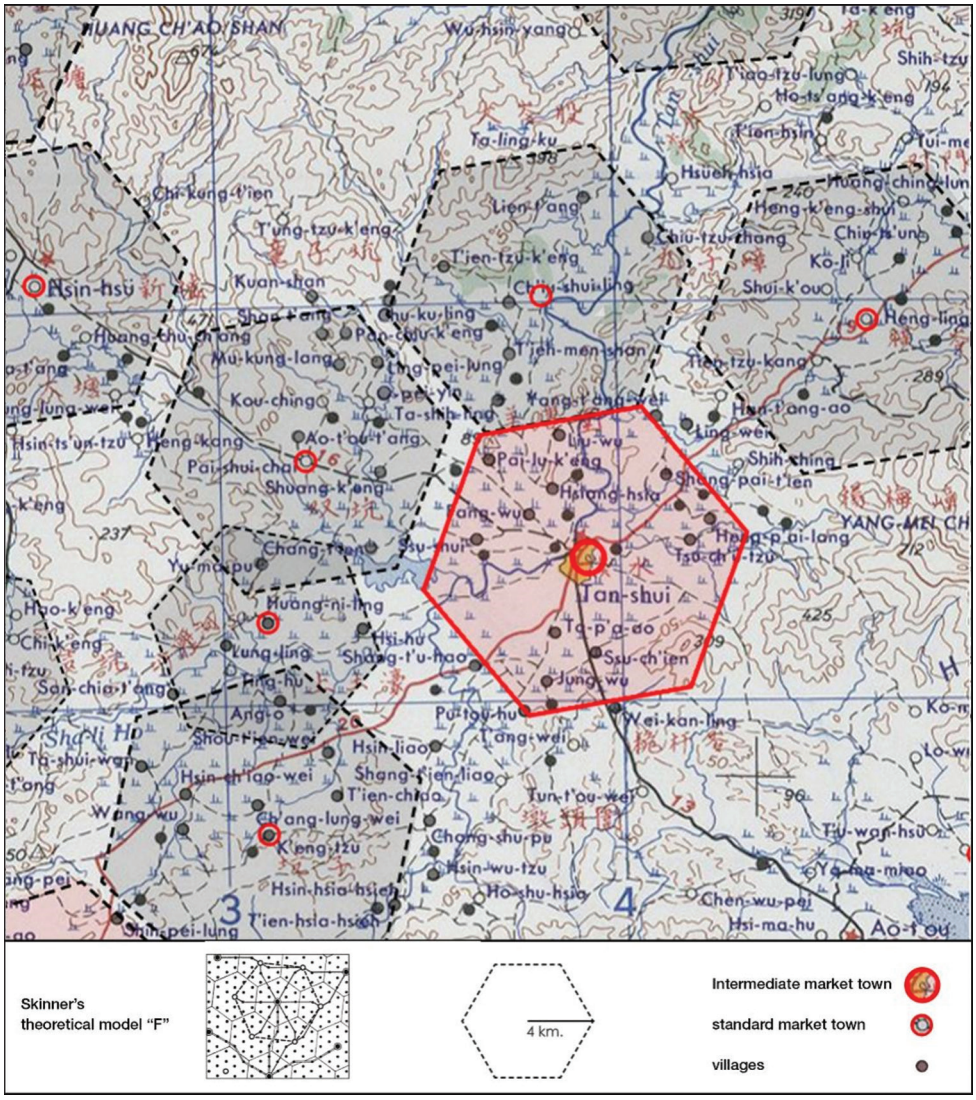

Figure 3. Marketing communities' areas in Huiyang. Source: Meriggi, 2018, p. 108

"Confucian academies," which can be found in specific buildings in *weilong* houses and villages. These academics served as training grounds for the local administrators of imperial bureaucracy (Meriggi, 2018). Their presence here illustrates how, in traditional settlements, the "rural" also encompassed aspects of the "urban."

In these lines, we have provided a synthetic description of the historical-geographical and economic model of the territorial structure of the Chinese countryside. This description stems from our research and design program, which was based on the following scientific questions: to what extent can the Chinese "urban-rural continuum" we observed in Huiyang and Huizhou, both as an analytical method and a design approach, be beneficial for contemporary development? To what extent can this model also explain other cases in the hinterland of city regions in China?

2. Research method: Mapping and designing the Chinese urban-rural continuum for the green city of the future

The cases presented here include a brief description of the design approach adopted in Huiyang (Meriggi, 2015, 2017; Chen *et al.*, 2023) and the attempt to apply a similar methodology based on Skinner's model of understanding the Chinese urban-rural continuum to two other cases of hybrid landscapes in China's city region rural hinterland – the Pidu district in the Chengdu metropolitan area and Kandun town in the Ningbo metropolitan area.

These cases were selected to encompass a wide range of architectural and village types, as well as different geographical situations – an inner plain in Chengdu and coastal for seawalls towns in Ningbo. In this way, these different situations provide the conditions for stress-testing Skinner's territorial model of the urban-rural continuum network.[7]

In all the cases we collected, we followed a methodology based on three steps:

(i) First, we addressed the problem of mapping the different forms that the urban-rural continuum model can assume, depending on geographical and cultural situations.
(ii) Second, we investigated the different architectural types and village morphology as part of the model.
(iii) Third, in some selected cases, we arrived at a design synthesis by proposing contemporary urban-rural continuum forms, drawing inspiration from the morphological and architectural models we found in the investigated cases.

These steps will be elaborated upon in detail within the descriptions of the case studies and design output in the following paragraphs.

All the projects we worked on assumed the form of the "green city" (Meriggi, 2009) as a possible model of urban development. This "green city" concept encompasses both "rural and urban" features and performances, taking into account landscape and activity complexity.

The cases of Pidu and Kandun, elaborated by the authors' Ph.D. and Master's Degree theses in 2021 (as described in the following paragraphs) illustrate how the phases of our methodology, initially experimented with in the case of Huiyang in 2010 – 2013, were consequently applied. Regarding the Huiyang case, where we have already provided substantial information, we will focus on the following lines on the design output.

3. Findings

3.1. Project: "Rebuilding from the countryside" (Huiyang, Huizhou, PRD)

Huiyang serves as the western intermediate market town in the triangular scheme of Huizhou prefecture's marketing urban-rural continuum structure, as illustrated in Figure 2. The territory of Huiyang consists of two "communes" (Figure 3): Danshui, with the town located in correspondence with the bridge of Danshui River (a tributary of Dong River) and Qiuchang, with two minor marketplaces (Xiang Ling, at the north, and Wei Bu, at the east). These marketplaces gather the marketing communities of 5 – 6 villages each, along with nearly one hundred *weilong*-type Hakka residences.

Both marketplaces were located alongside a river and a primary road – the former leading to Huizhou and the latter to Guangzhou.

The majority of urban development outlined in the Master Plan 2007 – 2020 (Figure 4) was concentrated in the Qiuchang commune territory. This development involved an increase in the presence of industrial compounds in Wei Bu villages, the establishment of new industrial areas, and the construction of residential and office blocks in Tie Men Shan villages. Agricultural land was preserved, with the exception of Zhoutian village, which was designated for use as an agricultural park. At that time, the common practice for the conservation of Hakka residences was the

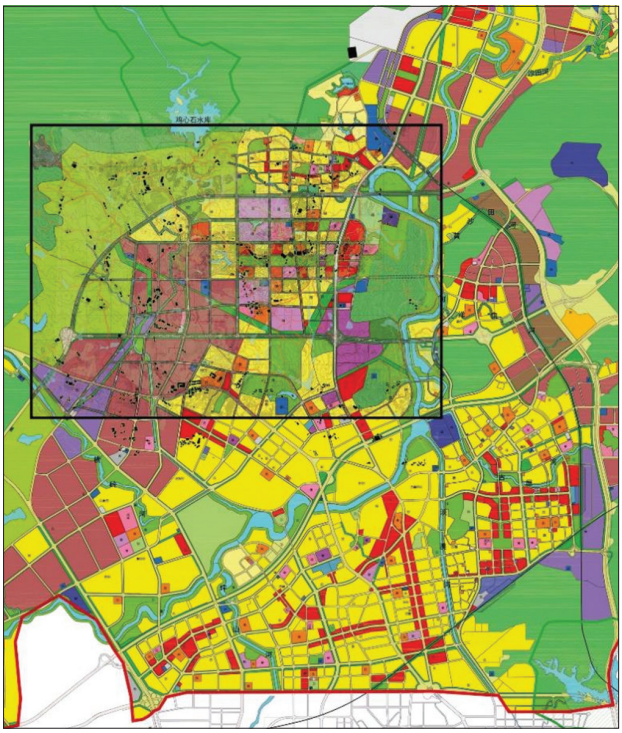

Figure 4. Huiyang Master Plan 2007 – 2020 (Huiyang Bureau of Housing and Urban-Rural Development, 2007). In the frame, the villages of the Qiuchang commune are highlighted in black (based on the 1979 Qiuchang Commune map). It is evident that the road network of the new city intersects and divides the historical Hakka residences. In addition, it is worth noting that many of the Hakka residences are situated within industrial areas. Source: Chen *et al.*, 2023, p. 11

[7] In addition to these cases, as part of a PhD research project, our research group also considered Minnan villages in the Julong River Delta (Fujian) and water villages in Jiangnan (Zhejiang), highlighting the nuances of the urban-rural continuum in deltaic areas. We also studied historical villages in Huizhou (Anhui), revealing the nuances of urban-rural continuum in a mountainous area. The outputs of these investigations, which compare 6 different forms of urban-rural continuum, will be presented in an ongoing book titled *Mapping Chinese Urban-Rural Continuum*.

establishment of a buffer area of 25 meters surrounding the building, excluding agricultural land (Huiyang Bureau of Housing and Urban-Rural Development, 2009).

Our proposal[8], based on a survey of 43 cases of single residences in the Qiuchang commune territory, used the geographical distribution of villages in the areas specified for future urbanization as the foundational structure for the city's future development.

The proposed scheme (Figure 5, left panel) features a substantial green belt that stretches from the southeast to the northwest, intersecting the urbanized area. This green space includes a central "parkway" and a segment of the Danshui River. It is surrounded by urban parks and agricultural areas, encompassing a significant number of Hakka residences along with their agricultural land. Within this scheme, the areas subject to more restrictive conservation rules are situated in Tie Men Shan and Zhou Tian villages, which collect agricultural lands containing the most important Hakka residences (A and B). Similar conservation rules are recommended for the natural areas along the Danshui River Valley on the east side (E). Additional satellite zones (C) have fewer restrictions on the conservation of the rural landscape. As for the densely urbanized industrial sectors on the west side of the city(D), it is proposed to shape the buffer zones surrounding the residences in a way that forms a continuous green corridor with integrated public facilities in the historical residences and villages.

Considering the significant number of residences in Huiyang territory with notable heritage value, a conservation strategy that would turn any of them into a museum was impractical, meaning that relying solely on tourism to support their conservation was not feasible. In addition, almost all Huiyang residences had been abandoned by the original Hakka communities. What appears to be a more realistic approach is to conserve the Hakka residences and their rural surrounding as part of the public facilities outlined in the Master Plan.

[8] The School of Civil Architecture at Politecnico di Milano organized a team of professors and PhD students (nearly 25 researchers) with expertise in Architectural Composition, Architectural and Landscape Restoration, Urban Planning, and Interior Design. Several field trips and surveys were conducted in Huiyang territory during 2010–2011, involving the analysis of nearly 50 Hakka residences. These efforts resulted in the formulation of guidelines for adjustments to the Masterplan presented in Huizhou on 10.03.2011 (see: Milan Polytechnic University – School of Civil Architecture – Department of Architectural Design, 2011), along with an additional report in 2013 (see: Milan Polytechnic University – School of Civil Architecture – Department of Architectural Design, 2013a). The research were presented in two exhibitions: one at the School of Civil Architecture in 2012 and another at the Milan "Urban Center" in 2013. Details of the project, concluded in 2016, are presented in the book by Chen, Meriggi, and Tan, published in October 2023.

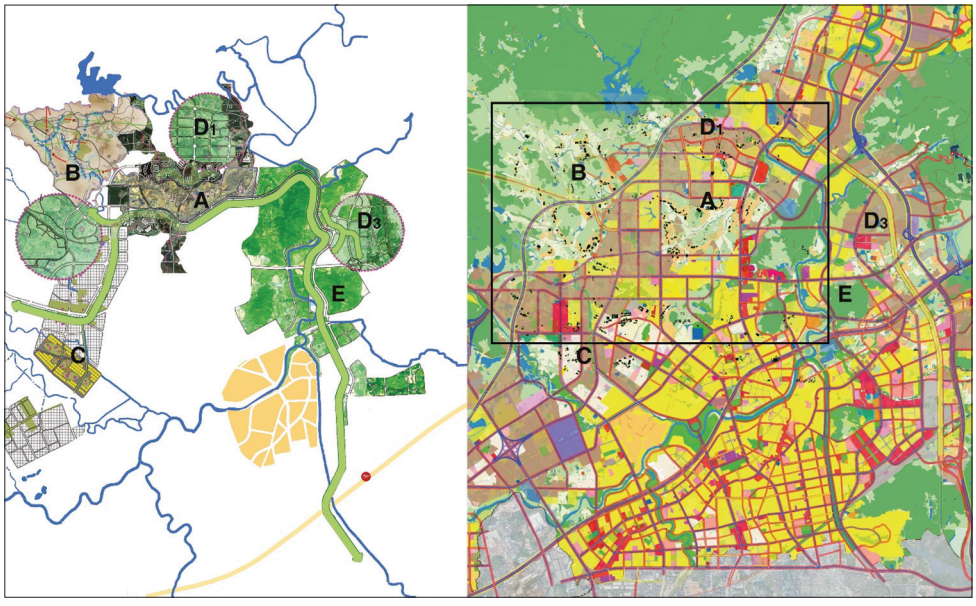

Figure 5. Left panel: Scheme of Huiyang's conservation plan for Hakka heritage, including the proposal of the "parkway" connecting the historical and natural areas of Qiuchang commune and Danshui commune. Right panel: Huiyang Master Plan 2021 – 2035 (Huiyang Bureau of Housing and Urban-Rural Development, 2021). Within the frame, the villages of the Qiuchang commune are highlighted in black (based on the 1979 Qiuchang Commune map), with the letters (A-E) corresponding to the areas of the plan proposed by our team from Politecnico di Milano. Source: Chen *et al*. 2023, p. 95

A proposed methodology involved subdividing the territory into "landscape units" corresponding to the clusters of Hakka residences sharing common orography (hills and plains) and a water network (rivers and irrigational canals) within the boundaries of the 12 villages that make up the Qiuchang commune. Each of these clusters comprises several residences built by the same family "clan" following the rules of Feng Shui.[9] Responding to the request of local administration, we provided a detailed plan for six landscape units (three in the "A" area and three in the "B" area).[10] In these plans, we outlined criteria for architectural restoration, the reuse of historical residences, and guidelines for achieving a balance between new construction and rural activities while preserving functionality within the rural landscape. In this way, our approach embraced Guldin's and Davis's vision of a new kind of settlement, one that blends elements of both urban and rural living. Despite the age of their publications, their insights were invaluable for understanding the situation we encountered in Huiyang over the past decade. Our project was developed in consideration of this situation. Surprisingly, many of the most relevant suggestions we presented in our reports 10 years ago to the local administration concerning a strategy for conserving an extensive heritage within a process of urban development have been incorporated into the new Huiyang Master Plan 2021 – 2035.

The planning process may be slow, but when comparing the New Master Plan (Figure 5, right panel) with the one from 2007 – 2020 (Figure 4), several significant changes become evident: "A" area, originally designated for offices and housing with a very narrow green strip, has now been transformed into a large central park that includes historical residences and their agricultural land; the facilities of the new city, originally located in blocks alternated with residences and offices, have been relocated in correspondence with the historical nuclei of villages; a "parkway" linking different villages and natural areas (Danshui river and Mountain Park E) is forecasted, following the path we suggested.

[9] Take the case of the clusters in Tie Men Shan and Ling Hu villages, which were built by the Ye family (Figure 6). See: Chen Z., 2023, Rural Fenshui in Huiyang Hakka villages in Tie Men Shan. In: Chen, Meriggi, Tan, 2023: 76-82; Tan, Z. (2023), Brief History of the Ye family in Huiyang. In: Chen, Meriggi, Tan, 2023: 189.

[10] See: Milan Polytechnic University – School of Civil Architecture – Department of Architectural Design, 2013b. An extended and more detailed description of the landscape units, which includes 10 units and 43 residences in Qiuchang commune territory is published in: Tan Z., (2023), Atlas of Hakka residences in Qiuchang "commune". In: Chen, Meriggi, Tan, 2023: 179-243.

In Figures 6-8, we present some samples of detailed projects for the C areas, featuring new activities whose morphology and typology are designed according to the hilly and historical context of the area.

An industrial park, a secondary school, a hospital, and samples of residential units are designed by incorporating Hakka architectural types and the logic of grouping buildings, following the land morphology of Hakka villages.

3.2. Project: "The New Linpan-er" (Pidu, Chengdu metropolitan area)

The project, "New Linpan-er,"[11] is located in Chengdu, where Skinner conducted his rural fieldwork and drew the rural marketing theory. It focuses on how to research rural settlements within the urban-rural continuum.

Linpan settlements are found in the Chengdu Plain, the fourth-largest city in China, with a population of 15 million people in 2016 (National Bureau of Statistics of China, 2022). In addition, Chengdu is a pilot city for urban-rural integration authorized by the Chinese central government, which means that many of the city's villages require transformation.

[11] The project, the "New Linpan-er", is based on Mao Lin's doctoral dissertation (2021), supervisor M. Meriggi. It has been developed by the author in a collaboration agreement since 2016 between Politecnico di Milano and the Faculty of Architecture of Chengdu Southwest Jiaotong University in collaboration with Pidu district (Chengdu) Linpan Association. The program was coordinated by prof. M. Meriggi (Politecnico di Milano) and prof. Liu Hongtao (Chengdu Southwest Jioatong University).

Figure 6. Proposal for Tie Men Shan and Ling Hu "landscape unit" in the clusters of Hakka residences of the Ye family. Green: green corridors; red: Hakka *weilong* houses; brown: villages; white: new buildings, including an industrial park (A), a secondary school (B), a hospital (C), and a residential compound (D). The road network follows the topography of the hilly landscape. Source: Meriggi, 2015, 2017 and Acuto & Meriggi, 2023, p. 166–167

The most common type of rural settlement in the Chengdu Plain is the "Lin Pan" form. The character "*Lin* (林)" means "forest," and "*Pan* (盘)" means "plate." Linpan is a residential form that refers to both a small residential unit and an entire settlement system. In each Linpan unit, there is at least one family household at the center, surrounded by bamboo and other local arbors (Figure 9). The outer layer typically consists of fields and rivers. The word "Linpan" vividly portrays the form and pattern of the residential space (Ji, 2015; Shu *et al.*, 2013).

Figure 7. Proposal of a new secondary school in Ling Hu Village. Source: Meriggi, 2015, 2017; Acuto & Meriggi, 2023, p. 176–177

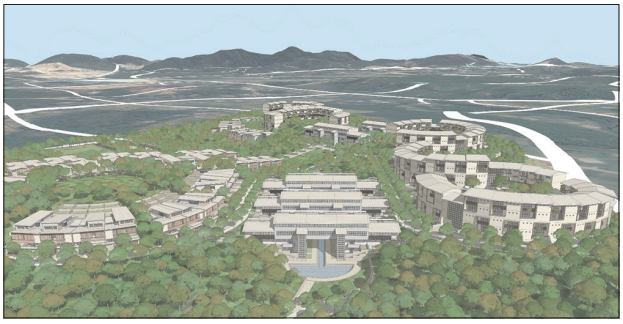

Figure 8. Proposal of new housing compound in Xiang Ling Village. Source: Meriggi, 2017; Meriggi, (with Belli), 2023, p. 158–159

The development and spatial distribution of Linpan settlements in the Chengdu Plain are greatly influenced by the ancient Dujiangyan dam and its irrigation system. This UNESCO World Heritage site features an irrigation water system that is over 2,200 years old and supports thriving agriculture across the Chengdu Plain. As a result, the region's settlements have adopted a scattered and flexible mode of housing, with the Linpan being the most common type. Within the framework of this irrigation system, towns in the area are densely distributed on a small scale, while numerous rural settlements are evenly scattered throughout the region. The overall urban-rural continuum structure in Chengdu can be seen as a residential network consisting of variously sized Linpan settlements.

A translated map, published by the Army Map Service and created by the Corps of Engineering in 1958, reveals an evenly distributed pattern of cities and towns across the Chengdu Plain (Figure 10). The majority of these towns and cities align with the direction of the water system and are interconnected by roads that either parallel or intersect the watercourses, forming a stable spatial network. Consequently, the Dujiangyan water system functions as the foundational environment for the development of Chengdu's urban-rural continuum structure (Fang, 2012).

To gain a better understanding of the scattered nature of Linpan settlements, we conducted a thorough analysis of their configuration logic by examining their satellite images. Our investigation focused on the morphology of these settlements and classified them into five distinct types based on the natural factors influencing their composition: camp, stream, concentration, meander, and line (Figure 11).

The research area, located in the Pidu District, lies between the Dujiangyan Irrigation System and Chengdu. The district has experienced rapid urbanization, transforming from a rural county into a thriving urban

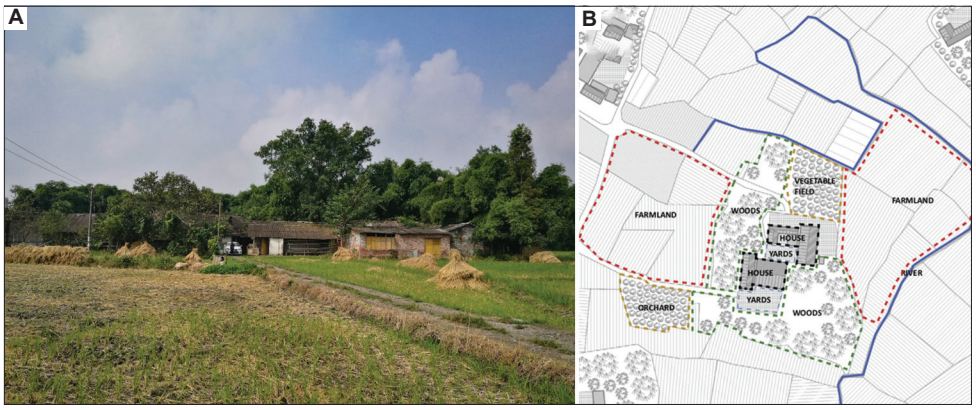

Figure 9. (A) The view of the Linpan landscape. (B) The composition of one Linpan settlement unit. Source: (A) Photograph by Mao Lin. (B) Lin, 2021

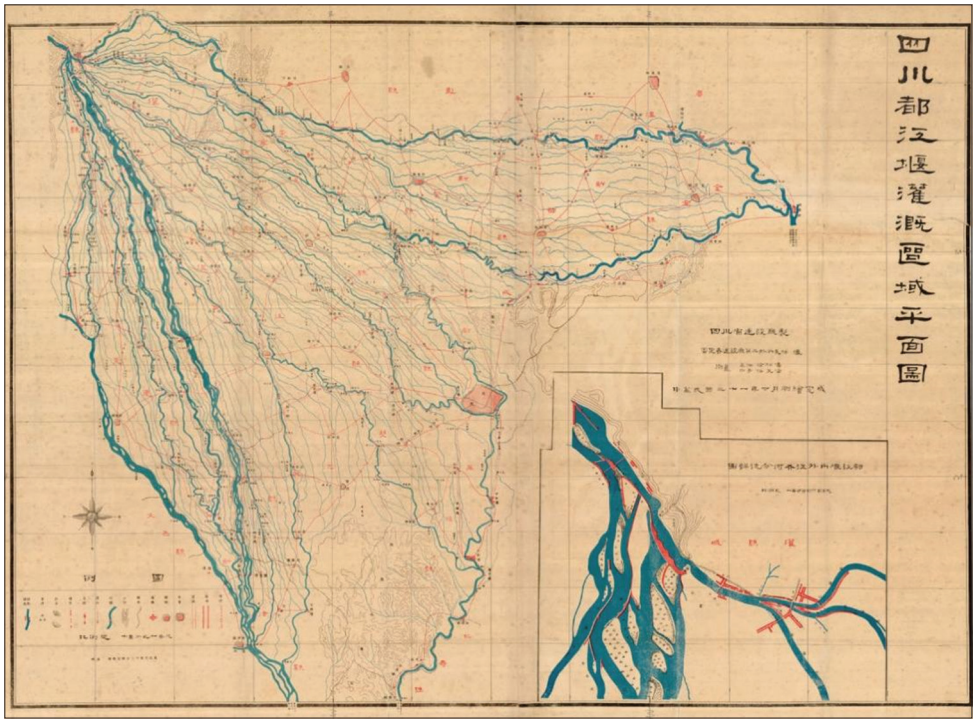

Figure 10. The water map of Dujiangyan Irrigation System was plotted in 1932. Source: Document of National Water Conservancy Bureau from Archives, Institute of Modern History, Academia Sinica(https://archives.sinica.edu.tw/en/index.php/nggallery/thumbnails?project=national-water-conservancy-bureau-2); the image was still downloadable in 2018 but appeared to have been taken down from the site as of November 1, 2023

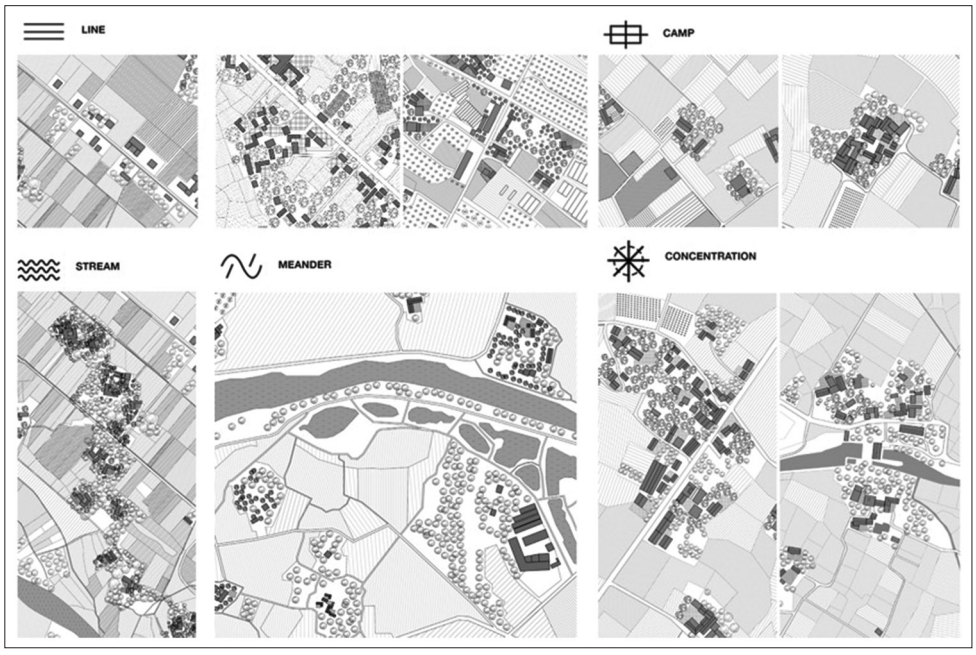

Figure 11. Morphology of Linpan settlements. Source: Compilation by Mao Lin

center, all while preserving its rural customs. This dynamic is clearly evident in the blending boundary, which vividly demonstrates the regional urbanization that takes place within the urban-rural continuum.

This project entailed an analysis of historical population data and population density, drawing on insights from Skinner's (1964) findings regarding the connection between community density and hexagonal radii to determine a

suitable radius for analysis in the studied area. Using the standard service radius of markets, defined as a person's 1-h walking distance (4 km), the gray-line hexagons were expanded to create a red-line hexagonal structure with a 3.71 km radius, effectively covering the entirety of Pidu (Figure 12). This result indicates a balanced and stable geographic distribution of standard markets, in line with Skinner's theory regarding the emergence of market towns and villages.

The decentralization of the urban population has inevitably led to an increase in rural populations. This trend underscores the need for improved transportation systems and increased settlement densities within the Linpan organizational structure. These transformative measures align with the growth of new villages under the traditional urban-rural continuum theory. Appropriately centralizing Linpan settlements and boosting their residential density achieve two crucial goals: meeting the housing requirements of modern rural communities and preserving cultivated land through more efficient land utilization.

3.2.1. Planning strategies under the urban-rural continuum

The dispersed configuration of Linpan settlements is characterized by a polycentric living style, rooted in the urban-rural continuum. In this arrangement, the population is not concentrated but resides in scattered groups, each occupying individual houses and land for both living and farming. The fact that the new residents have access to sufficient farming conditions and possess their own territory aligns with the development law observed in the emergence of new villages within the urban-rural continuum.

Tangchang Town is actively boosting its local transportation network to enhance connectivity among neighboring communities. As part of this initiative, a monorail system has been proposed for its environmentally sustainable features, aiming to establish a link between Ande and Tangchang, ultimately connecting to the Chengdu-Dujiangyan high-speed rail passenger station in Ande. The Tangchang-Ande line, anchored by the monorail, will serve as the backbone, with future plans to progressively expand its reach to include other rural communities along the route. Figure 13 provides a detailed strategy for the smaller-scale square plot on the left side of Tangchang Town (the boxed area in frame A), further elucidating this plan. Situated amid a multi-functional urban-rural land, this block embodies characteristics of both urban and rural areas.

The establishment of Tangchang Station enables the monorail system to encircle the primary line within the fields. Following a site analysis, vital residential areas will be identified as primary station points. The monorail will be installed in keeping with the texture of farmlands, incorporating interchange points that link the local

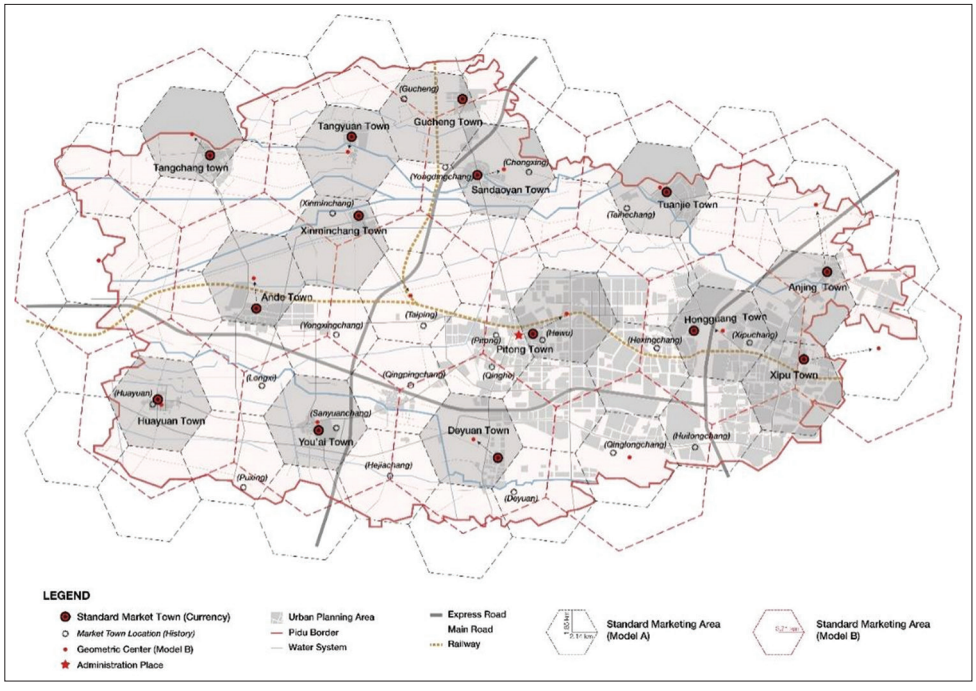

Figure 12. The urban-rural continuum based on the Pidu modern planning map. Source: Lin, 2021

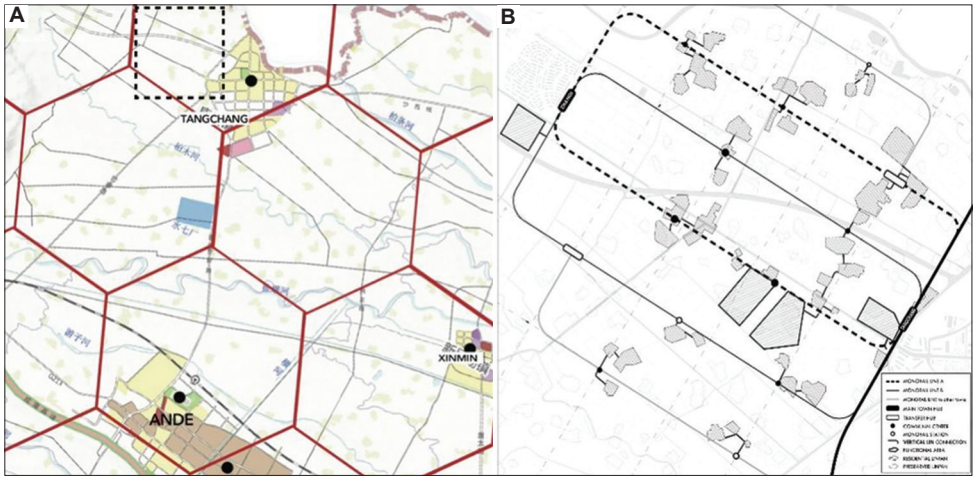

Figure 13. (A) The simplified urban-rural continuum structure around Tangchang Town. (B) The transportation network in the demonstration area. Source: Lin, 2021

communities to external areas. Stops will be positioned near essential public service facilities, thereby enhancing the visibility of communal architecture. Reserved Linpan settlements with specific functions will be seamlessly interlinked with adjacent stations, culminating in a holistic structural framework for this area.

3.2.2. The re-organization of rural communities in Pidu

The notion of "community" lies at the heart of the urban-rural continuum. Through the enhancement of transportation infrastructure and effective planning in Pidu, we can improve the accessibility of scattered rural settlements and strengthen the connections among Linpan communities of varying sizes. This method facilitates a more nuanced analysis of rural communities, allowing us to restore their organizational structure and identify the emerging potential for further development.

The introduction of monorail trains or other environmentally friendly forms of transportation brings about significant changes in the organizational structure of rural communities. It leads to the emergence of a group-based, transportation-centric arrangement, with major rail transit stations serving as the nuclei for large suburban communities. Secondary primary transportation systems then link these transit stations to peripheral rural areas, fostering the organization of these communities around the stations themselves. These communities become distinct entities within a certain scale while maintaining connections with smaller surrounding settlements at the local level.

As rural communities expand around monorail stations, transportation complexes can be established, featuring large-scale public service buildings (as illustrated in Figure 14). Given the dispersed spatial layouts of Linpan settlements and the need to protect agricultural land, redesign efforts should prioritize the utilization and management of existing renewable Linpan areas. Secondary service-type buildings may be extended and developed around these stations, incorporating field paths as part of the framework. These structures may require specialized functions and must be carefully erected in line with the topographical and climatic conditions of the site.

Transportation hubs play a key role in the enhancement of communal buildings, serving as critical nodes that can foster the development of public service facilities within their vicinity. These structures act as vital conduits, revitalizing rural areas and offering residents access to opportunities akin to those available in urban settings. Effective transport infrastructure planning is also crucial, as it ensures efficient connections between these facilities, creating a cohesive network of communal architecture. Ultimately, public service buildings are indispensable in unifying the residential settlements in these areas, thereby spurring a surge in diverse public services to enrich rural life and reduce disparities between rural and urban accessibility.

In the case of Linpan settlements dispersed throughout farmland, a fundamental structural layout can be established by connecting them through field paths. The selection of sites for public buildings in the Linpan area should take into account various factors, such as location, environmental conditions, and the potential for reusing existing settlements.

When addressing the issue of designing new functional buildings with reference to urban types and in pursuit of the goal of achieving parity in public service levels between

Figure 14. The vision of the future city in rural Chengdu which draws inspiration from Linpan settlements. The central area of the image features a new complex comprising a multifunctional courtyard, residential towers, the pavilions of a secondary school, and an agricultural university. The locations of the stops of the suspended monorail are in correspondence with different clusters. Source: Lin, 2021

urban and rural areas, it becomes evident that the existing rural public buildings are insufficient to meet the growing demands of the population. Our on-site investigations in rural areas have revealed a dearth of public buildings, particularly in the domains of education and health care. Schools in urban areas boast superior facilities, equipment, teaching quality, and educational resources compared to their rural counterparts. Similarly, medical and health-care services are concentrated in cities, resulting in a relative scarcity of such services in rural areas. The phenomenon of rural hollowing-out has further exacerbated this issue, with an increasing proportion of children and elderly individuals comprising the actual rural population.

To address this issue, the proposal recommends the establishment of various public service buildings, taking reference from analogous structures in urban areas. These buildings include kindergartens, schools, research institutes, nursing homes, hospitals, agricultural green food factories, and other public facilities. The proposed sites for these new buildings primarily encompassed abandoned Linpan settlements, which facilitate the preservation of agricultural land. Furthermore, rural factories, greenhouses, and storage spaces for goods are also located on arable land near urban areas due to urbanization, highlighting the need for essential production and processing facilities in rural agricultural land.

When considering how to design new Linpan residential forms by "learning from" Linpan morphology and addressing the challenge of inheriting the characteristics of vernacular architecture, we have integrated Linpan attributes into contemporary architectural design through the study of typology and morphology. The rules derived from this study may be applied to assess the integration of new developments within their environment. Architects can choose forms and types that align with the context of a location as references when conceptualizing design ideas for new urban settlements. This approach is particularly relevant for vernacular architectures, such as the Linpan settlement, which may lack distinctive architectural features compared to other Chinese dwellings.

In terms of morphological considerations, camp-style Linpan settlements are typically more secluded and situated away from main thoroughfares; therefore, they primarily serve residential purposes. Streamlined and linear Linpan settlements, influenced by farmland patterns, are often located along roads or rivers (ditches), possessing dual residential and public functions due to their proximity to busy routes. When transforming these areas, designers may incorporate certain public program elements. Meandering river Linpan settlements tend to feature large, open farmland areas suitable for group development, and their potential transformation should prioritize water resource management. Concentrated Linpan settlements, positioned at crossings of pathways, farmland textures, and waterways, usually exhibit more prominent public features. These sites represent potential candidates for adaptation into public buildings.

3.3. Project: "The Future of Seawall Towns" (Kandun, Cixi, Ningbo)

Cixi is a prefecture-level city under Ningbo, located on the Sanbei Plain along the southern coast of Hangzhou Bay. The main area in the Sanbei Plain has been shaped through sediment accumulation and artificial development. Since the Northern Song Dynasty (960 – 1127), the construction of seawalls has gradually reclaimed land, shifting the coastline northward. During the Ming Dynasty (1368 – 1644), the establishment of coastal defense stations accelerated the processes of polder reclamation and seawall construction. Over time, these developments, along with the continuous influx of immigrants, led to the gradual formation of settlements along the seawall.

The seawall system comprises the seawall itself, a buffer zone, and the seawall river. Given the absence of natural rivers in the newly acquired land, which hindered transportation and irrigation, an intricate network of canals was dug perpendicular to the seawall river, forming a dense water network throughout the Cixi area (Figure 15, left panel). The seawall rivers were termed *Tang*, while the canals were known as *Pu* (Guo *et al*., 2023).

The seawall rivers (*Tang*) and canals (*Pu*) have shaped the morphological framework of the area. They have partitioned the land into strips and distributed settlements among them, giving rise to a distinctive morphological character (Figure 15, right panel).

Figure 15. Left panel: The seawall rivers (*Tang*) and canals (*Pu*). Right panel: The morphological features of the Cixi area are shaped by seawalls, canals, and settlements. Source: Compilation by Chen & Chu, 2021

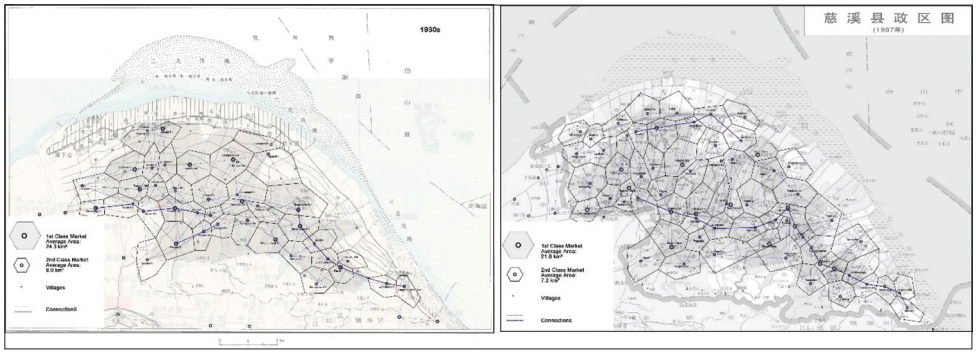

Figure 16. Market distribution in the Cixi area during the 1930s (left panel) and 1980s (right panel). Source: Compilation by Chen & Chu, 2021

This project[12] views the structure of the seawall in the area as a lasting framework. This framework is connected not only to history and memory but also demonstrates its adaptability to contemporary production models such as Taobao Village. Based on the urban-rural continuum, this study elucidates how the endurance of seawalls is manifested in the Cixi area, progressing from settlement cluster structures to morphological characteristics to building typologies at different scales, achieved through the use of Skinner's model, morphology analysis, and fieldwork. As a result, this project addresses this enduring aspect through an urban design proposal based on the research.

3.3.1. Skinner's model of the Cixi area according to the market system

The current settlement morphology pattern in the Cixi area demonstrates a tendency to spread, blurring the distinction between urban and rural structures due to rapid urbanization. At the scale of settlement cluster structure, the establishment of Skinner's model can reveal the underlying structure of the settlement in the Cixi area.

By combining the information from *Cixi Shi Zhi* (Cixi Local Chronicles Compilation Committee, 1992) and historical maps, the map (Figure 16) depicts the locations of the markets in the 1930s and 1980s. Skinner's model mapping is obtained by creating Voronoi diagrams using the markets as the centers on the maps. The two panels underscore the decisive role of the seawall system in influencing the distribution of the market. The recorded markets' locations align with the distribution direction of the seawalls. This alignment is attributed to the high salt content of the Sanbei Plain's soil. Historically, the area north of the *Dagu* seawall in the Cixi region was predominantly engaged in cotton cultivation. The transportation of cotton outward and grain inward required a canal system (Geng, 2022).

Following central place theory, which is grounded in the concept of the most efficient transportation, it is established that each high-level market contains four low-level markets (k = 4). After analyzing the area data in Figure 16, the standard hexagon model (standard Skinner's Model) is formulated based on the mode of k = 4. This model, which elucidates the relationship between higher- and lower-level municipalities, confirms the reliability of the system through an overlay with satellite images from the 1980s.

[12] The project is based on Chen Kan and Chu Xiao's Master's degree thesis (2021), supervised by M. Meriggi. In 2022, Chu Xiao extended the research through fieldwork and interviews in Kandun Taobao Villages, including Yulan Fruit and Vegetable Farm, Peninsula Flower Farm, Qingting Garden Farm, and Tian Shangjin Flowers. Part of the field research findings are published in Meriggi *et al*., 2022.

The seawall system directly shapes the settlement's morphology, spatial layout, and the framework for plot division: different villages are linearly distributed along the seawall rivers (*Tang*), and the long and narrow village plots within each village are distributed along the canals (*Pu*). This morphological system contrasts with common block cities (such as the defense cities in the Cixi area during the Ming Dynasty). The settlements resemble combs, with seawall rivers (*Tang*) forming the backbone, extending along the canals (*Pu*), as depicted in Figure 16.

The standard Skinner's Model, explained in the previous sections, serves as the framework. Through a comparative analysis of the relationship between the seawall framework and the settlement structure in 2020, the settlement forms in the Cixi area can be categorized into five types (Figure 17, left panel). Type I, Type II, and Type III have corresponding relationships with the seawall framework. However, Type IV lacks a clearly defined morphological relationship due to its scattered distribution and small scale. Type V, on the other hand, has evolved from the defense stations established during the Ming Dynasty. Among these settlement types, Type I and Type II are the most common in Cixi and directly exemplify the influence of the seawall system on settlement morphology. These settlements are distributed along the seawall river sand and expanded toward the canals. The key difference between Type I and Type II lies in the presence of two main axes in Type II. In addition to the seawall river, the canal also serves as the main axis to form a cross-shaped axis. Type III is distributed along the northernmost side, following the canal, and does not conform to a pattern along the seawall river.

The distribution of these five settlement types is also related to the expansion order of the coastline: Type IV and Type V areas are furthest from the current coastline and have been less affected by the construction of seawalls. Type I and Type II areas are distributed in the main seawall area. Type III areas are closest to the coastline, and they are of the most recent origin.

When considering the typology of the textures, particularly the relationship between settlement form and the building type, this relationship becomes apparent at the level of texture (Figure 17, right panel).

Based on the framework (comprising rivers and roads) and the filled areas (buildings) within this framework, the coordinate axis diagram depicted in Figure 17 is constructed. The abscissa axis in Type IV (Figure 17, left panel) indicates whether the built environment presented in the texture leans more toward a rural or urban character.

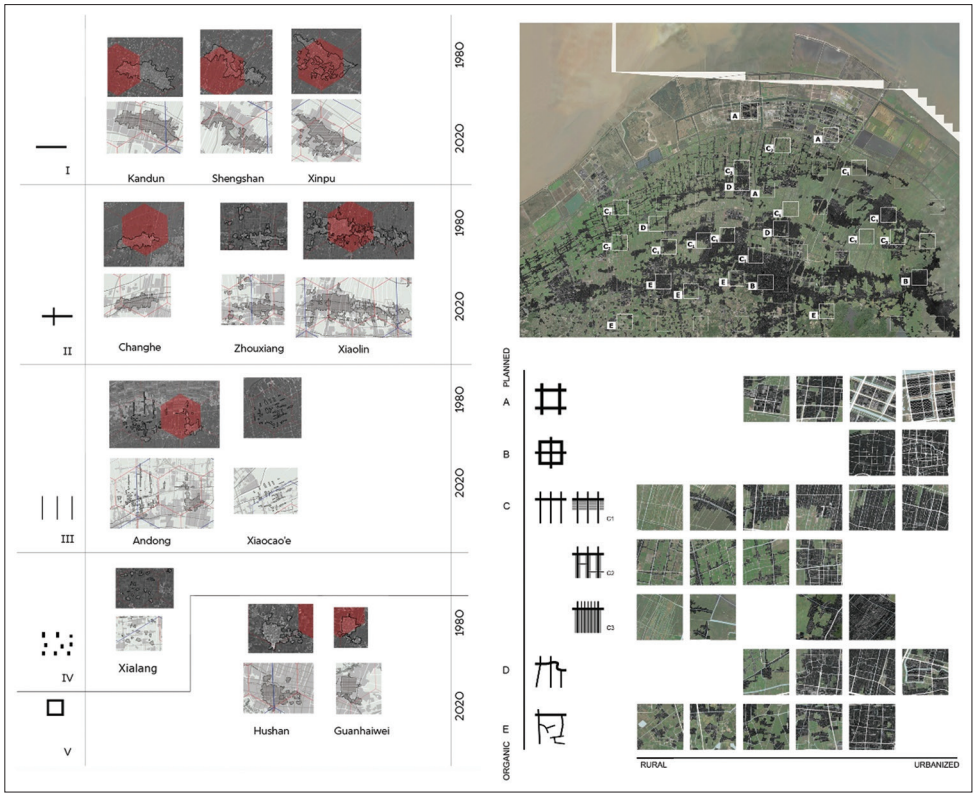

Figure 17. Morphological types of the settlement. Source: Compilation by Chen & Chu, 2021

The ordinate axis indicates whether the control grid of the settlement form is more inclined toward an organic or planned configuration. Unlike the simplistic urban-rural dichotomy, this classification provides a more nuanced response to the urban-rural division mentioned in Section 3.2.

Type III represents a morphological system determined by seawalls. As evident from the ordinate axis, this morphological system falls between planned and organic. The abscissa axis reveals that this morphological system spans the entire spectrum from rural to urban areas, demonstrating a high degree of adaptability.

3.3.2. Fieldwork in Kandun

Kandun is a town affiliated with Cixi, representing a typical example of the morphological adaptations previously mentioned. It adheres to the framework defined by seawalls and has adapted to populations of different sizes from the 1970s to the present.

The seawall framework not only serves as a morphological structure but also as an economic production structure. During the Jiajing period of the Ming Dynasty (1522 – 1566), residents in Kandun initially developed the salt and fishing industries along the beach. Subsequently, due to the continuous northward expansion of beaches, cotton and beans became widespread crops during the Qing Dynasty.

These main industries have fostered the growth of the handicraft industry. Salt workers required tools such as scrapers and shovels during the salt age, while fishermen needed fishing boats and hooks. The agricultural era necessitated items such as grass knives and fences, which local craftsmen provided. With the evolution of the cotton industry and the plantation of oil crops, cotton processing and manual oil workshops also began to be set up. Kandun has a long history of family workshops, where land is used for agricultural production, and housing plays a crucial role in the development of the handicraft industry (Fang, 2006). This production relationship has persisted in today's Taobao village[13].

In the present day, Kandun comprises four Taobao villages. The distribution pattern of villages, established through the construction of seawalls, has laid the foundation for the present-day distribution of production areas and residential areas. The plot distribution pattern along *Pu* within the village has also persisted into the contemporary era, adapting to the growth of the village population.

In the present situation, Kandun is demarcated by the Haitang river, resulting in a land use pattern where the built-up area lies to the south while the agricultural area extends to the north. The administrative boundaries of villages within Kandun are divided along the *Pu*, effectively segregating each village into two distinct areas (Figure 18).

Unlike the general case of single-function Taobao villages (AliResearch, 2019), this spatial configuration allows the four Taobao villages within Kandun to form an industrial model that encompasses both industry and agriculture.

Highly productive family workshops have played a pivotal role in driving industrial growth. However, driven primarily by economic considerations, individual villagers have been committed to maximizing and developing their homesteads[14] in the most cost-effective manner. This has led to a chaotic and disorganized situation in this part of the built-up area. The production scale within these family workshops cannot be further expanded due to the limitation of available residential land. However, field research has revealed a phenomenon in which farms in the northern agricultural area have engaged in street beautification in the southern built-up area. It is a return to the tradition of mutual promotion between agricultural and residential areas in the Kandun area. The examples from the field research illustrate that the development model, formed by the spatial morphology and production pattern highly related to the construction of the seawalls, remains highly adaptable in the latest trend of contemporary Taobao villages.

3.3.3. Reshaping urban-rural continuum in Kandun

The Seawall-based urban-rural continuum system in the Cixi region faces a threat from contemporary generic urban design. In 2020, the China Academy of Urban Planning & Design unveiled the Qianwan New Area, which primarily covers the northern part of the Sanbei Plain, incorporating Kandun into its development plan. The objective of the plan is to transform this area into a new high-tech manufacturing city accommodating 1.25 million people by 2035.[15] Within the Kandun area, a business office area dominated by towers is set to emerge, with the high-speed railway station as the center. This vision sharply contrasts

[13] Since 2009, China has witnessed the phenomenon of using e-commerce platforms such as Taobao for product sales in rural areas. If the sales volume and the number of participating villagers reach a certain scale, these areas are officially recognized as Taobao villages.

[14] Homestead is the land used by rural villagers to build residential houses, including land designated for housing, accessory houses, and yards.

[15] Ningbo Planning Bureau; China Academy of Urban Planning and Design, 2018.

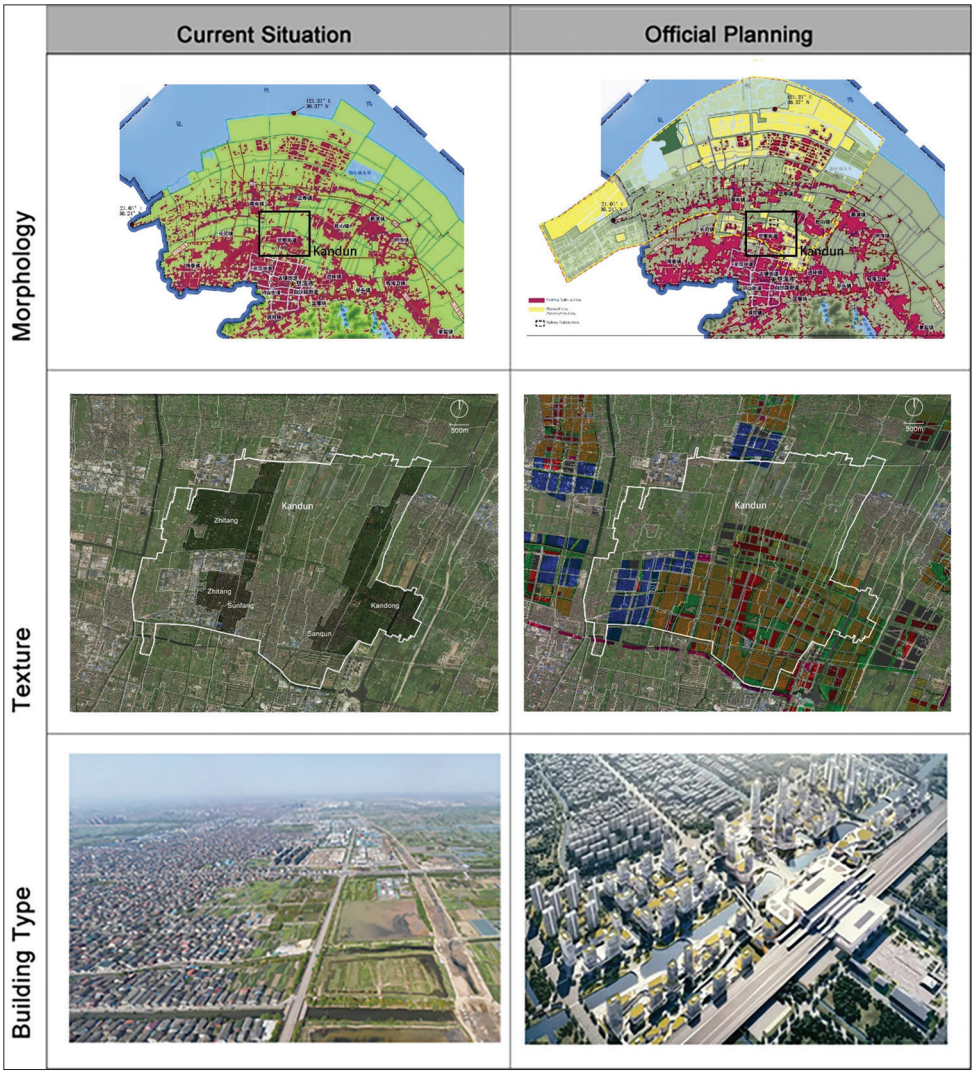

Figure 18. Comparison of planning and current situation. Source: Compilation by Chen & Chu, 2021

with the existing seawall-based settlement morphology within the planning scope and the dense arrangement of self-built houses by villagers based on the homestead concept in Kandun (Figure 18).

The realizability of the heroic imagination of official planning is doubtful, especially given the current high vacancy rate in office buildings in the central city of Ningbo. Moreover, it poses a threat to the bottom-up Taobao village economic model. However, the current low-quality built-up areas and small out-of-scale cottage industries in the Kandun area have become a constraint to development in the absence of guidance.

Drawing upon the insights presented in Sections 3.3.1 and 3.3.2, it becomes evident that the morphological characteristics associated with seawall-based morphology not only stand as remnants of historical processes but also harbor the potential for fostering the development of Taobao villages characterized by a high degree of adaptability. Consequently, transforming the morphological framework of seawalls emerges as an alternative means of integrating bottom-up development and top-down planning.

Considering the current morphological characteristics of the Kandun region and its surroundings, our proposal encompasses different strategic actions. First, in the context of urban renewal along seawall rivers, the recommendation is to replace low-quality industrial zones with medium and high-density residential and commercial areas. Along the direction of the canal, a continuous complex of facilities, designed in a strip-like configuration echoing *Pu*'s architectural form, is proposed. These facilities would serve as a structural framework for the growth of the village, accommodating growth through modular units

while maintaining defined spatial boundaries to prevent uncontrolled occupation on agricultural land. At the same time, this scheme exhibits a high degree of replicability within the Cixi area. By adopting similar strategies in adjacent villages and towns, it achieves the same development intensity requirements specified by official

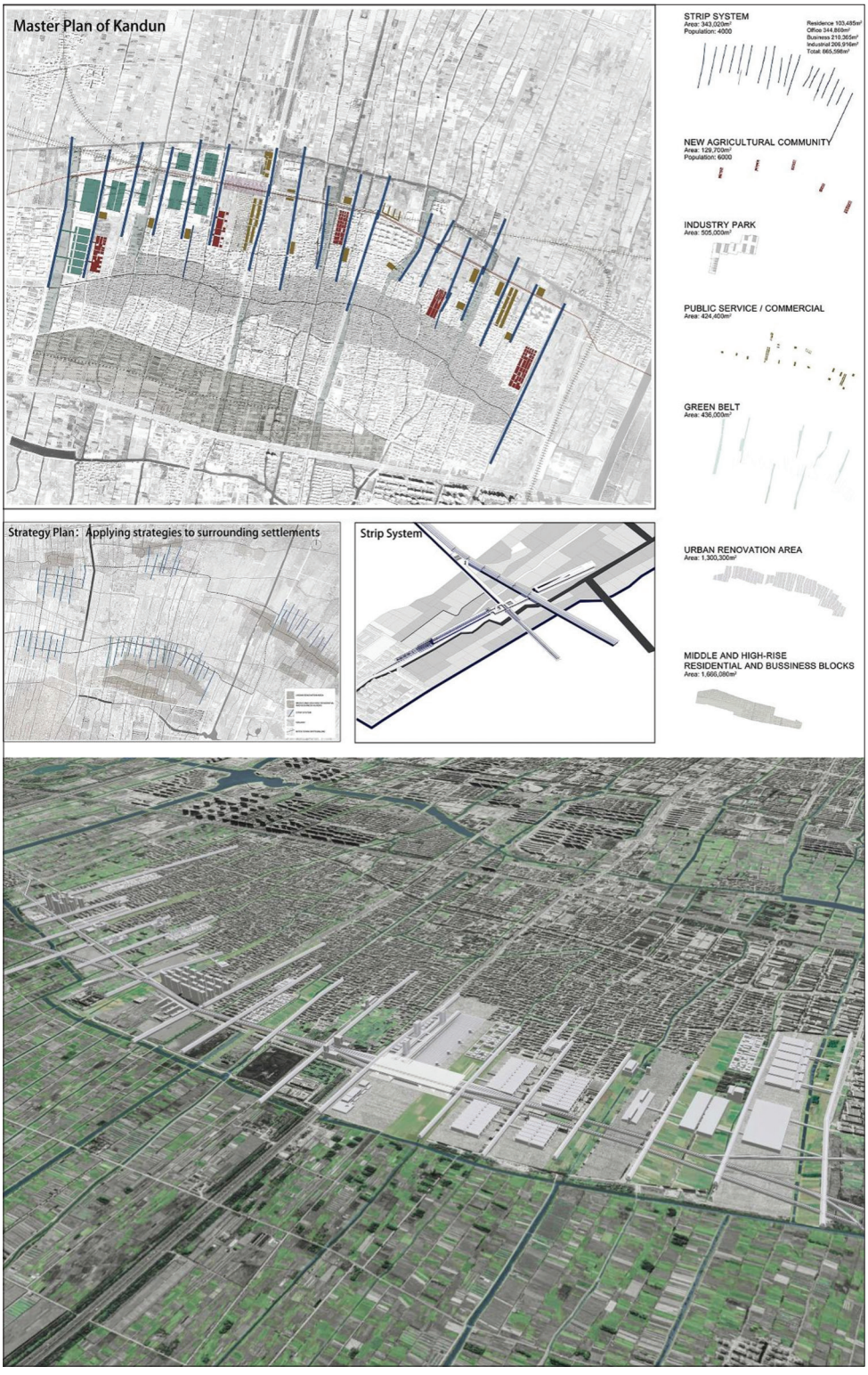

Figure 19. Seawall-based morphology scheme. Source: Compiled by Chen & Chu, 2021

planning requirements while injecting new vitality into the bottom-up economic model. Furthermore, capitalizing on the construction of a high-speed rail station as an opportunity, several nearby villages and towns can form a cluster of villages and towns with skyline connections. This configuration facilitates adequate linkages while maintaining the independence of individual villages and towns (Figure 19).

The master plan for Kandun presents more programmatic details: the strip volume defines the boundaries and becomes an infrastructure framework. Between the strips, volumes with different functions can be arranged. The distinctive morphological features can be reflected in a collage of top views and aerial views (Figure 19, upper panel). Within this framework formed between the buildings, areas for residences, factories, and a railway station can be flexibly arranged to form clusters with varying densities. The scheme provides a total of 860,000 square meters of new floor space for Kandun, fully addressing Kandun's recent development requirement.

The strip system operates as a system of modules capable of expansion, extending from the built-up area of the settlement to the surrounding farmland. The strip system demonstrates different variations in different areas, which are outlined as follows:

(i) As a supplement to the high-density built-up area, the strip serves as a corridor facility on the ground floor, offering villagers co-production spaces for handling spillover orders from family workshops. A flexible building framework effectively organizes logistics, storage, production lines, and more. The second and third floors of the strip can be used as a complex facility combining offices and shops to cater to the needs of online stores and incubators. The fourth level can be designated for housing the floating population. Between the strip systems, various types of buildings can be developed to complement the activities supported by the preset strip system. This combination of strip systems and diverse building types enhances the scheme's versatility and adaptability.

(ii) The SkyTrain station is connected to the strip system, functioning as a central node within the strip system. It facilitates transportation and commercial activities, serving as a hub that connects different infrastructures. It extends across both sides of the strip, spanning the carriageway and serving as an entrance to the park that leads to the skyline track.

(iii) The strip system's extension into farmland can accommodate a range of facilities. As depicted in the upper panel of Figure 19, the roof remains open to the public for viewing the farmland. The interior of the facility features space trusses, offering ample room for large exhibitions and product showcases.

4. Conclusion

The projects presented here aim to exemplify a design methodology based on the interpretation of the historical structure of the Chinese countryside. This methodology serves as a source of models from which to learn spatial configurations that originate from the specific context, perpetually evolving as one transition from one countryside landscape to another in China. It is important to note that this approach does not entail a simple repetition of history but rather a way to explore the values underlying these forms. This allows us to reshape our approach to future development in response to the current social situation. As an output of our first project in Huiyang, which embraced this approach and involved collaboration and dialog with the local administration, we could appreciate that the New Master Plan for Huiyang 2021 – 2037 effectively incorporates many of our suggestions. This integration has been thoroughly elaborated in Section 3.1 and Figures 4 and 5.

The perspective of the research presented in this study aims to include research materials from three ongoing case studies in peri-urban villages (Zhangzhou, Fujian; Jiang Nan, Zhejiang; Huizhou, Anhui) in a forthcoming publication. This publication will feature a methodological chapter intended for Chinese planners, illustrating potential approaches for integrating historical rural architectural and landscape forms into the construction of future urban development. This method will be based on six different case studies from monumental rural areas, each marked by unique local architectural cultures and geographical conditions.

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Conflict of interest

The authors declares no competing interests.

Author contributions

Conceptualization: Maurizio Meriggi
Investigation: All authors
Writing – original draft: All authors
Writing – review & editing: Maurizio Meriggi, Mao Lin, Xiao Chu

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Data will be made available from the corresponding author on reasonable request.

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ORIGINAL ARTICLE

A study on the residents' housing satisfaction with condominium apartments in the urban area of Henan, China

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Abstract

This study aimed to assess the satisfaction levels of condominium apartment residents regarding their housing and to identify potential improvements for apartment planning in Henan Province, a region characterized by a substantial population and rapid urbanization. To gauge resident's satisfaction, a specialized condominium apartment housing satisfaction measurement tool tailored to the specific conditions of Henan Province, China, was developed. This tool was subsequently employed to conduct an online survey, yielding a dataset of 594 responses, which were subjected to comprehensive analysis. The results of the study reveal that apartment residents in Henan Province evaluate their housing satisfaction based on seven content factors (internal facilities, internal structure, indoor environment, complex characteristics, location characteristics, management characteristics, and economic characteristics). Notably, the economic characteristics category, which encompasses the comparison of management levels to management costs and the assessment of management costs, emerged as the most influential factor affecting overall housing satisfaction. Following closely were management characteristics, which included aspects such as hygiene, security measures, maintenance, safety management, and operational management. These findings highlight the importance of considering not only the physical environment but also the need for systematic guidance regarding management costs and practices related to life after moving into condominium apartments when planning the supply of apartments in Henan Province, China.

Keywords: Housing satisfaction; Apartment residents; Improvement of apartment housing dissatisfaction; Henan Province of China; Structural equation modeling

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1. Introduction

Housing not only ensures basic living conditions for individuals but also serves as a foundation of their lives, with governments guaranteeing the right to housing. However, the rapid surge in housing demand, driven by industrialization and urbanization, has resulted in private construction companies being granted the authority to supply housing, leading to the construction of massive apartment complexes. These apartment developments offer new housing options and opportunities for relocations for local residents and neighboring communities. In regions such as Henan Province, where cities such as Zhengzhou and Xinxiang have experienced significant growth due to

industrialization, numerous high-rise apartments have been made available. Consequently, the proportion of apartments in Henan Province now stands at 61.6%. This surge in apartment supply has prompted residents to consider moving to new areas and choosing these newly supplied apartments as their preferred places of residence.

In the future, with the rapid urbanization and economic development not only in Henan Province but also in cities across China, there is an anticipated significant increase in the demand for new urban housing. The demand for new housing among urban households has already risen from 8.9% in 2000 to 21.7% in 2010 (China Government Network, 2021). Furthermore, the United Nations projects that urban expansion and the demand for new housing will continue to accelerate. Henan Province, much like other cities in China, is expected to align with this prevailing trend, remaining on the course of urbanization and housing demand growth.

The supply of apartment housing has significantly contributed to alleviating housing shortages in Henan Province, supporting population migration as the city develops (Yang, 2022). In addition, by providing apartments in various sizes, the living space and living conditions per capita for urban households have significantly improved. However, apartments in Henan Province tend to cater more to common demands rather than accommodating individual resident preferences. This underscores the importance of soliciting feedback from residents to enhance the quality of apartment housing. Gathering user evaluation feedback and exploring avenues for improvement are imperative in ensuring the continued supply of high-quality apartment housing.

The process of gathering feedback from residents or users is academically known as post-occupancy evaluation (POE). POE involves diagnosing and evaluating the quality of the living environment from the perspective of residents after a certain period of using the physical space. The evaluation results are subsequently utilized in the planning process for the development of future physical spaces to create optimal living environments. Preiser *et al*. (1988) proposed a comprehensive set of evaluation elements for this purpose, encompassing technical aspects (fire safety, structure, hygiene and ventilation, electrical systems, exterior walls, roofs, interior finishes, acoustics, lighting, and environmental control systems), functional aspects (human factors, storage spaces, communication and workflow, flexibility, and adaptability), and behavioral aspects (proximity and territoriality, privacy and interaction, environmental perception, image and meaning, environmental cognition, and orientation) (Oh & Yang, 2011). Drawing upon Presier *et al*.'s perspective of POE, in South Korea, apartment housing evaluation has been conducted through residential satisfaction surveys to identify areas for improvement. As a result, apartments have continued to evolve and progress. In China, an annual residential satisfaction survey, encompassing 10 key indicators, is carried out to improve the quality of apartments. However, it was reported that in 2021, for the first time since 2018, residential satisfaction with apartments across China had declined. The finding suggests a pressing need to address issues related to housing quality and real estate services, such as improvements in the maintenance of newly delivered facilities and service delivery (China Quality News Network, 2022).

When evaluating residential satisfaction in apartments located in Henan Province, China, it is essential to take into account the management aspect. Despite the surplus of apartment supply, there is a dearth of research focused on residential satisfaction. To enhance the quality of apartments in Henan Province, particularly by incorporating factors related to facility maintenance and management services, one can theoretically establish evaluation criteria based on the satisfaction assessment model proposed by Preiser *et al.* (1988). This approach can help identify areas with lower satisfaction ratings and subsequently address them, thereby contributing to the maintenance of apartment quality and preventing a decline in the performance level and real estate value of apartments in Henan province.

Therefore, in this study, POE was conducted through resident assessments of existing apartments, with a specific focus on Henan Province, a region characterized by a substantial population and ongoing rapid urbanization. The aim of the study is to identify areas for improvement in the apartments that have already been supplied, with the anticipation of continued apartment supply in the future. The objectives of the present study are as follows:

(i) The study aims to develop and verify a housing satisfaction measurement tool capable of evaluating the post-occupancy experiences of residents in Chinese condominium apartments within Henan Province.
(ii) The study seeks to measure and analyze housing satisfaction among apartment residents in Henan Province, China, with the goal of understanding the current state of their housing satisfaction. In addition, the study aims to identify the effects of the sub-factors that comprise the housing construct on their overall housing satisfaction and their inclination toward housing movement.
(iii) By identifying factors associated with the overall housing satisfaction related to residents' socio-demographic general characteristics or housing characteristics, the study aims to provide valuable

insights for improving the quality of condominium apartments in Henan, China. The identified factors will offer guidance for enhancing the housing satisfaction of residents, whether they are maintaining existing, aged condominium apartments or planning new ones in the region.

2. Literature review of housing satisfaction

2.1. Conceptual definition of residents' housing satisfaction in previous studies

The concept of housing satisfaction has its roots in customer satisfaction, with research in this area commencing in the 1980s when American scholars extended the theory of customer satisfaction to housing research (Bai, 2019). Housing satisfaction is a concept grounded in the subjective evaluation of the residential environment, encompassing an evaluation of the degree to which the technical, functional, and behavioral needs of the residential environment are satisfied. While different researchers have examined the evaluation of the residential environment from slightly varying perspectives, they all share a common focus on the subjective evaluation of services provided within the residential environment and residents' needs. For instance, Galster and Hesser (1981) viewed the difference between the actual residential environment and the desired residential environment as housing satisfaction. Baldassare (1982) characterized it as a subjective evaluation of residents' living environment. Kang and Lee (2004) regarded housing satisfaction as residential satisfaction in Korea and defined it as the subjective evaluation of the residence status or living environment in which the resident resides. Xue (2017) stated that housing satisfaction is a subjective judgment regarding the psychological state that represents the overall satisfaction of residents with China's living environment. As such, housing satisfaction revolves around the subjective evaluation and perception of residents. It plays a pivotal role in improving the residential environment by analyzing the subjective evaluation of residents and implementing improvement measures in response to the needs of actual residents. In other words, housing satisfaction is summarized as an individual's evaluation or perception of their residential environment. It represents a subjective evaluation of the interaction between the residents' needs and the technology, functionalities, and behaviors provided within the actual residential environment.

2.2. Factors related to residents' housing satisfaction

The assessment of housing satisfaction is subject to variation due to individual differences among residents, even when they are assessing the same objective reality or condition (Hur & Morrow-Jone, 2008; Schwanen & Mokhtarian, 2004). Housing satisfaction is affected by the resident's gender, age, ethnicity, education level, monthly income, occupation type, duration of residence, and housing size. In addition, the perception of the same object, such as a house, varies based on individual characteristics and one's career (Lu, 2002; Li, 2015; He & Qi, 2014). At present, several studies on housing satisfaction, including those in China, mainly concentrate on researching the factors affecting housing satisfaction. Some studies also delve into the consequences of housing satisfaction, such as complaints, adjustments, and migration. In the 1960s, Wolpert (1966) proposed the stress threshold theory and reviewed the relationship between housing satisfaction and mobility. His research uncovered that when residents found their housing unsatisfactory, housing-related stress exceeded a certain threshold (Wolpert, 1965; Morris & Winter, 1975).

In Korea, research on housing satisfaction, conducted to evaluate the housing environment through residents' POE, has encompassed various housing types, including apartments, detached houses, studios, and mixed-use apartments (Kim, 2002; Kang & Lee, 2004; Ju & Yang, 2004).

A study involving Beijing residents by Kan *et al.* (2014) in China suggested that housing conditions, physical environment, community facilities, and location characteristics are key components of housing satisfaction, and this satisfaction affects housing mobility. Factors such as house size, availability of elevators, natural light, noise reduction, medical accessibility, real estate management services, medical services, and the placement of community facilities for the elderly were found to positively impact housing satisfaction, according to Gao & Xie (2015).

Combining the findings of the aforementioned studies, it becomes evident that housing satisfaction, as depicted in Figure 1, assumes a central role in this relationship. This observation supports the establishment of a theoretical basis that links the personal or housing characteristics of residents to housing satisfaction, which, in turn, influences resident behavior.

3. Materials and methods

This study was conducted using an online survey method and received approval from Jeonbuk National University's IRB in Korean and Chinese (No. 2022-08-024-001).

3.1. Data collection method of questionnaire survey

The questionnaire survey tool encompasses three sections: demographic and sociological characteristics, housing characteristics, and housing satisfaction to gain insights into the survey's context. The measurement of housing

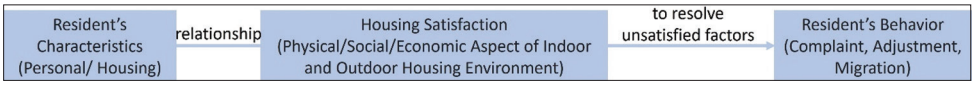

Figure 1. Conceptualization of housing satisfaction through literature review

satisfaction was divided into indoor and outdoor factors based on spatial aspects, while content that did not easily fit within these spatial categories focused on management and economic factors. In addition, the questionnaire included questions related to overall housing satisfaction, specifically pertaining to the participants' apartment housing.

The subjects of the survey consisted of residents residing in private apartments that correspond to commodity housing apartments in Henan Province, China. The regional scope of the survey was limited to urban areas where a substantial number of apartments were supplied in Henan Province. Due to the ongoing COVID-19 situation and the geographical distance of the researcher, the survey was conducted online. The questionnaire was prepared by the researcher and made available for online use through a Chinese online survey company (WENJUANXING). The online survey was distributed through the company from September 21, 2022, and continued for a total of 13 days, concluding on October 3, 2022. To ensure that only eligible participants took the survey, survey companies in China distributed survey links or posters, ensuring that the questionnaire could only be accessed by individuals meeting the pre-defined criteria (specifically, those residing in Henan urban areas and apartment residents). Upon a thorough review of the collected data, it was found that out of 962 copies of the collected data, 368 were invalidated. Ultimately, 594 response sets were considered valid for the purposes of this study. The main reason for the invalidation of a significant number of responses was the exclusion of respondents living in apartments without elevators from the evaluation related to elevator items.

3.2. Analysis method

The analysis methods utilized in this study are as follows:

(i) Using Amos 26.0, a structural equation model (SEM) analysis was conducted to verify the construct factors of housing satisfaction, identify the factors affecting overall housing satisfaction, and determine their impact on housing behavior. This included the verification of the path model involving these factors, overall housing satisfaction, and housing behavior through SEM analysis. Furthermore, the validity of the housing satisfaction measurement tool used by residents in Henan Province, China, was evaluated.

(ii) Technical statistics analysis was conducted using SPSS Statistics 22.0 to gain insights into the characteristics of the resident and their overall housing satisfaction. In addition, *t*-test and one-way ANOVA analyses were conducted using SPSS to explore the relationship between residents' personal and housing characteristics and their housing satisfaction.

3.3. Measurement tools for residents' housing satisfaction of apartments in Henan Province, China

3.3.1. Measurement items for housing satisfaction

Through the categorization of items for measuring housing satisfaction based on spatial and content factors in previous studies, a total of 7 content factors and 41 measurement items were extracted (Table 1). Previous studies employed a five-point Likert scale for responses, allowing residents to express their degree of satisfaction, ranging from "very dissatisfied" (1 point) to "very satisfied" (5 points).

3.3.2. Reliability analysis of housing satisfaction measurement scale

Following an analysis of the reliability of each housing satisfaction factor constructed through the literature review, it was confirmed that the Cronbach's α value for each factor exceeded 0.897, demonstrating internal consistency (Table 2).

4. Results

4.1. Socio-demographic characteristics of residents

The results presented in Table 3 demonstrate that the number of female respondents (62.3%) was approximately 1.6 times higher than that of male respondents (37.7%). Regarding the age distribution, 59.9% of the surveyed individuals are under the age of 40, indicating a predominantly younger-middle-aged or younger population among the apartment residents. In terms of the employment status of residents, a substantial portion of them fall into the categories of white-collar company employees, public corporations/public officials, and company management positions, accounting for 43.3% of the total. Regarding educational background, 68.7% of the respondents had attained a college degree or higher, indicating a high level of educational background among the residents.

When it comes to family size, 53.5% of the surveyed families consist of four or more members, while 28.1% have three members. Taken together, 81.7% of the families are composed of couples with one to two children, which align with the typical family composition. In terms of average

Table 1. Factors and items for evaluating housing satisfaction extracted from previous studies

Factors of housing satisfaction	Items	Measurement of content items	Item reference sources*
Interior facilities (S1)	S1_1	Kitchen facilities	1, 2, 3, 5, 8, 11, 14, 16
	S1_2	Bathroom and bathroom facilities	3, 4, 5, 14, 16
	S1_3	Interior condition status	1, 4, 5, 6, 7, 10, 13, 14, 16, 17
	S1_4	Lighting facilities	1, 4, 5, 6, 7, 10, 13, 14, 16, 17
	S1_5	Electrical switch, outlet facilities	3, 4, 5, 18
Interior structure (S2)	S2_1	House size	1, 2, 3, 6, 8, 9, 10, 11, 14
	S2_2	Number of bedrooms	4, 5, 8, 13, 14, 15, 17
	S2_3	Number of toilets	17, 18
	S2_4	Space arrangement of floor plan	1, 2, 4, 5, 7, 8, 10, 12, 14, 15, 17
	S2_5	Storage space	3, 4, 14, 15, 17, 18
	S2_6	Number of living floors	1, 3, 4, 9
Indoor environment (S3)	S3_1	Natural lighting	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17
	S3_2	Air quality (ventilation)	2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14
	S3_3	Indoor-floor noise	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15 17
	S3_4	External noise	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 17
	S3_5	View	2, 4, 5, 9, 10, 17
	S3_6	Thermal environment (insulation, temperature, and humidity cooling)	2, 4, 6, 8, 9, 17
Complex characteristics (S4)	S4_1	Exterior design	1, 3, 4, 5, 8, 13, 15, 17
	S4_2	Green space	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
	S4_3	Community facilities	1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 14, 15, 16, 17
	S4_4	Parking lot	1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16, 17
	S4_5	Apartment building density	1, 2, 5, 8, 9, 11
	S4_6	Securing neighborhood privacy	2, 5, 8, 11, 14, 17
	S4_7	Neighbor relationship	1, 2, 5, 7, 8, 9, 10, 11, 12, 13, 16
Location characteristics (S5)	S5_1	Accessibility to public transportation	1, 2, 4, 5, 7, 8, 9, 10, 11, 14, 15, 16, 17
	S5_2	Accessibility to medical facilities	1, 2, 5, 8, 10, 15, 16
	S5_3	Accessibility to educational facilities	1, 2, 4, 5, 7, 8, 9, 14, 15, 16, 17
	S5_4	Accessibility to public facilities	2, 4, 5, 7, 8, 9, 11, 14, 15, 16
	S5_5	Accessibility to amenities	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 14, 15, 16, 17
	S5_6	Work and school accessibility	1, 2, 5, 8, 9, 10, 14, 15, 17
	S5_7	Entertainment and cultural facilities	2, 5, 8, 10, 14, 15, 16, 17
Management characteristics (S6)	S6_1	Sanitary management (cleaning income garbage disposal)	1, 2, 3, 4, 5, 6 8 11 13 15
	S6_2	Security of crime prevention	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
	S6_3	Maintenance (defect repair facility maintenance)	2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 15
	S6_4	Fire and fire safety management	1, 2, 3, 4, 5, 8, 11
	S6_5	Operation management (management staff attitude and information provision)	2, 4, 6, 7, 8, 9, 11, 15
	S6_6	Elevator management (operational and safe condition)	3, 8, 10, 15, 18
Economic characteristics (S7)	S7_1	Administration cost	2, 3, 4, 5, 7, 8, 9, 10, 12, 14
	S7_2	Management level compared to management cost	18
	S7_3	Current apartment price	2, 5, 6, 9, 15
	S7_4	Future investment value	2, 5, 8, 9, 12, 15, 16

*Reference sources: 1. Ko (1997), 2. Kim (2002), 3. Choo & Yang (2004), 4. Kang & Lee (2004), 5. Choi (2005), 6. Lee (2004), 7. Nam & Choi (2007), 8. Lee & Jung (2008), 9. Son (2009), 10. Soh (2012), 11. Lee & Koh (2012), 12. Shim *et al.* (2014), 13. Bae & Jeon (2014), 14. Ahn (2014), 15. Roh *et al.* (2017), 16. Oh & Lee (2018), 17. Byun (2020), 18. Authors' opinion

Table 2. Reliability of housing satisfaction factors

Factors	S1	S2	S3	S4	S5	S6	S7
Cronbach's α value	0.929	0.918	0.897	0.925	0.945	0.948	0.914

Table 3. Sociodemographic characteristics of the surveyed condominium apartment residents (N=594)

Category	Frequency (n [%])
Gender	
Male	224 (37.7)
Female	370 (62.3)
Age (years)	
<25	120 (22.2)
25 – 29	60 (10.1)
30 – 39	164 (27.6)
40 – 49	105 (17.7)
50 – 59	98 (16.5)
≥60	47 (7.9)
Employment status	
Company employee	167 (28.1)
Company manager	29 (4.9)
Public corporation/public official	61 (10.3)
Self-employed	53 (8.9)
Student	78 (13.1)
Retirement	97 (16.3)
Unemployed	49 (8.2)
Others	60 (10.1)
Highest academic qualifications	
Lower than high school	78 (13.1)
High school	108 (18.2)
Junior college	171 (28.8)
University	201 (33.8)
Graduate school	36 (6.1)
Average monthly family income (yuan)	
<5,000	230 (38.7)
5,000 – 9,999	239 (40.2)
10,000 – 14,999	75 (12.6)
≥15,000	50 (8.4)
Family size (number of family members)	
1 (single person)	27 (4.5)
2	82 (13.8)
3	167 (28.1)
≥4	318 (53.5)

monthly family income, 40.2% of respondent families reported incomes ranging from 5,000 yuan to 9,999 yuan, while 38.7% reported incomes below 5,000 yuan, which is relatively moderate. It is worth noting that in 2021, China's Henan Province reported an average monthly disposable income of 3,091 yuan per capita in the city, and the average income for a family of three to four members was within the range of 9,273 – 12,356 yuan. Given that 12.6% of the surveyed families fall into the 10,000 – 15,000 yuan income range, it is evident that the income level of apartment residents is somewhat lower than the average for Henan Province, China.

4.2. Residential characteristics

The size of apartment units varies as follows: 38.7% of units are 90–119 m^2, 28.1% are 120–149 m^2, and 21.7% are 60–89 m^2 (Table 4). According to the China Census Yearbook (2020), the average living area per household in China is 111.18 m^2. It is noteworthy that this study also reveals the highest concentration of apartments within the range of 90–119 m^2. Consequently, the housing size of apartment residents slightly exceeds the average living area of Chinese households. In addition, the study found that the average number of residential floors in the apartments currently occupied by residents is 9.20 floors (standard deviation [SD] = 7.72), with a median value of 6 floors. The range spans from a minimum of 1 floor to a maximum of 34 floors.

In the case of residential areas, there is an even distribution between new and old cities, with each comprising 50%. This distribution was a deliberate choice, aimed at encompassing areas experiencing increased construction of new apartment complexes as a result of urbanization, while also representing existing urban areas during the sampling process. The residents' apartment residence periods exhibited varying durations, with 37.0% of respondents having resided in their apartments for 5 – 9 years, followed by 34.3% who have lived in their apartments for <5 years. In total, 71.3% of respondents have a residence history of <10 years. It is essential to recognize that the introduction of apartments for commodity housing in Henan Province, China, occurred in 1995, with a notable surge in construction during the period between 2000 and 2005. One might reasonably anticipate that apartments in Henan Province would typically have a maximum residence period of 15 – 20 years. However, our data reveal that the majority of the respondents have resided in their respective apartments for <10 years.

4.3. Housing satisfaction among residents

In this study, housing satisfaction among residents was assessed through the analysis of measurement tools designed specifically for the current research. Table 5 presents the average and overall housing satisfaction of the survey participants residing in apartments in Henan Province, China, categorized by factors and items.

Table 4. Residential characteristics of the investigated apartments (N=594)

Category	Frequency (n[%])
House size (m^2)	
<60	29 (4.9)
60 – 89	129 (21.7)
90 – 119	230 (38.7)
120 – 149	167 (28.1)
150 – 179	32 (5.4)
180 – 209	6 (1.0)
≥210	1 (0.2)
Residence period (years)	
<5	204 (34.3)
5 – 9	220 (37.0)
10 – 14	87 (14.6)
≥15	83 (14.0)
Residence area	
New town	297 (50.0)
Old town	297 (50.0)
Number of floors	
Maximum	34
Minimum	1
Median	6
Average	9.2
Standard deviation	7.72

To commence, the average housing satisfaction reported by residents for their apartments as a whole was notably above the mean score, registering at 3.47 points (SD = 0.88). Upon examining the average values of housing satisfaction by factors, it becomes evident that "Interior facilities" (mean [M] = 3.56, SD = 0.76) achieved the highest rating. The remaining factors, including "Location characteristics" (M = 3.50, SD = 0.79), "Indoor environment" (M = 3.47, SD = 0.78), "Interior structure" (M = 3.47, SD = 0.75), "Complex characteristics" (M = 3.34, SD = 0.80), "Management characteristics" (M = 3.27, SD = 0.88), and "Economic characteristics" (M = 3.16, SD = 0.86), all exceeded the average of 3.0 points. Among these 7 factors, the "Management characteristics" and "Economic characteristics" factors displayed relatively lower average ratings.

Examining the housing satisfaction of apartment residents at the item levels (Table 5) reveals that all items scored above 3 points. The lowest satisfaction rating was recorded for "Management level compared to management costs," with an average score of 3.03 points (SD = 1.04). Similarly, "Parking lot" received a relatively low average rating of 3.04 points (SD = 1.09). In contrast, the items "Natural lighting" and "Air quality (ventilation)" achieved the highest satisfaction ratings, each with an average of 3.68 points.

When delving into the specific items associated with each factor, we find a range of satisfaction levels among residents. In the realm of "Interior facilities," "Lighting facilities" received notably high satisfaction scores (M = 3.61). However, satisfaction with "Interior conditions" was relatively lower (M = 3.52). In terms of "Interior structure," residents reported high satisfaction (M = 3.61) regarding the "Number of living floors," yet the satisfaction with "Storage space" was relatively lower (M = 3.36). The "Indoor environment" factor showcased high satisfaction levels in the areas of "Air quality (ventilation)" and "Natural lighting," both receiving impressive average scores (M = 3.68). In contrast, satisfaction with "External noise" was relatively lower (M = 3.21). When exploring "Complex characteristic," it was evident that "Neighborhood relationship" received high satisfaction ratings (M = 3.59). However, satisfaction with the use of "Parking lots" was the lowest (M = 3.04). In terms of "Location characteristics," residents expressed high satisfaction with "Accessibility to public transportation" (M = 3.62) and "Accessibility to amenities" (M = 3.59). However, satisfaction with "Entertainment and cultural facilities" was relatively lower (M = 3.35). "Management characteristics" displayed varying levels of satisfaction among residents. Satisfaction with "Security of crime prevention" was notably high (M = 3.34). In contrast, satisfaction with "Elevator management (operational and safe condition)" was lower (M = 3.11). Finally, within the domain of "Economic characteristics," satisfaction with "Management level compared to management costs" (M = 3.03) and "Administration cost" (M = 3.10) was relatively low. However, it is noteworthy that satisfaction with the "Future investment value" was not low (M = 3.27). Upon closer examination, it becomes evident that the items with relatively low satisfaction scores were "Management level compared to management cost," "Parking lot," and "Administration cost," indicating lower levels of satisfaction among residents in these particular areas.

4.4. Differences in housing satisfaction according to resident characteristics

Independent sample *t*-test and one-way ANOVA were conducted to verify significant differences in the main variables of this study according to the socio-demographic and housing characteristics. These characteristics encompass residents' general characteristics (Figure 1). Subsequently, significant results from the ANOVA analysis were validated using Duncan's post-analysis of variables. The analysis results are detailed in (Tables 6 and 7).

Table 5. Housing satisfaction among apartment residents (N=594)

Factors of housing satisfaction	M (SD)	Measurement contents of item	M (SD)	Skewness	Kurtosis
Interior facilities (S1)	3.56 (0.76)	Kitchen facilities	3.58 (0.87)	−0.23	0.02
		Bathroom and bathroom facilities	3.55 (0.86)	−0.14	−0.12
		Interior conditions	3.52 (0.85)	−0.14	−0.07
		Lighting facilities*	3.61 (0.85)	−0.20	−0.18
		Electrical switch and outlet facilities	3.56 (0.87)	−0.24	−0.04
Interior structure (S2)	3.47 (0.78)	House size	3.48 (0.93)	−0.35	−0.12
		Number of bedrooms	3.41 (0.94)	−0.17	−0.49
		Number of toilets	3.44 (0.93)	−0.20	−0.49
		Plan structure	3.51 (0.93)	−0.32	−0.23
		Storage space	3.36 (0.93)	0.01	−0.48
		Number of living floors*	3.61 (0.92)	−0.49	0.08
Indoor environment (S3)	3.47 (0.78)	Natural lighting*	3.68 (0.93)	−0.50	0.01
		Air quality (ventilation)*	3.68 (0.89)	−0.46	0.07
		Indoor-floor noise	3.27 (1.01)	−0.09	−0.51
		External noise	3.21 (1.05)	−0.09	−0.57
		View	3.52 (0.97)	−0.19	−0.48
		Thermal environment (insulation, temperature, and humidity cooling)	3.47 (0.94)	−0.25	−0.21
Complex characteristics (S4)	3.34 (0.80)	Exterior design	3.50 (0.89)	−0.17	−0.09
		Green space	3.34 (1.02)	−0.19	−0.45
		Community facilities	3.23 (1.03)	−0.08	−0.55
		Parking lot	3.04 (1.09)	0.05	−0.66
		Apartment building density	3.35 (0.94)	−0.18	−0.07
		Privacy	3.35 (0.93)	−0.16	−0.12
		Neighborhood relationship*	3.59 (0.80)	−0.04	−0.06
Location characteristics (S5)	3.50 (0.79)	Accessibility to public transportation*	3.62 (0.88)	−0.58	0.49
		Accessibility to medical facilities	3.49 (0.91)	−0.38	−0.04
		Accessibility to educational facilities	3.45 (0.94)	−0.37	−0.02
		Accessibility to public facilities	3.48 (0.90)	−0.36	0.04
		Accessibility to amenities	3.59 (0.86)	−0.54	0.57
		Work and school accessibility	3.50 (0.92)	−0.41	0.20
		Entertainment and cultural facilities	3.35 (0.93)	−0.22	−0.02
Management characteristics (S6)	3.27 (0.88)	Sanitary management (cleaning income garbage disposal)	3.33 (0.97)	−0.20	−0.21
		Security of crime prevention*	3.34 (0.98)	−0.29	−0.18
		Maintenance (defect repair facility maintenance)	3.25 (0.99)	−0.15	−0.32
		Fire and fire safety management	3.32 (0.95)	−0.21	−0.16
		Operation management (management staff attitude and information provision)	3.25 (0.97)	−0.12	−0.25
		Elevator management (operational and safe condition)	3.11 (1.08)	−0.25	−0.44
Economic characteristics (S7)	3.16 (0.86)	Administration cost	3.10 (1.00)	0.00	−0.29
		Management level compared to management cost	3.03 (1.04)	−0.02	−0.44
		Current apartment price	3.25 (0.91)	−0.05	−0.12
		Future investment value*	3.27 (0.90)	0.00	0.07
Overall housing satisfaction (S)		Satisfaction with the overall apartment residents live in	3.47 (0.88)	−0.17	0.20

Notes: Satisfaction scores were rated out of 5 points; *The highest score among the items in the same factor.
Next, skewness values and kurtosis values were examined to verify the normality of each variable. The analysis revealed that the skewness of each measurement item variable ranged from -0.58 to 0.27 points, while the kurtosis fell within the range of -0.66 to 0.60 points. Notably, all variables exhibited absolute skewness values below 3.0, and their absolute kurtosis values were <10.0. These results conform to the normality assumption and indicate that the data do not violate the normality assumption (Kline, 2011)

Table 6. Differences in housing satisfaction according to sociodemographic characteristics of apartment residents

Variables	n	Overall housing satisfaction		
		Mean	Standard deviation	*t*/*F*
Gender				*t*=0.45
Male	224	3.50	0.93	
Female	370	3.46	0.84	
Age (years)				*F*=0.50
<25	120	3.58	0.75	
25 – 29	60	3.50	0.70	
30 – 39	164	3.44	0.92	
40 – 49	105	3.49	0.82	
50 – 59	98	3.35	1.08	
≥60	47	3.55	0.88	
Employment status				*F*=2.49*
Company employee	167	3.49^{ab}	0.81	
Company manager	29	3.66^{b}	1.04	
Public corporation/public official	61	3.70^{b}	0.74	
Self-employed	53	3.47^{ab}	0.87	
Student	78	3.59^{b}	0.71	
Retirement	97	3.35^{ab}	1.02	
Unemployed	49	3.51^{b}	0.96	
Others	60	3.15^{a}	0.88	
Highest academic qualifications				*F*=0.44
Lower than high school graduate	78	3.40	0.98	
High school graduate	108	3.49	0.92	
Junior college	171	3.43	0.91	
University graduation	201	3.52	0.82	
Graduate school	36	3.53	0.61	
Average monthly family income (yuan)				*F*=7.34***
<5,000	230	3.29^{a}	0.96	
5,000 – 9,999	50	3.55^{b}	0.80	
10,000 – 14,999	239	3.77^{b}	0.78	
≥15,000	75	3.52^{ab}	0.79	
Family size (number of family members)				*F*=0.12
1 (single person)	27	3.41	0.69	
2	82	3.44	1.00	
3	167	3.49	0.83	
≥4	318	3.48	0.88	

Notes: *p<0.05, **p<0.01, ***p<0.001; Superscripted a and b represent the groups categorized based on Duncan's *post hoc* analysis results using the corresponding mean values

4.4.1. Socio-demographic characteristics and overall housing satisfaction

In assessing the relationship with housing satisfaction, the main variables, including gender, age, occupation, and family size, did not exhibit statistically significant differences at a significance level below 0.05. Notably, only the variables "Employment status" and "Average monthly family income" demonstrated statistical significance. Subsequently, a *post hoc* analysis using Duncan's test was conducted on the two variables that displayed significant differences. The findings

indicated that residents categorized under "employment status – other" reported the lowest overall housing satisfaction (M = 3.15). Retirees receiving pensions also expressed relatively lower levels of satisfaction (M = 3.35), while those associated with public corporations/public officials exhibited the highest levels of satisfaction (M = 3.70). It is worth noting that white-collar workers, unemployed individuals, students, and those holding company management positions reported notably high levels of satisfaction. As for "Average monthly family income," it was revealed that variations in overall housing satisfaction existed between income classes below and above 10,000 yuan.

4.4.2. Relationship between housing characteristics and overall housing satisfaction

Through a one-way ANOVA analysis involving the reclassification of housing characteristic variables, significant associations were discovered between variables such as housing size, residence period, and residential area and overall housing satisfaction (Table 7). Notably, overall housing satisfaction demonstrated a positive correlation with larger house sizes, shorter residence periods, and residing in the new city areas. Specifically, variations in overall housing satisfaction were evident across house size groups; the group with houses <60 m^2 reported lower satisfaction (M = 3.25), while the group with houses exceeding 150 m^2 reported higher satisfaction (M = 3.82). In addition, differences were observed in residence period groups; the group with residence periods exceeding 5 years expressed lower satisfaction (M = 3.34 – 3.43), while the group with residence periods of <5 years reported higher satisfaction (M = 3.63). Furthermore, overall housing satisfaction was found to be higher in the new town (M = 3.60) compared to the old town (M = 3.35) based on the residential area.

4.5. Housing satisfaction factors influencing overall housing satisfaction and housing movement behavior

To assess the impact of interior facilities, interior structures, indoor environments, complex characteristics, location characteristics, management characteristics, and economic characteristics on overall housing satisfaction, an SEM analysis was conducted (Figure 2). The confirmatory factor analysis and regression results are presented (Table 8).

The SEM analysis demonstrated a satisfactory model fit (Kim *et al.*, 2009), with χ^2 = 2802.581 (p = 0.000, df = 826), comparative fit index (CFI) = 0.918, Tucker-Lewis index (TLI) = 0.910, and root mean square error of approximation (RMSEA) = 0.064. Convergent validity for the seven factors that constitute housing satisfaction was confirmed with the average variance extracted value of 0.5 or more and the construct reliability of 0.7 or more.

Table 7. Differences in housing satisfaction according to housing characteristics of residents' apartments

Variables	n	Overall housing satisfaction		
		Mean	Standard deviation	*t/F*
House size (m^2)				*F*=8.50***
<60	29	3.03[a]	0.98	
60 – 89	129	3.25[ab]	0.87	
90 – 119	230	3.44[bc]	0.86	
120 – 149	167	3.69[cd]	0.85	
≥150	39	3.82[d]	0.68	
Residence period				*F*=3.50***
<5	204	3.63[b]	0.86	
5 – 9	220	3.43[ab]	0.81	
10 – 14	87	3.34[a]	0.90	
≥15	83	3.35[ab]	1.02	
Residential area				*t*=3.41**
New town	297	3.60	0.83	
Old town	297	3.35	0.90	

Notes: *p<0.05, **p<0.01, ***p<0.001; Superscripted a, b, c, and d represent the group categorized based on Duncan's *post hoc* analysis results using the corresponding mean values

4.5.1. Housing satisfaction factors influencing overall housing satisfaction

Five out of the seven factors related to housing satisfaction exhibited a significant influence on overall housing satisfaction, while two factors, indoor environment (S3) and location characteristics (S5), did not demonstrate a substantial impact. Notably, economic characteristics (S7) emerged as the most influential factor (β = 0.297) when compared to other factors, while the impact of management characteristics (S6) was relatively modest (β = 0.130). In addition, both interior facilities (S1) and complex characteristics (S4) exhibited a comparable level of impact, both characterized by β = 0.177. Meanwhile, the influence of the interior structure (S2) was β = 0.144 (Table 8).

Furthermore, it was observed that overall housing satisfaction (S) exerted a negative influence on the intention to move ([M], β = −0.146). This negative influence suggests that higher levels of housing satisfaction correlate with a reduced intention to move.

4.5.2. Housing satisfaction factors influencing housing intention to move

Four out of the seven lower factors pertaining to housing satisfaction were found to influence the intention to move,

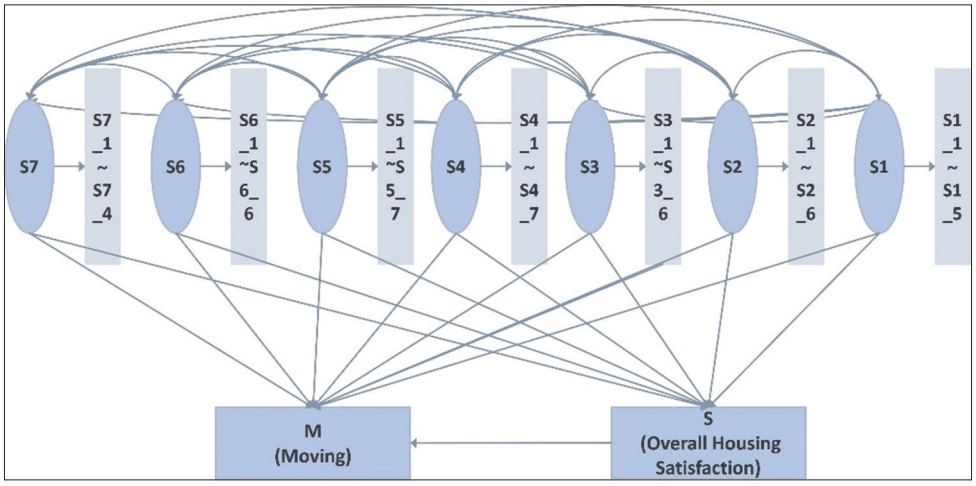

Figure 2. Design of structural equation modeling

while three factors (indoor environment [S3], complex characteristics [S4], and location characteristics [S5]) did not exhibit a significant impact on housing intention to move. Among the factors that did affect it, interior structure (β = −0.227) and management characteristics (β = −0.448) were identified as having a negative effect. In practical terms, this implies that if the housing satisfaction levels with management and interior structure are low, the intention to move is higher. In addition, it is noteworthy that satisfaction with management characteristics surpasses other satisfaction factors, indicating a stronger influence in deterring the intention to move. Satisfaction with interior facilities (β = 0.210) and economic characteristics (β = 0.242) demonstrated a similar influence on the intention to move. Interestingly, for interior facilities, even if satisfaction is high, the intention to move remains elevated. Similarly, high satisfaction with economic characteristics, including management costs, apartment prices, and future investment values, was linked to an elevated intention to move. These results suggest that greater satisfaction with facility amenities may paradoxically lead to an increased intention of moving, while higher satisfaction with economic characteristics amplifies the inclination to move.

These findings illuminate a negative relationship between housing satisfaction and the intention to move, as conceptualized in (Figure 1). In particular, housing satisfaction factors encompassing interior facilities, interior structure, management characteristics, and economic characteristics influence both overall housing satisfaction and housing intention to move.

5. Discussion

This study aimed to establish a housing satisfaction scale for condominium apartments and analyzed online survey responses from 594 apartment residents in Henan Province, China. The objective was to identify potential improvements based on the results of their housing satisfaction, with the ultimate goal of influencing residents' intention to move.

First, convergent validity was established by measuring the housing satisfaction of condominium apartment residents in Henan, China, considering 7 content factors (interior facilities, interior structure, indoor environment, complex characteristics, location characteristics, management characteristics, and economic characteristics). These factors align with the rationale presented by Huang and Du (2015), who argue for the inclusion of physical, social, and economic characteristics as contributing factors to housing satisfaction. This comprehensive approach acknowledges that housing satisfaction is influenced not only by physical attributes such as neighborhood characteristics, public facilities, and residential characteristics but also by social considerations such as social relations, safety, and economic factors such as public housing costs.

Second, the residents' evaluations of the apartment residential environment indicated above-average satisfaction levels. All 7 factors and all 41 measurement items related to housing satisfaction received an average rating of 3 points or higher, with overall housing satisfaction averaging 3.47 points. It is noteworthy that this elevated housing satisfaction was found to exert a negative effect on the intention to move (β = −0.146), supporting the existing body of research on housing satisfaction and migration intentions, as seen in previous findings (Speare, 1974). However, research studies such as those conducted by Fang (2006) in Beijing City and Diaz-Serrano and Stoyanova (2010) in 12 EU countries have suggested that the willingness to move does not always

Table 8. Structural equation modeling analysis on "Housing Satisfaction Factors-Overall Satisfaction-Movement Behavior"

The route	Estimate		S.E.	C.R.	*p*-value	AVE	CR
	B	β					
S1→S	0.215	0.177	0.072	2.999	**	-	-
S2→S	0.163	0.144	0.088	1.853	*		
S3→S	−0.071	−0.057	0.127	−0.557	0.578		
S4→S	0.215	0.177	0.103	2.081	*		
S5→S	0.062	0.049	0.054	1.138	0.255		
S6→S	0.132	0.130	0.067	1.965	*		
S7→S	0.291	0.297	0.060	4.867	***		
S1_1←S1	1	0.825				0.782	0.947
S1_2←S1	1.045	0.871	0.040	26.282	***		
S1_3←S1	1.041	0.878	0.039	26.631	***		
S1_4←S1	1.021	0.860	0.040	25.764	***		
S1_5←S1	1	0.828	0.041	24.299	***		
S2_1←S2	1	0.828				0.695	0.931
S2_2←S2	1.017	0.836	0.041	24.860	***		
S2_3←S2	1.052	0.869	0.040	26.463	***		
S2_4←S2	0.999	0.829	0.041	24.532	***		
S2_5←S2	1.016	0.843	0.040	25.192	***		
S2_6←S2	0.781	0.656	0.044	17.648	***		
S3_1←S3	1	0.756				0.612	0.904
S3_2←S3	0.967	0.768	0.050	19.459	***		
S3_3←S3	1.135	0.790	0.056	20.096	***		
S3_4←S3	1.081	0.729	0.059	18.312	***		
S3_5←S3	1.087	0.793	0.054	20.193	***		
S3_6←S3	1.047	0.788	0.052	20.026	***		
S4_1←S4	1	0.808				0.666	0.933
S4_2←S4	1.215	0.854	0.049	24.717	***		
S4_3←S4	1.207	0.842	0.050	24.214	***		
S4_4←S4	1.194	0.791	0.054	22.152	***		
S4_5←S4	1.013	0.778	0.047	21.646	***		
S4_6←S4	1.037	0.803	0.046	22.628	***		
S4_7←S4	0.808	0.729	0.041	19.816	***		
S5_1←S5	1	0.782				0.752	0.955
S5_2←S5	1.134	0.859	0.048	23.682	***		
S5_3←S5	1.156	0.849	0.050	23.338	***		
S5_4←S5	1.131	0.871	0.047	24.141	***		
S5_5←S5	1.055	0.851	0.045	23.410	***		
S5_6←S5	1.125	0.844	0.049	23.138	***		
S5_7←S5	1.149	0.850	0.049	23.348	***		
S6_1←S6	1	0.890				0.763	0.950
S6_2←S6	1.025	0.909	0.030	34.441	***		
S6_3←S6	1.040	0.904	0.031	34.030	***		
S6_4←S6	0.982	0.896	0.029	33.307	***		
S6_5←S6	1.015	0.901	0.030	33.698	***		
S6_6←S6	0.918	0.735	0.041	22.589	***		
S7_1←S7	1	0.895				0.753	0.924
S7_2←S7	1.031	0.889	0.032	31.789	***		
S7_3←S7	0.855	0.839	0.030	28.191	***		
S7_4←S7	0.806	0.797	0.032	25.526	***		
S1→M	0.189	0.210	0.089	2.128	***	-	-
S2→M	−0.211	−0.227	0.097	−2.175	***		
S3→M	0.041	0.035	0.078	0.523	0.325		
S4→M	−0.006	−0.005	0.150	−0.037	0.971		
S5→M	0.181	0.159	0.184	0.985	0.601		
S6→M	−0.467	−0.448	0.129	−3.622	*		
S7→M	0.270	0.242	0.105	2.575	*		
S→M	−0.134	−0.146	0.062	−2.168	*	-	-

(Contd...)

Table 8. ***(Continued)***

Notes: AVE: Average variance extracted; *B*: Regression weight (coefficient); *ß*: Standardized regression weight (coefficient); CR: Construct reliability; C.R.: Critical ratio; S.E.: Standard error; **p*<0.05, ***p*<0.01, ****p*<0.001

translate into actual residential move behavior, especially when vulnerable populations face constraints related to housing market conditions. Rather, in such cases, they may lower their expectations for the residential environment and conform to reality. In this study, asserting a definitive negative impact on housing satisfaction and housing movement solely based on willingness to move becomes a complex task, particularly in situations where residents report high levels of satisfaction with internal facilities or cost-related economic characteristics. Moreover, this study does not include a separate analysis for the low-income demographic. Therefore, when determining the relationship between housing satisfaction and housing movement behavior, a cautious approach is necessary, accounting for economic conditions. On the other hand, given that housing satisfaction in this study surpasses the average, one might question whether maintaining the current status of housing satisfaction or further elevating satisfaction levels would stimulate a substantial demand for housing movement. Under such circumstances, the housing market could experience a stabilization, subject to various economic and social factors.

To enhance residents' housing satisfaction, it is evident that considerable efforts should be directed toward economic characteristics, management characteristics

(crime prevention security, maintenance, fire and fire safety management, operation management, and elevator management), interior structure, interior facilities, and complex characteristics. Therefore, when planning and supplying the apartments, it is imperative to prioritize management or economic aspects that closely relate to residents' interior spaces and living services, rather than focusing solely on the external space of the apartment.

Third, after identifying the factors affecting both overall housing satisfaction and housing movement, economic characteristics emerged as significant factors in both areas. Among the various measurement items constituting economic characteristics, satisfaction with "Management level compared to cost" received the lowest rating among the 41 measurement items of housing satisfaction (3.03 points), followed by "Management costs" (3.10 points). This result underscores the vital importance of maintaining residential hygiene, safety, crime prevention, and effective operation to support the residents' daily lives. It is clear that these aspects are as critical as the physical environment of the apartment, including interior facilities and structure and external complexes. Consistent with the perspective presented by Hui and Zheng (2010), which underscores the significance of residential facility management service quality, specifically customer satisfaction, over the sole consideration of management quality in the housing sector, this study also underscores the importance of satisfaction with the "Management level compared to cost." Given the substantial influence of economic characteristics related to management costs and housing prices on both housing satisfaction and housing movement ($\beta = 0.297, 0.247$), it is anticipated that higher resident satisfaction will lead to a reduced willingness to move. This, in turn, can contribute to the stabilization of the housing market.

Fourth, when examining the differences in overall housing satisfaction according to the characteristics of residents, significant differences were observed concerning occupation, average monthly family income, house size, period of residence, and residential area. Notably, it was observed that overall housing satisfaction was high among white-collar company employees, public corporations/public officials, company management, and the unemployed. In addition, residents with a high average monthly family income reported elevated overall housing satisfaction, as did those residing in new city areas. These results have particular relevance for the assessment of housing satisfaction, especially in the context of apartments recently supplied in new city areas, emphasizing the importance of incorporating these insights into future housing planning. Previous studies consistently highlight differences in housing satisfaction according to employment status, with individuals in higher professional positions typically reporting greater housing satisfaction in relation to interior facilities (Kang *et al*., 2004; Ju & Yang, 2004; Shim *et al*., 2014; Kang & Jeong, 2015; Han & Jun, 2021). In addition, our findings align with the outcomes of a previous study (Shim *et al*., 2014), which demonstrated that larger houses tend to yield higher levels of satisfaction. In addition, research conducted in China by Fang and Zhang (2018) emphasizes the pivotal role of house size in determining overall happiness. Conversely, an inverse relationship was observed between the length of residence and overall housing satisfaction. Longer periods of residence were associated with lower overall housing satisfaction levels, likely due to the extended construction periods of the apartments in which residents lived, leading to a decline in interior facility quality and an increase in human demand. In terms of residential areas, the old city areas of Henan Province, characterized by a lack of modern residential facilities, reported lower overall residential satisfaction. These areas, steeped in history, often exhibited inferior facilities and environments. Through these results, our study underscores the critical role that housing quality, including factors such as size and interior facilities, plays in shaping housing satisfaction (Fang *et al*., 2018; Ren & Folmer, 2017). In light of these findings, it is clear that, even in the old city areas, there is a compelling need to gradually enhance housing quality through house maintenance and renovations.

6. Conclusions

In conclusion, this study has yielded several key findings: first, this study introduced the post-residential perspective, based on POE theory, to evaluate housing satisfaction among Chinese condominium apartment residents. It involved an in-depth examination of prior studies on housing satisfaction, aiming to establish a measure of housing satisfaction for condominium apartment residents in Henan Province, a region undergoing rapid urbanization. The validity of this measure was demonstrated, laying the groundwork for the development of measurement tools for evaluating housing satisfaction among condominium apartment residents in Henan. An important achievement of this study is the establishment of a POE framework for Henan Province's apartments, which extends beyond physical environmental aspects to encompass spatial management dimensions, including maintenance and economic evaluation factors. This approach, in line with the framework proposed by Preiser *et al*. (1988), holds significant implications, especially in the context of Henan Province and China's volatile real estate market. It provides valuable insights into both management and economic satisfaction, essential for maintaining the quality, performance, and economic viability of apartments.

Second, this study identified key factors (internal facilities, internal structure, management characteristics, and economic characteristics) that can improve housing satisfaction for residents in Henan Province's apartments. These factors, encompassing not only spatial aspects but also post-moving-in living and management aspects, should be reviewed and considered in the planning and provision of condominium apartments to elevate resident satisfaction. On the other hand, the decline in residential satisfaction for apartments is associated with a reduced consumer willingness to purchase, potentially contributing to a slowdown in the housing market (China Quality News Network, 2022). In the face of a sluggish economic environment, improving satisfaction through new supply may prove to be a challenging task. Instead, transitioning beyond the era of apartment bubbles and moving toward market stability can be achieved by elevating satisfaction through ongoing maintenance and post-supply economic characteristics. This approach should take precedence over relying solely on adjustments to indoor facilities or structural features that may be available in new supply.

Third, the study identified several resident characteristics, including occupation, income, region, residence period, and housing area, as important factors related to housing satisfaction. While the structural equation revealed the relationship between housing satisfaction factors, overall housing satisfaction, and housing movement intention, it is important to note that this study did not identify actual housing movement intentions, leaving this as an avenue for future studies. In addition, the results emphasize the importance of maintaining a high level of housing satisfaction through effective maintenance management and economic value enhancement. This approach is favored over the reliance on adjustments in housing satisfaction through the housing movement, as it has implications for housing market stability. However, it is essential to recognize the challenges posed by real estate bubbles resulting from urbanization. In this context, long-term urban housing may encounter limitations if it relies solely on management strategies rather than the supply of high-quality new housing. Therefore, it is necessary to consider strategies that focus on improving performance management and enhancing economic value through remodeling processes.

As the housing satisfaction measurement tool proposed in this study has been validated exclusively for apartments in urban areas of Henan Province, it is necessary to generalize it as a housing satisfaction measurement tool for condominium apartment residents across China through continuous research. Future research should delve more deeply into discussions with Chinese residential experts to better understand the characteristics of the Chinese apartment residential environment reflected in housing satisfaction measurement tools. In addition, research should explore residents' housing movement between different housing types by comparing and analyzing housing satisfaction and residential intentions to move between condominium apartments and public rental housing, offering insights for housing policy development.

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Ethics approval and consent to participate

In this study, an online survey was conducted on apartment residents in Henan Province, China, with approval from the Jeonbuk National University's Institutional Review Board (IRB No. 2022-08-024-001).

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Availability of data

The data are available upon reasonable request by contacting the corresponding author through email.

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ORIGINAL ARTICLE

Comprehensive versus incremental industrial redevelopment: The role of planning

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Abstract

Urban planning has been pivotal in shaping China's urban landscape since the early 2000s, with statutory plans regulating every detail of urban land. However, this planning-led development approach has proven inadequate for the redevelopment of inner-city industrial land, necessitating alternative approaches. To explore this issue, a comprehensive study was conducted, analyzing 395 industrial land redevelopment projects in four districts of Shanghai (Hongkou District, Putuo District, Yangpu District, and Jing'an District). Surprisingly, nearly half of these projects deviated from the established land use plans, indicating the emergence of an alternative (semi-)informal practice-led approach, specifically tailored to incremental industrial redevelopment. This study aims to dissect and compare the redevelopment processes under both approaches, examine the shifting role of planning as the alternative (re)development approach emerges, and address its legitimate issues. Key arguments presented include (i) challenges faced by the conventional planning-led development approach due to shifting national urban redevelopment strategies, paving the way for the emergence of an alternative approach in inner-city redevelopment; (ii) the Shanghai local government's choice not to restructure the existing conformist urban planning system to accommodate land redevelopment demands, maintaining an ambiguous stance on the legitimacy of the practice-led redevelopment to retain the flexibility and discretionary authority of local government officials in decision-making; and (iii) due to their legitimate issues, incremental redevelopment projects executed through the practice-led approach may eventually be replaced by comprehensive planning-led redevelopment projects. Consequently, the former assumes a subordinate role to the latter and is viewed as temporary land reuse practices. Despite the observed emergence of the practice-led approach in industrial redevelopment in Shanghai, it is deemed not yet robust enough to offer a viable alternative path for inner-city redevelopment.

Keywords: Urban planning; Urban redevelopment; Shanghai; Industrial land

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1. Introduction

The urban planning system in China is predominantly characterized by a regulatory (or zoning) framework. In this system, statutory plans play a pivotal role in determining the land and space uses within a designated statutory area for the subsequent several

decades. Notably, planning officials have minimal discretionary power when it comes to individual planning applications (Biggar & Siemiatycki, 2020; Talen *et al*., 2016). The inherent drawbacks of such a planning system include its unresponsiveness to the needs and dynamics of individuals, communities, and market forces, leaving land investors without the capacity to optimize land use (Carmona *et al*., 2003; Munneke, 2005).

The consistent planning reforms observed in the international context over the past decades have presented a spectrum of solutions. These solutions range from the introduction of long-term temporary uses and the promotion of mixed land use to allow greater flexibility and shift the planning system toward a more discretionary model. However, the past planning reforms in China, specifically aimed toward establishing a unified National Territorial Spatial Planning system, have not addressed the challenge of ineffective land uses resulting from zoning constraints. Instead, the newly implemented territorial planning system consistently strengthens the roles of different sets of plans and reclarifies their relationships (Liu & Zhou, 2021). This restructuring has resulted in even less discretionary power for planning officials. As the subsequent sections of this article will unveil, the pursuit of improved urban land utilization necessitates mechanisms beyond the confines of the planning system to address the challenges posed by zoning-related inefficiencies.

In the examination of China's national governance structure, Zhou (2017) points out the persistent historical tension between central and local authorities. The upper-tier government(s) traditionally lean toward centralization as a means of maintaining control, while local governments advocate for a substantial degree of flexibility to ensure effective local governance. Addressing this tension in contemporary China involves an institutional mechanism described as "centrally policy-making and local policy implementation." This framework grants local governments the flexibility to determine the applicability and implementation of certain policy decisions in their specific areas. Within the field of urban land (re) development, the central-local tension manifests as a confrontation between the top-down formulated statutory land use plans and the locally conceived, deemed more "appropriate" land use strategies. This conflict results in a significant disparity between the planned objectives and the actual implementation on the ground, a phenomenon widely noted in existing literature (Liu *et al*., 2020; Long *et al*., 2012; Tian & Shen, 2011).

Contemporary research predominantly concentrates on the implementation of urban planning measures aimed at curbing urban sprawl. However, this study diverges from the mainstream focus by delving into the realm of industrial land redevelopment and reuse projects in Shanghai, with a specific emphasis on two categories: Comprehensive redevelopment and incremental redevelopment. Through a comparative analysis of these practices, the study explores the emergence of alternative approaches to industrial redevelopment and discerns the relationship between these practices in shaping inner-city spaces. It argues that, despite receiving support from local government officials, institutional arrangements still maintain the subordinate status of the additional redevelopment strategy compared to the dominant model of conventional planning-led comprehensive redevelopment, characterized by large-scale demolition and subsequent reconstruction.

2. Urban redevelopment: The perspective of urban planning

Urban planning, originally conceived to facilitate sustainable urban development (UN-Habitat, 2015), has faced criticism for its ineffectiveness in managing urban development (Choguill, 1994), particularly in rapidly changing developing countries. The complex institutional and socioeconomic contexts in China have presented significant challenges to the implementation of urban planning. Research indicates that projects in China often struggle to adhere to planning intentions throughout construction, resulting in unconformity between plans and actual implementation (Liu *et al*., 2014). A body of literature has explored the unconformity between plans and actual implementations in China's urban planning system, identifying two distinct types of unconformity. Firstly, plans are directly violated through illegal or unpermitted land use and development projects (Long *et al*., 2020; Tian & Shen, 2011; Zhao *et al*., 2009). Second, plans undergo frequent adjustments to incorporate new development concepts initiated by local government leaders who assume direct responsibility for economic growth (Zhang, 2002; Wang *et al*., 2017; Long *et al*., 2012). In both instances, the statutory nature of the initially adopted urban plans is not respected, and, in some cases, inappropriate adjustments of plans have resulted in adverse environmental, cultural, and social consequences (Yin *et al*., 2023; Bakir *et al*., 2018). Despite these issues, both the direct and indirect violations are often deliberately ignored, driven by economic concerns. Moreover, over the past decades, a set of post facto planning manipulations has emerged to legitimize such violations. In other words, planning serves as one of the instruments to empower legitimacy for growth-oriented (re)development (Wu, 2015).

Urban redevelopment practices in China were historically dominated by a property-led approach characterized by

widespread demolition and relocation (Jiang *et al*., 2018). Collaborations between real estate developers and local state entrepreneurs played a pivotal role in steering urban transformation (Zhang & Fang, 2004; Guo *et al*., 2018). The financing of these projects was often facilitated through the increased land value resulting from intensified land use (Gyourko *et al*., 2022). Driven by land finance, urban redevelopment projects tended to be performed on a large scale, narrated as "property-led redevelopment" since the late 1990s (He & Wu, 2005; 2009). This particular form of redevelopment finds legitimacy through statutory urban planning, complemented by corresponding formal regulations encompassing planning-related laws, property rights, and other relevant aspects. Urban planning operates as a governance activity characterized by a policy-driven approach (Healey, 1997, p. 205–242).

However, the sole approach to urban redevelopment has shifted toward multi-approaches since the late 2000s. The state's motivation for initiating redevelopment extends far beyond land profiting and real estate speculation (Wu *et al*., 2021). First, since the global financial crisis in 2008, economic restructuring has been harnessed with urban redevelopment to boost sustainable development (He, 2019a; Wu, 2016). Multiple dimensions of economic forms have received increased attention. Meanwhile, social tensions escalated alongside large-scale demolition and relocation of residents since the 2000s. The slogan "Building a Harmonious Society" was introduced at the Chinese Communist Party National Congresses in 2002 and 2007 to respond to the escalating social instability. On residential land, the central government mandated a more considerate compensation strategy for dislocated residents to maintain social stability (Shih, 2017). In addition, appeals for heritage conservation have been widely reported through social media, coinciding with the growing influence of civil societies and the middle classes. This macro-political-economic environment calls for alternatives to urban redevelopment beyond the property-led approach. Wu *et al*. (2021) have observed three types of non-property-led redevelopment, that is, rural vitalization in villages, heritage preservation in traditional neighborhoods, and community participation in regenerating dilapidated neighborhoods, collectively narrated as "incremental regeneration."

Accordingly, this study adopts the categorization that there are comprehensive redevelopment and incremental redevelopment. The former refers to conventional property-led redevelopment involving large-scale demolition and relocation, and the latter refers to small-scale progressive redevelopment with more extensive local community involvement.

One of the critical differences between the two categories of redevelopment, apart from the project size and orientations, is their relations with the existing planning system. While comprehensive redevelopment projects are guided by master plans produced by the local planning authorities and follow rigid planning determination procedures, incremental redevelopment projects might encounter legitimacy issues due to their difficulties in complying with existing planning regulations. To be more specific, because the existing planning system operates with the presumption that land (re)development captures significant land value, and the local government — as the *de facto* owner of urban land — takes huge revenue out of the process through land leasing (Wu, 2015), the redevelopment projects would not be financially feasible without large-scale demolition and reconstruction to comprehensively improve the physical environment, increase building volumes, and shift the image of the urban blocks. As a result, incremental redevelopment is left to be achieved through informal or semi-informal approaches.

This study examines the difference between the two categories of redevelopment. It addresses how existing incremental redevelopment projects have dealt with the legitimacy issues in urban planning and what role urban planning plays in this process. Through a comparison between comprehensive redevelopment and incremental redevelopment of former industrial sites in inner Shanghai, this study depicts the critical features and procedures of the emerging industrial redevelopment approach. It provides insights into how industrial redevelopment's emerging demands and approaches interact with the existing planning system.

3. Methods

3.1. Sample selection and data collection

This study commences with an investigation into industrial redevelopment projects within four districts in inner Shanghai: Putuo District, Jing'an District, Hongkou District, and Yangpu District. These districts are located along either Suzhou Creek or Huangpu River and have a historical concentration of manufacturing sites. As urban sprawl continued and Shanghai underwent consistent deindustrialization, numerous industrial sites in these districts were abandoned, leading to redevelopment projects.

Three hundred and ninety-five industrial land redevelopment/reuse projects undertaken between 2000 and 2020 were investigated using Google Earth and Baidu Map. Subsequent site investigations were conducted in October 2019 and October 2022. Interviews were conducted with various stakeholders, including urban

planning authorities, site management companies, tenants of the business park, and urban planning professionals (Appendix for the list of interviews).

3.2. Framework of analysis

This research paper aims to analyze various types of regenerations through case studies, adopting a holistic approach that extends beyond single cases with significant media exposure. Special focus is given to the common yet rarely researched type of adaptive reuse for normal business/industrial parks.

The analytical framework consisted of two steps. First, the 395 projects were investigated and categorized into "comprehensive redevelopment" or "incremental redevelopment." A descriptive analysis of, and comparison between, the two categories of industrial redevelopment in Shanghai is presented. Second, the institutional roots and underpinning rationales of the different approaches to redevelopment were analyzed. This analysis provides insights into the role of planning and the understanding of legitimacy issues in current industrial redevelopment practices.

3.3. Data description and preliminary results

Among the 395 projects, comprehensive redevelopment through large-scale demolition and reconstruction accounts for 208 cases. The remaining almost half of the cases (187 cases) adopt incremental strategies, where adaptive reuse for business or industrial parks is common, some of which feature publicly accessible facilities like the well-known M50 Creative Industrial Park.

In a comprehensive approach, a new settlement with high-rise buildings featuring mid-rise industrial buildings replaces the formal manufacturing site. The new functions are dominated by commodity housing, offices, and commerce, with only a few cases retaining industrial parks. Through an incremental approach, the original buildings are spared from demolition and are instead refurbished and renovated for non-industrial uses. The result is a dense and heterogeneous agglomeration of small-scale mixed uses for offices and commerce, catering to individual tenants. Occasionally, creative uses can also be found. Although the number of projects for each type is nearly 50%, the scale of projects with comprehensive redevelopment is much larger than projects with incremental redevelopment. Comprehensive projects tend to occupy larger plot sizes, higher floor area ratios (FAR), and more floor numbers. In incremental redevelopment projects, the status quo of industrial sites has been maintained, resulting in a spatial form typical of industrial sites. Comprehensive redevelopment projects cover a much larger land area (2.7 times larger) than the other. The average plot size of comprehensive projects is 5 hectares, while only 2 hectares are for incremental projects. The former also has a higher average FAR than the latter. The average floor number in the incremental approach is 19 floors, almost 4 times higher than incremental projects. An overview of projects in the two approaches is presented in Table 1.

A notable difference between cases in the two categories of industrial redevelopment is that the comprehensive redevelopment projects, involving demolition and reconstruction, often follow rigid planning control procedures. On the other hand, incremental redevelopment projects through adaptive reuse are not regulated by the planning system, making them more controversial regarding their legitimacy. Nevertheless, the adaptive reuse of industrial land for business parks catering exclusively to the needs of office tenants contributes to social infrastructure provision, partially demonstrating their legitimacy through practices. Accordingly, the frequent approaches associated with the two categories of industrial redevelopment in Shanghai are named planning-led and practice-led approaches, respectively. The two approaches to industrial land redevelopment are further illustrated and compared below, with two cases presented as examples to reveal more details.

4. Case study-based comparison: Planning-led and practice-led industrial redevelopment

4.1. Planning-led industrial redevelopment

4.1.1. The formal approach

In China, a master land use plan typically has a planning horizon of 20 years and functions as a long-term orientation of development strategies, covering the entire territory of a city. At the land parcel level, the regulatory plan has a legal status that defines the FAR, building height, and plot density through a land use classification and control index system. Driven by a "pro-growth" approach, urban plans have been formatted to promote economic growth (Wu, 2015). In the process of plan-making and implementation, local political leaders play a more determining role than urban planners (Yin *et al*., 2023). In urban redevelopment projects, the local government tends to build a coalition with developers to maximize their benefits through the urban planning system, typically resulting in a gentrification process (Zhu, 1999; He & Wu, 2005; Zhang & Fang, 2004). As the local government does not have *de facto* control over all land in its territory, land acquisition must occur before a redevelopment project. As a historical legacy, the

Table 1. Overview of regeneration projects in two approaches on industrial land in four districts in Shanghai (Putuo, Jing'an, Hongkou, Yangpu) 2000–2020

Key features	Regeneration approach	
	Comprehensive	Incremental
Number of projects	208	187
Land size of all projects	1042 ha	375 ha
Average plot size of projects	5 ha	2 ha
Average floor area ratios of projects	3.0	2.2
Average floor numbers of projects	19	5
Dominant new functions	Commodity housing, office, commerce	Office, commerce (particularly economic hotels)
Implementation strategy	Demolition and redevelopment	Refurbishment and renovation
Description	High-rise buildings, either dense agglomeration or embedded in park-like green areas, sometimes additional retail	Dense and heterogeneous agglomeration of small-scale offices, renting of space to individual tenants, and sometimes creative uses

Source: The authors, 2023

state enterprises occupied a large scale of industrial land in the inner city of Shanghai. Thus, on industrial land not occupied by the local government, a formal redevelopment project follows a series of formal procedures aligning with urban planning.

First, the industrial land should be reclaimed by the local government, compensating the *de facto* landowners as the first-hand land (*sheng di*). Subsequently, this land undergoes preparation for further reuse in accordance with the municipal urban plan. This preparation involves the demolition of existing physical structures, as well as the establishment of road systems, utilities (water, electricity, drainage, heating, telecommunication, and gas), and land leveling — a process collectively known as "seven connections and one leveling" (*qitong yiping*), or in some cases, "five connections and one leveling."[1] The resulting land, ready for the new round of construction, is deemed second-hand land, referred to as mature land (*shu di*). In the case of profitable land use, the land use right is transferred to commercial users through a transparent market-driven bidding and auction process, with a maximum usage period of 40, 50, or 70 years. In cases where a state enterprise seeks to redevelop the land it occupies for profitable use based on formal procedures, the only avenue is to sell it to the government or its representatives in exchange for land compensation. Subsequently, the enterprise can participate in the bidding and auction process to repurchase the land. Thus, this type of land transforms from free use with an unlimited period to a limited period, incurring significant land transfer fees.

[1] For example, refer to Article 4 of the *2017 Land Banking Management Measures (Tudi Chubei Guanli Banfa)* issued jointly by the Ministry of Natural Resources and the Ministry of Finance of the People's Republic of China.

Meanwhile, the land designated for industrial purposes undergoes a formal conversion to commercial use, as regulated by the statutory plan. The shift to commercial use grants the land higher building height allowances, increased floor space, and a higher FAR compared to its previous industrial use. Post-redevelopment, the once-formal industrial site, typically characterized by groups of mid-rise buildings, transforms into high-rise buildings in accordance with regulatory planning. Land developers are obligated to adhere strictly to the technical requirements affiliated with each land parcel, as stipulated in both the regulatory plan and the land leasing contract.

4.1.2. The case of Red Rooster Commercial Office Buildings (1151 Zhenbei Road, Putuo District, Shanghai)

Located at Zhenbei Road 1151, Putuo District, the site was formerly home to the Shanghai Changzheng Printing Plant. After the factory closed, the land was transferred to Shanghai Red Rooster Development Company through bidding. The conversion of land use from industrial to office and commercial use was subject to strict adherence to urban planning regulations, as emphasized in the *Planning and Design Requirements on Land Transfer for Plots of Transferred State-owned Land Use Rights.*

In 2017, the new project received approval from the Shanghai Putuo District Planning and Land Management Bureau (SPPLMB) (Figure 1). Detailed provisions from urban planning authorities covered various aspects, including land size, floor area, FAR, building height, building color, material, and setbacks from the road. The project encompasses a land area of 6258 m², with a floor space of 10,000 m² and an FAR of 1.6. Specific building regulations apply, including a maximum building height of 24 meters. The proportion of green area to the total land

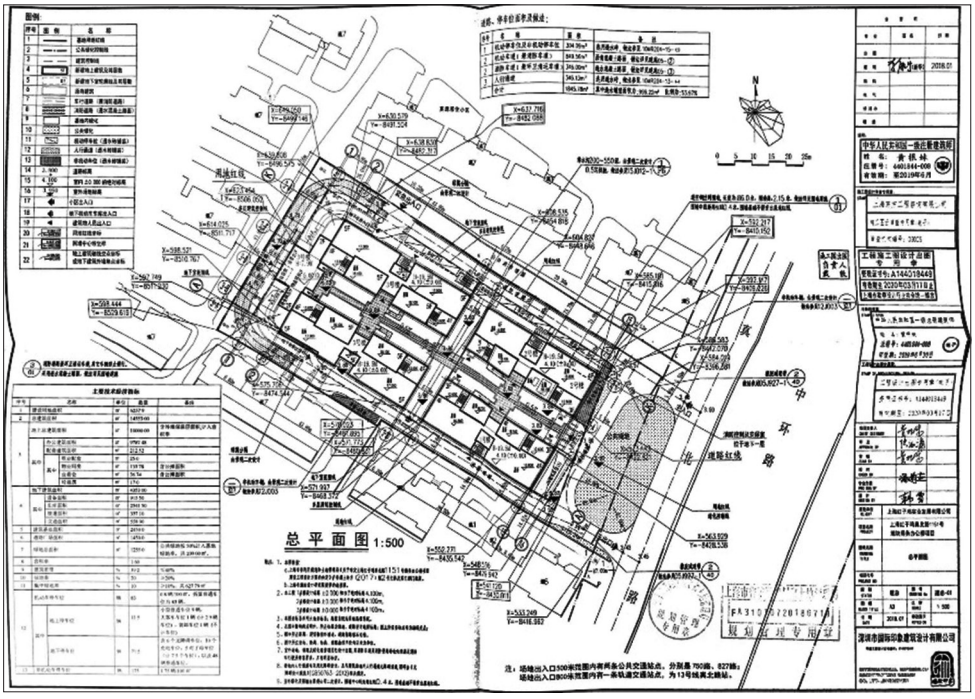

Figure 1. The Masterplan of Red Rooster 1151 Zhenbei Road Commercial Office Building Project. Source: Shanghai Putuo District Government[5]

area must not be less than 20%. The building's color and materials should be warm-toned, and the building must be set back at least 15 meters from the road. The design style should align coherently with neighboring residential buildings.

The detailed regulatory plans and approval documents at each stage of the project development were published on the website of the Shanghai Putuo District Government for a limited period. According to Google Earth, all former industrial buildings were demolished, and the site was cleared in 2012. Throughout the entire process, the SPPLMB represented the authorities overseeing the regeneration process. On April 18, 2017, the SPPLMB approved the construction project proposed by the Shanghai Red Rooster Development Company in the document titled *Shanghai Putuo Planning Land (2016) Grant Contract No. 4 (Version 1.0)*.[2] On February 28, 2018, the Planning Permit for Construction Project was issued by the SPPLMB[3]. The construction work commenced in 2018 and was completed in 2021. The SPPLMB reviewed the project and confirmed its adherence to all the provisions on January 29, 2021.[4] A site visit in July 2023 revealed that the complex remained unoccupied and is seeking tenants to rent the available office space (Figure 2).

4.2. Practice-led industrial redevelopment

4.2.1. The semi-informal approach

The Shanghai Economic and Information Commission, a government agency overseeing manufacturing factories in Shanghai, introduced a "three kinds of unchanges and five kinds of changes (*sanbubian wubian*)" policy in 2004. According to this policy, industrial land reuse projects with unchanged building structures, an unchanged (registered) land use status (*tudi xingzhi*), and unchanged ownership of premises could be treated as building renovation projects — instead of land redevelopment projects — thus do not need planning permissions. This policy strongly implies an alternative approach to industrial land redevelopment, enabling the bypassing of planning controls and fostering

2 Website of Shanghai Putuo District Government, https://www.shpt.gov.cn/guituju/upload/202103/0308_162552_718.pdf, accessed on July 28, 2023.

3 Website of Shanghai Putuo District Government, https://www.shpt.gov.cn/guituju/jsgcghxukz-zdgzzfwj2021/20211005/712008.html, accessed on July 28, 2023.

4 Website of Shanghai Putuo District Government, https://www.shpt.gov.cn/guituju/jsgcsjfascyj-zdgzzfwj2021/202 11005/711723.html, https://www.shpt.gov.cn/guituju/upload/202106/0616_151521_581.pdf, accessed on July 24, 2023.

5 The masterplan was retrieved from Shanghai Putuo District Government's website http://www.shpt.gov.cn/guituju/gcxuke/20180320/314052.html, visited on 20 April 2020

Figure 2. Current view of the Red Rooster Commercial Office Buildings. Source: Photograph by one of the authors in July 2023

diverse collaborations between local government, developers/investors, and landholders (state enterprises).

The following case study shows how a redevelopment project was undertaken with the support of this institution.

4.2.2. The case of Daning Central Square (700 Wanrong Road, Jing'an District, Shanghai)

Founded in 1944, Shanghai No. 1 Machine Tool Factory belongs to Shanghai Electrical Group, a state enterprise with a municipal hierarchy. The site, covering an area of 7.8 hectares, stands as one of the largest creative parks in Jing'an District.[6] Statutorily, the site was designated for renewal for commercial use. According to formal procedures, land acquisition should be managed by a land banking agency, and presented to the district government after negotiation and a land compensation process. Subsequently, land use rights should be conveyed to commercial users through bidding and auction in a transparent market. However, as the landlord is a state enterprise at the municipal level, holding a higher hierarchy level than the Zhabei District government, the negotiation process is likely to be complicated, time-consuming, or may require high compensation. Moreover, the substantial compensation could become a financial burden that the district government cannot afford. Inspired by "three unchanges" policies, the Zhabei District Government decided to cooperate with the landlord, Shanghai Electrical Group, to informally convert it into a business park without changing its formal land use, that is, industrial use (SICDRI, 2017, p. 184).

In 2010, the factory buildings underwent a complete renovation without changing the building structure, land,

[6] The conversion project was undertaken by the Zhabei District government, as the case of Daning Central Square originally belonged to the Zhabei District. Then in 2015 the Zhabei District was merged into Jing'an District.

Figure 3. The appearance of the renovated Daning Central Square. Source: Photograph by one of the authors in October 2020

and premises ownership, strictly adhering to the "three unchanges" principles (Figure 3). A total investment of 450 million RMB was dedicated to a fundamental and careful restoration and renovation under the guidance of the Japanese architecture design company HMA. Through adaptive reuse, the former industrial spaces were converted into space comprising 22,000 m² of business office area and 13,000 m² of commercial space. Shortly after its opening in 2011, prominent international companies chose the industrial buildings in the park as their office locations instead of modern-style high-rise business buildings, including several world top 500 enterprises such as Kyocera and Kimberly-Clark.

Formally, the new urban space remains classified as industrial land use in zoning but is, in reality, used for non-industrial purposes such as office and commercial use.

Although informal, a project of adaptive reuse also requires approval from government agencies. According to an interview with a site management company operating 55 business parks based on adaptive reuse, an informal institution oversees the approval process for such projects. Before renovation activities are undertaken, related government departments are invited to a meeting organized by the Shanghai Economic and Information Committee, the inventor of "three unchanges" policies. The purpose of the meeting is to inform the relevant administration departments about the plan for the industrial site and seek their approval. For instance, the fire department checks if safety issues are sufficiently considered in the building renovation plans. The commerce department prepares for new business registration after redevelopment. The building management department ensures that the renovation plan complies with regulations to guarantee the safety of the dilapidated structures after renovation. The

planning authority checks for violations of urban planning. However, the participation of planning authority is often seen as mere tokenism. "If all other departments agree with the project, the planning authority is then isolated and reluctant to object" (Interview with a site management company in October 2022). Typically, planning authorities send only low-ranking officials to join such meetings, who refrain from giving opinions. An official from Shanghai planning authorities noted that "we do not support this type of redevelopment, nor do we oppose it" (Interview in October 2022).

4.3. Comparison of comprehensive and incremental industrial redevelopments

Table 2 summarizes and compares key aspects of comprehensive and incremental industrial redevelopment projects in Shanghai, highlighting their differences. The different nature of these projects has influenced their

Table 2. Comparisons between the comprehensive and incremental industrial redevelopment in Shanghai

Aspect	Comprehensive	Incremental
Formalities of the project process		
Master plan	Rigid master plan	No master plan
Procedures	A series of formal procedures to follow, approvals by various government agencies	Each project needs to be negotiated individually
Publicity	The approval documents will be published on the website of local governments within a limited time	No publicity actions
Institutional arrangements and actors involved		
Decision-making departments in the government	Land-related agencies and urban planning authorities (Shanghai Urban Planning and Land Recourse Management Bureau or corresponding authorities at the district level)	Agencies in charge of industrial properties (Shanghai Economic and Information Committee)
De Facto land owners	Subordinate to urban planning	Proactively promote regeneration
Developers	Work closely with the government to implement projects with no connection with de facto landowners	Work closely with de facto land owners and Shanghai as well as agencies responsible for industrial properties
Land use		
Before regeneration	Originally industrial use, but often closed or used for non-industrial use, industrial use identified in planning documents	Originally industrial use, but often closed or used for non-industrial use, industrial use identified in planning documents
After regeneration	Non-industrial use (office or commercial), adhere to urban planning	Non-industrial use (office or commercial), but not adhere to urban planning, which still indicates industrial use
Physical features after regeneration		
Treatment of existing buildings and sites	Demolition of buildings and cleaning the sites; in a few projects, existing buildings conserved occasionally	Maintenance, refurbishment, and renovation of existing buildings
Physical structure after regeneration	Increase in floor space, floor area ratios	No increase or decrease of floor space and floor area ratios formally, but often additional space is created informally, such as using a container for office space, as a container is not counted as a building structure under planning regulations
Heritage aspect	Except for a few listed monuments or a few buildings occasionally, the heritage aspect is not focused	Heritage is not the main driving force of regeneration, but as an outcome, industrial heritage is well-conserved and revitalized. The cultural and economic value of heritage value has been enhanced through adaptive reuse
Landscape aspect	Larger space of greenery following planning regulations	Micro-landscape improved through design and place-making
Open space	Larger space of open space through planning	Micro-open space improved through design and place-making

implementation. Comprehensive redevelopment, guided by a planning-led approach, results in large-scale site clearing and significant improvements to the physical environment in a relatively short time. On the other hand, incremental redevelopment, following a practice-led approach, leads to more moderate changes in the neighborhood.

The major differentiator between the two categories of industrial redevelopment in Shanghai lies in institutional arrangements and associated implementation strategies. Comprehensive redevelopment strictly adheres to planning regulations, making it more extensively shaped by planning policies and existing master plans. Public participation is secured through planning regulations, and original landowners are irrelevant to developers' work. In contrast, incremental redevelopment has an ambiguous legitimate status and relies on decisions made by government agencies on a project-by-project basis. Therefore, developers need close relations with government agencies, original landowners, and other influential actors to obtain permission. Consequently, close collaboration among these actors is encouraged, while the general public is excluded from the decision-making process.

Both types of redevelopment approaches aim to repurpose underused industrial land for non-industrial use, suggesting a common direction. Incremental redevelopment changes the *de facto* land use of former industrial land but does not shift the *de jure* land use of the sites, as it is not considered as "planning implementation." Thus, incremental redevelopment can be viewed as temporary land use projects or a transitional stage toward comprehensive redevelopment, which eventually "implements the plan."

5. Discussion

5.1. Challenges of planning-led industrial redevelopment: Why alternative approaches are needed?

The formal approach of industrial redevelopment faces several constraints, mainly related to land transactions and rent gap levels. One significant challenge is that the land use plan does not fully address implementation challenges, such as land ownership. Developed by the municipal government in a top-down approach, the land use plan aims to regulate the type of land use within its administrative boundary. However, it does not consider how the local government may gain the *de facto* control of the land. Ambiguity exists in the ownership of industrial land, as both state enterprises and local governments can represent the state in owning the land, and their power in controlling land varies. During the socialist planned economy, there was no competition for urban land between state enterprises and local governments. Industrial development, led by state enterprises, was the overwhelming priority in cities. The land was allocated to state enterprises for free without a limited period of use. Urban development was based on sprawling industrial work-unit compounds in random patches rather than following urban planning to balance conflicting land use interests. The individual self-sufficient state enterprise compounds were located within the territories of the city administration. However, state enterprises held more decision power in land use than local authorities since they reported directly to central ministries. In contrast, sectoral departments were responsible for planning project-specific sites based on 5-year plans instead of local authorities.

The situation changed with the introduction of the land leasing system in 1988, allowing local authorities to lease urban land for commercial use. With political and economic decentralization, the control of urban land by local governments strengthened. Revenue generated from land commodification provided substantial funds for local governments to invest in urban (re)development projects, leading to an increased emphasis on urban planning to coordinate development interests and achieve ambitious development goals.

Since local governments only own a small proportion of urban land, they are eager to convert land owned by state enterprises into leasing land, particularly land with advantaged locations. Theoretically, local governments can reacquire land from state enterprises by paying compensation fees and then selling the land to commercial users at a higher conveyance price. Urban planning is one of the legal instruments employed by local governments to legitimize land acquisition activities for land redevelopment. It serves the needs of a development a list state for rapid economic and urban growth (Wu, 2015). However, negotiations with sitting landowners are not always successful (Hsing, 2006). As *de facto* landowners, state enterprises tend to hold the allocated land. The competition between state enterprises and local governments for land is complex, depending on their relative power and strength (Wu *et al.*, 2007, p. 92). State enterprises are often referred to as "entrepreneurial bureaucrats" (McGee *et al.*, 2007, p. 14), enjoying both economic and political status. Unlike private residents who may not have bargaining power in giving up land use rights, state enterprises have a certain level of political hierarchy, sometimes even higher than local governments (Zhu, 2004, p. 1255). The acquisition of existing administratively allocated urban land in inner cities is much more difficult than acquiring rural land and unoccupied urban land (Yeh & Wu, 1996; Yeh, 2005).

In the land acquisition process, state enterprises have strong bargaining positions with local government

officials and political leaders. It is not surprising that state enterprises, occupying land in inner Shanghai — where land value has significantly multiplied in the past decades and is expected to continue increasing — are often reluctant to relinquish their land rights. As long as the state enterprise does not agree to relinquish its land rights, the implementation of the land use plan has to be suspended. Unless significant public interests are involved, such as public infrastructure or projects with national or municipal significance (Ren, 2014), state enterprises tend to hold onto the land for their own uses.

The dilemma of land acquisition has been taken into consideration by the local government when making a plan. A land use plan needs to balance the proportion of various land uses, such as commercial and non-commercial land use, to obtain approval from the upper government. The local government tends to use the land it occupies to plan for projects that generate land revenue. Meanwhile, land occupied by state enterprises is planned for non-commercial purposes. This approach ensures that the proportion between commercial and non-commercial land use is balanced and aligns with planning guidelines. For instance, in Baoshan District, Shanghai, land occupied by state enterprises — which is less likely to be retrieved by the local government for profitable uses — is largely planned for non-commercial uses such as green open space (Xia, 2017, p. 209).

Due to the various ownerships of industrial land, land transactions have become challenging for implementing the land redevelopment plan. Furthermore, even for industrial land occupied by the local government, redevelopment activities may stagnate despite the approval of plans. The government will need to take steps to implement the plan in a top-down approach. The latest Shanghai Master Plan was developed in 2015 and approved in 2018, serving as the future scheme of urban development in 2035. However, this does not mean that all the land will be transformed from its current use to the planned use all at once. The implementation of the plan is a long-term process, with some urban sites redeveloped earlier than others. The decision on which sites to implement first is subject to internal and external social and economic circumstances, such as location factors, land property rights, and land use status.

One of the main driving forces for the local government to promote land redevelopment is to obtain the "land rent gap." It is highly profitable for the local government as the subsequent land transfer fee through land leasing is much higher than the previous land compensation, contributing significantly to the local budget. Driven by the concept of the "land rent gap," the government tends to favor land in the inner city, which is easier to lease for profitable use compared with land in less favorable locations. In addition, the size of the land plot also plays a role in land profitability. A small piece of land is less profitable for leasing compared to a large-sized land plot. For instance, the Shanghai Medicine Group, which controlled 54 small, distributed pieces of industrial land, intended to acquire a large piece of land in Shanghai's satellite towns to relocate their factory in exchange for the 54 inner-city industrial land pieces. However, the government did not favor this plan as the small, distributed pieces of land were not profitable enough to lease (Interview in October 2019). Studies on redevelopment projects in Shenzhen have also shown that urban sites with high land rent gap levels and low transaction costs are more likely to be redeveloped earlier (Lai *et al.*, 2021). This implies that the local government is selective in choosing parcels of industrial land for redevelopment while leaving others suspended or awaiting future opportunities.

However, for the industrial land that is not yet in the forthcoming implementation agenda, there is a market-driven, bottom-up motivation for redevelopment. On the land supply side, original manufacturing production activities have been terminated or reduced, leaving industrial buildings idle and providing potential space for new uses. On the land demand side, potential tenants require more space for emerging businesses. The situation sets the stage for an alternative form of redevelopment beyond the planning-led approach.

5.2. The underpinning rationales of legitimating the practice-led approach

The afore-described practice-led industrial redevelopment approach emerged and gained support from the local government for multiple reasons. It can be seen as a consequence of interactions among different local authorities and agencies within the specific institutional environment.

First, the current planning system does not provide adequate solutions for industrial land retrieval, leading to land redevelopment being suspended for extended periods. In response to this issue, the introduction of the "three unchanged" policy indicates that the local government prioritizes immediate social and economic interests over strict development control legitimacy. The planning authority compromises by accepting that, as long as the formal or registered land use of the land does not violate the existing zoning plans, it would remain silent on the proposed adaptive reuse of industrial sites.

Second, industrial land reuse projects still require permission from the local government. In the absence

of strict regulations established in statutory plans, political leaders, various local government authorities, and departments must come together to discuss project-specific controlling policies for each proposed adaptive reuse project. This process allows local government officials to significantly increase their discretionary power over development control. Consequently, because granting such permissions is often viewed as making exceptions for proposed industrial land reuse projects, those projects preferred by the local government, especially by the political leaders, are more likely to receive approvals. However, this also involves substantial transaction costs in cultivating good relations with local government officials and political leaders, and such projects are exposed to higher political risks compared to planning-led land redevelopment ones. Political decentralization provides government agencies like the Shanghai Economic and Information Committee with greater capacity to promote local economic development through these loopholes.

Third and related to the above, to obtain exceptional permission from the local government, the proposed industrial land reuse projects must comply with the local government's social and economic development plan. Evidence of this can be seen in the inclusion of the "three unchanges" policy in the "The Eleventh 5-year Plan of Development of Shanghai Creative Industry Plan" issued by the Shanghai Municipal Government in 2005. As a result, the current industrial land reuse projects in Shanghai are overwhelmingly dominated by creative industrial parks.

Therefore, it can be argued that the practice-led redevelopment approach and its associated institutional establishment in Shanghai encourage redevelopment projects in response to policies while capturing land values in market dynamics. Tertiarization has been incorporated into the national development agenda with the issuance of the Tenth 5-Year Plan (2001–2005) by the State Council. In terms of industrial redevelopment, "withdrawing secondary industry and promoting tertiary industry" has been applied and clearly stated in the master plan of Shanghai (1999–2020). Economic restructuring, rather than economic growth, has been given higher priority. In urban redevelopment, the government has more goals than just land revenue generation, such as heritage conservation and employment creation, to respond to the new mandate of the central government (Wu *et al.*, 2021).

Overall, the observed practice-led industrial redevelopment approach in Shanghai reveals the conflict between the local government (or at least a large part of the local government) and the planning system regarding how industrial sites shall be used. The local government and other stakeholders such as developers, landholders, and potential tenants have constructed a new path toward industrial land reuse, temporarily bypassing the current planning system through institutional innovation and restructuring. This institutional restructuring leads to the increased discretionary power of local government officials and eventually turns industrial land reuse projects into responses to policy and market forces.

5.3. Relations between planning-led redevelopment and practice-led redevelopment

We suggest that in Shanghai, an alternative redevelopment model has emerged for industrial land: a formal planning-led approach involving demolition and relocation, and an informal practice-led approach of incremental regeneration without demolition. In the former approach, land redevelopment adheres more to urban planning on land controlled by the local government, while in the latter approach, the type of urban redevelopment is not regulated in urban planning.

These two approaches coexist in the practice of industrial redevelopment in Shanghai, which is coordinated by informal rules rather than standing in conflicts.

The planning-led redevelopment holds a higher priority of implementation than practice-led redevelopment. Informal redevelopment is a tentative approach before formal redevelopment is enacted. Subject to specific circumstances, informal redevelopment can be replaced by the formal one legitimized by urban planning. The invention of the "three unchanges" policy shows respect for formal urban planning while the informal redevelopment is underway. If a decision is made for formal land redevelopment, the informal use will most likely be paved away, regardless of the success of the businesses. One typical example is Red Town in Shanghai; after 10 years of successful development of the industrial site into a cultural landmark of Shanghai, Red Town did not survive demolition according to urban planning (He, 2019b). In the informal approach, when a tenant signs the contract to rent the space, it is clearly stated in the contract that, even though a contract is signed, the land may still be taken back by the government for land redevelopment according to urban planning before the term of the contract ends (Interview in October 2022). The tenants are aware that the use of such space is temporary.

A government officer from planning authorities argued that, in the long run, all the sites would be redeveloped according to urban planning (Interview in October 2019), i.e., informal redevelopment replaced by formal redevelopment. Observation shows that the two approaches will continue to coexist. In Shanghai, the first generation

of creative parks has existed for nearly 20 years, with no sign indicating plans for redevelopment in the near future. For instance, by 2023, Bridge Eight Creative Industry Park will be in existence for 19 years in the center of Shanghai in Luwan District, an area with high land value, and will continue to function as a creative park. It may not be necessary for the district government to undertake formal land conversion, as the district is rich enough and does not prioritize the economic output of such a small piece of land. Instead, it values its political, cultural, and social impact (Interview with a government officer in 2020). Meanwhile, more and more business parks are emerging in Shanghai. One of the newest well-known projects is Shangsheng Xinsuo, which opened in 2022, representing the first industrial redevelopment project in Shanghai by Vanke Real Estate Company, a real estate giant in China.

5.4. The role of planning and the legitimacy issue of incremental industrial redevelopment

In short, the local government in Shanghai has provided a solution to partially and temporarily legitimize existing informal industrial land reuse practices by reclarifying and redefining what should be considered as the "implementation of land use plans" and what may not. This approach limits the scope of urban planning control and creates institutional spaces for the local government (including government agencies other than the planning authority) and developers to explore alternative approaches to industrial land reuse and redevelopment.

However, there is a possibility that land reuse projects may eventually be replaced by conventional planning-led redevelopment projects. This introduces high policy risks for developers and tenants of the investigated creative parks. Without full legitimization, such semi-informal redevelopment approaches are unlikely to capture the optimal land uses of the sites.

In contrast, the local governments in Guangdong province chose to restructure the planning system to adapt to the emerging needs of urban regeneration. They introduced prefecture-level urban regeneration laws[7] to legitimize the institutional rearrangements for various types of regeneration approaches. In addition, specific plans were introduced for urban regeneration schemes[8], and cities like Shenzhen and Guangzhou established an Urban Regeneration Bureau (Chen *et al.*, 2020) under the local urban planning authority to address issues related to urban regeneration. In short, local governments in Guangdong expanded the scope of planning control to fully legitimize different urban regeneration approaches at an early stage of their emergence.

The institutional rearrangements in Guangdong demonstrate that it is possible to place emerging urban redevelopment approaches under the control of the planning system, thereby fully addressing the legitimacy issue. However, the local government in Shanghai has opted to slightly withdraw the role of planning in exchange for greater discretionary power of government officials. This decision comes at the cost of developers and tenants bearing higher policy risks.

6. Conclusion

This study argues for the coexistence of comprehensive redevelopment and incremental redevelopment strategies for industrial land reuse/redevelopment in Shanghai. The former is implemented through a planning-led approach, with legitimacy rooted in the national planning system, and often follows property development routines, including large-scale demolition and relocations. The latter is implemented through an informal and practice-led approach, encouraged by the "three unchanges" policy. It serves as a complementary and temporary approach to pursue a better use of existing industrial land/buildings when the proposed/planned real estate redevelopment is suspended.

The intricated relations between urban planning and urban regeneration in the given context reflect a mismatch between shifting urban redevelopment strategies (from pro-economic growth to pro-economic restructuring) and the conformist planning system. As a result, the conventional planning-led approach to land redevelopment is being challenged, necessitating alternative approaches. Instead of reforming the planning system to adapt to the shifting land market, the government of Shanghai chooses to restrain planning control power by re-delineating what constitutes "planning implementation" and what does not. This has given rise to the practice-led approach of incremental industrial redevelopment, characterized by an ambiguous legitimate status as a consequence of collusion between the local government and market demands. It enables local government officials, especially local political leaders, to directly intervene in the decision-making regarding underused industrial land, regardless of what is stated in the master plan. At the same time, the capability of planning control is sustained whenever a planning-led

[7] For example, the 2021 *Shenzhen Economic Special Zone Urban Regeneration Act* (深圳经济特区城市更新条例), available at http://www.sz.gov.cn/szcsgxtdz/gkmlpt/content/8/8614/post_8614017.html#19169

[8] As has been stated in 2012 *Shenzhen Urban Regeneration Scheme Implementation Details* (深圳城市更新办法实施细则), available at http://www.gd.gov.cn/attachment/0/369/369378/2532051.pdf

comprehensive redevelopment project becomes feasible, leaving developers and tenants to bear the brunt of most policy risks.

Therefore, while the number of practice-led industrial redevelopment projects in Shanghai is nearly equivalent to that of planning-led comprehensive industrial redevelopment projects, the former is subordinate to the latter. The incremental industrial redevelopment in Shanghai should be understood as temporary and semi-informal practices, with a good chance of eventually being replaced by planning-led comprehensive projects. In that sense, the planning-led approach associated with comprehensive industrial redevelopment sustains its dominant role in shaping inner-city spaces, while the current approach of incremental industrial redevelopment is not robust enough to offer an alternative path for inner-city redevelopment.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Li Fan, Uwe Altrock
Formal analysis: Li Fan, Xueying Chen
Investigation: Li Fan
Methodology: Li Fan
Writing – original draft: Li Fan, Xueying Chen
Writing – review & editing: All authors

Ethics approval and consent to participate

This study is approved by the University of Kassel. The authors obtain verbal consent from participants before interviews and hold permission from interviewees to use relevant data in this article.

Consent for publication

Verbal consent was obtained from each of the participants involved to publish the data, images, and/or quotes relevant to the investigated projects.

Availability of data

Data are available on request.

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Appendix

List of interviews

Date	Occupations	Institutions	Occasions
June 12, 2019	Former officer	Shanghai Urban Planning Authority	In-person
June 22, 2019	Project manager	A state-owned enterprise	In-person
August 23, 2019	Officer	Shanghai Urban Planning Authority	In-person
August 29, 2019	Former officer	Shanghai Urban Planning Authority	In-person
September 1, 2019	Officer	Shanghai Urban Planning Authority	In-person
September 9, 2019	Officer	Shanghai Urban Planning Authority	In-person
Octpber 10, 2019	Officer	Shanghai Urban Planning Authority	In-person
July 24, 2020	Officer	Shanghai Urban Planning Authority	Online
November 23, 2020	Senior urban planner	Shanghai Urban Planning and Research Institute	Online
December 08, 2020	Senior urban planner	Shanghai Urban Planning and Research Institute	Online
October 13, 2022	Project manager	Shanghai Institute of Industry Transition and Development	In-person
October 17, 2022	Former vice director	A site management company of a business park	In-person
October 24, 2022	Officer	Shanghai Urban Planning Authority	In-person
October 25, 2022	Project manager	Shanghai Institute of Industry Transition and Development	In-person
October 25, 2022	Tenant	Shanghai Hongkou Debo Industrial Park	In-person
October 26, 2022	Associated professor	Tongji University	In-person

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ORIGINAL ARTICLE

Cultural landscape characteristics and zoning of traditional villages in Huizhou City

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Abstract

Traditional villages and cultural landscapes harbor rich historical information, representing a crucial agricultural heritage. This systematic categorization of these zones is essential for scientifically identifying their distinctive characteristics and values, thereby focusing protection efforts effectively. This paper focuses on Huizhou City, a typical multicultural area, examining its rich traditional villages and cultural landscapes through a comprehensive index system covering four levels and 22 factors. To categorize the city's diverse cultural landscape, K-means cluster analysis is employed, resulting in the identification of five traditional village cultural landscape zones, namely the northern mountain valley, the central plain of the Dongjiang River basin, the south-central plain of the Xizhi River basin, the southern coastal area, and the eastern mountainous hills. Each zone exhibits different spatial patterns and landscape characteristics. While this paper offers a preliminary analysis, future research should integrate advanced data analysis methods to comprehensively examine the cultural landscape to guide dynamic protection strategies and facilitate the adaptive reuse of traditional villages.

Keywords: Traditional village; Cultural landscape; K-means cluster analysis method; Zoning; Huizhou City

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1. Introduction

China has a rich history as a traditional agricultural country, spanning ancient times, with thousands of years of farming shaping the landscapes of traditional villages scattered among mountains and rivers, each with unique characteristics. These ancient settlements serve as repositories of rich historical information. The formation of their cultural landscape is a testament to the symbiotic relationship that has evolved over millennia among human production, living practices, and the surrounding environment. This intricate interplay stands out as the most vivid reflection of the regional characteristics of traditional villages among the many elements of their components (Li *et al*., 2020). Cultural landscape refers to the synthesis formed through the long-term integration of natural and human factors within a certain region during a specific period (Gordon, 2018). It undergoes continuous changes with human activities, creating connections between people and their natural, cultural, and socio-economic environments. A cultural

landscape is a continuous, living entity characterized by a high degree of integration (Abdullah, 2011). Despite this rich cultural heritage, the rapid development of China's economy has subjected traditional villages to significant challenges. Urbanization, industrialization, tourism development, and other factors have placed these villages under immense pressure. The regional and heterogeneous nature of their cultural landscapes has been diminishing due to excessive development, construction, or misguided protection behaviors (Lin *et al*., 2018). This predicament is particularly evident in traditional villages located in multicultural areas. The formation of cultural landscapes in these areas often involves intricate and complex factors, rendering them highly fragile and non-renewable in the face of external disturbances and impacts. Therefore, it is urgent to conduct specialized research and implement targeted protection measures.

Research on the cultural landscape has yielded rich results in recent years, primarily categorized into conceptual identification and type classification of cultural landscapes (Wang, 2009; Li & Xiao, 2009). This encompasses specialized protection planning for cultural landscapes (Cao & Xiao, 2013), the revitalization and renewal of cultural landscapes (Gan *et al*., 2017), and innovative research methods in cultural landscape studies (Song *et al*., 2022).

Within the realm of traditional villages, scholars have produced a substantial body of research. Many have conducted in-depth analyses of the connotations of traditional village cultural landscapes. They have substantiated the classification of cultural landscape types and the identification of characteristics by examining traditional village cultural landscapes in different countries and regions. Building on these analyses, scholars have introduced a range of cultural landscape concepts (An & Park, 2017; Shen *et al.*, 2006). Furthermore, multidisciplinary theories and methods have been introduced to explore the responses and development strategies of traditional village cultural landscapes under different development dilemmas (Zhang, 2011; Harun *et al*., 2017). Among these, Chinese scholar Liu Peilin innovatively put forward the landscape gene theory, advocating for the complex cultural landscape to be split into interacting factors through the structure of "cell-chain-form" (Liu, 2003).

Following the contributions of numerous scholars, the landscape gene theory has evolved into a research method represented by K-means cluster analysis, shaping a mature research system encompassing the "deconstruction of cultural landscape factors – data collection and processing– principal component extraction and systematic clustering – zoning" methodology (Song *et al*., 2022). In China, for example, this method has seen widespread application, particularly in the research of traditional villages and cultural landscapes in provinces such as Yunnan, Anhui, and Hebei. Notably, it has not only produced numerous research outcomes based on the zoning and classification of regional cultures but has also categorized them into types such as excavation and innovation, balance and coordination, revitalization and stimulation, as well as ecological livability, cultural and tourism resources, and characteristic folklore. These classifications are approached from the perspectives of conservation and development (Li & Lan, 2016; Zhang & Liu, 2023; Yao *et al*., 2022; Zhang *et al*., 2023).

The research results support the scientific identification and effective protection of traditional villages and cultural landscapes. It can be seen that the landscape gene and K-means cluster analysis method exhibit a high degree of flexibility in related research. This flexibility aids in extracting different components, types, and characteristics of traditional village cultural landscapes, providing a fresh perspective for further research.

Huizhou City in Guangdong Province, China, serves as a typical representative of a multicultural integration area. Influenced by its location, topography, and socioeconomic factors, a diverse array of cultures – Hakka, Guangfu, and Fukuo – converges here, giving rise to exceptionally rich traditional villages and cultural landscapes. This paper focuses on the traditional villages in Huizhou City, employing the genetic theory of cultural landscape and the K-means cluster analysis method. It dissects the various subdivisions of traditional villages in Huizhou City, meticulously summarizing the characteristics of each subdivision. The aim is to identify the characteristics and values of the traditional villages in Huizhou City, providing a constructive and insightful reference for scientific research and effective protection of the traditional villages in the area where multiple cultures are blending.

2. Methods

2.1. Overview of traditional villages in Huizhou

In the southeast of Guangdong Province, Huizhou is located in the eastern part of the Pearl River Delta and the middle and lower reaches of the Dongjiang River Basin. It leans against the Julian Mountains in the north and the South China Sea in the south, boasting a rich topography that includes mountains, hills, plains, and basins. The diverse natural geographic environment has fostered the merging of different folk cultures, giving rise to a blossoming traditional village cultural landscape (Lai & Yang, 2022). Examples of this cultural landscape abound. Consider the neatly organized comb-style village texture and the

simple, pragmatic three-room and two-porch buildings of the Guangfu settlement, the "negative yin and embracing yang" feng shui layout and majestic roundhouse buildings characterize the Hakka settlement, while the dense village layout and ornate decorations of the "downhill tiger" in the Chaoshan settlement showcase the "Four Points of Gold" architecture. Each village and its cultural landscape hold high cultural research and artistic esthetic value (Figure 1).

This study focuses on the cultural landscapes of 132 traditional villages in Huizhou City. The research encompasses 10 national-level traditional villages in China, 10 provincial-level traditional villages in Guangdong Province, 15 municipal-level traditional villages in Huizhou City, and several typical villages not included in the protection list. These villages exhibit good appearance, cultural characteristics, and certain protection values, ensuring a comprehensive, objective, and scientifically reflective examination of the cultural landscape characteristics and values of traditional villages in Huizhou City (Figure 2).

2.2. Research methodology

Drawing a comprehensive overview of existing studies in the preceding section, this study aims to adopt the well-established research mode of "cultural landscape factor deconstruction-data collection and processing-principal component extraction and systematic clustering-zoning" from related studies. It seeks to analyze, in-depth, the cultural landscape gene theory and the K-means cluster analysis method to categorize the cultural landscape of traditional villages in Huizhou into different zones, summarizing their corresponding characteristics.

The process involves four key steps:

(i) Combine literature and research to select the culturally significant landscape factors for traditional villages in Huizhou City. Construct an indicator system comprising data-based indicators and descriptive indicators.

(ii) Input indicator data from 132 research cases. Utilize SPSS26.0 statistical analysis software to perform factor analysis, downsizing several data-type cultural landscape factor indicators to a few key independent factors.

(iii) Apply K-means clustering analysis to the key public factor data. Use the clustering results, along with indicator data, natural geographic characteristics of Huizhou City, and administrative divisions of villages and towns, to divide the traditional villages and cultural landscapes into distinctive sub-districts.

(iv) Summarize and compare the landscape pattern characteristics, landscape spatial characteristics, and landscape unit characteristics among different subdivisions of the traditional village landscape in Huizhou City. Reveal the regional characteristics of its cultural landscape.

2.3. Division of traditional village cultural landscape zones in Huizhou City

2.3.1. Construction of cultural landscape factor index system

To objectively and comprehensively reflect the characteristics of traditional villages and cultural landscapes in Huizhou City and to highlight Huizhou's uniqueness compared to other regional cultural landscapes, the construction of the indicator system mainly revolves around the "natural ecological landscape features," "village spatial form features," "village architectural features," and "village landscape element features" of traditional villages in Huizhou City. Cultural technicians have dismantled and constructed this system across four levels, resulting in 22 indicators in the evaluation system, comprising 17 data-type

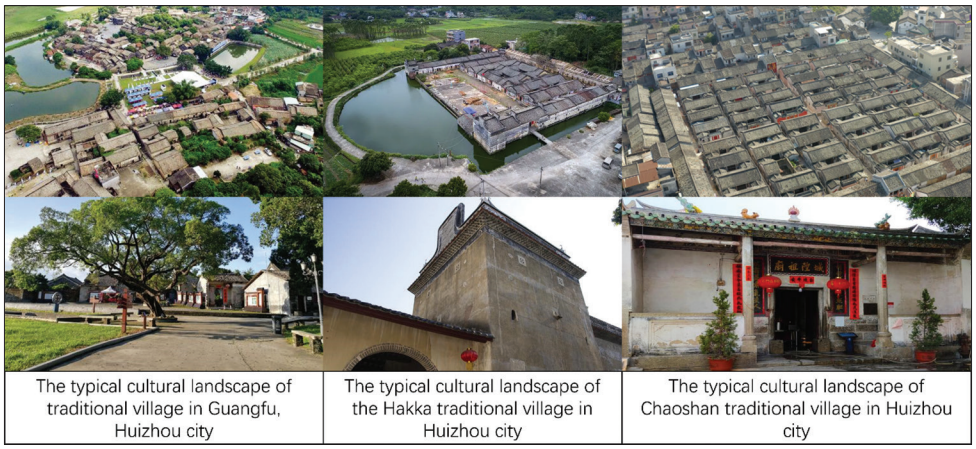

Figure 1. The typical cultural landscape of traditional villages in Huizhou City. Source: Photographs by the authors

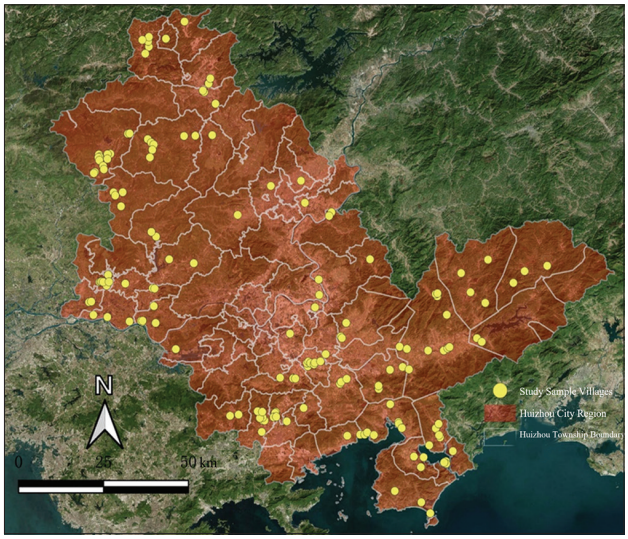

Figure 2. Distribution of research subjects. Source: Drawing by the authors

cultural landscape factor indicators and 5 descriptive-type cultural landscape factor indicators (Table 1).

The "natural ecological landscape features" refer to the relationship between traditional villages and their peripheral ecological environment, reflecting the influence of factors such as topography, altitude, village location, river relationship, and slope on the formation of the village cultural landscape. The "village spatial form features" include factors such as texture form, village area, the ratio of natural landscape area and building area, village orientation, and street structure, which highly condenses the settlement form and spatial pattern of the village. "Village architectural features" take into account significant differences in the architectural features of villages influenced by Guangfu, Hakka, and Fukao cultures. They vividly reflect regional cultural characteristics through architectural form, roof, wall, decoration, and the relationship between the ancestral hall and the residence. The "village landscape element features" include various factors such as feng shui ponds, feng shui forests, streets, alleys, courtyards, and public spaces. Similar to "village architectural features," these elements exhibit distinct differences under the influence of different cultures, serving as an important basis for delineating various zones of cultural landscapes.

2.3.2. Data sources

Three approaches were employed to source and collect data on the data-based cultural landscape factors. First, data were organized and statistically analyzed based on relevant literature and field research. Second, the BIGEMAP map software was utilized to search for place names and identify and statistically analyze the relevant cultural landscape factors. Third, the sample villages were treated as "point elements," and the geometric centers of representative architectural clusters were chosen. These center's latitude and longitude coordinates were marked and imported into ArcGIS for vectorization. Combined with the Digital Elevation Model (DEM) data of Huizhou City, the data collection and statistical analysis of relevant cultural landscape factors were carried out. For the descriptive cultural landscape factors, data were sourced and collected through various means, including drone and camera photography, mapping of relevant landscape elements and drawings, and interviews with villagers. These methods contribute to the archival and descriptive statistical organization of the village data.

2.3.3. Dimensionality reduction of multiple indicators using factor analysis

Factor analysis is a commonly used method for dimensionality reduction analysis, consolidating numerous cultural landscape elements into several independent cultural landscape key factors that reflect the main information. This is achieved by exploring the matrix of correlation coefficients between cultural landscape factors. This calculation process unfolds in the following steps:

(i) Model test: The SPSS26.0 statistical software is employed for the test calculation of cultural landscape factor indicator data. The resulting Kaiser-Meyer-Olkin (KMO) value is 0.623, exceeding 0.5, indicating a robust correlation among the cultural landscape factors (Table 2). At the same time, the approximate chi-square value of Bartlett's sphericity test is 838.376, with 91 degrees of freedom and a significance of 0.000. This significance, much less than 0.001, suggests a strong correlation among the cultural landscape factors, making them suitable for factor analysis.

(ii) Eigenvalue and contribution rate calculation: Utilizing SPSS26.0 statistical software to perform factor analysis on the data-based cultural landscape factor indicators, the selection of the number of key factors for the cultural landscape is based on the initial eigenvalue and cumulative variance contribution rate. Upon calculation, 7 principal components can be extracted by the requirement of initial eigenvalue $\lambda \geq 1$. The cumulative variance contribution rate is 70.56%, covering 70.56% of the information from the original 18 data-type cultural landscape factors. Consequently, the first 7 principal components serve as the key factors for cultural landscape, replacing the original 17 datatype cultural landscape factors in subsequent statistical analysis.

(iii) Cultural landscape key factor function: The maximum variance method is adopted to rotate the factors, resulting in 7 principal components as the cultural

Table 1. Indicator system for cultural landscape factors in traditional villages, Huizhou City

Cultural landscape level	Cultural landscape factor	Reference values of the cultural landscape factor classification	Indicator type
Natural ecological landscape features	Topography	1. Mountains 2. Mountain basins 3. Hills 4. Tablelands 5. Plains	Data-type
	Elevation	1. Altitude ≤50 m 2. Altitude 51 – 300 m 3. Altitude 301 – 600 m 4. Altitude 601 – 900 m 5. Altitude >901 m	Data-type
	Elevation angle	1. ≤5° 2. 6 – 15° 3. 16 – 25° 4. 26 – 35° 5. 36 – 45° 6. >45°	Data-type
	Village setting	1. Close to both the mountains and the water 2. Close to the mountains and far away from the water 3. Far away from the mountains and close to the water 4. Far away from the mountains and far away from the water	Data-type
	River relations	1. Coastal 2. Around the river 3. Closer to the river 4. Close to the river (farther than 3, closer than 5) 5. Far away from the river	Data-type
	Water level	1. Large river basins: basin area ≥1001 km^2 2. Medium-sized river basins: 501–1000 km^2 3. Small river basins: 101–500 km^2 4. Micro river basins: ≤100 km^2	Data-type
Village spatial form features	Village texture pattern	1. Comb layout 2. Group layout 3. Dense layout 4. Free layout 5. Line layout 6. Free-standing layout 7. Walled layout	Data-type
	Village area	1. Micro ≤2 hectares 2. Small: 2–5 hectares 3. Medium: 5–10 hectares 4. Large: 10–20 hectares 5. Super-large: ≥20 hectares	Data-type
	Ratio of the natural landscape area to the floor area	Area of the natural landscape such as farmland, windswept ponds, and windswept forests/traditional built-up area	Data-type
	Village orientation	1. Sitting north to south 2. Sitting south to north 3. Sitting east to west 4. Sitting west to east 5. Multi-facing	Data-type
	Traditional street structures	1. Main road introduction 2. Through the village 3. Around the village 4. Branching off 5. Vertically and horizontally gridded	Descriptive-type

(Contd...)

Table 1. ***(Continued)***

Cultural landscape level	Cultural landscape factor	Reference values of the cultural landscape factor classification	Indicator type
Village spatial form features	Width (W)-to-height (H) ratio of traditional street	1. W/H<0.8 2. W/H=0.8–1.0 3. W/H=1.0–1.2 4. W/H>1.2	Data-type
Village architectural features	Forms of the main building	1. Three rooms and two corridors 2. Row houses 3. Tang Yokoyama 4. Wailing hut 5. Four-cornered house (*jiaolou*) 6. Siege fortress-style residence 7. Bamboo pole house 8. Downhill tiger 9. Four-pointed gold	Descriptive-type
	Forms of the building roof	1. Overhanging peak 2. Hard peak 3. Hiatus peak 4. Others	Descriptive-type
	Forms of the building's mountain wall	1. Herringbone mountain wall 2. Wok ear wall 3. Five-element-corresponding mountain wall 4. Others	Descriptive-type
	Overall decorative style	1. Refined 2. Rich 3. Simple	Descriptive-type
	Relationship with the temple	1. Ancestral leadership 2. Integration of residence and ancestral hall 3. Separation of residence and ancestral hall 4. Residence around the ancestral hall	Descriptive-type
Village landscape element features	Feng shui pond	1. Half-moon 2. Free 3. Windless	Descriptive-type
	Feng Shui Lin (Fengshui forest)	1. Village entrance forest 2. Dragon sitting forest 3. Pad foot forest 4. House foundation forest 5. No feng shui forest	Descriptive-type
	Traditional street surface	1. Slate type 2. Gravel type 3. Rammed earth type 4. Mixed slate and gravel type 5. Concrete type	Descriptive-type
	Courtyards	1. Single patio type (single courtyard type) 2. Multiple patio type (multiple courtyard type) 3. Courtyard dam type (in front of and behind the house)	Descriptive-type
	Square in front of the shrine	1. Building accessory type 2. Road integration type 3. Independent type	Descriptive-type
	Major agricultural landscapes	1. Rice fields 2. Fish ponds 3. Terraces 4. Fruit forests	Descriptive-type

landscape key factors. The factor loading matrix, presented in Table 3, indicates the contribution value of the 17 original data-type cultural landscape factors to each principal component.

2.3.4. Cluster analysis of key factors for cultural landscape

This study employed a combination of qualitative and quantitative classification and zoning. Initially, K-means clustering was applied to the seven key factors of the cultural landscape in conjunction with descriptive indicators that reflect the information. The synthesis of objective and accurate cultural landscape zoning of traditional villages in Huizhou City was pursued through statistical data analysis and map visualization methods. The calculation steps are mainly divided into two parts:

(i) Determination of K value (number of clusters): The K-means cluster analysis algorithm required the researcher to preset the K value, introducing some subjective interference. To avoid interference, the elbow method was adopted in this study to determine the K value. Using SPSS26.0 on the seven key factors of the cultural landscape for the 132 research villages, several different K values were tested for clustering, as illustrated in Figure 3. When the K value = 5, the sum of squares error (SSE) begins to fold, and the distortion rate slows down. This is considered the first critical point. Combining this with the natural geographic characteristics of Huizhou City and the characteristics of the humanities and landscape, it is considered that the K=5, representing the number of clusters for the 132 traditional villages, is the most reasonable choice.

(ii) Cluster analysis results of the study villages: Utilizing SPSS 26.0 statistical analysis software, K-means cluster analysis was conducted on the 7 key factors of the cultural landscape for the 132 study villages with K-value set to 5. This process yielded the values of the cluster centers for the 7 key factors (Table 4). At the same time, adhering to the principle of the shortest Euclidean distance (3.3), the 132 study sample villages were classified into 5 distinct classes. These classes were spatially superimposed, laying the foundation for the subsequent step in the traditional village cultural landscape zoning.

Table 2. Kaiser-Meyer-Olkin (KMO) and Bartlett's correlation test

KMO value	0.623
Bartlett's test of sphericity	
Approximate Chi-square (mathematics)	838.376
Degrees of freedom (physics)	231
Significance	0.000

3. Results

3.1. Results of zoning

According to the K-means clustering analysis of traditional villages in Huizhou City, the 132 traditional

Table 3. Matrix of key factor loadings for cultural landscapes

Cultural landscape factor	F1	F2	F3	F4	F5	F6	F7
X_1 (River relations)	−0.787	−0.206	0.137	0.063	0.010	0.059	0.099
X_2 (Village area)	0.718	−0.242	−0.161	0.150	0.203	0.179	−0.174
X_3 (Plaza in front of the shrine)	0.647	0.010	0.099	0.215	0.121	−0.399	0.259
X_4 (Village site selection)	−0.184	−0.844	−0.055	0.000	0.170	−0.075	0.011
X_5 (Elevation)	−0.280	0.609	0.111	0.144	0.426	0.027	0.135
X_6 (Village texture patterns)	0.105	0.179	0.824	−0.155	0.044	0.111	0.015
X_7 (Traditional street aspect ratio)	−0.193	−0.005	0.723	0.364	0.071	0.067	−0.017
X_8 (Traditional street structures)	0.359	0.302	−0.580	−0.226	0.289	−0.085	−0.077
X_9 (Water class)	0.200	0.010	0.138	0.789	0.043	0.189	0.010
X_{10} (Terrain)	−0.045	0.605	−0.103	−0.621	0.129	−0.060	−0.106
X_{11} (Natural landscape to floor area ratio)	0.410	−0.288	0.117	−0.504	−0.033	0.115	0.289
X_{12} (Village orientation)	0.089	−0.055	0.040	−0.007	0.797	0.065	−0.001
X_{13} (Feng shui pond)	0.213	0.119	−0.324	0.010	0.523	−0.455	0.021
X_{14} (Major building forms)	−0.106	0.011	0.102	0.173	−0.035	0.849	0.110
X_{15} (Cuji relationship)	0.383	0.183	0.123	0.041	0.377	0.565	−0.051
X_{16} (Feng shui forest)	0.148	−0.181	0.116	−0.089	0.244	−0.045	−0.769
X_{17} (Courtyard)	0.040	−0.137	0.112	−0.094	0.223	0.018	0.725

villages were regarded as point elements. These villages were classified as points on the map after vectorized processing on the ArcGIS geographic information platform. The results of the clustering analysis of cultural landscape factors were then combined with four descriptive indexes to identify common features in images, mapping, and other aspects. Spatial superposition and fine-tuning of boundaries were carried out. Finally, the traditional villages in Huizhou City were categorized into five traditional villages and cultural landscape areas (Figure 4). Drawing on a "three-stage" naming method, these sub-districts were named based on the topographical features of each area. The names follow the format "geographic location + major topographical features + traditional villages and cultural landscape areas," resulting in the following designations for the sub-districts: Northern Mountain Valley Traditional Village Cultural Landscape Area, Central Dongjiang River Basin Plain Traditional Village Cultural Landscape Area, South-Central Xizhijiang River Basin Plain Traditional Village Cultural Landscape Area, Southern Coastal Traditional Village Cultural Landscape Area, and Eastern Mountainous Hills Traditional Village Cultural Landscape Area.

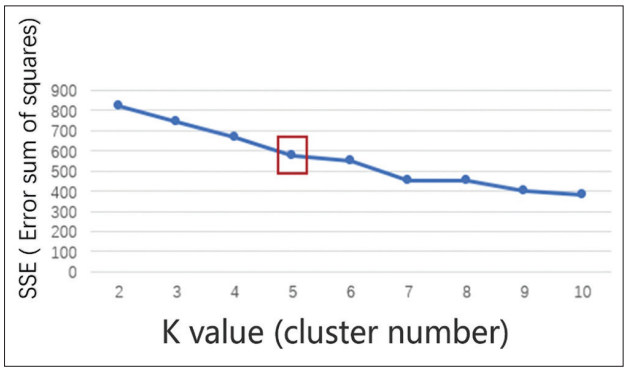

Figure 3. Elbow law plot for determining K-value in K-means cluster analysis.

3.2. Characteristics of cultural landscape areas of traditional villages in Huizhou City

3.2.1. Cultural landscape area of traditional villages in the northern mountain valleys

The Northern Mountain and River Valley Traditional Village Road Cultural Landscape Area is located in the northern part of Huizhou City, encompassing six districts and counties, including Longmen County and Henghe Town. The landscape pattern of this area is characterized by mountains and river valleys positioned between the Jiulian Mountains and Luofu Mountains. The primary terrain consists of mountainous hills featuring heavy rocks, peaks, and varying elevations. The village locations are significantly influenced by the natural geographic environment. This cultural landscape area, adjacent to Heyuan, a city within the Hakka cultural circle, intersects with Guangfu and Hakka cultures. Historically, it has been a settlement for a large Hakka population, mirroring the mountainous areas they originally inhabited. Consequently, this cultural landscape area is deeply influenced by Hakka culture, showcasing distinctive feng shui concepts of the Hakka people. Traditional villages in this cultural landscape area are mostly located in relatively flat river basins or hilly plains near the river, with an orientation toward sunny places. This orientation results in a landscape pattern of "mountain-forest-village-field." This pattern not only addresses the practical needs of villagers for production and daily life but also aligns with their traditional feng shui beliefs and their desire for a stable and secure life (Figure 5).

The landscape space of the traditional village cultural landscape area in the northern mountainous valley is characterized by grouping around enclosures, which are well organized. Positioned at the intersection of the Guangfu and Hakka cultural circles, the spatial layout and form of the villages distinctly emphasize regional cultural integration. Due to limitations imposed by the natural geographical environment, traditional villages in

Table 4. Final clustering centers for key factors of the cultural landscape

Cultural landscape key factors	Clustering				
	1	2	3	4	5
Spatial scale factor	−0.07499	−0.66840	−0.23598	−0.45181	2.00417
Natural terrain factor	0.49667	1.40021	−0.29343	−0.41375	0.11214
Spatial form factor	1.26412	0.32281	−0.72396	−0.10823	−0.26252
Village water system factor	−0.95651	0.82967	−0.69733	0.50478	0.54006
Feng shui landscape factor	−0.45141	1.77795	0.00599	−0.19464	−0.00094
Architectural landscape factor	0.15605	−0.14661	−0.95472	0.58514	−0.02457
Public space factor	−0.24020	0.33191	−0.15547	0.18199	−0.10750

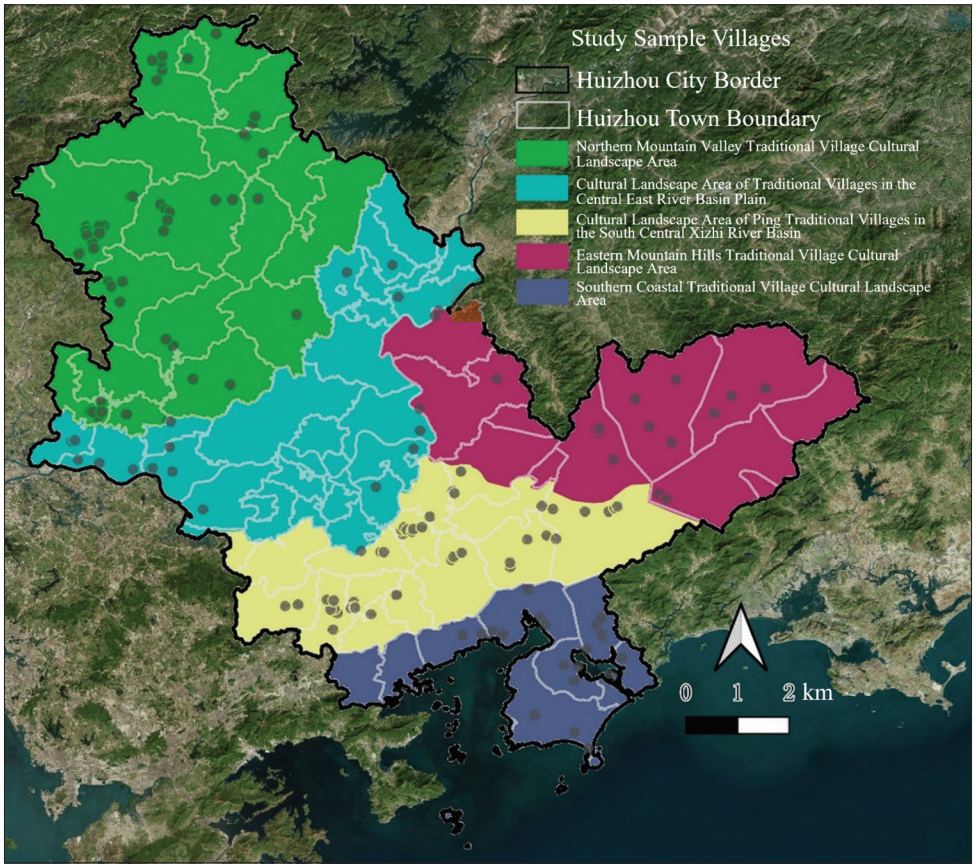

Figure 4. Zoning map of the cultural landscape of traditional villages in Huizhou. Source: Drawing by the authors

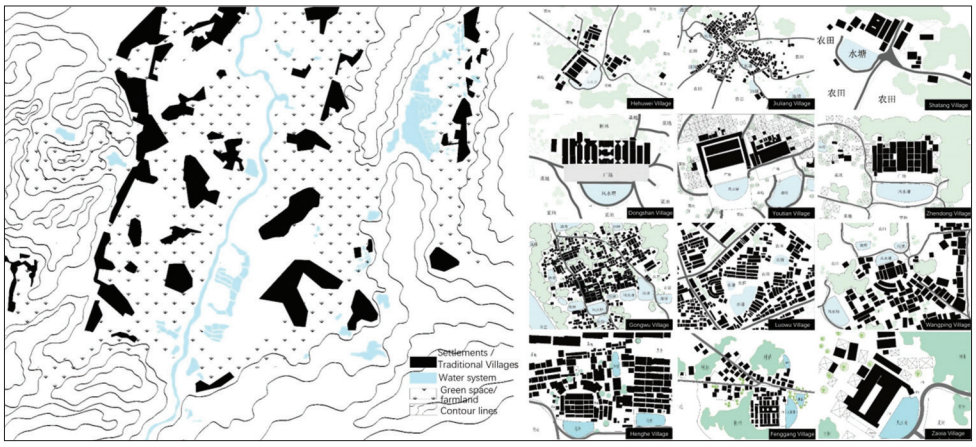

Figure 5. Landscape illustration of the traditional village cultural landscape area in the northern mountain valley. Source: Drawing by the authors

this cultural landscape area are generally small in scale. Influenced by the clan concept, most of the villages are laid out in clusters, with a Hakka house serving as the center of the settlement. In some mountainous areas, a few villages are formed as independent entities with only one Hakka house. Most villages adopt a layout where Hakka houses serve as the center of the settlement, forming several clusters along the mountains and the water. The landscape unit of this cultural landscape area is characterized by a grand village enclosure and subsidiary landscape. The core building of the village is the large-scale Hakka fortress-style houses, enclosed by rows of houses or walls to form a "perimeter." Inside this perimeter, ancestral halls and houses are orderly and neatly arranged.

3.2.2. Cultural landscape area of traditional villages in the Central Dongjiang Basin Plain

The Central Dongjiang Basin Plain Traditional Villages Cultural Landscape Area is located in the central north of Huizhou City, encompassing villages and towns in Huicheng District, Boro County, and Huiyang District, through which the Dongjiang River flows. The landscape pattern of this cultural landscape area is characterized by a vast plain and a close water connection. The region features a dense river network and generally gentle terrain, primarily consisting of river alluvial plains with some mountains and hills in the north. Due to favorable natural geographical conditions, the cultural landscape area has a deep-rooted history of village settlement and development. Given the smaller topographic barrier with the Pearl River Delta Guangfu area, the cultural landscape area generally exhibits relatively strong Guangfu cultural characteristics. At the same time, the Dongjiang River mainstem traverses the entire region from west to east, establishing connections with the Pearl River Delta and the Hakka region of Heyuan. However, there are certain regional differences from east to west along the Dongjiang River mainstem. The eastern and central parts showcase more typical Guangfu culture, while the western part reflects the influence of Hakka immigrant culture, presenting a certain degree of cultural landscape characteristics indicative of Guangzhou-Hakka fusion. The overall terrain of this cultural landscape is flat, and villages are mostly located in river plains or alluvial plains near the Dongjiang River and its tributaries. The flat terrain and sufficient water sources are advantageous for village development and construction. Consequently, most of the villages in this cultural landscape area are large in scale and have a high distribution density. Despite their density, villages maintain certain boundaries and distances from each other, forming a picturesque scene of scattered villages across the landscape.

The landscape space of traditional villages in the plains of the Central Dongjiang Basin is characterized by sparse rows and streets (Figure 6). Villages in this cultural landscape area mainly take regular blocks, often separated into several blocks by river networks or reservoirs. The texture of the village blocks typically follows a comb layout, consisting of neatly arranged buildings of the same shape. The village buildings uniformly face one direction, and the streets and lanes are horizontal and vertical, maintaining an orderly layout mostly in the longitudinal direction. They extend with a long and straight depth, distributed in parallel among the village clusters and vertically connected to the squares in front of the ancestral halls. The landscape unit of this cultural landscape area is characterized by independent houses and extensive water ponds. The main architectural form of village houses is the three-room, two-porch design with multiple courtyards, which is characteristic of Guangfu. Some villages also feature Hakka-style row houses, arranged independently and neatly around the ancestral halls. The agricultural landscape in this cultural landscape area is dominated by paddy fields and fishponds distributed along the rivers. Some villages combine fishpond farming with crop cultivation to develop mulberry fish pond, showcasing the unique agricultural landscape characteristics of Guangfu villages.

3.3.3. Cultural landscape area of traditional villages in the South Central Xizhi River Basin Plain

The South Central Xizhi River Basin Plain Traditional Villages Cultural Landscape Area is located in the south-central part of Huizhou City, encompassing villages and

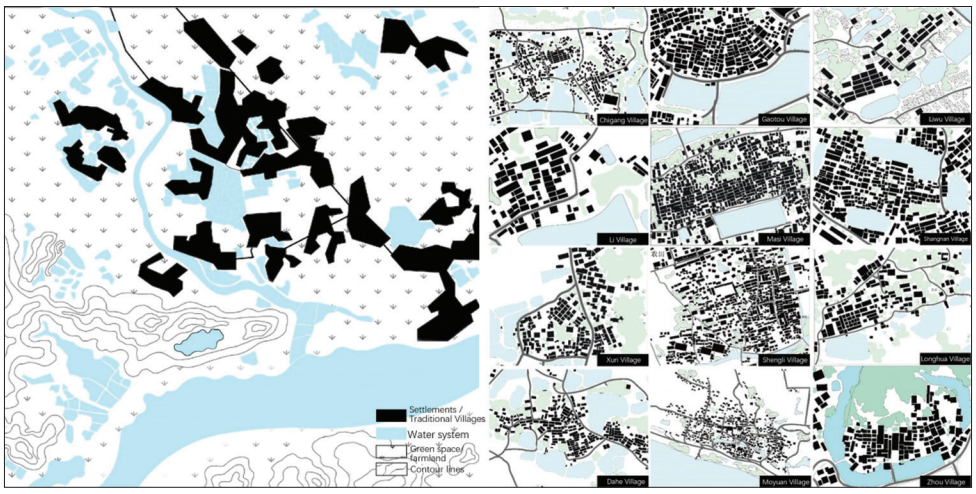

Figure 6. Landscape illustration of the traditional village cultural landscape area in the Central Dongjiang Basin Plain. Source: Drawing by the authors

towns in Huiyang District and Huidong County, where the Xizhi River flows through. The landscape pattern of this cultural landscape area is characterized by a harmonious blend of mountains and rivers and a preference for flat land. The southern part of the cultural landscape area is mountainous and hilly, while the other areas feature flat alluvial plains. The Xizhi River traverses the area from east to west, contributing a well-developed water system. This cultural landscape area holds significance as an early settlement for the Hakka people who moved to Huizhou for prosperity. Compared to the traditional village cultural landscape area in the northern mountainous valley, this area exudes a stronger traditional Hakka character and style. The gentle terrain, abundant water sources, and early development history have led to the growth of larger and denser villages. Transportation roads often serve as natural boundaries between villages. Influenced by traditional feng shui concepts, villages near the mountains and hills typically embody the traditional Hakka style. These villages are nestled amidst the mountains and water, arranged in tiers, backed by the mountains and facing the water, symbolically embracing the yin and the yang. Villages in the plains mostly face south or follow the water's flow in their orientation layout (Figure 7).

The landscape space of the traditional village cultural landscape area in the plains of the Xizhi River Basin in the south-central part of the country is characterized by a core-peripheral and centripetal grouping. Influenced by Hakka clan culture, the spatial layout of villages in this cultural landscape area exhibits a pronounced centripetal character. The village texture mainly centers around the Hakka house, with small residential buildings arranged in a peripheral layout, fostering the development and growth of the village scale. The structure of the grouping is relatively informal, often lacking clear planning and organization, with small residential buildings arranged around the house or staggered based on topography and water features, both in straight and curved patterns. The landscape unit of this cultural landscape area is characterized by its magnificent, defense-oriented houses. The core architectural form of the village grouping is the large-scale, multi-functional fortress-type house. While this fortress-style house exhibits a clear inheritance relationship with structures like the *Weilong* House, it emphasizes a more defensive and holistic design. On the one hand, it is crafted for compatibility to adapt to the relatively flat terrain of Huizhou. On the other hand, its design enhances defensibility, preventing various destabilizing factors, protecting the survival of the clan groups, and fostering a stable environment for reproduction and development.

3.3.4. Cultural landscape area of traditional villages in the southern coastal area

The Southern Coastal Traditional Villages Cultural Landscape Area mainly includes villages and towns along the coast of Huiyang District and Huidong County. The landscape pattern of this cultural landscape area is characterized by dense rivers and mountains leaning against the sea. The southern part of the cultural landscape area faces the sea, featuring rich and varied terrain, including mountains, hills, basins, and plains, which are distributed coherently. The water system is well developed, with many rivers from Huizhou entering the sea here, providing a diversified natural environment for the development of traditional villages. Adjacent to the Chaoshan area, a significant population of Fulao people moved here during the late Ming and early Ching dynasties, influencing the local cultural landscape. Additionally, the Hakka and

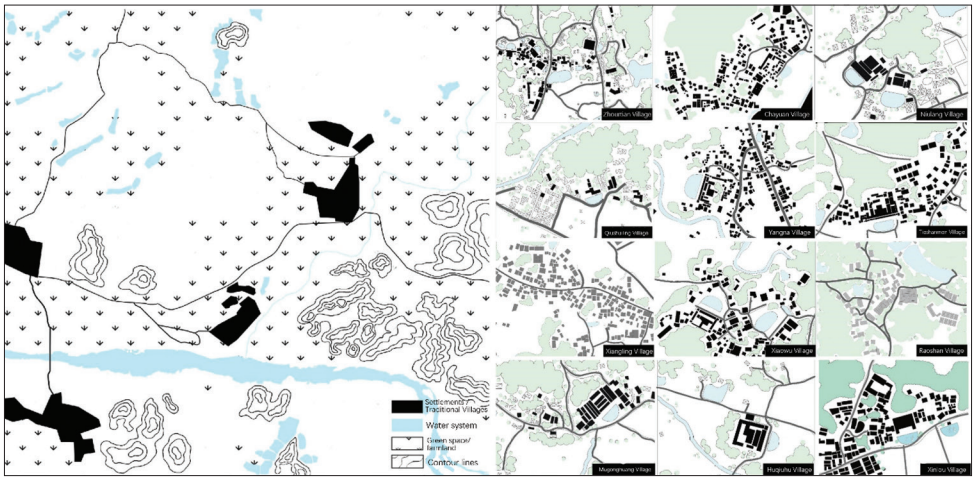

Figure 7. Illustration of the traditional village cultural landscape in the plains of the Xizhi River Basin in south-central China. Source: Drawing by the authors

Guangfu people reside in this cultural landscape area, and the interplay of these three folk cultures has resulted in various traditional village cultural landscapes. The cultural landscape area is interspersed with hills and plains, and the rivers are dense, creating a landscape relationship near the mountains and the water. The village buildings are densely laid out along the terrain and rivers, featuring large-scale structures at the core of the village landscape pattern. Farmland is distributed around the buildings according to the water, and fishponds are constructed for fishery culture near the sea. This gives rise to a landscape pattern of "mountain-village-water-field-pond-sea" (Figure 8).

The landscape space of the Southern Coastal Traditional Village Cultural Landscape Area is characterized by a centralized, dense, and multi-directional layout. The Fulao people, settling in this cultural landscape area early on, built villages that flourished thanks to favorable natural conditions and a stable social environment, leading to the continued development and growth of the village scale. In terms of the village texture, during the early construction by the Fulao people, the layout of village buildings and lanes was neatly and uniformly planned with a walled design, creating a well-organized pattern with a certain degree of defensiveness. However, with the village's development and the natural expansion of the population, an increasing number of dwellings outside the old houses, not subject to strict uniform control, led to the evolution of the village texture. It transformed into a dense layout with a well-organized interior and a dense, messy exterior featuring various orientations. The landscape unit of this cultural landscape area is characterized by diverse landscapes and disaster prevention. Villages in this cultural landscape area mainly consist of small families, resulting in predominantly small- and medium-sized houses. The residential building forms include bamboo pole houses, downhill tigers, and four-pointed gold, reflecting the characteristics of the Chaoshan area. Additionally, multi-courtyard buildings evolved from the three-room-and-two-corridor layout of the Guangfu area, Hakka-style row houses in some of the villages, and various architectural forms contribute to the lack of uniformity in residential buildings across most of the villages, often featuring a mix of style within a single village.

3.3.5. Cultural landscape area of traditional villages in eastern hilly area

The Eastern Hilly Traditional Villages Cultural Landscape Area mainly includes the area traversed by the Wuqiu Roach Mountain Range, a branch of the Lotus Mountain Range, in the northeastern part of Huicheng District and the northeast part of Huidong County. The landscape pattern of this cultural landscape area is characterized by rugged mountains and water, with communities integrated into the terrain. The mountains in the area are lofty, with continuous peaks, and numerous small rivers converge into the Xizhi River from north to south, forming a natural ecological environment of mountains and valleys, providing a robust ecological base. The cultural landscape area mainly originated from the migration of the Hakka people, who settled to build villages. The mountainous environment challenged village construction and development, making it unsuitable for large-scale clans living. This, in turn, determined that the villages in this area would be relatively small, scattered in the small depressions between the mountains or river valleys. Farmland is predominantly located around the villages, following the natural contours of the mountains and the water. This arrangement facilitates continuous farmland, making it convenient for cultivation, water diversion, and irrigation. As a result, the villages in this cultural landscape area have developed a distinctive landscape pattern of "mountain-forest-village-field-water" (Figure 9).

The landscape space of the eastern hilly traditional village cultural landscape area is characterized by

Figure 8. Landscape illustration of the cultural landscape area of traditional villages in the southern coastal area. Source: Drawing by the authors

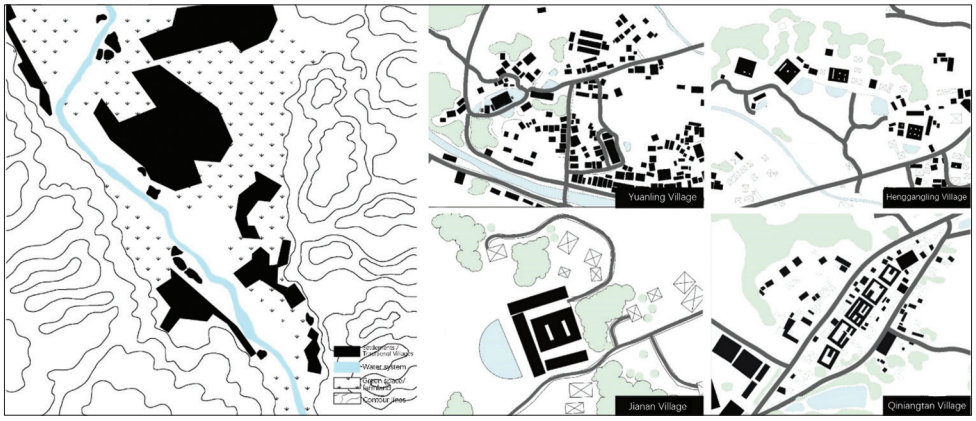

Figure 9. Illustration of the landscape of the traditional village cultural landscape area in the eastern hills and mountains. Source: Drawing by the authors

scattered settlements and clan communities. Influenced by the complex natural environment, forming large-scale, concentrated building groups in villages becomes challenging. The predominant texture pattern is either a free layout of scattered points following the topography or a linear layout along rivers, lacking a prominent village core. Buildings are sparsely distributed, showing no apparent planning and organization, with significant distances between them. The orientations of the buildings vary, enhancing the village's adaptability to the hilly environment. Street structures are mostly absent in these villages due to the limitation of the natural environment and the scattered layout of buildings. The landscape units in this cultural landscape area are characterized by simplicity and land efficiency. The large-scale buildings in these villages are mainly Tang Hengwu houses, serving multiple functions and providing space for clan gatherings on a smaller site. This approach addresses land constraints in the villages, leaving more land available for agricultural production. Small-scale buildings in the villages are mostly row houses strategically dispersed based on the topography of the terrain.

4. Discussion

This study focuses on Huizhou City, known for its multicultural compatibility and rich, diverse landscape resources. The traditional villages within this city serve as the study object of analysis, delving into the multidimensional landscape characteristics across various zones in Huizhou City. Employing diverse analytical methods, the study explores the clustering of these villages to identify the unique features characterizing each cultural landscape zone. The key findings of this study are outlined below:

(i) The construction of the traditional village cultural landscape factor indicator system contributes to the analysis of both commonality and individuality of regional cultural landscape features. Based on the multi-level and diversified cultural landscapes of Huizhou City, this study establishes a traditional village cultural landscape indicator system encompassing four levels: natural ecological landscape features, village spatial form features, village architectural features, and village landscape element features. This framework aids in the identification and systematic categorization of fundamental data derived from the investigation of 132 research sample villages, allowing for scientific and comprehensive processing of this information.

(ii) Through K-means clustering analysis applied to the cultural landscape key factor function data of each sample village, the villages were divided into five distinct categories. These categories, coupled with spatial superposition techniques incorporating four descriptive indicators and boundary fine-tuning, facilitated the delineation of five major traditional village cultural landscape zones in Huizhou City. These zones include the northern mountain valley traditional village cultural landscape area, the central Dongjiang basin plain traditional village cultural landscape area, the south-central Xizhi River basin plain traditional village cultural landscape area, the southern coastal traditional village cultural landscape area, and the eastern mountainous traditional village cultural landscape area.

5. Conclusion

Due to the constraints of the length of the article, only a preliminary analysis of the evaluation system for the construction of the cultural landscape of traditional villages in Huizhou City and the resulting cultural landscape area divisions are presented. Future research endeavors should employ advanced data analysis methods to conduct more objective and scientifically rigorous analyses of the cultural

landscape. This will not only enhance the innovation and depth of the study but also contribute to enriching existing research outcomes. Ultimately, such endeavors will provide more scientific guidance for the dynamic protection strategy and adaptive reuse of traditional villages.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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Writing – original draft: Jiaping Huang, Qihua Deng
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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

In the case of reasonable requests, the method of obtaining the original data can be consulted through the email of the corresponding author of this article.

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ACCSCIENCE PUBLISHING

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BOOK REVIEW

What we are studying when we are studying home: A book review of *Home Beyond the House*

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(This article belongs to the *Special Issue: Reshaping Rural China*)

Abstract

Home Beyond the House takes Yanxia, a village of Han nationality in the Zhejiang province in southern China as an example, and explores the relationship between the local sociocultural factors and vernacular built environment in rural China, examining how its cultural traditions influence the physical, psychological, and social construction of home for people living in the rural area, to illustrate the home's cultural connotations. Meanwhile, it offers solutions for sustainable development of the built environment, cultural diversity, and social life in rural China under globalization and modernization processes. China is undergoing rapid social transformation, and many aspects of rural society are changing drastically. *Home Beyond the House* may provide a worthy reference viewpoint on how to grasp and understand the trajectory of change and the future direction of rural China from the architectural perspective.

Keywords: Rural China; Home; Sociocultural; Family relationship; Tradition

Home Beyond the House: Transformation of Life, Place, and Tradition in Rural China. By Wei Zhao. Taylor & Francis. 2022, 327 pp. ISBN 9781032280158

1. Introduction

Agriculture is the bedrock of China's social development, and the importance of the countryside to China cannot be overstated. Modernization is not yet complete for China's current development, and its drastic changes are shaking and impacting the foundation of rural development. With the dynamic evolution of the overall development of the countryside and the new contradictions arising from the integration of urban and rural areas, the complexity and uncertainty of the countryside have gradually emerged as a fundamental issue that directly constrains the modernization of China (Zhang *et al.*, 2014), and the construction of the countryside has become the main theme of China's urbanization process (Wang & Ding, 2010). What does rural society consist of? What is the key to rural society? How to construct the countryside during the transition? Thinking about and answering these questions will help us understand Chinese rural society and its transformation. *Home Beyond the House* provides a worthy perspective to comprehend and grasp the changes and future direction of rural China.

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2. Sociology and rural China

As a Chinese reader and a trained architect, I can feel that the book approaches architecture from a sociological perspective, based on its title, emphasizing the social and cultural connotations carried by the material entity of houses, and focusing on rural China, a very culturally representative region.

It is common for architecture to be observed and studied from a sociological point of view. On the one hand, modern architects have intentionally or unintentionally used sociological thinking in architectural design, such as the geometry and flow embedded in Mies' German Pavilion, which expresses the relationship between architecture and people. Moreover, Shu Wang also said that to build a house is to create a small world (Wang, 2016). On the other hand, sociology has also played an essential role in expanding and applying architectural theory. Among them, in the process of sinicization of sociology, the sociological study of Chinese rural areas, which began in the early 20th century, was pursued with the primary objective of recognizing national conditions and transforming society, focusing on the analysis of social organizations linked to the economy and informal social institutions related to culture. In particular, social anthropologists, represented by Xiaotong Fei (1910 – 2005), conducted field surveys on Chinese rural areas and wrote a series of books, which profoundly revealed the completely different social structural model of Chinese rural society from that of modern western society, and put forward the theory of "Rural China" (Fei, 2006), which laid the theoretical basis for the study of Chinese rural areas. After the 1980s, Zhihua Chen integrated sociology into architecture and proposed the essential elements of architectural sociology, indicating the relationship between architecture and social production, science, technology, various social institutions, social consciousness, and social problems, and focusing on southern Chinese villages, exploring the traditional culture rooted in the national spirit through multiple types of buildings, such as houses, ancestral shrines, temples, and theaters (Chen, 1999). Since then, many reflections on the sociological methods and theories of architecture, the social meaning and social relations of architecture, and sociology and architectural design for rural construction have emerged from academic research.

What kind of existence is the Chinese countryside? So far, Fei's assertion of the "vernacular" of traditional Chinese rural society is still regarded as the mainstream view of Chinese rural and traditional Chinese society. For thousands of years, people living off agriculture have been bound by the land, resulting in little mobility and solid local characteristics, giving rise to the primary form of farmers living in villages, determining a self-sufficient mode of production and a relatively closed way of life, and on that basis, forming a rural society with a "pattern of difference sequence" as its fundamental characteristics, which is a "ritual society" different from the "legal society." With the development of China's modernization process, the rural society is being transformed by the industrialization of agriculture, the urbanization of the countryside, and the mobility of farmers. However, scholars believe that the Chinese countryside still retains the cultural traits of "vernacular" and still profoundly affects all aspects of social life. Thus, it has led to the theory of "post-rural China" (Lu, 2017), which states that the transformed rural society is still a rural society, not an urbanized one (Meng, 2020).

As a result, modern civilization is impacting traditional society. As evidenced by the distorted or neglected spiritual support and wisdom crystallization of rural society, and the value and significance of traditional culture are gradually vanishing. Farmers have alienated their cultural identity and abandoned their responsibility to passively or actively transmit traditional culture. In addition, the Chinese countryside faces more complex rural interests and social contradictions, and the cultural developers not in the "field" redefine and reinterpret traditional culture with their own opinions, leading to the deterioration of traditional culture. As such, there is an urgent need to reshape traditional culture and find a path for rural development.

3. Home in rural China

Thinking about what a house is, why we build houses, and what kind of houses are built is the basis of research and construction (Fathy, 2023). *Home Beyond the House* puts these thoughts at the forefront, pointing out that we should clarify what "home" is before understanding and constructing houses. Taking "jia" in Chinese rural society as an entry point, the translation is home, which means "the family members who live together and their residential space" (p. 15), and it refers to home and family as physical and social spaces. It is used as a microcosm of Chinese rural society to explore the relationship between home and the natural environment, production and lifestyle, economic technology, and traditional customs.

The book provides a self-examination perspective that a house should offer skills and connect emotions and responsibilities to become a home. As the author says, only when residents feel comfortable to inhabit the renovated or newly built environment, can they start to make this built environment their home (p. 300). In this regard, the book provides detailed explanations and answers to the question of "home" in the Chinese countryside, both from theoretical debate and empirical research.

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The introduction indicates that existing theories and studies about the home are primarily based on European and North American cultures, while different cultural backgrounds have different definitions, perceptions, and feelings of "home," so it is not fully applicable to the Chinese countryside. Moreover, the current research is mainly focused on physical space. The relationship between social culture and the built environment is not explored deeply enough. Therefore, examining and investigating the "home" in rural China is necessary.

Then, take the example of Yanxia, a village of the Han nationality in southern China as a representative case, because the roots of everything from the soil and lineage-based settlements are of typical rural Chinese characteristics, and the profound socio-cultural changes caused by the modernization transition can be found in other rural settlements. In addition, Yanxia is unique in that its religious activities have led to the development of a home-based hospitality industry, which is also a typical sample of rural economic practices. In this way, the meaning of "home" has expanded and modified in response to social activities.

The book also investigates the relationship between the sociocultural influences and the built environment of Yanxia in two periods, with three stages before and after 1850. The first stage is the maturity of the relationship, a phase of sociocultural development based on land bondage, as with the blood ties of the Cheng family before the 1850s, which influenced the early development and construction of vernacular settlements, housing, and ancestral halls. The second stage, which is a turning point in the development of relationships after 1850, is characterized by the continuous growth of religious activities; local areas started providing services to pilgrims, thereby promoting the development of the service industry. Economic factors had a huge influence on the local social and cultural aspects, which led to changes in the corresponding architectural environment. The first deconstruction of the relationship between social culture and the built environment occurred. The third stage of the relationship transformation was the local government intervention in the heritage management of Yanxia in 2006. Subsequently, under the national policy of Building a New Socialist Countryside in 2014, further relationships were restructured. However, this restructuring is still ongoing and has not yet been completed.

Furthermore, the residents' understanding of home was analyzed in four aspects: place-bound relationships, family tradition, family-based economic practices, and the younger generation. Ultimately, the meaning of home in Yanxia was expanded and summarized as follows: (i) "Home" on (or above) the land, including homesteads, private plots, agricultural land, and collective property, that provide the primary resources for survival, support daily activities, social relations, cultural performances, and land ownership, that provide people with a sense of belonging and identity to the local community, giving residents a sense of ownership and establishing individual and collective identities. (ii) "Home" depends on blood, family history, lineage structure, and kinship affairs such as Hugong temple fair, ancestor worship activities, weddings, and funerals. The locals are tightly united by their lineage, making the ancestor-worshipping place and personal belongings part of the home. (iii) Owing to the economy's influence, residents from the same "home" need to earn enough money in a limited period each year, so they have less and less time to participate in family activities. Moreover, they were not friendly with their neighbors because of competition. The home (inn) is isolated and separated from the social environment in which it was located, becoming a space reserved for strangers and losing its private meaning. (iv) The new national policy has gradually erased the "home" concept in the new countryside construction. Its connotation is being reconstructed with the rebuilding of houses and communities, in which home has become an abstracted and romanticized "jiaxiang," which is close to the idea of home as roots and only an ideology form. To summarize, the meaning of home depends on traditional ideas of identity, lineage, collectivity, social relations, land ownership, and rural life. Home, for them, can be independent of the physical house in which they live. Therefore, a house can be demolished and rebuilt while the idea of the home continues (p. 296).

4. Tradition of rural China

Focusing on rural China, a social group the authors believe is underrepresented in scholarship and underserved in modern China (p. 289). The research object has a more realistic value in the promotion of rural revitalization. When numerous suggestions for rural governance are being made, this book intends to address the following questions: Is building modern houses for farmers equivalent to building home for them? What kind of buildings and environment can become home, and what is the relationship between tradition and home in the Chinese countryside? How should traditions be inherited and continued? In this regard, the author provides a comprehensive analysis and clear exposition to explain the significance of studying "home," emphasizing the sociological implications of "house," which is of great significance for understanding and gaining knowledge of Chinese rural traditions.

First, an interdisciplinary approach, combining various theories and methods, including architecture,

anthropology, cultural geography, and sociology, based on ethnographic fieldwork and archival research, participant observation, interviews, and oral history was adopted to analyze the concept of "home" in various social stages in Yanxia and demonstrate that the built environment in the Chinese countryside changes with social and cultural transitions. In particular, the photo-voice method of ethnographic fieldwork was introduced to help analyze and understand the concept of home by asking residents to take photos related to the home from their unique views. These approaches will minimize researchers' bias and help amplify easily overlooked information. Compared with the popular judgments of rural finality and urbanization, the small-to-large perspective seems more consistent and convincing with the facts of rural social change. It helps us understand the residents' needs, values, and cultural background, prompting them to participate in the design process and highlighting their subjectivity and participation in the built environment.

Second, through the home of the Chinese countryside, the status of traditional culture and its profound impact on residents was explained, indicating the importance of tradition in times of social transition. How to grasp the fundamental issues of vernacular construction in an era of rapid transformation and significant social change? In an era of rapid transformation and significant social change, how can we grasp the fundamental issues of rural construction? How the locals construct their houses in the countryside shows the importance of continuing and developing rural traditions. Tradition is a cultural heritage, the spiritual pillar of rural communities, and a shaper of the social environment. As the title suggests, at a time of construction of modern houses, the author wants to tell and remind us, who are gradually getting lost in urban and rural construction and departing from local traditions, that a house is not a home, and more importantly, a "home" is no longer a physical space catered for social and emotional connection. The focus and overview of *Home Beyond the House* provide a relatively unique insight into the social traditions of rural China from a microscopic perspective.

Third, it provides a solution path to realize the sustainable development of the built environment, cultural diversity, and social life in the Chinese countryside. Since traditions have been re-represented and re-articulated, always resting on specific ideas deeply rooted in post-rural China, rural reform may not provide a more comfortable living space and happier life for residents, if tradition is ignored. Thus, the study gives general guidelines, advocating renovation instead of relocation, and emphasizing that building houses are not the final goal, but the ideas behind cultural traditions, and the meaning of home must be preserved. It reminded us that designers should fully respect local history, traditions, and lifestyles, avoid pursuing modernization and standardization, and create a built environment compatible with local culture.

In addition, the book shows the effect of heritage conservation on traditions. While traditions can be assessed as heritage, heritage is oriented toward traditions that are not always accepted and recognized by local stakeholders, but rather as a tool for reinterpreting local social values, and can lead to misinterpretations of traditions. It warns us that heritage is not a flawless concept either and that improper perceptions and manipulations of tradition may disproportionately impact traditions. Tradition should be carefully treated in heritage conservation.

With the improvement of the cognition of heritage and the demand for traditional cultural identity and inheritance, there are changes in the methods for rural China. At first, the construction of vernacular settlements and houses should take into consideration the following: avoiding large-scale demolition and construction, preserving as much as possible the local customs and traditional culture, and exploring transformational strategies that respect local social development law and meet the needs of production and life, such as the preservation and transformation of traditional fire ponds (China Architecture Society, 2021). Next, rural governance has changed from top-down governance to top-down policy support and bottom-up capital injection and operation management by enterprises and non-governmental organizations to stimulate the endogenous dynamics of rural areas and achieve the restoration and reshaping of the reproduction function of rural society to realize the sustainable development of rural society. For example, in the rural areas of Songyang County, by proposing strategies for acupuncture activation, cultural cultivation, and traditional industrial upgrading (Zhi & He, 2018), the continuation and development of traditional culture are stressed, providing specific guidance for the sustainable development of rural society.

Indeed, this book expounds on a case of a lineage-based, Han nationality village located in southern China, which can only represent a part of China's rural society. In China, there are not only Han Chinese vernacular societies based on geo-relationships but also many rural societies composed of national minorities. The different concepts, customs, cultural beliefs, and values give rise to social structures and cultural elements, so the perceptions of home and the needs for a house can be very different. There is never a single answer to traditional culture, but at least

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there can be a response that the traditional culture behind the formation and development of the built environment needs to be passed on in today's rural construction. Exploring the relationship between house and home is an exploration of the relationship between construction and tradition.

5. Development and continuation of tradition

Chinese society has entered a new period of social transformation, and the forces of change will inevitably cause a series of social transitions. Rural China is the most critical part, and policy reform will change the social structure of rural society and residents' traditional way of life, further causing environmental changes. In this process, the law of moving social development is inevitable, some traditions will be lost, and new ones will be born. Rural residents will never oppose to building a more comfortable environment. They desire modern facilities such as running water, gas, and electricity, but do not want them at the cost of losing their sense of ownership and changing their lifestyle. In contrast to living under the strong land dependency of the past, the new life, "I will have to spend money from the moment I wake up" (p. 315), a modern house cannot be called a better home for residents until it offers them the opportunity to adapt to a new way of living that involves continuing daily rituals (p. 48), so they are bound to resist the new houses and miss their old homes. In other words, as we reveal home's ever-changing meanings and symbols, we want to explore better how tradition can gain development and continuity.

As stated at the beginning of the book, it is hoped that local government officials and design professionals have a new perspective in their vision and planning for other renovation, revitalization, and modernization projects, where cultural traditions can be preserved and promoted, social relations can be sustained, and the meaning of home can be supported and enriched (p. 3). Designers and planners should go beyond form and function to understand and respect the cultural features and traditions of the countryside and explore their connotations and values in depth before incorporating them into rural environmental transformation and housing design. Meanwhile, it is crucial to emphasize public participation, foster close collaboration and communication with residents, listen to their opinions and feedback, and incorporate them into the decision-making process. In this way, it is possible to meet the needs and expectations of rural residents while preserving and passing on their cultural traditions. In addition, using sustainable building materials and technologies can promote environmental friendliness, and contribute to the community's economic development and social stability.

Home Beyond the House tells us that the development and continuation of traditional culture in China and other societies worldwide are powered by cultural self-awareness, and the foundation is a complete interpretation and respect for rural culture. In other words, in the process of rural transformation, the frequently mentioned "reconstruction" and "restructuring," where "building" and "constructing" are just means, and the purpose is how to achieve "revitalization".

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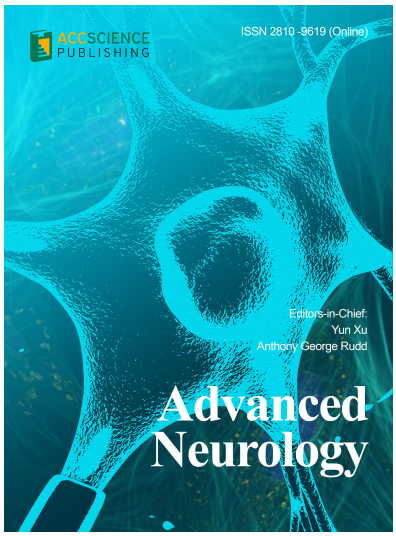

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